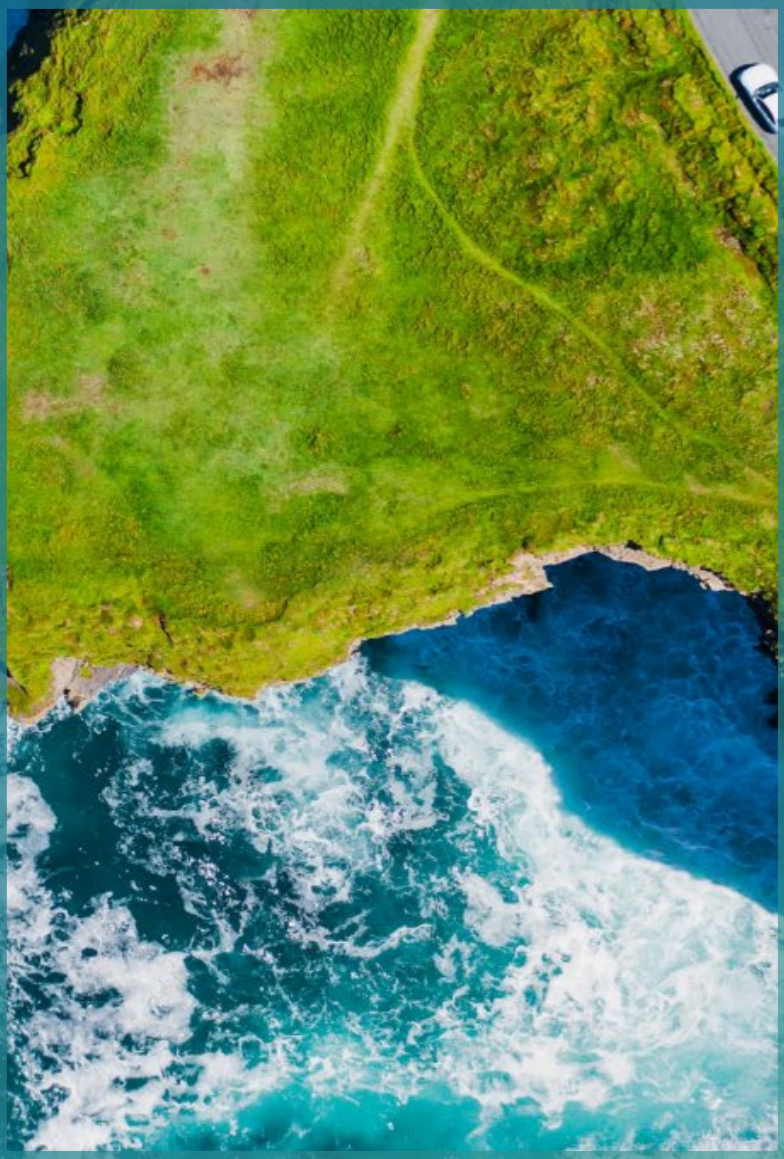
Rialtas na hÉireann
Government of Ireland

National Climate Change Risk Assessment

Technical Report

June 2025



Published by the Environmental Protection Agency

An Ghníomhaireacht um Chaomhnú Comhshaoil
Johnstown Castle
Wexford
Ireland
Telephone: +353 53 916 0600
LoCall: 1890 33 55 99
Fax: +353 53 916 0699
Email: info@epa.ie
Website: www.epa.ie

Disclaimer

Although every effort has been made to ensure the accuracy of the material contained in this publication, complete accuracy cannot be guaranteed. Neither the Environmental Protection Agency nor the author(s) accepts any responsibility whatsoever for loss or damage occasioned, or claimed to have been occasioned, in part or in full, as a consequence of any person acting or refraining from acting, as a result of a matter contained in this publication. All or part of this publication may be reproduced without further permission, provided the source is acknowledged.

Acknowledgements

This report was prepared on behalf of the EPA by KPMG Ireland. A steering committee was established to provide direction to the NCCRA process and to participate in reviews of NCCRA outputs, including this guidance document. The membership of the steering committee included representatives from: The Environmental Protection Agency, The Commission for the Regulation of Utilities, Department of Agriculture, Food and the Marine, Department of Defence - Office of Emergency Planning, Department of Environment, Climate and Communications, Department of Health, Department of Housing, Local Government and Heritage, Department of Tourism, Culture, Arts, the Gaeltacht, Sports, and Media, Department of Transport, Department of the Taoiseach, Met Éireann , National Economic and Social Council, National Parks & Wildlife Service, Office of Public Works, Teagasc.

The report was also reviewed prior to finalisation by the NCCRA expert working groups comprising representatives from the following organisations: The Environmental Protection Agency, Atlantic Seaboard North, Atlantic Seaboard South, and Eastern & Midlands Climate Action Regional Offices, Central Statistics Office, Climate Change Advisory Council, Commission For Communications Regulation, Commission for the Regulation of Utilities, County and City

Management Association, Department of Agriculture, Food and the Marine, Department of Environment, Climate and Communications, Department of Health, Department of Housing, Local Government and Heritage, Department of Tourism, Culture, Arts, the Gaeltacht, Sports, and Media, Department of Transport, Dublin City University, Geological Survey Ireland, Health Service Executive, The Irish Climate Analysis and Research UnitS (ICARUS, Maynooth University), Irish Centre for High End Computing, The Marine Institute, Maritime Area Regulatory Authority, Met Éireann, National Economic and Social Council, National Parks & Wildlife Service, Office of Public Works.

Table of Contents

Executive Summary 6
1 Introduction 15
2 Climate Change in Ireland 32
3 Biodiversity and Ecosystems 67
4 Built Environment 128
5 Economy and Finance 278
6 Energy 294
7 Food Production and Supply Chain 357
8 Health 391
9 Marine and Coastal Ecosystems 465
10 Social 501
11 Water Security 513
12 International Dimensions 531
13 Opportunities 537
14 Knowledge Gaps 540
15 Glossary 546
16 Acronyms 550
17 References 551
Appendix A: Detailed Hazard and Climate Information 563

Executive Summary

Introduction

Ireland's climate is changing in line with global trends. These changes are unprecedented, and it is now established fact that human activities are resulting in the warming of our climate system. Over the last century, Ireland's climate has become warmer, with patterns of precipitation changing, and rising sea levels. These changes in our average climate conditions are also being reflected in changes in the frequency and severity of extreme weather events. Projections indicate that changes to Ireland's climate will continue and intensify, with far reaching consequences for its environment, economy, and society.

Ireland's first National Climate Change Risk Assessment (NCCRA) provides a comprehensive national overview of the potential risks and opportunities posed by climate change for Ireland. It will play a critical role in meeting national policy objectives and supporting sectoral and local authority climate adaptation planning processes. The NCCRA integrates scientific and technical knowledge with input from expert stakeholders, to identify, assess, and prioritise climate change risks to build a comprehensive understanding of risks.

The NCCRA is delivered through three reports:

- A Summary for Policymakers which contains a summary of policy-relevant aspects of the NCCRA in non-technical and accessible language.
- A Main Report which provides an overview of the methodology, findings, and recommendations to improve climate risk assessments.
- A Technical Report (this report) which sets out the evidence base for the NCCRA and further detail on the risk assessment findings, including descriptions of exposure, vulnerability, and consequence and outlines knowledge gaps.

Approach

To assess climate risk for Ireland, the NCCRA adopts a systematic semi-quantitative risk assessment approach. This approach makes use of a qualitative and quantitative perspective to advance national understanding of climate change risks. A similar approach has been taken for the New Zealand Climate Risk Assessment, and for the UK Climate Risk Assessment processes.

The NCCRA follows the conceptual risk framework for climate change risks used in the Intergovernmental Panel on Climate Change (IPCC) Assessment Report (AR6) and assesses risks across nine systems that represent nationally important functions across the natural, social, infrastructure, and economic domains that support human activity in Ireland. The systems include Biodiversity and Ecosystems, Built Environment, Economy and Finance, Energy, Food Production and Supply Chain, Health, Marine and Coastal Ecosystems, Social, and Water Security.

Across these systems, climate change risks are defined by levels of consequence of their impact, and levels of urgency for action to be taken in response to them. The levels of consequence considered in the NCCRA are Limited, Substantial, Critical, and Catastrophic. The NCCRA's assessment of consequence demonstrates how the levels of consequence of risks change through time from the current period to the mid-century, and to the late century. As well as assessing consequence, the NCCRA integrates consequence ratings into a decision urgency framework, inclusive of adaptation effectiveness, to describe the need for action to be taken on each risk within the next five years. The criteria for decision urgency are Watching Brief, Sustain Current Action, Further Investigation, and More Action Needed.

Climate Change in Ireland and the NCCRA Evidence Base

Observed changes in Ireland are projected to continue and intensify into the future. To understand how the climate may change in the future, the NCCRA used climate change projections from Met Éireann TRANSLATE, OPW Flood Mapping, and IPCC and EPA reports:

The assessment of risks was considered across two IPCC Representative Concentration Pathways (RCPs) – RCP 4.5 and RCP 8.5. Assessing risks across these two scenarios allows for different scoring of risks depending on the amount of global emissions in the future which can influence the level of impact risks could have.

Findings of the NCCRA

The NCCRA identifies a total and assesses 115 risks across the nine systems, the risks include:

- **Biodiversity and Ecosystems**: The risk with the highest level of consequence include freshwater quality deterioration due to flooding and droughts, degradation of peats due to extreme heat and drought. Other risks identified include, increased landslide susceptibility, forest damage from flooding and wildfire, stress on forests due to pest and disease outbreaks, reduced yields from managed forests. There are also risks related to the degradation and loss of habitats in terrestrial and peatland ecosystems, as well as disruptions to freshwater flora and fauna. Invasive species, extreme weather events, and changes in phenology pose additional risks to ecosystems.

- **Built Environment:** The risks with the highest level of consequence include risks to communication infrastructure due to extreme wind, and coastal and river flooding of buildings and transport infrastructure. Other risks include damage and loss of buildings from extreme weather events, and wildfires. Communication infrastructure is at risk from flooding, ground movement, and extreme weather conditions. Cultural heritage sites, including underwater and protected structures, face potential damage and loss due to changing ocean conditions, sea level rise, flooding, and extreme weather. Recreational amenities, transport infrastructure, and water services infrastructure are also at risk to disruptions and damage.

- **Economy and Finance:** The risks with the highest level of consequence include increased insurance claims and premiums, a widening protection

gap, higher probability of default, loss of asset value, reduced tax revenues, increased government expenditure, lower credit ratings, and higher cost of borrowing

- **Energy:** The risks with the highest level of consequence include disruption and damage to energy transmission and distribution from extreme wind, and increased cooling demand due to extreme heat. Other risks include the risk of flooding of generation and conversion facilities and flood control measures during extreme precipitation events leading to decreased hydropower generation. Increased temperatures are a risk due to the strain this may put on energy systems due to higher demand for cooling. Additionally, changes in wind speed and extreme conditions can impact wind energy generation.

- **Food Production and Supply Chain:** The risk with the highest level of consequence is the risk of reduced crop yields due to changing climate conditions. Other risks include reduced yields from aquaculture operations impacted by extreme winds and waves, and diminished fish stocks from changes in ocean conditions. Agricultural productivity may be further affected by nutrient loss and sedimentation due to extreme precipitation, increased transmission of vector-borne diseases among livestock during floods, heat stress on animals in extreme heat, and crop damage and loss from wildfires, lightning strikes, and extreme wind events.

- **Health:** The risks with the highest level of consequence are the risk to human health due to flooding and extreme heat. Healthcare services and facilities are also at risk of disruption and damage from sea level rise, coastal flooding, extreme cold, extreme precipitation, and extreme heat events. Increased demand for healthcare services during extreme heat events and potential overheating in facilities are additional risks. Climate change can also contribute to challenges such as antimicrobial resistance and the spread of vector-borne diseases. Risks to human health include physical injuries, mental health issues, illnesses from harmful algal blooms and pathogens, cold-related ailments, respiratory impacts from wildfires,

and various health consequences related to changes in temperature, precipitation, and air quality.

- **Marine and Coastal Ecosystems:** The risks with the highest level of consequence are associated with the changes in ocean conditions which can lead to disturbances in marine habitats, reduced reproduction rates of species, shifts in species distributions, and alterations in ecosystem functioning. Additionally, ocean acidification poses a threat to cold-water coral reefs and shellfish populations, potentially causing increased mortality. Harmful algal blooms and other sources of contamination can affect seafood safety. Phenological changes further contribute to the degradation and loss of marine ecosystems and habitats.

- **Social:** The risk with the highest level of consequence is associated with the maladaptation to climate change which poses risks such as compromised emergency responses, loss of public trust in government, and exacerbation of social justice issues. Inadequate responses to climate-related challenges can lead to ineffective emergency management, erode trust between the public and governing bodies, and contribute to social inequalities. Climate change impacts on community well-being, employment, education, and social services can further exacerbate societal inequalities and marginalised communities.

- **Water Security:** The risks with the highest level of consequence include risk to water supply due to contamination from overland flows, and reduced water supply due to extreme heat. Climate change also poses risks to water supplies, due to contamination from saline intrusion due to sea level rise and coastal flooding, and increased demand during extreme cold.

Risks in a system also have the potential to cascade and impact upon other systems. For example, extreme winds during Storm Darragh in December 2024 and Storm Éowyn in February 2025 resulted in damage and disruption to the energy system resulting in loss of power to approximately 395,000 and 768,000 households, farms and businesses respectively. This also led to cascading

impacts on other sectors, including communication networks and water treatment and supply. The NCCRA identified the cascading impacts across systems, with the Biodiversity and Ecosystem, Economy and Finance, Health, and Social systems being particularly impacted by risks from other systems.

It should be noted that the current main risk drivers for some risks are existing environmental pressures, such as pollution and habitat destruction, or population growth. However, these pressures will be increasingly compounded by climate impacts as time goes on.

The NCCRA also identifies potential transboundary impacts for Ireland related to food security, supply chains, economic stability, and human mobility that may result from impacts of climate change that occur outside the state.

While there are significant risks from climate change, there are also potential for opportunities to enhance Ireland's resilience and sustainability. The NCCRA identifies five potential opportunities as a result of projected changes in Ireland's climate. These opportunities include:

- Increased tourism and expansion of outdoor activity tourism,
- Increased hydropower generation.
- Increased shellfish growth and diversity of marine species.
- Increased growing season and improved livestock nutrition and grazing.
- Improved mental and physical health by increased time spent outdoors and reduced cold-related deaths.

Knowledge Gaps

Through the NCCRA a number of knowledge gaps were identified. These include:

- National downscaled projections are currently unavailable for several critical climatic, atmospheric, and oceanic variables including humidity, sea level rise rates, extreme wind, fire weather and wildfire projections, changes in ocean chemistry, drought conditions, and lightning

- National downscaled projections for key geophysical hazards related to climate change, such as coastal erosion, landslides, groundwater flooding, and surface water flooding, are currently unavailable, hindering accurate risk assessment

- The Office of Public Works (OPW) adopted the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS) for flood risk assessment in the CFRAM Programme, without designated future timeframes. To align with the NCCRA Methodology, the changes in precipitation and mean sea level in the MRFS and HEFS have been aligned to correspond with the RCP4.5 and RCP8.5 scenarios, utilising global sea level rise data and TRANSLATE proxy variables (such as winter precipitation change). However, uncertainties persist regarding the timing of changes in coastal and fluvial flooding extents due to this alignment approach.

- The methodology used in developing the TRANSLATE national downscaled climate projections involves detrending which may inadvertently remove extreme events associated with interannual variability. Consequently, there is potential to underestimate the frequency and intensity of extreme events, leading to an underassessment of risk.

- The uncertainty surrounding climate tipping points and associated risks is challenging to include into national climate risk assessments due to their unpredictable and abrupt nature. This uncertainty increases the risk of underestimating the potential impacts and failing to adequately prepare for these high-impact, low-probability events.

- Limited availability of spatial information on asset locations and operating thresholds, along with the absence of ecosystem tipping points, pose challenges in determining current and future exposure and measuring risk levels consistently across different elements at risk. The lack of detailed vulnerability data, encompassing socio-economic factors, infrastructure

and environmental sensitivities, and adaptive capacities, further impedes accurate assessments of potential impacts on populations and systems.

- Assessing climate risks is complicated by the uncertainty associated with changes in exposure and vulnerability, such as population growth, demographic shifts, and land use changes. These dynamic factors introduce variability and uncertainty into risk assessments, making it challenging to assess future exposure accurately.

- Consideration of evolving government policies is essential in climate risk assessments to understand their impacts on exposure and vulnerability. Policies promoting urban densification, renewable energy adoption, decarbonisation of the built environment, sustainable farming practices, promotion of electric vehicles and public transit, nature-based water solutions, and green space enhancement can significantly influence the risk landscape and need to be understood to decrease uncertainty.

- Current risk assessments focus on single acute hazards, missing compounding impacts of sequential events. For example, drought leading to wildfires and then flooding. Lack of integrated assessments across sectors limits preparedness for complex scenarios.

- Assessing the effectiveness of current adaptation strategies in mitigating climate risks is challenging due to high uncertainty levels. A significant gap exists in understanding the extent to which existing adaptation plans provide protection against various degrees of climate change. The absence of a national repository or knowledge base documenting adaptation actions and their anticipated outcomes hinders progress tracking and knowledge sharing.

- Assessing the financial implications of climate risks is essential for both the public and private sectors to ensure economic stability, informed decision-making, risk management, insurance planning, financial sustainability, and regulatory compliance. The complexity and uncertainty in predicting the economic impacts of climate change across sectors

hinder accurate assessment of financial implications. The inherent uncertainty of climate risks makes it challenging to quantify potential costs and benefits effectively and therefore the future levels of consequence.

1 Introduction

Ireland is being affected by climate change now, and the severity of the impacts is likely to increase significantly in the coming years. A National Climate Change Risk Assessment (NCCRA) is an essential pre-requisite for the development of evidence-based and robust climate change adaptation at the country scale, facilitating risk-based decision making, and for developing appropriate adaptation and mitigation actions.

It is recognised that standardised national climate change scenarios, guidance and risk assessment processes can support integration and consistency across local and sectoral adaptation plans. At the European Union (EU) level, the first European Climate Risk Assessment (EUCRA) has been developed to provide a consistent EU-wide point of reference for conducting and updating national or subnational climate risk assessments and has been designed to support the identification of adaptation-related policy priorities in Europe and policy development in climate-sensitive sectors during the next EU policy cycle.

In Ireland, the development of the new National Adaptation Framework (NAF, 2024), Climate Action and Low Carbon Development (Amendment) Act 2021, annually updated Climate Action Plan, and local and sectoral adaptation strategies, have led to significant progress in climate change risk assessment and adaptation planning. Until now, individual stakeholders developed these strategies and plans using a range of different approaches, datasets, time periods and scenarios. These differences can lead to continued use of outdated climate modelling and scenarios and result in contradictory conclusions and policy decisions and hinder the ability to determine national priority risks.

In the context of these developments, there is a need to develop a consistent national climate change risk assessment for Ireland which identifies and prioritises climate change risks, both within and across sectors, and provides a basis for the development of consistent and integrated national and local adaptation plans and strategies. This need is explicitly recognised through Action 457 of Ireland's Climate Action Plan (2021) '*Further develop Ireland's national*

climate change risk assessment capacity to identify the priority physical risks of climate change to Ireland'.

Ireland's first National Climate Change Risk Assessment (NCCRA) was developed between 2024 and 2025 and focuses on the risks to Ireland from hazards caused, intensified, or influenced by climate change including both acute hazards, such as fluvial flooding, heatwaves, and wildfires, as well as chronic hazards like rising sea levels, changing precipitation patterns, and long-term temperature shifts. Consideration is also given to the transboundary and cascading climate risks, and to the potential benefits or opportunities that may arise from a changing climate.

The development of the NCCRA adopted a systematic semi-quantitative [1] risk assessment process to advance national understanding of climate change risks from a qualitative to a quantitative perspective that supports the identification, assessment, and prioritisation of climate change risks. The NCCRA integrates scientific and technical knowledge, and input from expert stakeholders to provide for a comprehensive understanding of climate change risks.

More specifically, the purpose of the NCCRA was to provide for an iterative and scalable approach to assessing climate change risk which will:

- Identify areas where action needs to be prioritised to make Ireland more resilient to the impacts of climate change.
- Support the prioritisation of adaptation-related investments in infrastructure and improve the robustness of policy development in climate-sensitive sectors.
- Provide a consistent evidence base to inform the National Adaptation Framework.

[1] Semi-quantitative climate risk assessments builds upon qualitative CCRAs and are often based on nationally consistent sources of climate change in combination with qualitative information (assigned a numeric value), expert judgement and elicitation and stakeholder knowledge. They provide for the identification and prioritisation of national climate change risks to assess adaptation urgency.

- Provide a national reference for conducting and updating sectoral, local and other Ireland-specific risk assessments.

1.1 Purpose

The outcomes of the NCCRA are presented in three reports (Table 1.1). The purpose of the NCCRA Technical Report is to provide the evidence base and reflect the current knowledge of climate change risks in Ireland. It provides an overview of the systems assessed, interactions with subsystems, and introduce key concepts such as exposure, vulnerability, consequence, adaptation and decision urgency that provide the framework on which risks are assessed. The report highlights knowledge gaps across systems presented through detailed findings of the NCCRA. A detailed methodological description is contained in the NCCRA Method Report.

Table 1.1: Overview of the NCCRA reports and their purpose.

Report	Purpose
Summary Report for Policymakers	Concise summary of policy-relevant aspects of the risk assessment in non-technical and accessible language
Main Report	Provides an overview of the methodology, findings, and recommendations to improve climate risk assessments.
Technical Report *(this report)*	This report sets out the evidence base for the assessment and further detail on the risk assessment findings, including knowledge gaps for each system and qualitative descriptions of exposure, vulnerability, and consequence.

1.2 Overview of the systems and cross-cutting concepts

In line with the EU CCRA and as set out in the NCCRA Methodology (EPA, 2024), the NCCRA aims to identify and assess cross-cutting and complex interactions as much as feasibly possible to provide a comprehensive understanding of

climate change risks. To enable this the NCCRA adopts a systems-based approach that reflects the inherent complexities and cross-cutting interactions associated with climate risk. The following sections sets out the systems-based approach in more detail.

1.2.1 Systems

Within the NCCRA, a system is defined as a group of interacting or interrelated elements that provide nationally important functions (DCCEEW, 2023). The systems employed in the NCCRA are varied and multi-faceted and include Biodiversity and Ecosystems, Built Environment, Energy, Food Production and Supply Chain, Health, Marine and Coastal Ecosystems, Social, and Water Security. Definitions for each system are shown in Table 1.2. These systems encompass the wide range of natural, physical, and human elements which make up Ireland's natural world, society, and economy. The elements within each system will evolve in the future in response to environmental, societal, technological, economic, and policy drivers that will differ across low, medium, and high emissions scenarios. For example, under a low emissions scenario, the Energy system is projected to transition to a new low carbon electricity system (generation, storage and network).

1.2.1.1 Sub-systems

Each of the systems in Table 1.2 are made up of a series of sub-systems. Sub-systems describe distinct elements of systems. For example, the system Built Environment is made up of four different sub-systems which describe the built world – buildings, communication infrastructure cultural heritage, recreational amenities, transport infrastructure, and water services infrastructure. Table 1.2 shows the systems and their related sub-systems, employed as part of the NCCRA.

Table 1.2: The systems and the associated sub-systems used within the National Climate Change Risk Assessment.

System	Description	Subsystems
Biodiversity and Ecosystems	Encompasses diverse natural habitats and their ecological functions	Forests, Freshwater Systems, Peatland, Terrestrial Ecosystems
Built Environment	Includes human structures and systems supporting daily life	Buildings, Communication, Cultural Heritage, Recreational, Transport Infrastructure, Water Services Infrastructure
Economy and Finance	Includes finance, insurance, and public economic stability	Finance and Insurance, Economic Stability
Energy	Covers the production, conversions, and distribution of energy resources	Energy Generation and Conversion, Energy Transmission and Distribution
Food Production and Supply Chain	Involves the processes and systems for growing and distributing food	Food Production, Supply Chain
Health	Pertains to medical services and overall human well-being	Healthcare, Human Health

System	Description	Subsystems
Marine and Coastal Ecosystems	Relates to oceanic and coastal habitats and their biodiversity	Coastal Ecosystems, Marine Ecosystems
Water Security	Focuses on the availability and management of water resources for domestic and non-domestic use	Water Supply
Social	Encompasses societal structures and governance systems	Governance, Society

1.2.1.2 Elements at risk

Each of the sub-systems in Table 1.2 are comprised of elements at risk. Elements at risk are objects, persons, animals, plants, activities, and processes of value to Ireland that may be exposed to climate change and potentially impacted, negatively or positively, directly, or indirectly. For instance, within the Built Environment system, and under the transport infrastructure sub-system, elements at risks include road, rail, ports/harbours, and airports/runways. Another example would be within the Biodiversity and Ecosystem system, where the forest sub-system is made up two elements at risk – managed forests and unmanaged forests. A breakdown from system to sub-system, to elements at risk, is shown in Figure 1.1.

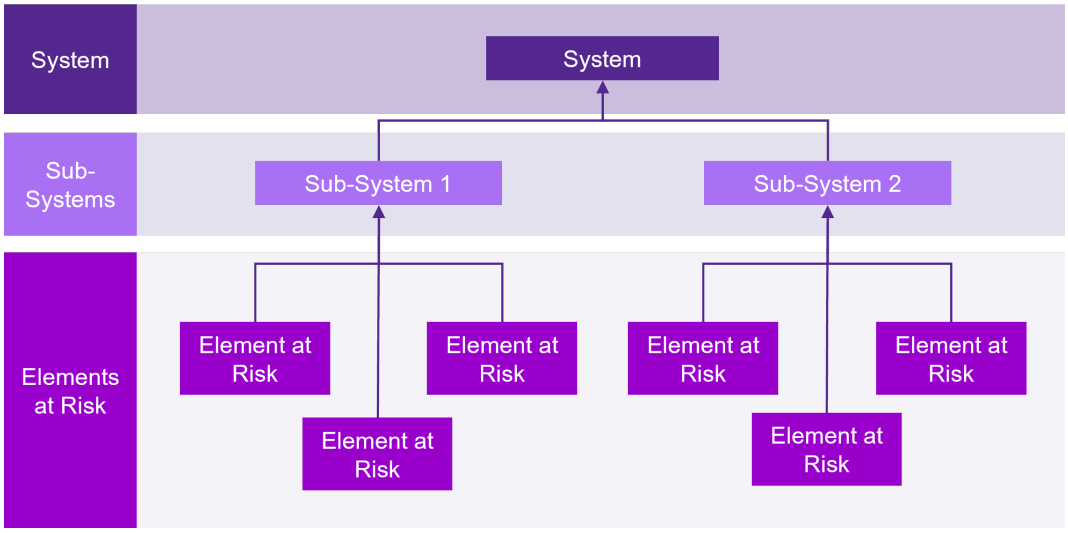


Figure 1.1: Systems, Sub-systems, and Elements at Risk.

1.2.1.3 Systems and Adaptation Policy Sectors

The systems for analysis adopted by the NCCRA can be aligned with Irish Adaptation sectors. This supports sectors in using the NCCRA as a reference point for adaptation planning by linking each system with relevant sectors. The systems approach also illustrates the cross-cutting nature of risks across sectors. Table 1. shows the alignment between each system and Irish as well as European policy sectors for adaptation. Some sectors will align with more than one system, underlining the interrelated nature of climate change risks across sectors.

Within each system a single element at risk can be relevant to numerous sectors, and an individual sector may rely and could impact upon, a range of systems, sub-systems, and elements at risk. The Irish policy sectors for adaptation overlap considerably with the EU policy sectors for adaptation, except in the absence of Business and Industry, and Financial sectors, while the Flood Risk Management sector is present in Ireland but not in the EU. Many of the sub-systems and elements at risk are relevant to Business and Industry and Financial sectors such as non-residential buildings and energy transmission and distribution infrastructure, while Mountain Areas is not a prominent area of focus in Ireland compared to continental Europe.

Table 1.3: Alignment between the systems used with the National Climate Change Risk Assessment and the Irish Adaptation Sectors outlined in the NAF2024.

System	Irish Adaptation Sector
Biodiversity and Ecosystems	Biodiversity
	Forestry
Built Environment	Built and Archaeological Heritage
	Built Environment and Planning
	Communication Networks
	Flood Risk Management
	Tourism
	Transport Infrastructure
Economy and Finance	Cross-cutting
Energy	Electricity and Gas Networks
Food Production and Supply Chain	Agriculture
	Seafood
Health	Health
Social	Cross-cutting
Water Security	Water Quality and Water Services Infrastructure

1.3 Key Concepts

The NCCRA follows the conceptual risk framework for climate change risks used in the Intergovernmental Panel on Climate Change (IPCC) Assessment Report (AR6) (IPCC, 2023). In this framework, risk is a function of climate hazards, exposure to the hazard, and vulnerability of the asset to the effects of the hazard (Figure 2 and Table). Risk is defined as the potential for adverse consequences for human or ecological systems. A 'Key Risk' is a risk that has potential to cause severe adverse consequences for humans and social-ecological systems. As the

IPCC Risk Framework has been adopted for the NCCRA, the method components have been developed to align with this framework.

The IPCC Risk Framework incorporates complex climate risks by showing the different ways in which risks can interact (Figure 1.2). This includes compounding risk in single or multiple directions, cascades with one event triggering another, and aggregate, e.g., with independent determinants of risks co-occurring.

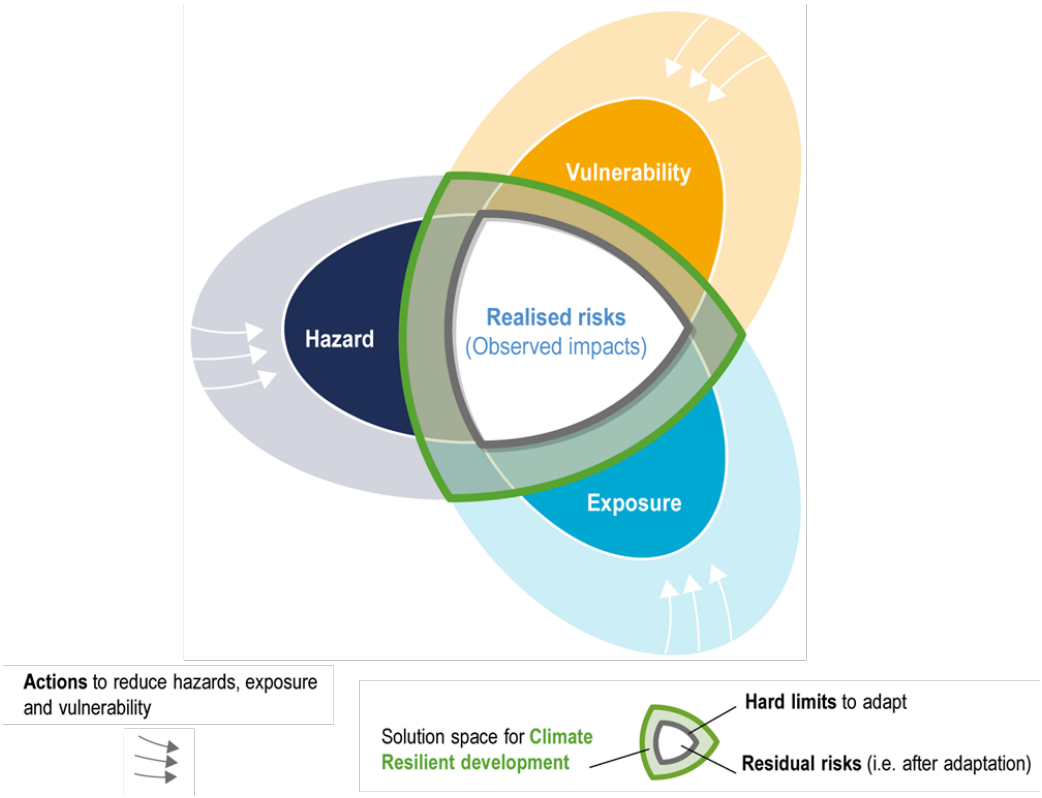


Figure 1.2: Risk is a result of the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems (amended from IPCC, 2022).

Table 1.4: Definitions of the risk determinants from the Intergovernmental Panel on Climate Change (IPCC) Risk Framework.

Risk Determinant	Definition
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.
Exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural

	assets in places and settings that could be adversely affected.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
Risk	The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change.

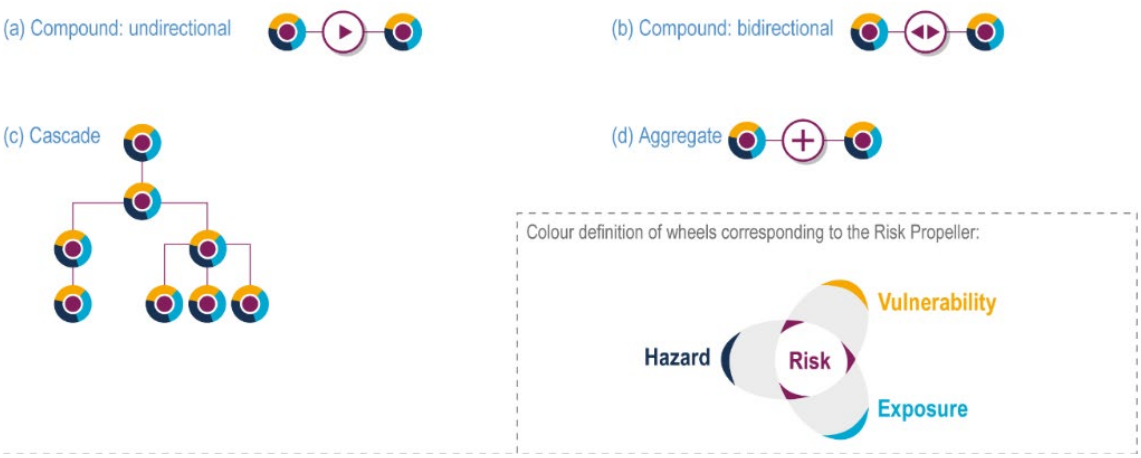


Figure 1.3: The potential interactions between climate risks O'Neill et al, 2022, adapted from Simpson et al., 2021).

To ensure consistency in the application of complex risk terms, the definitions of the complex risk terminology are shown in Table 1..

Table 1.5: Definitions of different types of complex risk (Simpson et al. 2021).

Complex Risk	Definition
Aggregate Risk	The accumulation of independent determinants of risk
Cascading Risk	One event or trend triggering others; interactions can be one way (e.g., domino or contagion effects) but can also have feedbacks; cascading risk is often associated with the vulnerability component of risk, such as critical infrastructure

Compound Risk	Compound risks arise from the interaction of hazards, which can be characterised by single extreme events or multiple coincident or sequential events that interact with exposed systems or sectors
Interacting Risk	The combinations of hazards and their reciprocal influences between different factors and coincidences among environmental drivers
Interdependent Risk	Complex systems involve interactions and interdependencies that cannot be separated and lead to a range of unforeseeable risks

1.3.1 Exposure

Exposure refers to the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected. Table 1. shows the criteria descriptions for levels of exposure.

Table 1.6: Exposure criteria. Based on the New Zealand CCRA (Ministry for the Environment, 2020).

Level	Exposure
Extreme (4)	The majority (>75%) of the element at risk is exposed to the hazard.
High (3)	A high proportion (50–70%) of the element at risk is exposed to the hazard.
Moderate (2)	Up to half (25–50%) of the element at risk is exposed to the hazard.
Low (1)	A small proportion (5–25%) of the element at risk is exposed to the hazard.

1.3.2 Vulnerability

Vulnerability refers to the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including **sensitivity**, the degree to which populations, systems, or species are affected, either adversely or beneficially, by climate variability or change. and **adaptive capacity**, the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to impacts. Table 1. shows the criteria descriptions for levels of vulnerability.

Table 1.7: Vulnerability criteria. Based on the New Zealand CCRA (Ministry for the Environment, 2020).

Level	Vulnerability
Extreme (4)	Extremely likely to be adversely affected, because the 'element at risk' is highly sensitive to a given hazard and has a low capacity to adapt.
High (3)	Highly likely to be adversely affected, because the 'element at risk' is highly sensitive to a given hazard and has a low capacity to adapt.
Moderate (2)	Moderately likely to be adversely affected, because the 'element at risk' is moderately sensitive to a given hazard and has a low or moderate capacity to adapt.
Low (1)	Low likelihood of being adversely affected, because the 'element at risk' has low sensitivity to a given hazard and a high capacity to adapt.

1.3.3 Consequence

The effects or outcomes of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services) and infrastructure (IPCC, 2022, Annex II).

Table 1.8: Magnitude of consequence criteria based on the EU CRA (2024)

Risk Severity	Damage	System Functionality	Extent and Pervasiveness	Cascading Effects
Catastrophic	Very large and frequent	Irreversible loss	Very large extent or very high pervasiveness	Irreversible cascading effects beyond system boundaries
Critical	Large and frequent	Long-term disturbance	Large extent and high pervasiveness	Long-term cascading effects beyond system boundaries
Substantial	Substantial losses	Temporary or moderate disturbance	Moderate extent or pervasiveness	Temporary cascading effects beyond system boundaries
Limited	Limited or rare losses	No significant disturbance	Limited extent or pervasiveness	No cascading effects beyond system boundaries

When assessing and prioritising climate risks, an assessment of consequence of each risk is required. Table 1.8 and Table 1.9 show the magnitude of

consequence criteria to be employed as part of the NCCRA. The categories of consequence are based on the EU CRA (2024).

1.3.4 Assessing Adaptation Responses

Adaptation measures can be categorised according to the Four R's: Reliability, Resistance, Recovery and Response, and Redundancy, to provide a comprehensive understanding of resilience measures and a framework for enhancing resilience against climate impacts. This approach assesses not only whether the systems and structures designed to perform consistently under varying conditions but also whether they are built to withstand adverse events, recover swiftly from disruptions, and incorporate backups to maintain functionality. In combination, the 4R's provide for the development of robust and adaptable strategies that safeguard communities and infrastructure against the challenges posed by a changing climate.

- *Reliability:* Ensuring consistent performance and functionality under varying conditions, reliability involves using durable materials, robust designs, and reliable systems that can withstand different environmental and operational stresses. The goal is to maintain functionality and service levels despite challenges.

- *Resistance:* The ability to withstand and endure adverse conditions, resistance focuses on constructing and designing systems, structures, and processes that can effectively resist impacts from external forces, such as natural disasters or climate change. Examples include flood-resistant buildings and infrastructure designed to withstand earthquakes.

- *Recovery and Response:* The capacity to quickly return to normal operations after a disruption, recovery and response involve having emergency response plans, recovery strategies, and resources in place to ensure that services and operations can be restored swiftly after an event. It emphasizes preparedness and the ability to bounce back from setbacks.

Table 1.9: Risk consequence for different types of impacts — benchmarks based on annualised impacts. Based on EU CRA (2024) with absolute thresholds adjusted for the 2023 Irish GNI*, population or area (2024). See the NCCRA Methodology Report for further information.

Risk Severity	Economic Damage	Impact on People	Other Impact Categories
Catastrophic	At least 1% of GNI* (IE: €2.91 bn)	> 100 deaths or >1,000 health impacts or >10,000 people affected	• >710,000 ha of land lost or severely damaged (10% of land area)
Critical	0.25-1% of GNI* (IE: ca €727.5 mn - 2.91 bn)	>10 - 100 deaths or >100 - 1,000 health impacts or >1,000 - 10,000 people affected	• 71,000 ha to 710,000 of land lost or severely damaged • Major impact (10% or more) on valued habitat or landscape types; • Major impacts on or loss of species groups; • Major impact (10% or more) on an individual natural capital asset and associated goods and services; • Major loss or irreversible damage to iconic heritage assets
Substantial	0.05-0.25% of GNI* (IE: ca €145.5 mn - 727.5 mn)	>1 - 10 deaths or >10 - 100 health impacts or >100 - 1,000 people affected	• 7,100 to 71,000 ha of land lost or severely damaged • Intermediate impact (1-10%) on valued habitat or landscape types; • Intermediate impacts on or loss of species groups; • Intermediate impact (1-10%) on an individual natural capital asset and associated goods and services; • Medium loss or irreversible damage of iconic heritage assets.
Limited	<0.05% of GNI* (IE: ca < €145.5 mn)	≤1 death and ≤10 health impacts and ≤100 people affected	• Less than 7,100 ha of land lost or severely damaged • Minor impact (less than 1%) on valued habitat or landscape types; • Minor impacts on loss of species groups; • Minor impact (less than 1%) on an individual natural capital asset and associated goods and services; • Low loss or irreversible damage to iconic heritage assets.

- *Redundancy:* Incorporating backups and alternatives to enhance resilience, redundancy includes having additional systems, resources, or pathways that can take over if the primary ones fail. Examples are backup power supplies, redundant communication systems, and alternative supply chains to ensure continuity in case of disruptions.

Based on the information collated on existing adaptation measures and stakeholder feedback, the effectiveness of existing and planned adaptation measures to address a risk was assessed. The degree of adaptation effectiveness was categorised as follows:

- **Very Effective**: Existing adaptation measures are considered effective in managing current and future risk to an acceptable level.
- **Effective**: Existing adaptation measures are considered effective in managing the current risk to an acceptable level but are only partially effective in managing future risk resulting in unacceptable consequences.
- **Moderately Effective**: Existing adaptation measures are considered partially effective in managing both current and future risk to an acceptable level.
- **Slightly Effective**: Existing adaptation measures are considered partially effective in managing the current risk to an acceptable level but are ineffective in managing future the risk resulting in unacceptable consequences.
- **Ineffective**: Existing adaptation measures are considered ineffective in managing both current and future risk resulting in unacceptable consequences across both current and future time periods.

1.3.4.1 Adaptation Decision Urgency

The NCCRA uses decision urgency ratings to identify the need for adaptation decision-making. Urgency is defined as "*a measure of the degree to which further action is needed in the next five years to reduce a risk or realise an opportunity from climate change*" (Committee on Climate Change, 2022). There are four levels of urgency described in Figure 1.4.

Informed by risk identification, hazard confidence, consequence confidence and current adaptation effectiveness. A level of Decision Urgency was assigned to each risk using the decision tree in Figure 1.5.

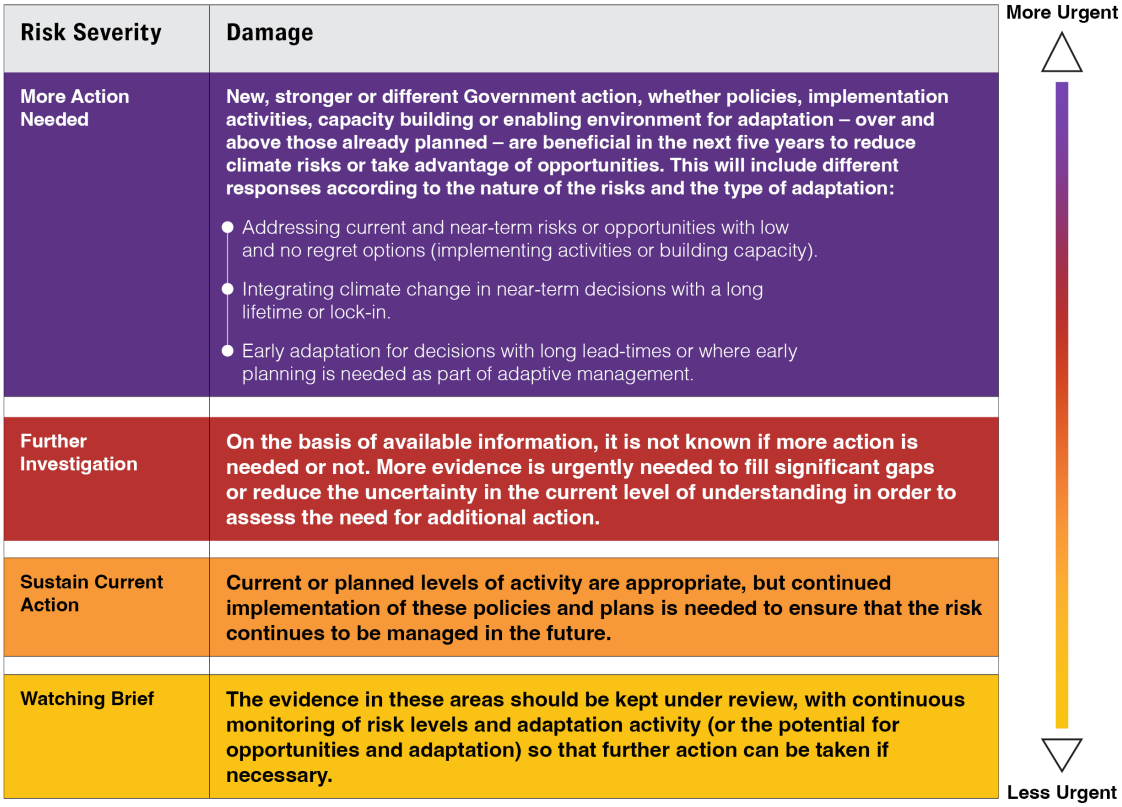


Figure 1.4: The criteria to assign urgency to each risk (Committee on Climate Change, 2022).

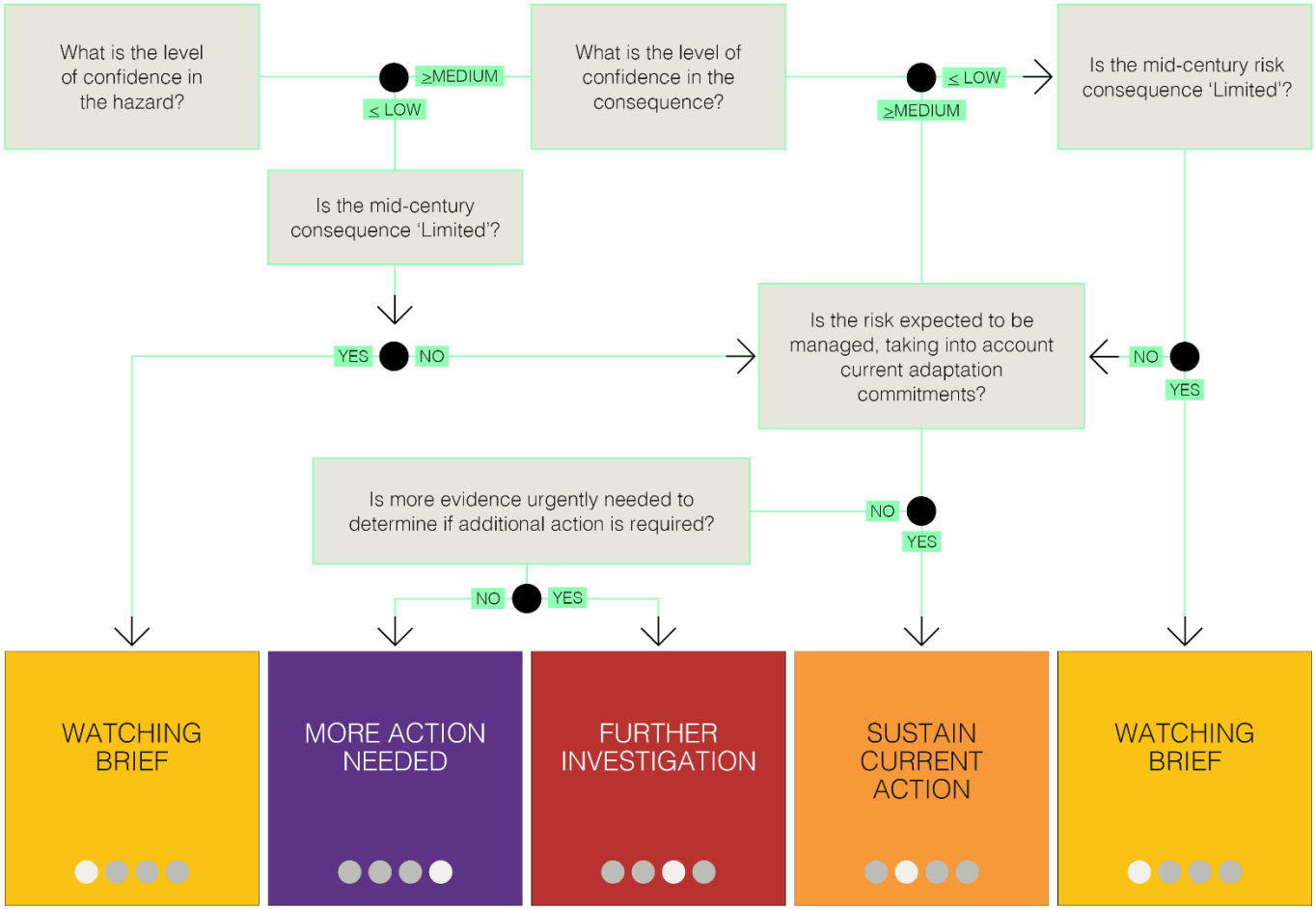


Figure 1.5: The decision tree used to determine the level of decision urgency. Current adaptation effectiveness that were classified as 'Effective' or 'Very Effective' were considered to be managing a risk**.**

2 Climate Change in Ireland

2.1 Introduction

Ireland's climate is continuing to warm in line with global warming with annual average surface temperatures approximately 1°C higher than the early 20th century (Thorne et al., 2023) and 7 of the top 10 warmest years on the island occurring since 2005 (Met Éireann, 2024). Sea surface temperatures across the North Atlantic have continued at or near record levels contributing to higher-than-average temperatures and increased moisture content in the atmosphere (Met Éireann, 2024). There has been an increase in heavy precipitation extremes across the island with relative increases in the frequency and intensity of these events attributed to global warming. Sea levels are rising across all coastal areas and recent studies have highlighted higher rates of sea level rise than the global average since the late 20th century in Cork and Dublin.

2.2 Global Context

It is now unequivocal that human activity has led to widespread and rapid change in all components of the climate system which are unprecedented over many centuries to many thousands of years. Global annual average surface temperatures have increased by ~1.15°C from the period 1850 - 1900 to 2013 - 2022 and this warming is mainly due to increased greenhouse gas concentrations as a result of fossil fuel combustion. Human induced climate change is also modifying the frequency and intensity of extremes globally and this is particularly the case for heatwaves and extreme precipitation. Since 1900, global sea level has risen by 0.2 m and the rate of global sea level rise is accelerating.

Different future scenarios are used within climate risks assessments to reduce uncertainty associated with the identification and assessment of future risks. To project and explore credible future climates, the Coupled Model Intercomparison Project (CMIP) a project of the World Climate Research Programme (WCRP) has published extensive climate model simulations which give an understanding of what future changes are likely across a range of variables for the emission scenarios globally. These simulations are based on Representative

Concentration Pathways (RCPs) which provide scenarios of possible future emissions trajectories that encompass a range of possible climate futures.

Met Éireann has refined these global projections to develop more highly resolved projections for Ireland based on the climate projections (CMIP5) used within the fifth IPCC Assessment report (AR5), which enables localised risk assessments to be undertaken. The IPCC AR5 (IPCC, 2014) used four Representative Concentration Pathways (RCPs) to represent different levels of climate change: RCP2.6, RCP4.5, RCP6.0, and RCP8.5. Standardised climate projections for Ireland based upon Shared Socioeconomic Pathways (SSPs) employed through the sixth IPCC Assessment Report (AR6) are currently not available for Ireland and have not been used within the NCCRA.

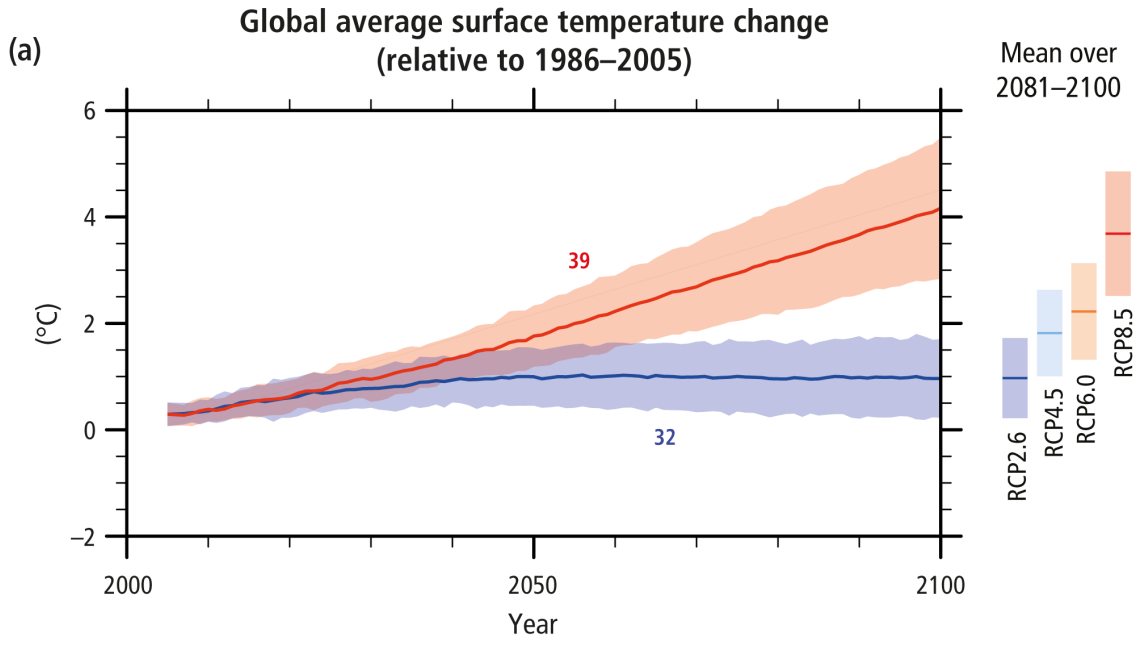


Figure 2.1: Global average surface temperature change from 2006 to 2100 as determined by multi-model simulations from the IPCC AR5 for RCP 2.6 (blue) and RCP8.5 (red) with a measure of uncertainty provided (shaded). The mean and associated uncertainties averaged over 2081-2100 are given for all scenarios as coloured vertical bars at the right-hand side of the figure.

2.3 Climate Scenarios employed in the NCCRA

Ireland has committed to halving greenhouse gas emissions by 2030 and reaching net zero by 2050 at the latest. However, the degree of physical risks that Ireland will experience is dependent upon the success of global efforts to

reduce greenhouse gas emissions. Therefore, even if Ireland meet's its greenhouse gas emissions targets, it could still be impacted by high levels of global warming due to inadequate emission reduction measures being pursued at the global scale. Consequently, there is uncertainty in the future climate that Ireland will be exposed to.

In the NCCRA, a conservative approach is taken to assess risks to Ireland and assumes global emission reduction targets are not met. This aligns with the principle of precaution as stated in the NAF 2024, and follows the approach used within the NZ CCRA (Ministry for the Environment, 2020). As a result, within the NCCRA, RCP8.5 and RCP4.5 [2] are adopted to assess risks to Ireland:

- RCP8.5 was selected as it represents a high-emissions scenario and achieves the highest level of modelled temperature increases by the end of the century. This scenario corresponds to a radiative forcing of approximately 8.5 W/m². Consequently, this scenario will result in the highest level of physical risk for Ireland, and would require the highest levels of adaptation. The use of RCP8.5 aligns with a conservative approach to the NCCRA.

- RCP4.5 was selected as it represents a moderate-emissions scenario. RCP4.5 is more closely aligned with current levels of global climate action and policies than RCP8.5, and therefore can be considered aligned with the global temperature trajectory.

RCP2.6, is a representative of a mitigation scenario (<2°C) and forms the low end of the scenario literature in terms of levels of emissions, radiative forcing and physical climate risks. As such, RCP2.6 is not used within the NCCRA as it is associated with lower levels of physical risks when compared to RCP8.5 and RCP4.5.

[2] These scenario corresponds to a radiative forcing of approximately 8.5 W/m² and 4.5 W/m² respectively by the end of the century.

2.4 Climate Projections and Hazards

Observed changes in Ireland are projected to continue and intensify into the future. Projected changes in the frequency and intensity of climate hazards pose significant risks to Ireland's communities and environment with adaptation required to increase resilience to climate change impacts.

The climate change projections used in this report have been obtained from Met Éireann, OPW, IPCC and the EPA (see Appendix A for further information).

To project future changes in Ireland's climate, the Met Éireann funded TRANSLATE project was developed to produce a standardised set of climate projections for Ireland. The TRANSLATE project employed two separate ensembles of downscaled CMIP5 projections comprising 30 separate detrended and bias corrected climate projections for Ireland for 3 RCP scenarios (RCP2.6, RCP4.5 and RCP8.5) and three representative time periods. TRANSLATE data is also available for a range of global warming levels, though these have not been used in the NCCRA. TRANSLATE data employed through this report are based on the mean projection for the relevant RCP scenario. Data provided through the TRANSLATE project has been supplemented with climate projection data sourced from Nolan and Flanagan 2020, IPCC AR6, the EPA funded HydroPredict project and academic literature.

The Office of Public Works (OPW) has developed flood maps for Ireland as part of the National Indicative Flood Mapping (NIFM), the Catchment Flood Risk Assessment and Management (CFRAM), and the National Coastal Flood Hazard Mapping (NCFHM) (developed from the Irish Coastal Water Level and Wave Study (ICCWS)) programmes.[3] These flood maps show the extent of land exposed to coastal and fluvial flooding during a theoretical or design flood with an estimated probability of occurrence (referred to in terms of a % Annual Exceedance Probability, or 'AEP'. Flood maps have been developed for both current and future scenarios based on projected sea level rise and changes in river flow. For the purposes of the NCCRA and as detailed in the NCCRA

[3] The NFCS has developed introductory material to this data which is available at https://www.met.ie/nfcs/sectoral-adaptation-plan-support.

methodology, OPW future scenarios have been aligned to the RCP4.5 and RCP8.5 for the 2050 and 2100 time horizons. The data provided through this report are based on the current and projected flood extents for the 5%, 1% and 0.1% AEP for the relevant RCP and time horizon.

The IPCC have developed projections of change in sea surface temperature and chemistry (pH) as part of the IPCC AR6.

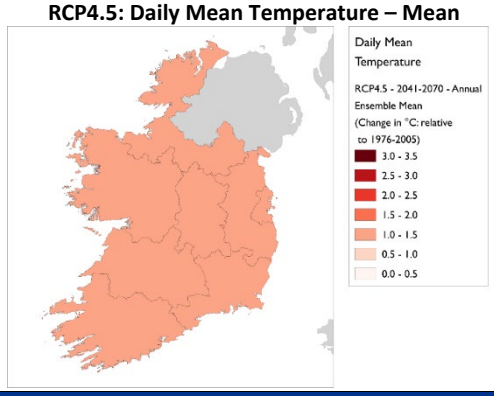
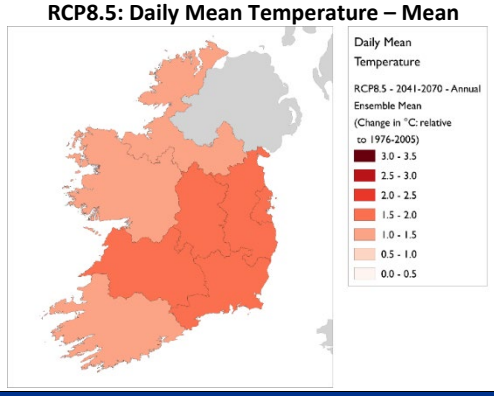
Projected changes in the Standardised Precipitation Evapotranspiration Index (SPEI) have been sourced from Murphy and Meresa (2024). SPEI provides a multi-scalar drought index based on climatic data and can be used to determine the onset, duration, and magnitude of drought events.

For the purpose of the NCCRA, all data with the exception of marine has been upscaled and presented across eight sub-national regions based on the NUTS3 (Nomenclature of Territorial Units for Statistics) classification, a geocode standard for the European Union (EU). For the marine environment, the Irish Exclusive Economic Zone (EEZ) will be used as the outer limit of assessment (200 nautical miles, 370.4 km offshore), with Transitional Waters (12 nautical miles, 22.2 km offshore) also used if required (Figure 2.7). The EEZ and Territorial Waters region can be described according to the seas they intersect, such as the Irish Sea and St. George's Channel, the Celtic Sea, the North Atlantic Ocean, and the Inner Seas off the West Coast of Scotland.

The following sub-sections provide a summary of the climate projections across the full range of climate variables considered in the NCCRA. For climate hazard information based on TRANSLATE or IPCC data, the mean projection for 2050 is shown. See Appendix A for further information, such as maps and statistics for the 10^{th} and 90^{th} percentiles.

2.4.1 Heat

2.4.1.1 Changes in Average Temperature

Daily Mean Temperature
Recent observations or changes
• Ireland's warming trend is consistent with the global warming trend. Over the last 100 years, Ireland's mean annual temperature has increased by approximately 1°C and 16 of the top 20 warmest years have occurred since 1990 (Noone et al., 2023; Cámaro García and Dwyer, 2020). • Observed seasonal temperature anomalies indicate that all seasons exhibit a warming trend (Met Éireann, 2023). Minimum temperature anomalies show a higher increase in the summer while winter anomalies indicate a more consistent but relatively smaller increase (Cámaro García and Dwyer, 2020). • During the baseline period (1976 - 2005), Ireland's mean annual temperature was 9.3°C (O'Brien et al., 2023).
Sub-national zones affected
• At the NUTS 3 level, all regions are projected to experience an increase in air temperature, with the Mid-East and South-East regions most affected across both RCP4.5 and RCP8.5 scenarios.
Projected changes by 2050
• **RCP4.5:** Nationally, daily mean temperature is projected to increase by 1.1°C (0.6-1.72°C) by 2050. with the Mid-East region experiencing the largest increase (1.1°C (0.6-1.8°C)). Considering seasonality, highest daily mean temperature increase is expected in autumn (1.5°C (1.1-2.3°C)), and lowest is in spring (0.7°C (0.1-1.1°C)). • **RCP8.5:** Nationally, daily mean temperature is projected to increase by 1.5°C (1.1-1.9°C) by 2050s. with the Mid-East region experiencing the largest increase (1.6°C (1.2-2.0°C)). Considering the seasonality, highest daily mean temperature increase is expected in autumn (2.7°C (1.7-2.7°C)), and lowest is in spring (1.0°C (0.5-1.3°C)).
RCP4.5: Daily Mean Temperature – Mean 
RCP8.5: Daily Mean Temperature – Mean 
Confidence - High
• **Agreement:** The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for this variable. The 10th percentile, ensemble mean, and the 90th percentile of the TRANSLATE projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios. See Appendix A for additional statistics and maps. • **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

2.4.1.2 Extreme Heat

Summer Days (Days above >25°C) and Heatwaves (Periods of at least 5 consecutive summer days)

Recent observations or changes

- In Ireland heatwave events have occurred in 1983, 1984, 1995, 2003, 2006, 2018 and 2021 (Paranunzio et al., 2021; Pascal et al., 2013)
- During the baseline period (1976 - 2005) there was an average of 0.09 heatwaves per year across the country, totalling 2.7 heatwaves over the 30-year period. Additionally, there were 2.3 days per year with temperatures exceeding 25°C (O'Brien et al., 2023).

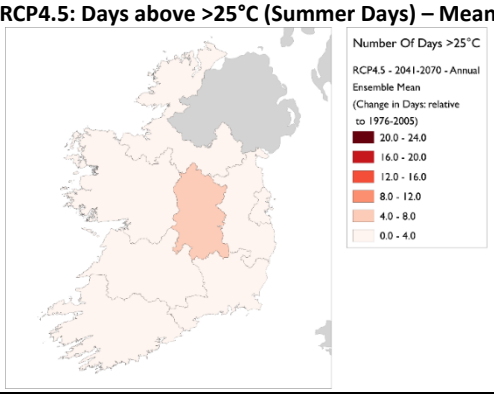
Sub-national zones affected

- At the NUTS3 level, all regions are projected to experience an increase in the number of summer days and number of heatwave events with the South-East region most affected in both RCP4.5 and RCP8.5 scenarios.

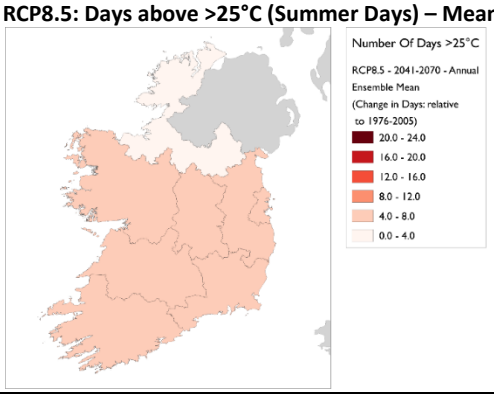
Projected changes by 2050

- **RCP4.5 (Summer Days):** Nationally, summer days are expected to increase by 3.0 days (0.9-5.3 days) by 2050 with the Midland region experiencing the largest increase (4.1 days (1.3-6.7)).
- **RCP4.5 (Heatwaves):** Nationally, there is an increase in the number of heatwave events by 0.06 events (-0.05-0.21 per year) by 2050, with the South-East region experiencing the largest increase (0.12 per year (--0.01-0.32)).
- **RCP8.5 (Summer Days):** Nationally, summer days are projected to increase by 4.7 days (2.5-6.7 days) by 2050 with the Midland region experiencing the largest increase (6.4 days (3.4-8.8)).
- **RCP8.5 (Heatwaves):** Nationally, there is an increase in the number of heatwave events by 0.15 (0.04-0.28 per year) by 2050, with the South-East region experiencing the largest increase (0.25 per year (0.1-0.4)).

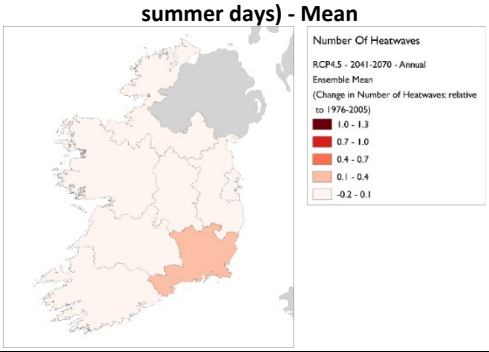
RCP4.5: Days above >25°C (Summer Days) – Mean



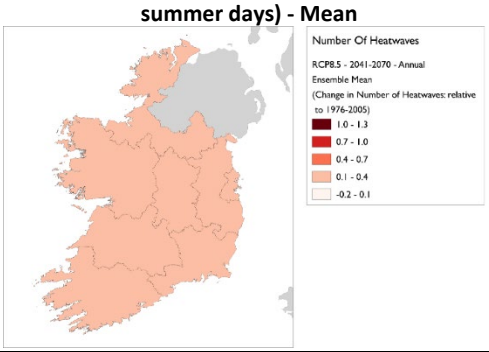
RCP8.5: Days above >25°C (Summer Days) – Mean



RCP4.5: Heatwaves (Periods of at least 5 consecutive summer days) - Mean



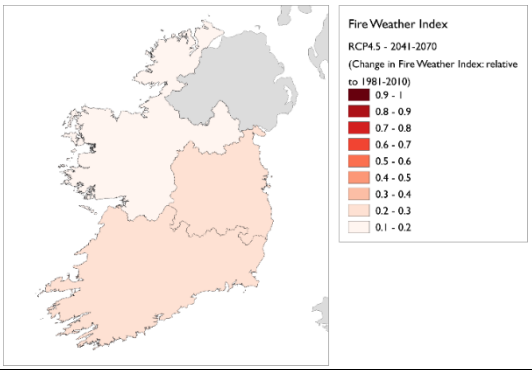
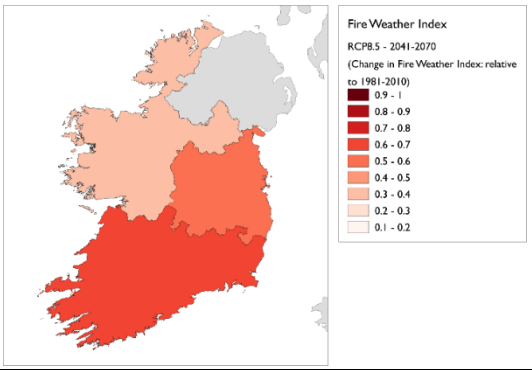
RCP8.5: Heatwaves (Periods of at least 5 consecutive summer days) - Mean



Confidence - High

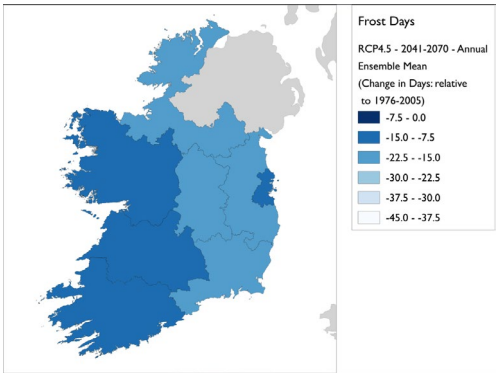
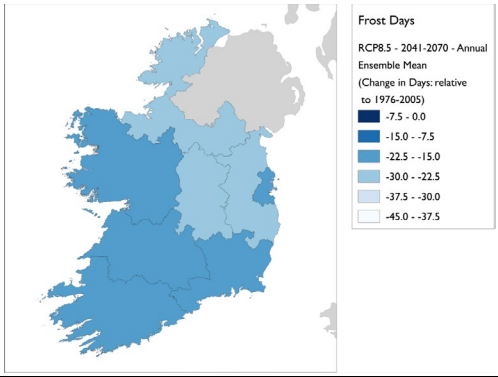
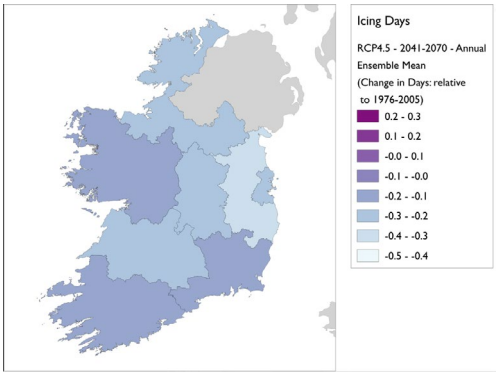
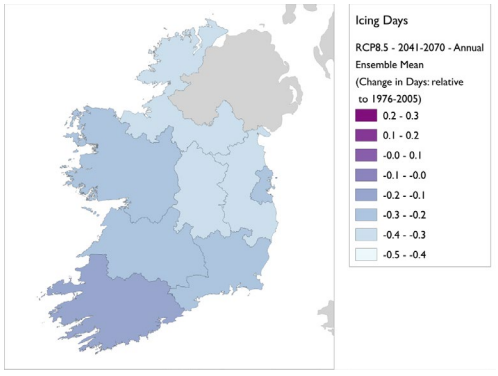
- **Agreement:** The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for this variable. The 10th percentile, ensemble mean, and the 90th percentile of the TRANSLATE projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios. See Appendix A for additional statistics and maps.
- **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

2.4.1.3 *Wildfire*

Wildfire (Fire Weather Index (FWI))	
Recent observations or changes	
• Recent observations suggest that peatlands and lowland blanket bogs have the highest frequency of wildfire incidents. In Ireland, fires occur primarily between March and June. A time series of combined forest area burned, and annual fire service mobilisation indicates a slight decreasing trend over the last two decades (Cámaro García and Dwyer, 2021). • Additionally, historical analysis (1981-2010) of the Fire Weather Index (FWI) using ERA5 reanalysis data shows no discernible trends (Climate ADAPT).	
Sub-national zones affected	
• At the NUTS 2 level, projected FWI anomaly (from 1980-2010) shows the Southern region is projected to experience the largest increase in SWI (0.62).	
Projected changes by 2050	
• **RCP4.5:** All regions in Ireland are projected to experience a small increase in FWI, with the Southern region (0.27) showing the highest increase from the 1981-2010 baseline. • **RCP8.5:** All regions in Ireland are projected to experience a small increase in FWI, with the Southern region (0.62) showing the highest increase from the 1981-2010 baseline	
RCP4.5 Fire Weather Index	**RCP8.5: Fire Weather Index**
	
Confidence - Low	
• **Agreement:** There are limited global, regional, and national scale projections available related to the changes in fire weather for Ireland. See Appendix A for additional maps. • **Robustness:** National scale projections do not exist for fire weather; therefore, European scale projections (EURO-CORDEX) have been used.	

2.4.2 Cold

2.4.2.1 Extreme Cold

Frost Days (daily minimum temperature < 0˚C) and Icing Days (daily maximum temperature < 0˚C)	
Recent observations or changes	
• Historical analysis (1885 - 2018) shows a significant decreasing trend in the number of frost days annually (−13.7 days) and in the spring (−5.8 days), autumn (−3.4 days), and winter (−4.9 days). Additionally, there is a significant increasing trend in the annual minimum temperature (1.1°C), with greater increases observed in the autumn (1.6°C) and spring (1.4°C) seasons (Mateus and Potito, 2022). • During the baseline period of 1976-2005, Ireland experienced an average of 40.6 frost days and 0.4 icing days per year (O'Brien et al., 2023).	
Sub-national zones affected	
• At the NUTS 3 level, all regions are projected to experience a decrease in the number of frost days and a decrease in the number of icing days across RCP4.5 and RCP8.5 scenarios.	
Projected changes by 2050	
• **RCP4.5 (Frost Days):** Nationally, the number of frost days is expected to decrease by 16.18 days (-22.1 - -8.8) by 2050, with the Border region experiencing the largest decrease (-18.8 days (-26.0 - -10.3)) in number of frost days. • **RCP4.5 (Icing Days):** Nationally, the number of icing days is expected to decrease by 0.24 days (-0.36- -0.10) by 2050, with the Mid-East region experiencing the largest decrease (-0.32 days) in number of icing days. • **RCP8.5 (Frost Days):** Nationally, number of frost days are expected to decrease by 21.6 days (-27.8- -15.5) by 2050, minimum temperature also expected to increase during this period. with the Border region experiencing the largest decrease (-25.3 days (-32.6 - -18.2)) in number of frost days. • **RCP8.5 (Icing Days):** Nationally, the number of icing days is expected to decrease by 0.30 days (-0.36- -0.20) by 2050, with the Mid-East region experiencing the largest decrease (-0.38 days) in number of frost days.	
RCP4.5: Frost Days (daily minimum temperature < 0˚C) – Mean	**RCP8.5: Frost Days (daily minimum temperature < 0˚C) – Mean**
	
RCP4.5: Icing Days (daily maximum temperature < 0˚C) – Mean	**RCP 8.5: Icing Days (daily maximum temperature < 0˚C) – Mean**
	

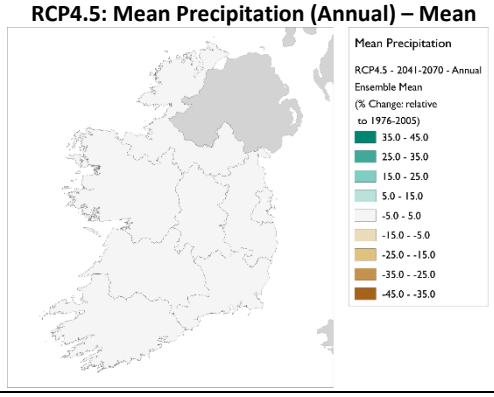
Confidence - High
• **Agreement:** The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is a decreasing trend for these variables. The 10th, ensemble mean, and the 90th percentile of the TRANSLATE projections all show a decreasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios. See Appendix A for additional statistics and maps. • **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform these variables using a robust and peer-reviewed modelling approach.

2.4.3 Precipitation

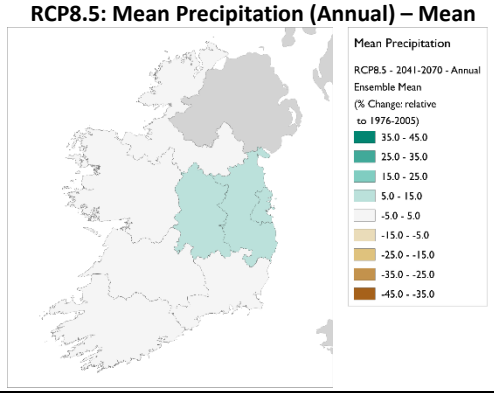
2.4.3.1 Changes in Precipitation

Average Precipitation (Mean Precipitation)
Recent observations or changes
• Annual average amounts of precipitation are increasing in Ireland. Average annual rainfall has increased from 1961-1990 to 1991-2020 by 7% (Met Éireann, 2023). This observed trend also shows an increase in winter precipitation and a decrease in summer precipitation. Overall, the precipitation pattern also exhibits a strong decadal variability (Cámaro García and Dwyer, 2020). • The period 2006-2015 was the wettest decade in the 305-year record for the island of Ireland (Cámaro García and Dwyer, 2020). • During the baseline period (1976 – 2005), Ireland experienced a mean annual total precipitation of 1,209 mm per year (O'Brien et al., 2023).
Sub-national zones affected
• At the NUTS 3 level, all regions are projected to experience an increase in mean annual precipitation with the Mid-East and Dublin regions registering the highest increase across both RCP4.5 and RCP8.5.
Projected changes by 2050
• **RCP4.5 (Annual Precipitation):** Nationally, mean annual precipitation is expected to increase by 2.86 % (-1.60 – 7.84%) by 2050, with the Midland East region have the largest increase (4.16%). • **RCP4.5 (Seasonal Precipitation):** The winter season is projected to experience the highest increase precipitation of 7.7% (-1.1-19.7%), and the summer season is projected to see a decrease in precipitation of -1.8% (-12.5-8.7%). • **RCP 8.5 (Annual Precipitation):** Nationally, mean annual precipitation is expected to increase by 4.81 % (-0.22 – 10.34%) by 2050, with the Dublin region experiencing the largest increase (6.71%). • **RCP 8.5 (Seasonal Precipitation):** The winter season is projected to have the highest increase in precipitation of 12.5% (3.7-22.2%) , and the summer season is expected to see a decrease in precipitation of -5.5% (-15.6-4.9%).

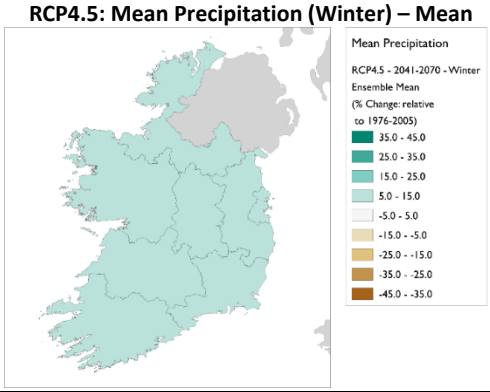
RCP4.5: Mean Precipitation (Annual) – Mean



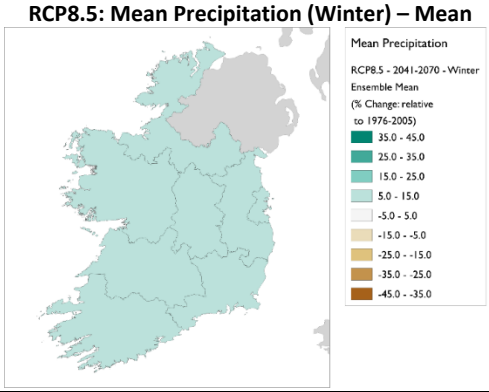
RCP8.5: Mean Precipitation (Annual) – Mean



RCP4.5: Mean Precipitation (Winter) – Mean

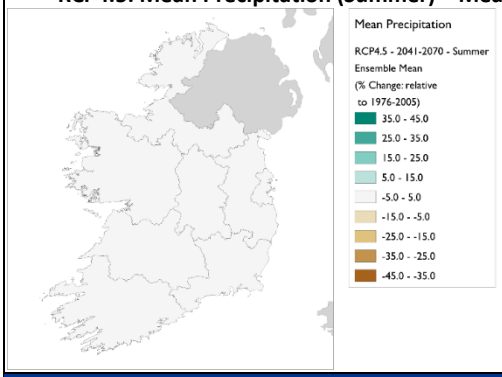


RCP8.5: Mean Precipitation (Winter) – Mean

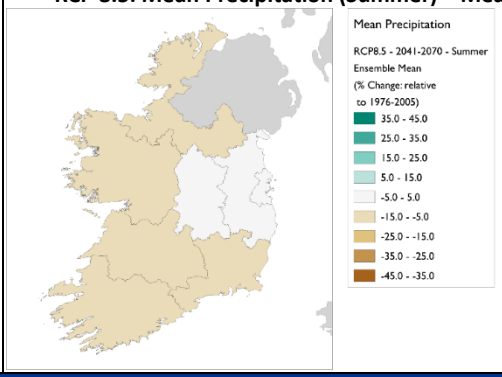


Average Precipitation (Mean Precipitation)

RCP4.5: Mean Precipitation (Summer) – Mean



RCP 8.5: Mean Precipitation (Summer) – Mean



Confidence - Low

- **Agreement:** The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections generally agree that there is an increasing trend for annual precipitation. However, within the national projections, the 10th percentile shows a different trend to the ensemble mean, and the 90th percentile, with the 10th percentile showing decreases in this variable in both scenarios, whereas the ensemble mean and 90th percentile show an increasing trend. See Appendix A for additional statistics and maps.

  For Winter precipitation, within the national projections, the 10th percentile shows a spatial different trend to the ensemble mean, and the 90th percentile, with the 10th percentile showing a decrease in the west of Ireland in Winter precipitation in both scenarios in 2030, and in the RCP4.5 scenario in 2050, whereas the ensemble mean and 90th percentile show an increasing trend.

  For Summer precipitation, within the national projections, the 90th percentile shows a different trend to the ensemble mean, and the 10th percentile, with the 90th percentile showing increases in Summer precipitation in both scenarios, whereas the ensemble mean and 10th percentile show a decreasing trend.

- **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

2.4.3.2 *Extreme Precipitation*

Maximum Consecutive 5-day Precipitation and Very Wet Days (Number of days with rainfall >30mm)

Recent observations or changes

- Historical analysis of recent extreme precipitation trends indicates that in Ireland, the intensity of precipitation is increasing, notably in the East and South-East of Ireland. Additionally, the contribution from heavy and extreme precipitation to annual totals is increasing. However, no persistent trends in annual totals or consecutive wet days have been observed (Ryan et al., 2022).
- During the baseline period (1976 - 2005) there was the average maximum 5-day precipitation was 74.27 mm and there was an average of 1.76 very wet days per year (O'Brien et al., 2023).

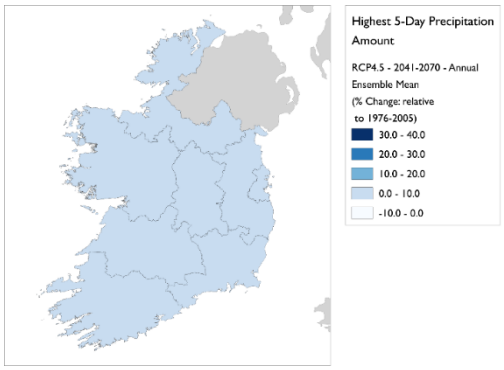
Sub-national zones affected

- At the NUTS 3 level, all regions are projected to experience an increase in intense 5-day precipitation across both scenarios.
- Ireland will also experience an increase in the number of very wet days.

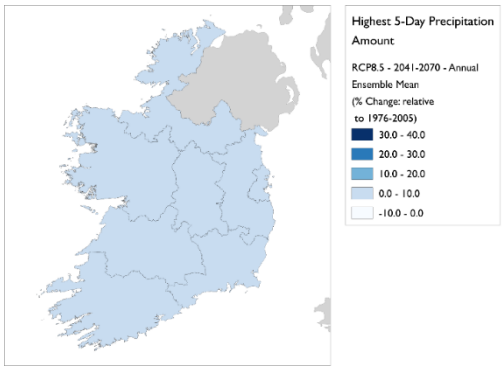
Projected changes by 2050

- **RCP4.5 (Max 5 Day Precipitation):** Nationally, there is a projected increase in the maximum 5-day precipitation of 6.7% (-4.1 - 18.9%) by 2050, with the South-East (9.0% (-2.5-21.0%)) and South-West (9.0% (-1.3-21.2%)) regions experiencing the largest increases.
- **RCP4.5 (Very Wet Days):** Very wet days also indicate a small increasing trend of 0.54 days per year (0.10 – 1.07 days per year).
- **RCP 8.5 (Max 5 Day Precipitation):** Nationally, there is a projected increase in maximum 5-day precipitation by 6.9% (-3.1-18.0%) by 2050, with the Mid-East (9.5% (-3.1-22.8%)) region experiencing the largest increase.
- **RCP 8.5 (Very Wet Days):** Projections for very wet days also indicate a small increasing trend of 0.74 days per year (0.25 – 1.26 days per year).

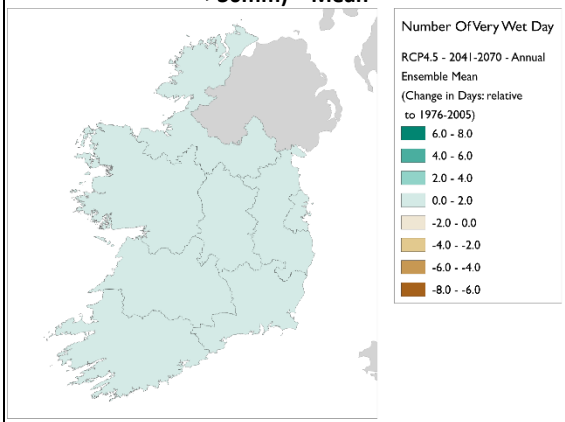
RCP4.5: Maximum consecutive 5-day precipitation – Mean



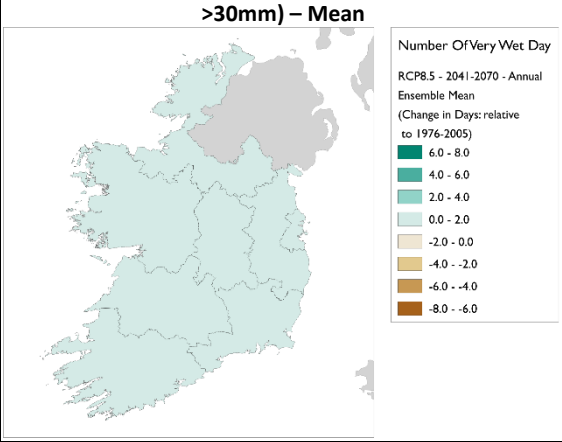
RCP8.5: Maximum consecutive 5-day precipitation – Mean



RCP4.5: Very Wet Days (Number of days with rainfall >30mm) – Mean



RCP8.5: Very Wet Days (Number of days with rainfall >30mm) – Mean



Confidence - Low

- **Agreement:** The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections generally agree that there is an increasing trend for these variables. However, within the national

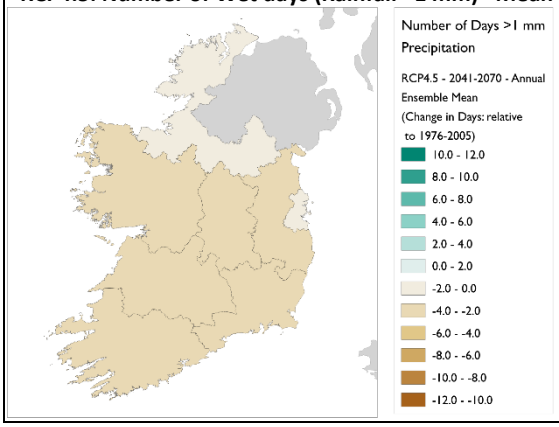
projections, the 10th percentile shows a different trend to the ensemble mean, and the 90th percentile, with the 10th percentile showing decreases in these variables for both scenarios, whereas the ensemble mean and 90th percentile show an increasing trend. See Appendix A for additional statistics and maps.

- **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

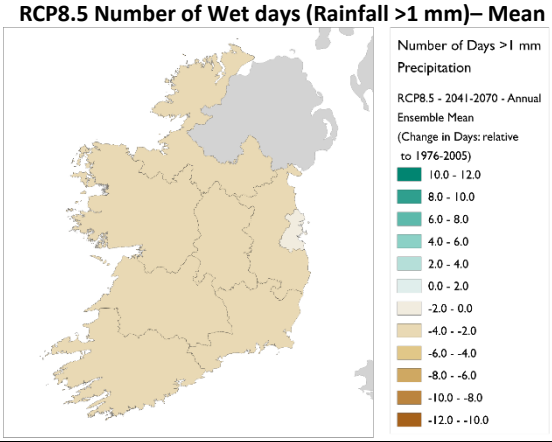
2.4.3.3 Drought

Number of Wet Days (Daily Precipitation >1mm) and SPEI-3 (Standardised Precipitation Evapotranspiration Index – 3 month)
Recent observations or changes
• Ireland in past, subjected to several drought episodes. During 1850 - 2015, seven major droughts events have been identified and analysis of data for a shorter period suggesting an increase in drought conditions notably over the eastern part of Ireland variability (Cámaro García and Dwyer, 2020). • During the baseline period (1976 – 2005) there was an annual average of 188.66 wet days per year (O'Brien et al., 2023). • Analysing the Hydropredict SPEI indices for the reference period (1976-2005) indicates that the summer on average is more prone to droughts (SPEI3 < -1), East and Southern regions are prone to droughts.
Sub-national zones affected
• All zones will be expected to experience a decrease in number of wet days with the East and South-East regions most affected. SPEI-3 index shows that, in summer and spring season, most of the zones indicated an increase in drought conditions and a general decrease in drought condition in other months. East and Southern regions have higher prevalence of drought conditions in summer and spring with Dublin zones showing the lowest SPEI-3 values (-1.74).
Projected changes by 2050
• **RCP4.5 (Wet Days):** Nationally, mean annual number of wet days is expected to decrease by 2.42% (-6.52 – 1.53%) by 2050, with the East region experiencing the largest decrease (3.17%). • **RCP4.5 (SPEI-3):** SPEI-3 shows lower values (<-1) and prevalence of drought conditions in summer season, followed by the spring season with milder drought condition. In winter and autumn seasons, and in all zones, with all positive SPEI-3 values, indicating absence of drought episodes. Compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, mostly decreasing trend in autumn season. • **RCP 8.5 (Wet Days):** Nationally, mean annual number of wet days are expected to decrease by 2.61% (-6.21 – 1.11%) by 2050, with the East region experiencing the largest decrease (-3.28%). • **RCP8.5 (SPEI-3):** SPEI-3 shows lower values (<-1) and higher prevalence of drought conditions in summer season, followed by the spring season with milder drought condition. In winter and autumn seasons, and in all zones, with all positive SPEI-3 values, indicating absence of drought episodes. Compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season.

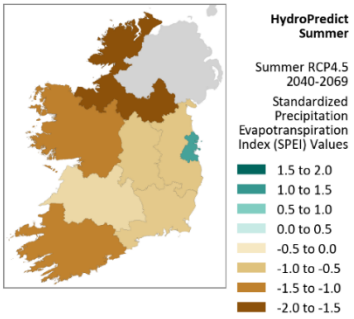
RCP4.5: Number of Wet days (Rainfall >1 mm)– Mean



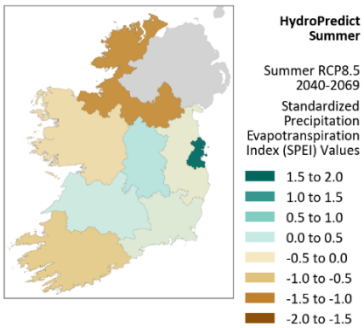
RCP8.5 Number of Wet days (Rainfall >1 mm)– Mean



RCP4.5: SPEI-3



RCP8.5: SPEI-3



Confidence - Low

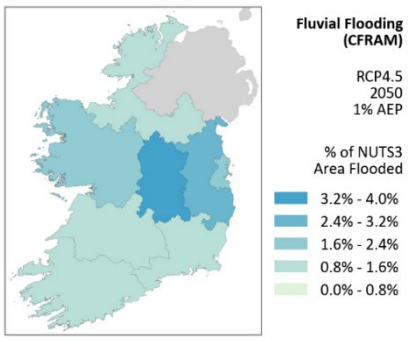
- **Agreement:** The national projections, the 90th percentile shows a different trend to the ensemble mean, and the 10th percentile, with the 90th percentile showing increases in this variable in both scenarios, whereas the ensemble mean and 10th percentile show an increasing trend. See Appendix A for additional statistics and maps.
- **Robustness**: National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform the number of wet days using a robust and peer-reviewed modelling approach. Published peer-reviewed research has been used to inform SPEI-3.

2.4.4 Flooding

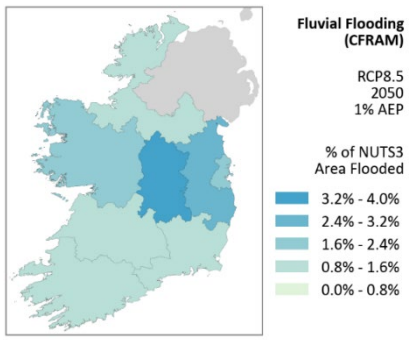
2.4.4.1 Fluvial Flooding

Fluvial Flooding (1% AEP)
Recent observations or changes
• Ireland has been subject to a number of major flood fluvial events over recent decades. Notable or significant past fluvial flood events since 1980 include November 1980, August 1986, January 1995, January 1996, November 2000, November 2002, November 2009, October 2011, June 2012, Winter 2015/16, August 2017, and November 2017 (Flood Risk Management SAP, 2019). • More recently, in October 2023, an extreme 2-day rainfall event caused by Storm Babet brought record rainfall amounts to the south of Ireland, leading to significant flooding, with the town of Midleton, County Cork, severely impacted (Clarke et al., 2024).
Sub-national zones affected
• At the NUTS 3 level, all regions are projected to experience an increase in total land area impacted by flooding with the Midland region most affected.
Projected changes by 2050
• **RCP4.5 (NIFM):** Nationally, under the 1% AEP scenario, NIFM projects that 2.29% of the total land area could be at risk of flooding by 2050. The Midlands region is most at risk, with 3.06% of the total land area impacted. • **RCP4.5 (CFRAM):** Nationally, under the 1% AEP scenario, CFRAM projects that 1.73% of the total land area could be at risk of flooding by 2050. The Midlands region is most at risk, with 3.36% of the total land area impacted. • **RCP 8.5 (NIFM):** Nationally, under the 1% AEP scenario, NIFM projects that 2.29% of the total land area could be at risk of flooding by 2050. The Midlands region is most at risk, with 3.06% of the total land area impacted. • **RCP 8.5 (CFRAM):** Nationally, under the 1% AEP scenario, CFRAM projects that 1.73% of the total land area could be at risk of flooding by 2050. The Midlands region is most at risk, with 3.36% of the total land area impacted.

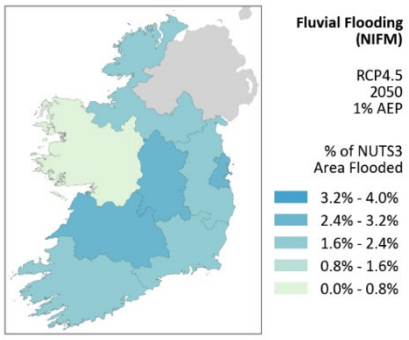
RCP4.5: Fluvial Flooding (1% AEP) - CFRAM



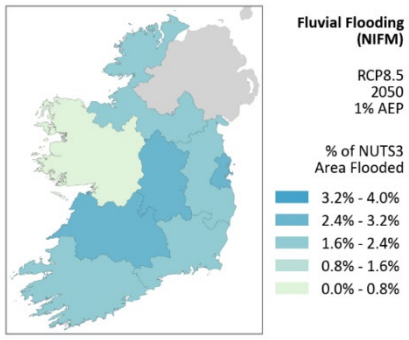
RCP8.5: Fluvial Flooding (1% AEP) - CFRAM



RCP4.5: Fluvial Flooding (1% AEP) - NIFM



RCP8.5: Fluvial Flooding (1% AEP) - NIFM



Confidence - Medium
• **Agreement:** Two assessments of flood extent have been produced by OPW (NIFM and CFRAM) that show an increase in flood extent and frequency in the future. It should be noted that the 1% AEP projections for 2050 for RCP4.5 and RCP8.5 both assume the 1%AEP MRFS value therefore there is no variation numbers for area exposed between scenarios (see the NCCRA Methodology for further information). See Appendix A for additional statistics and maps. • **Robustness:** The change in flood extent and frequency has been assessed by the national authority (OPW) following a rigorous modelling approach, however, projections for changes in daily extreme precipitation are not available therefore to inform the timing of changes in flood extent and frequency, hence a proxy of seasonal changes have been used (TRANSLATE Winter precipitation projections).The NIFM Flood Maps do not account for flood defences.

2.4.4.2 *Surface Water Flooding*

Very Wet Days (Number of days with rainfall >30mm) and Maximum 1-day Precipitation

Recent observations or changes

- Pluvial flooding happens when rainfall surpasses the capacity of urban stormwater drainage systems or the ground's ability to absorb it.
- During the baseline period (1976 - 2005) there was an average of 1.76 very wet days per year (O'Brien et al., 2023).
- Ireland has been subject to a number of major flood pluvial events over recent decades. Notable or significant past floods in Ireland have occurred in October 2011 and June 2012 (Flood Risk Management SAP, 2019).

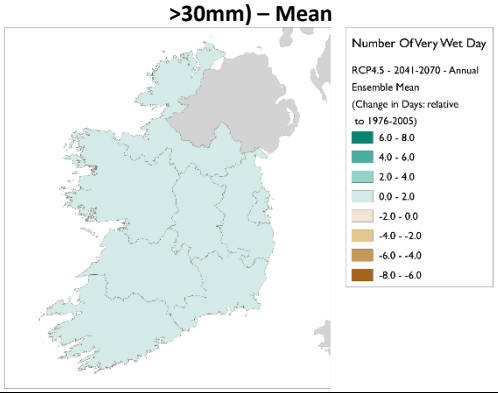
Sub-national zones affected

- At the NUTS 3 level, all regions are projected to experience an increase in very wet days by 2050. Additionally, maximum 1-day precipitation is projected to increase across all regions with the Dublin and West regions experiencing the highest increases.

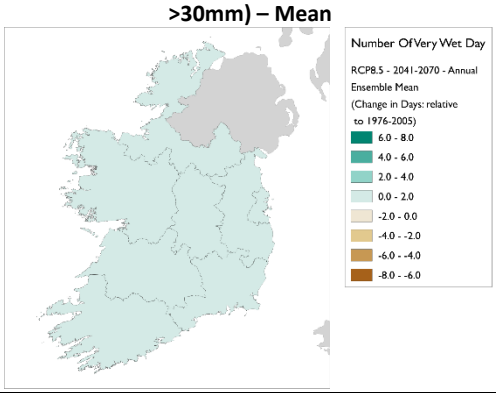
Projected changes by 2050

- **RCP4.5 (Very Wet Days):** Very wet days (above 30 mm of precipitation) indicate a small increasing trend of 0.5 days per year (0.1 – 1.1 days per year).
- **RCP4.5 (Max 1 Day Precipitation):** Nationally, maximum 1-day precipitation is projected to increase by 18.7% (7.1 – 31.8%), with the Dublin (21.4% (6.7-36.0%)) region experiencing the highest increase.
- **RCP 8.5 (Very Wet Days):** Very wet days (above 30 mm of precipitation) indicate a small increasing trend of 0.7 days per year (0.3 – 1.3 days per year).
- **RCP 8.5 (Max 1 Day Precipitation):** Nationally, maximum 1-day precipitation is projected to increase by 22.7% (10.8 – 36.1%), with the Dublin (26.3% (12.0-42.6%) and region experiencing the highest increase.

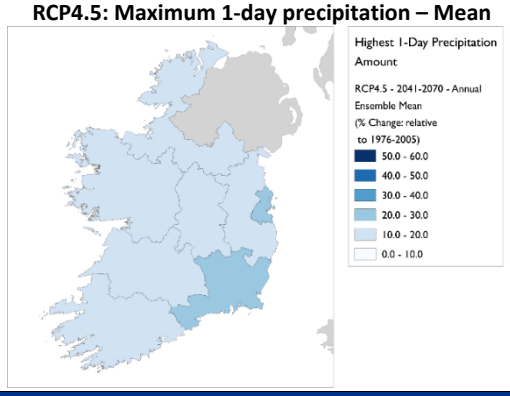
RCP4.5: Very Wet Days (Number of days with rainfall >30mm) – Mean



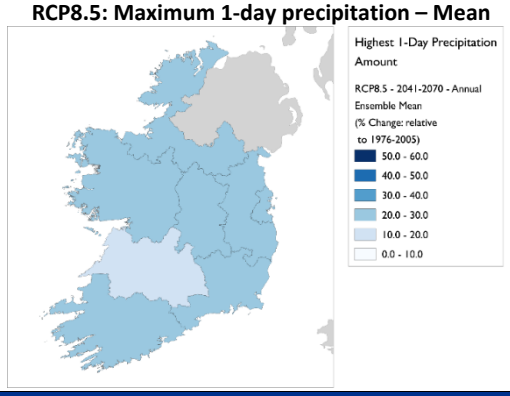
RCP8.5: Very Wet Days (Number of days with rainfall >30mm) – Mean



RCP4.5: Maximum 1-day precipitation – Mean



RCP8.5: Maximum 1-day precipitation – Mean

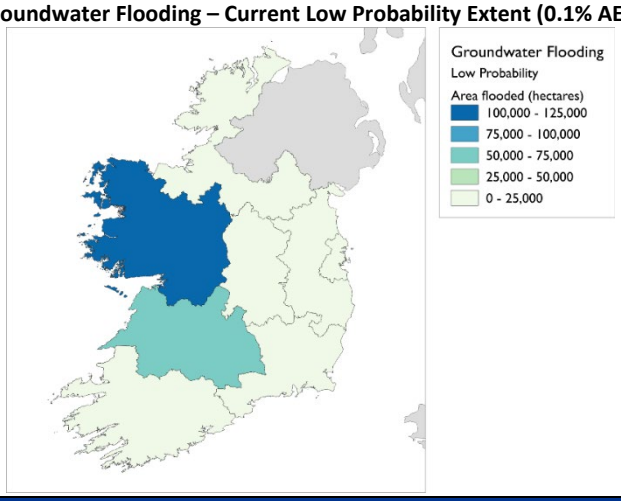


Confidence - Low

- **Agreement:** The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections generally agree that there is an increasing trend for these variables. However, within the national projections, the 10th percentile shows a different trend to the ensemble mean, and the 90th percentile, with the 10th percentile showing decreases in these variables for both scenarios, whereas the ensemble mean and 90th percentile show an increasing trend. See Appendix A for additional statistics and maps.

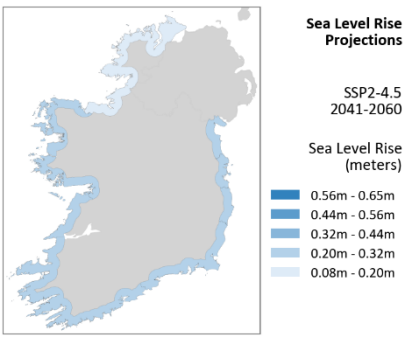
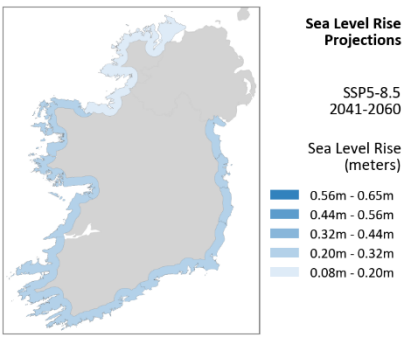
- **Robustness:** No modelling currently exist that show the current or future extents of surface water flooding events, therefore proxies of Very Wet Days (Number of days with rainfall >30mm) and Maximum 1-day Precipitation have been used. National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform these variables using a robust and peer-reviewed modelling approach.

2.4.4.3 Groundwater Flooding

Groundwater Flooding
Recent observations or changes
• Groundwater Flooding in Ireland is primarily associated with the limestone areas of the western lowlands, which extend from the River Fergus in Co. Clare in the south upwards to the areas east of Lough Mask and Corrib in Co. Galway and southern Co. Mayo (McCormack et al., 2020). • Floods during the winters of 2009/2010 and 2015/2016 caused widespread damage and disruption to communities across the country, particularly in the extensive karstic limestone lowlands on the western seaboard (McCormack et al., 2020).
Sub-national zones affected
• There are currently no national-scale projections for groundwater flooding in Ireland under the RCP4.5 and RCP8.5 scenarios for 2050.
Groundwater Flooding – Current Low Probability Extent (0.1% AEP) 
Confidence - Low
• **Agreement:** There are no projections available on the changes in groundwater flood extent and frequency currently available. • **Robustness:** National groundwater flood extents have been developed for Ireland, however, a number of limitations apply as outlined in McCormack et al. (2020), i.e., not all sources of groundwater flooding were mapped.

2.4.5 Coastal

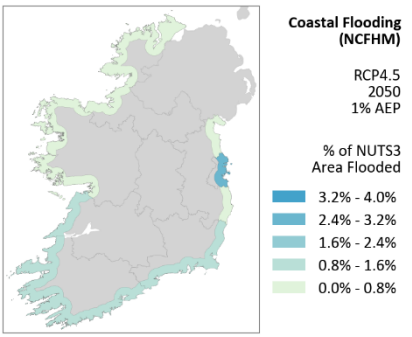
2.4.5.1 Sea Level Rise

Sea Level Rise
Recent observations or changes
• Past relative sea level rise (SLR) in the northeastern Atlantic region shows an increasing trend at 1.2 mm/yr (1950-2014) with strong decadal variability from the Atlantic Multidecadal Oscillation (van den Hurk et al. 2024). • Recent studies have shown that in Ireland (Cork and Dublin), sea level rise rates are higher than the global SLR since the late 20th century (Noone et al. 2024). • Using the long-term sea-level record from Dublin port, estimated that long term SLR is 1.1 mm yr^{-1}(1953-2016) and a recent increase of SLR of 7 mm yr^{-1} (1997-2006) (Nejad et al. 2022). This recent increase is mainly attributed to large multi decadal variability. • Mean Sea Level measurements from Cork Harbour, indicates a 2.2 mm yr^{-1} SLR rate using data from 1842 to 2019-2020 (Pugh et al., 2021).
Sub-national zones affected
• The sea level around Ireland is projected to rise under both RCP4.5 and RCP8.5 scenarios by 2050 affecting all coastal NUTS3 regions.
Projected changes by 2050
• **RCP4.5:** Sea levels around Ireland are projected to increase with the sea level rise of 0.24 m (South West) for 2041-2060 with a maximum sea level rise of 0.32 m (0.15 - 0.55 m) by 2060 (longitude: 50, latitude: -10). • **RCP 8.5:** Sea levels around Ireland are projected to increase with the sea level rise of 0.26 m (South West) for 2041-2060 with a maximum sea level rise of 0.35 m (0.17 - 0.60 m) by 2060 (longitude: 50, latitude: -10).
RCP4.5: Sea Level Rise 
RCP8.5: Sea Level Rise 
Confidence - High
Agreement: National and global observations of sea level and climate projections for both scenarios show an increase in sea level around Ireland. There is uncertainty surrounding future sea level rise due to low probability events, such as rapid ice sheet collapse, which, despite their low likelihood, could lead to large increases in sea levels. See Appendix A for additional statistics and maps. **Robustness:** Global projections been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6.

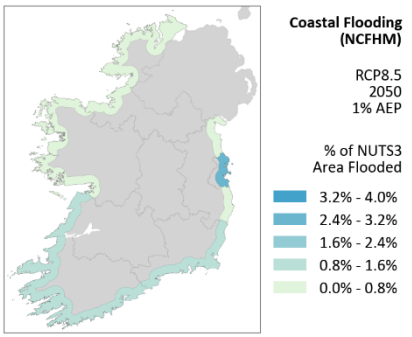
2.4.5.2 Coastal Flooding

Coastal Flooding
Recent observations or changes
• Coastal flooding poses a significant threat, especially in low-lying areas along the east coast from Dundalk to Dublin and the Wicklow to Wexford coast. The south coast, including Waterford, Dungarvan, Youghal, and Cork City, as well as the west coast areas like Galway City and the Shannon Estuary, are also at high risk (Climate Ireland, 2023).
Sub-national zones affected
• At the NUTS 3 level, all coastal regions are projected to experience an increase in total land area impacted by coastal flooding.
Projected changes by 2050
• **RCP4.5:** Nationally, under the 1% AEP scenario, NCFHM projects that 0.95% of the total land area could be at risk of coastal flooding by 2050. The Dublin region is most at risk, with 2.41% of the total land area impacted. • **RCP 8.5:** Nationally, under the 1% AEP scenario, NCFHM projects that 0.95% of the total land area could be at risk of coastal flooding by 2050. The Dublin region is most at risk, with 2.41% of the total land area impacted.

RCP4.5: Costal Flooding – NCFHM

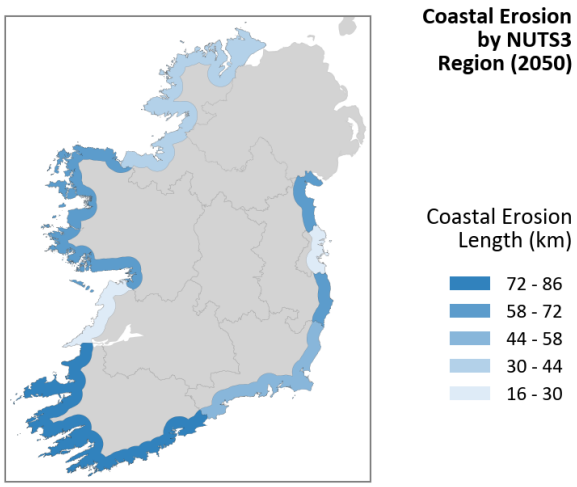


RCP8.5: Costal Flooding – NCFHM



Confidence - High
• **Agreement:** National and global projections for sea level rise show an increase, which will result in an increase in coastal flood extent and frequency. See Appendix A for additional statistics and maps. • **Robustness:** The change in flood extent and frequency has been assessed by the national authority (OPW) following a rigorous modelling approach, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used. The NCFHM Flood Maps do not account for flood defences

2.4.5.3 Coastal Erosion

Coastal Erosion
Recent observations or changes
• Ireland is exposed to coastal erosion risk primarily because majority of the populated areas are located close to the sea, and in particular coastal zones with softer sediments (Devoy, 2008; Thorne et al., 2023) • 19.9% Ireland's coast already experiencing coastal erosion (EUROSION, 2004). • Sea level rise, along with tides, storm surges, waves, are some of the environmental factors that can drive coastal erosion (van de Wal et al., 2024)
Sub-national zones affected
• At the NUTS 3 level, all coastal regions are projected to experience an increase in coastal erosion rates.
Projected changes by 2050
• The length of coastline projected to be at risk of coastal erosion in Ireland by 2050 is 328 km. The South-West (85 km) and South-East (46 km) regions are most at risk (Irish Coastal Protection Strategy Study ()). However, the effects of climate change have not been included within this assessment (ICPSS, RPS Consulting Engineers (2010)).
Costal Erosion- ICPSS 2010-2014: NUTS3 Region 
Confidence - Low
• **Agreement:** Research highlights that increases in sea level are expected to result in coastal change (erosion or accretion), however, the impact (spatial extent and rates of change) this will have on Ireland's coastline is currently unknown. • **Robustness:** There are no national scale projections for coastal change (erosion or accretion) available, however, a standard approach of extrapolation of existing rates of erosion have been used for the 2050 time horizon and does not include the effects of climate change.

2.4.6 Wind

2.4.6.1 Extreme Wind

Extreme Wind Days (Daily 10 m Wind Speed Exceeding the 98th Percentile Threshold) and Surface Wind Speed (10 m)

Recent observations or changes

- Between 1991 and 2020, the annual mean hourly wind speed ranges from 9 knots at Shannon airport to 15 knots at Malin Head (Met Éireann, 2023). Historical wind trends in Ireland do not show a robust signal, as they are mostly dominated by decadal variability (Cámaro García and Dwyer, 2020).
- A recent study identified the 2013/14 winter as the stormiest in records dating back to 1871. The study utilised a metric based on storm frequency and intensity derived from reanalysis data (Matthews et al, 2014, 2016).

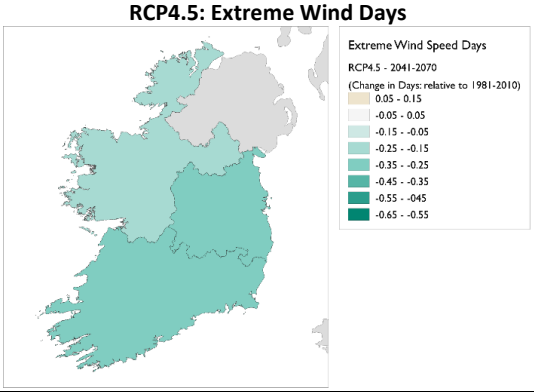
Sub-national zones affected

- At the NUTS 2 level, projected Extreme wind days index anomaly (from 1981-2010) shows the Northern and Western region with the largest decrease in extreme wind days (-0.62 days).

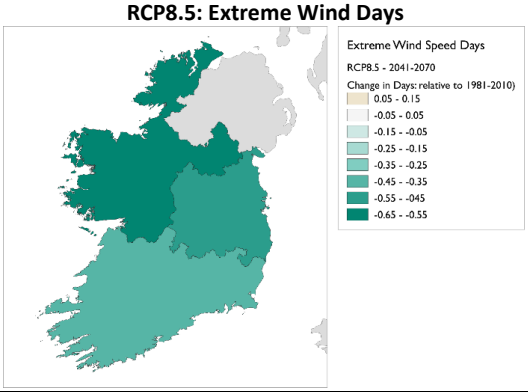
Projected changes by 2050

- **RCP4.5:** Overall, Ireland is projected to experience a small decrease in extreme wind days, with the Northern and Western region showing the largest decrease (-0.32 days) from the 1981-2010 baseline.
- **RCP4.5:** There is a projected small reduction in the 10-m wind speed of 1.0–2.7% (mean value 1.8%) compared to the 1981-2000 baseline.
- **RCP 8.5:** Overall, Ireland is projected to experience a small decrease in extreme wind days, with the Northern and Western region showing the largest decrease (-0.61 days) from the 1981-2010 baseline.
- **RCP: 8.5:** There is a projected small reduction in the 10-m wind speed of 1.6–3.3% (mean value 2.6%) compared to the 1981-2000 baseline.

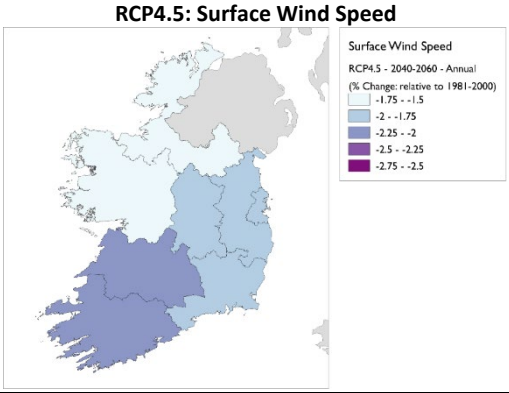
RCP4.5: Extreme Wind Days



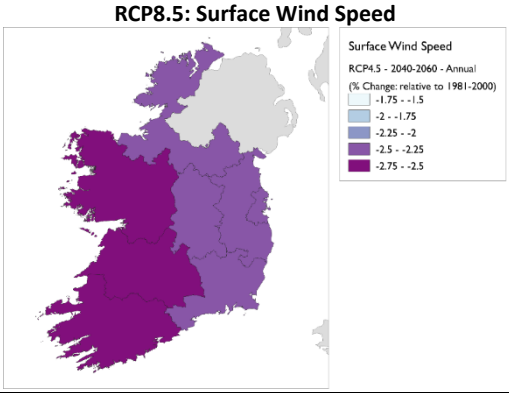
RCP8.5: Extreme Wind Days



RCP4.5: Surface Wind Speed



RCP8.5: Surface Wind Speed



Confidence – Very Low

- **Agreement:** There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. See Appendix A for additional statistics and maps.
- **Robustness:** National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used, plus national scale data for average wind speed have been used as a proxy.

2.4.7 Marine

2.4.7.1 Ocean Acidification

Ocean Acidification (pH at surface)

Recent observations or changes

- Increased carbon concentrations from human activities have been detected not only at the ocean surface but also at depths of 2500 m and potentially reaching 5000 m in the North Atlantic (Nolan et al., 2023).
- Observations in the Rockall Trough show a decrease in pH by 0.04 units in subsurface waters (200-500 m) and by 0.03 units in deeper waters (1500-2000 m) where Labrador Sea Water is found, indicating significant acidification over time (Nolan et al., 2023).

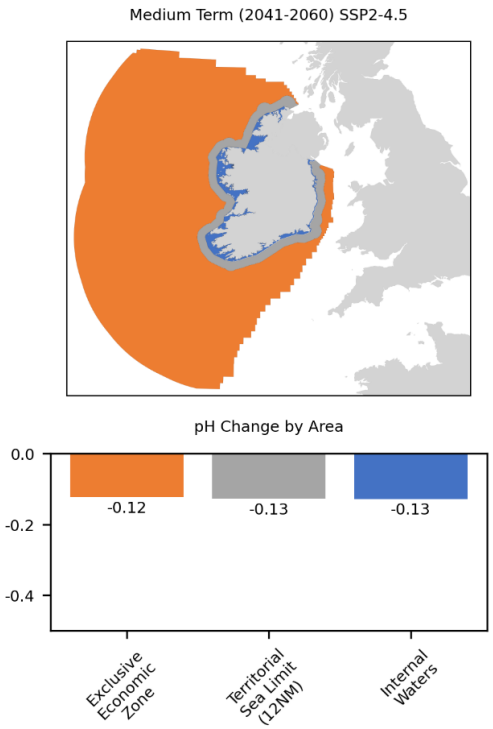
Sub-national zones affected

- Inland Waters, Transitional Waters, and the Exclusive Economic Zone waters around Ireland are all projected to experience ocean acidification (a decrease in pH) by 2050.

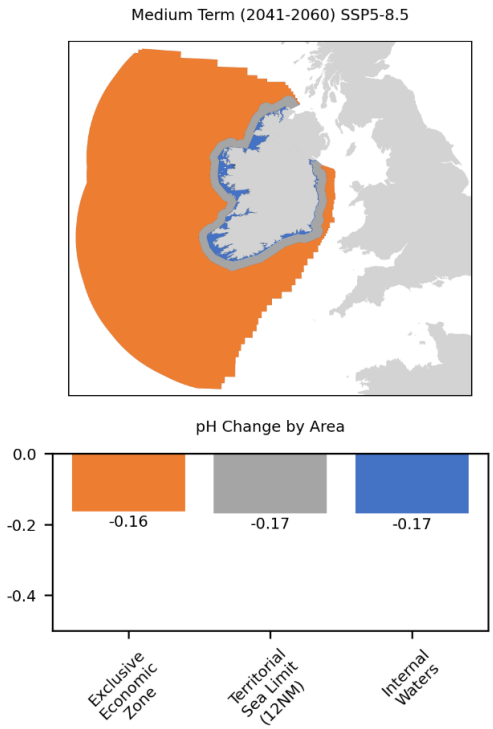
Projected changes by 2050

- **RCP4.5:** The projected mean change in pH at the surface for 2041-2060 relative to 1995-2014:
  - Inland Waters: -0.13
  - Transitional Waters: -0.13
  - Exclusive Economic Zone: -0.12
- **RCP 8.5:** The projected mean change in pH at the surface for 2041-2060 relative to 1995-2014:
  - Inland Waters: -0.17
  - Transitional Waters: -0.17
  - Exclusive Economic Zone: -0.16

RCP4.5: Ocean Acidification (pH at surface)



RCP8.5: Ocean Acidification (pH at surface)



Confidence - Medium

- **Agreement:** Across both scenarios there is a decrease in pH at the surface identified in all waters surrounding Ireland. This aligns the global trend of increasing ocean acidity due to climate change. See Appendix A for additional statistics and maps.
- **Robustness:** Global projections been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment

Report 6, however, no national downscaled projections exist.

2.4.7.2 Sea Surface Temperature

Sea Surface Temperature

Recent observations or changes

- Temperature records from Malin Head Coastal station show significant warming trend from 1960 to 2020 period, with 0.3°C per decade (Cornes et al., 2023).
- Irish waters have warmed since the 1980s, with the highest annual sea surface temperature recorded in 2007 at over 0.8°C above the 1960–1990 average. Recent years have seen a cooling trend of -0.3°C per decade., although they remain 0.4°C warmer in the 21st century relative to 1960–1990 (Nolan et al., 2023).
- In the summer of 2023, the North Atlantic experienced its highest sea-surface temperatures since 1982, leading to a severe marine heatwave west of Ireland, with SSTs reaching up to 4°C above average (McCarthy, et al., 2023).

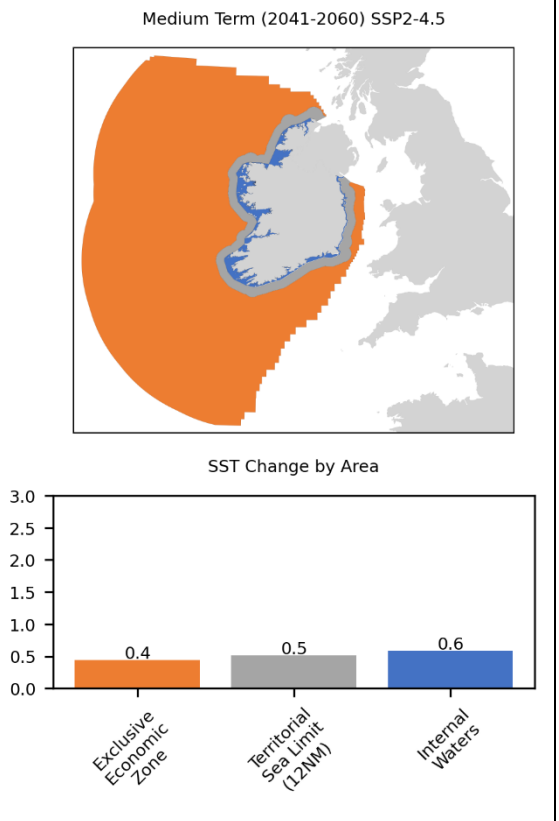
Sub-national zones affected

- Inland Waters, Transitional Waters, and the Exclusive Economic Zone waters around Ireland are all projected to experience an increase in sea surface temperature by 2050

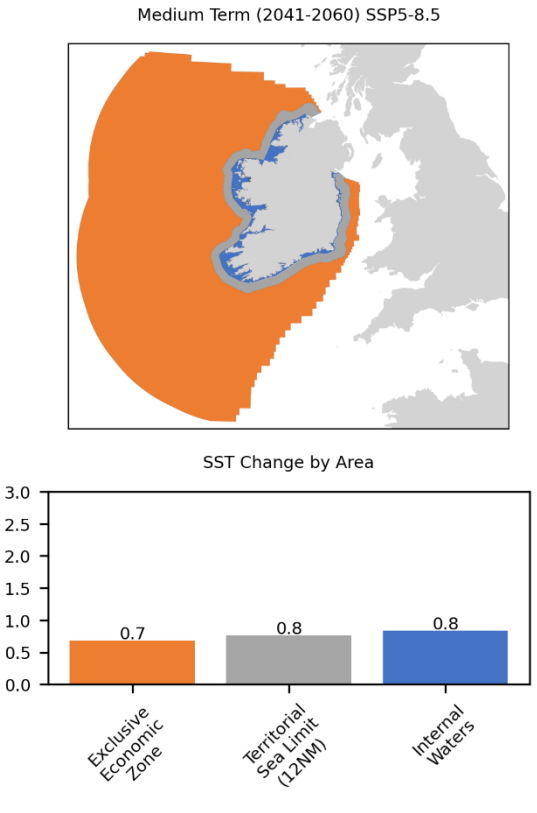
Projected changes by 2050

- **RCP4.5:** The projected mean change in sea surface temperature for 2041-2060 relative to 1995-2014:
  - Inland Waters: 0.6°C (0.4-0.9°C)
  - Transitional Waters: 0.5°C (0.3-0.8°C)
  - Exclusive Economic Zone: 0.4°C (0.3-0.8)
- **RCP 8.5:** The projected mean change in sea surface temperature for 2041-2060 relative to 1995-2014:
  - Inland Waters: 0.8°C (0.6-1.2°C)
  - Transitional Waters: 0.8°C (0.6-1.2°C)
  - Exclusive Economic Zone: 0.7°C (0.5-1.1°C)

RCP4.5: Sea Surface Temperature



RCP8.5: Sea Surface Temperature



Confidence - Low

- **Agreement:** Across both scenarios there is an increase in sea surface temperature identified in all waters surrounding Ireland. This aligns the global trend of increasing sea surface temperature due to climate change. See Appendix A for additional statistics and maps.
- **Robustness:** Global projections been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6, however, no national downscaled projections exist.

2.4.8 Other

2.4.8.1 Lightning

Lightning
Recent observations or changes
• In Ireland, 2011 to 2019, time series data shows that lightning usually occurs during the summer months also exhibit strong annual variability. The majority of lightning strikes occurs over of sea area than land (Cámaro García and Dwyer, 2020). • Time series of lightning over the land and sea indicates no discernible trend (Cámaro García and Dwyer, 2020)
Sub-national zones affected
• No projections are available.
Projected changes by 2050
• **RCP4.5:** No projections are available. • **RCP 8.5:** No projections are available.
Confidence – Very Low
• **Agreement:** There are very limited number of projections for changes in lightning in Ireland. • **Robustness:** The projections for Ireland are obtained from a peer-reviewed publication, however, the research takes a European focus, rather than Irish focus.

2.4.8.2 Changes in Phenology

Changes in Phenology (Growing Season Start (First annual instance of 6 consecutive days where mean temperature > 5˚C) and Growing Season Length (Number of days between growing season start and end))

Recent observations or changes

- During the baseline period (1976 - 2005) the average growing season length was 314.27 days. The growing season started on the 30.5th day of the year during this period (O'Brien et al., 2023).

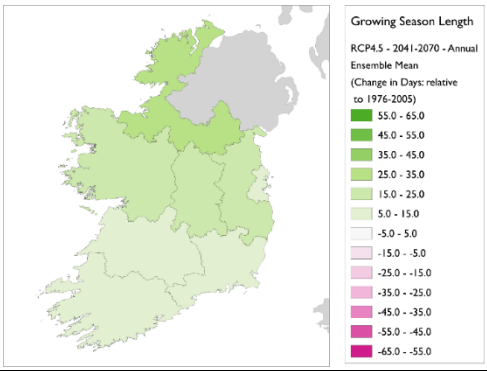
Sub-national zones affected

- At the NUTS 3 level, all regions are projected to experience changes in phenology, with the Border, Midlands, Mid-East and Dublin regions experiencing the largest decreases in growing season start, and largest increases in growing season length in RCP4.5 and RCP8.5 scenarios.

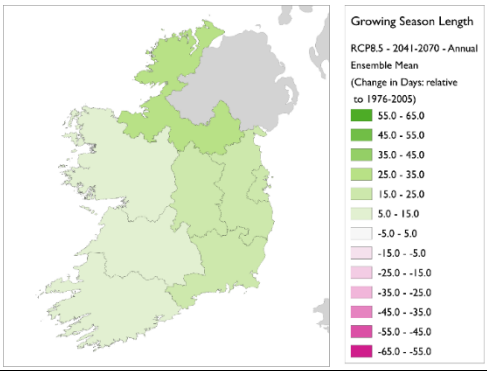
Projected changes by 2050

- **RCP4.5 (Growing Season Length):** Nationally, growing season length is projected to increase by 19.70 days (-5.9 – 40.9) by 2050, with the Border (28.0 days (-0.5-52.5 days)), region experiencing the highest increases.
- **RCP4.5 (Growing Season Start):** Considering the growing season start, it is projected to be occur earlier by -5.1 days (-23.0 – 18.7) by 2050.
- **RCP 8.5 (Growing Season Length):** Nationally, growing season length is projected to increase by 19.8 days (-15.6 – 43.8) by 2050, with the Border (26.5 days (15.6-57.2 days)) region experiencing the highest increase.
- **RCP 8.5 (Growing Season Start):** Considering the growing season start, it is projected to occur earlier by -7.9 days (-21.4 – 25.5) by 2050.

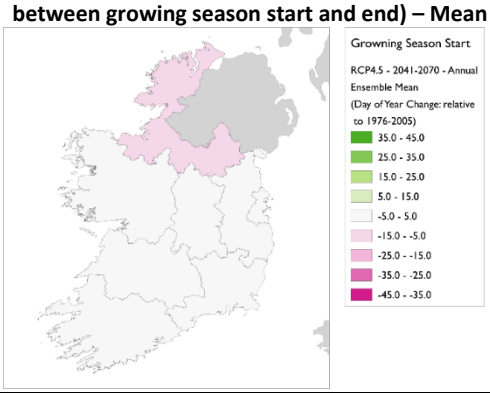
RCP4.5: Growing Season Length (First annual instance of 6 consecutive days where temperature mean > 5˚C) – Mean



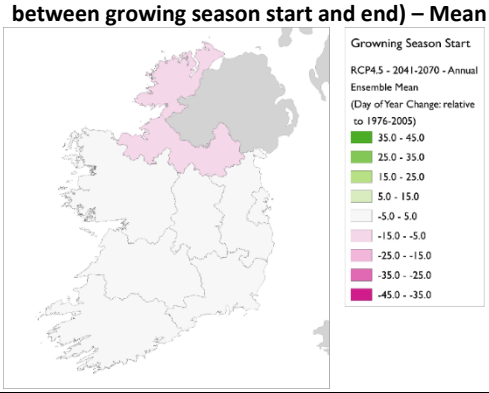
RCP8.5: Growing Season Length (First annual instance of 6 consecutive days where temperature mean > 5˚C) – Mean



RCP4.5: Growing Season Start (Number of days between growing season start and end) – Mean



RCP 8.5: Growing Season Start (Number of days between growing season start and end) – Mean



Confidence - Medium

- **Agreement:** For Growing Season Length, within the national projections, the 10th percentile shows a different trend to the ensemble mean, and the 90th percentile, with the 10th percentile showing decreases in the Growing Season Length for 2030 and 2050 and increases in 2100 in both scenarios, whereas the ensemble mean and 90th percentile show a decreasing trend across all time periods.
  For Growing Season Start, within the national projections, the 90th percentile shows a different trend to the ensemble mean, and the 10th percentile, with the 90th percentile showing increases in the Growing Season

Start for 2030 and 2050 and decreases in 2100 in both scenarios, whereas the ensemble mean and 10th percentile show a decreasing trend across all time periods. See Appendix A for additional statistics and maps.

- **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

2.4.9 Low-Likelihood High-Impact Events

Climate change poses numerous challenges, but among the most concerning are Low Likelihood High Impact events. These are extreme occurrences that, while unlikely, can have devastating consequences. Tipping points are critical thresholds within the Earth's climate system that, when crossed, can lead to significant and often irreversible changes.

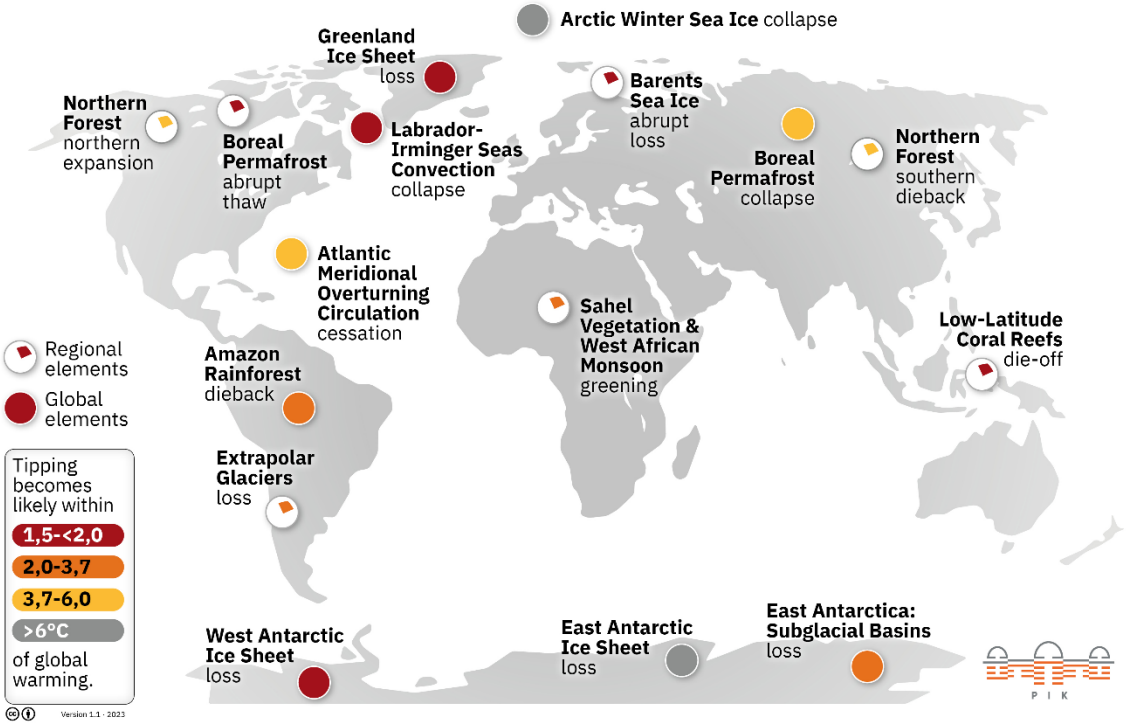


Figure 2.2: The geographical distribution of global and regional tipping elements, color-coded according to the best estimate for their temperature thresholds, beyond which the element would likely be 'tipped'. Figure designed at Potsdam Institute for Climate Impact Research (2023), based on Armstrong McKay et al., (2022).

Key environmental tipping points that can occur as a result of climate change are described by Armstrong McKay et al., (2022) (Figure 2.2), and include:

- **Atlantic Meridional Overturning Circulation (AMOC) Changes:** The AMOC is a crucial component of the global ocean circulation system, responsible for transporting warm water from the tropics to the North Atlantic. [4] A significant weakening or collapse of the AMOC could lead to drastic climate changes, including severe cooling in Northern Europe, increased storminess,

[4] Further information on the AMOC is available at https://www.met.ie/the-evolution-of-the-atlantic-meridional-overturning-circulation-amoc

and shifts in precipitation patterns. For Ireland, this could mean harsher winters, more frequent and intense storms, and disruptions to marine ecosystems.

- **Greenland and West Antarctic Ice Sheet Collapse:** The Greenland and West Antarctic Ice Sheets hold vast amounts of ice, and their collapse could lead to a significant rise in sea levels. This would exacerbate coastal erosion and flooding, posing a severe risk to Ireland's coastal communities and infrastructure. The dire consequences of such events would impact coastal regions worldwide, including Ireland.

- **Arctic Sea Ice Loss:** The loss of Arctic sea ice reduces the Earth's albedo, meaning less sunlight is reflected back into space, leading to further warming. This can accelerate climate change and impact weather patterns, potentially leading to more extreme weather events in Ireland.

- **Amazon Rainforest Dieback**: The Amazon rainforest is a critical component of the Earth's climate system. A tipping point could be reached where large-scale deforestation and climate change cause the rainforest to transition to a savannah-like state. This would release vast amounts of carbon dioxide, further accelerating global warming and impacting global climate patterns, including those affecting Ireland.

- **Boreal Forest Dieback:** Boreal forests, which span across the northern hemisphere, are vital carbon sinks. A dieback due to increased temperatures and changing precipitation patterns could release significant amounts of carbon dioxide, exacerbating global warming and affecting climate patterns in Ireland.

- **Permafrost Thaw:** Thawing permafrost in the Arctic can release large amounts of greenhouse gases, such as methane and carbon dioxide, into the atmosphere. This can accelerate global warming and lead to more extreme weather events. The resulting changes in climate patterns could impact Ireland's agriculture, water resources, and overall climate stability.

- **Coral Reef Die-off:** Coral reefs are highly sensitive to temperature changes and ocean acidification. A tipping point could lead to widespread coral die-offs, which would disrupt marine ecosystems and fisheries. While Ireland is not directly affected by tropical coral reefs, the global impact on marine biodiversity and fisheries could have indirect effects.

- **East Antarctic Ice Sheet Instability:** Although less likely than the West Antarctic Ice Sheet, instability in the East Antarctic Ice Sheet could also contribute to significant sea level rise. This would further exacerbate the risks to coastal regions, including Ireland.

The NCCRA did not consider Low-Likelihood High-Impact events in determining risks and their consequences due to the uncertainties associated with these phenomena. The assessment focused on more predictable scenarios, adhering to the Representative Concentration Pathways (RCP) 4.5 and 8.5. These pathways represent intermediate and high greenhouse gas concentration scenarios, respectively, and provide a more reliable basis for projecting future climate impacts. However, the exclusion of Low-Likelihood High-Impact events means that the potential for sudden and severe climate shifts, which could have profound effects on Ireland, remains an area of concern that requires further research and monitoring.

3 Biodiversity and Ecosystems

3.1 System Description

Biodiversity and Ecosystems describe the diverse set of natural habitats and their various ecological functions. The Biodiversity and Ecosystems system is made up of several sub-systems, including forests, freshwater systems, peatlands, and terrestrial ecosystems.

Each of these sub-systems also consists of elements at risk from climate change. Elements at risk within forests can include trees and managed forests. Peatlands encompass bogs and flora and fauna as elements at risk. Terrestrial ecosystems capture all elements of terrestrial ecosystems impacted by climate change risks, including flora and fauna, karst landscapes, forests, and riparian zones. Freshwater systems capture flora and fauna, lakes, rivers, and streams.

Ireland's biodiversity and ecosystems are already experiencing significant pressures and of the 59 habitats listed for Ireland in EU Habitats Directive (92/43/EEC), most have an unfavourable status with almost half showing ongoing declines (NPWS, 2019a). This means that the Biodiversity and Ecosystem System will be further strained by the compounding effects of climate change, making it more difficult for the system to adapt and recover in the face of the additional impacts of climate change.

Biodiversity and Ecosystems has an impact on other policy sectors for adaptation. The sub-systems and elements at risk within the Biodiversity and Ecosystem system are particularly relevant for the adaptation sectors of Biodiversity, Water Quality, Flood Risk Management, Built and Archaeological Heritage, Agriculture, Forestry, and Tourism.

3.2 Summary of Climate Change Risks

Table 3.1 shows a summary of the consequences for the risks identified to the Biodiversity and Ecosystems System under both RCP4.5 and RCP8.5 scenarios across three-time horizons (2030, 2050, and 2100).

Table 3.1: Summary of Climate Change Risks in the Biodiversity and Ecosystems System. Lim = Limited, Sub = Substantial, Cri = Critical, Cat = Catastrophic.

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
B01	Risk of increased landslide susceptibility due to changes in average precipitation and extreme precipitation	Lim	Lim	Lim	Lim	Lim	Sub
B02	Risk of damage to forests due to flooding (fluvial, surface water, and groundwater)	Lim	Lim	Lim	Lim	Lim	Lim
B03	Risk of increased stress and tree mortality within forests due to increased dispersal and survival of pests and diseases as a result of changing climate conditions	Lim	Sub	Cri	Lim	Sub	Cri
B04	Risk of damage to forests due to wildfire	Sub	Sub	Sub	Sub	Sub	Cri
B05	Risk of reduced yields from managed forests due to phenological changes	Lim	Sub	Sub	Lim	Sub	Cri
B06	Risk of damage to forests due to extreme wind	Sub	Sub	Sub	Sub	Sub	Sub
B07	Risk of deterioration of freshwater quality due to overland flows as a result of flooding (fluvial, surface water, and groundwater)	Sub	Sub	Cri	Sub	Sub	Cri
B08	Risk of alteration of freshwater flora and fauna due to changes in freshwater temperature	Lim	Sub	Cri	Lim	Sub	Cri
B09	Risk of decreased freshwater quality (i.e., low assimilative capacity, low levels of dissolved oxygen) due to reduced water flows as a result of drought conditions	Sub	Sub	Cri	Sub	Sub	Cri
B10	Risk of degradation/loss of peatland ecosystems and habitats due to extreme heat and drought conditions	Sub	Sub	Cri	Sub	Sub	Cri
B11	Risk of degradation and loss of terrestrial ecosystems due to extreme cold	Lim	Lim	Lim	Lim	Lim	Lim
B12	Risk of increased landslide susceptibility due to the degradation of terrestrial ecosystems as a result of changes in climate conditions	Lim	Lim	Lim	Lim	Lim	Lim
B13	Risk of degradation and loss of terrestrial habitats due to flooding (fluvial, surface water, and groundwater)	Lim	Lim	Lim	Lim	Lim	Lim
B14	Risk of degradation and loss of terrestrial habitats due to extreme heat and drought conditions	Lim	Sub	Sub	Lim	Sub	Cri
B15	Risk of terrestrial ecosystem and habitat disturbance as a result of increased outdoor recreation due to increases in average temperature	Lim	Sub	Sub	Lim	Sub	Sub

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
B16	Risk of increases in occurrence of invasive species resulting in habitat disturbance due to changes in climate conditions	Lim	Sub	Cri	Lim	Sub	Cri
B17	Risk of degradation and loss of terrestrial ecosystems and habitats due to phenological changes	Lim	Sub	Cri	Lim	Sub	Cri

3.3 Risks

3.3.1 B01 Risk of increased landslide susceptibility due to changes in average precipitation and extreme precipitation

3.3.1.1 Risk Summary

Table 3.2: B01 Risk of increased landslide susceptibility due to changes in average precipitation and extreme precipitation.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased landslide susceptibility due to changes in average precipitation and extreme precipitation	Limited	Limited	Limited	Limited	Limited	Substantial
Urgency	Sustain Current Action					
Hazard Confidence	Low					
Consequence Confidence	High					

Changes in average precipitation and the frequency of extreme precipitation events due to climate change are expected to destabilise slopes and therefore increase susceptibility to landslides. Areas with steep terrain, loose soil, and areas that have been recently deforested or with land disturbances are particularly vulnerable.

3.3.1.2 Exposure and Vulnerability

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5.0 % (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios.

In terms of seasonality, the winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) and 20.9% (10.0-33.0%), (RCP8.5) by 2100. The summer season is expected to see a decrease in precipitation of -2.0% (-12.9 - -6.8%) (RCP4.5) and -7.3% (-21.8 - -6.6%). (RCP8.5) by 2100. All NUTS3 regions are projected to experience an increase in five-day precipitation across both RCP4.5 (10.2% (0.4 - 21.1%) by 2100) and

RCP8.5 (16.5% (3.8 - 31.4%) by 2100). Similarly, each region will see an increase in the number of very wet days under both RCP4.5 (an increase of 0.8 days (0.3 - 1.3 days per year) by 2100) and RCP8.5 (an increase of 1.4 days (0.7-2.1 days per year) by 2100).

The GSI Landslide Susceptibility Map shows that all NUTS3 Regions have areas that can be considered highly susceptible to landslides.

Forested areas may be vulnerable to this risk, including areas of managed forests which have recently been subject to harvesting activity. Other land management uses are also exposed to this risk (e.g., peatland and grassland). According to the GSI Landslide Susceptibility Map, 3.5% of Ireland's area has High susceptibility, with all NUTS3 regions containing areas with this level of susceptibility.

Ireland's Forest Strategy (2023-2030) sets an ambition of 18% forest cover nationally by 2050. This will entail the planting of an additional 450,000 hectares of new forests over the next 25 years, increasing the size and potentially broadening the distribution of this exposure.

3.3.1.3 Adaptation

To address the increased risk of landslides due to changes in precipitation patterns, several adaptation measures are in place. The following measures collectively aim to enhance resilience against landslides and ensure sustainable land management practices.

Reliability

- *Policy and Governance:* The Climate Action Plan and related forestry strategies are implemented to support sustainable land management. Effective resource allocation and integration of adaptation measures into broader climate resilience efforts are ensured.
- *Monitoring and Early Warning Systems:* Ongoing monitoring of water-related factors, such as soil moisture levels and precipitation patterns, is part of the DAFM assessment for forestry grants and applications.

- *Risk Assessment:* The Geological Survey of Ireland (GSI) have developed a Landslide Susceptibility Map to map spatial distribution of exposure.

Resistance

- *Forest Cover Enhancement***:** The Forestry Programme 2023-2027 includes a range of forest types for afforestation, following the principles of sustainable forest management.
- *Community Engagement and Education: DAFM Forestry provide guidance and best practice for forestry operations in relation to water systems (DAFM 2024).*
- *Research and Development:* Riparian zones are established to stabilise banks and reduce landslide risks. Research is conducted on the effectiveness of these zones and other forestry practices.

Recovery and Response

- *Knowledge Transfer and Training:* Capacity-building initiatives for forest managers and stakeholders are included through the observation of forestry guidelines.

Redundancy

- Forestry Programme 2023-2027 may facilitate the restoration of forest land and forest ecosystems following significant damage by natural causes.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Effective for managing this risk.

3.3.1.4 Consequences

- **Damage**: Limited or rare losses initially and by 2050, with increased substantial losses in the RCP8.5 scenario.
- **System Functionality**: Landslides can cause temporary disturbances and short-term disruptions to Biodiversity and Ecosystem system; however, under

an RCP8.5 scenario, these disturbances could become more long-term if the frequency and severity of events increases.

- **Extent and Pervasiveness**: Due to the localised nature of the risk the extent and pervasiveness is likely to be limited, with an increase in extent possible in 2100 under an RCP8.5 scenario.

- **Cascading Effects**: There are temporary cascading effects on Built Environment, an increase in landslides could result in disruption and damage to assets and infrastructure, e.g., roads and Water Security, which could result in a decrease in water quality due to large amounts of material entering freshwater bodies over a short time period.

- **Change through time**: Under a RCP4.5 scenario, the consequence of this risk is projected to remain at Limited from 2030 to 2100 as Ireland is projected to experience minor changes in annual precipitation, winter precipitation, five-day precipitation, and very wet days. There is also likely to be an increase in exposure due to the expansion in forested area as outlined in Ireland's Forest Strategy (2023-2030). Under a RCP8.5 scenario the consequence of this risk is projected to remain at Limited in 2030 and 2050 increasing to Substantial by 2100 due to an increase in the frequency and severity of the hazard resulting in an increase in the potential damage and extent.

3.3.1.1 Confidence

Hazard Confidence: There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for the direction and degree of change.

Consequence Confidence: There is high confidence in the consequence as this risk has and is already occurring in Ireland.

3.3.1.2 Decision urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is to Sustain Current Action.

3.3.2 B02 Risk of damage to forests due to flooding (fluvial, surface water, and groundwater)

Table 3.3: B02 Risk of damage to forests due to flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage to forests due to flooding (fluvial, surface water, and groundwater)	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Sustain Current Action					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

3.3.3 B03 Risk of increased stress and tree mortality within forests due to increased dispersal and survival of pests and diseases as a result of changing climate conditions

3.3.3.1 Risk Summary

Table 3.4: B03 Risk of increased stress and tree mortality within forests due to increased dispersal and survival of pests and diseases as a result of changing climate conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased stress and tree mortality within forests due to increased dispersal and survival of pests and diseases as a result of changing climate conditions	Limited	Substantial	Critical	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Changing climate conditions, such as increasing temperatures and changing precipitation patterns, will potentially allow pests and pathogens to survive and spread more easily. Climate change effects on forest ecosystems, managed forests, and tree species will be cumulative and interactive. For example, forest species stressed by changes in site conditions (such as an increase in the magnitude and frequency of moisture deficits) will be more susceptible to insects and diseases that become more active due to changing climatic conditions. These ecosystem interactions and feedbacks add to the complexity of climate change effects.

3.3.3.2 Exposure and Vulnerability

All NUTS3 regions will experience changing climate conditions, including increasing air temperatures with the Mid-East and South-East regions the most

affected by increases in air temperature under both the RCP4.5 ((1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100). Increases in annual precipitation, winter precipitation, five-day precipitation, and very wet days are also projected with the Mid-East and Dublin regions expected to experience the highest increase in annual precipitation across both RCP4.5 (5% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios.

Land cover data shows that forests are present across all eight NUTS3 regions. Forests include broadleaved forest, coniferous forest, mixed forest, and transitional forest, totalling 808,848 (National Forest Inventory 2022) hectares of land. Based on OSi Prime2 data, managed woodlands encompass 595,525 hectares of land over the eight NUTS3 regions. The largest volumes of managed woodlands are located in the West Region (approximately 119,000 hectares), and the South-West Region (approximately 113,00 hectares).

Ireland's Forestry Strategy (2023-2030) sets an ambition of 18% forest cover nationally by 2050. This will entail the planting of an additional 450,000 hectares of new forests over the next 25 years, increasing the size and potentially broadening the distribution of this exposure.

3.3.3.3 Consequence

- **Damage:** The disturbance and loss to the forestry industry, which is worth €2.1 bn to the economy and supports 9,423 jobs (DAFM, 2023) is potentially substantial and becoming critical by 2100.
- **System Functionality:** The change in climate conditions can ultimately lead to long-term disturbances in this system with major impact or loss of species.
- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent with the potential to affect all forestry type.
- **Cascading Effects:** There are temporary to long-term cascading effects on the Social System, the survival of pests and diseases in forests could not only impact the biodiversity but also negatively impact the economy and jobs e.g.,

increased expenditure on pest control measures and jobs dependant on forest products could experience job loss.

- **Change through time**: In both scenarios, the changing climate conditions will continually become more suitable for the dispersal and survival of pests and diseases. There is also likely to be an increase in exposure due to the expansion in forested area as outlined in Ireland's Forest Strategy (2023-2030). In both scenarios, a Critical level consequence is reached by 2100.

3.3.3.4 Confidence

Hazard Confidence: There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for the direction and degree of change. However, there is more confidence in the temperature related climate projections, in both the direction and degree of change. Therefore, an overall confidence of medium is assigned to this hazard.

Consequence Confidence: There is medium confidence in the consequence There is medium confidence in the consequence as there are a number of pests and diseases that can either currently or potentially damage Irish forests because of climate change. There is also a risk of introduction of new diseases or pests with new species. Furthermore, there is uncertainty on the scale of increased forestry in the future and therefore the change in exposure.

3.3.3.5 Adaptation

Measures are in place to address the risk of increased stress to forests from pests and diseases due to climate change.

Reliability

- *Policy and Governance:* The Forest Strategy and Forestry Act ensure coordinated efforts in forest management and adaptation.
- *Practices in Place:* Climate Risk Assessments and the Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan are implemented to evaluate and mitigate risks. The Forest Strategy 2023-2030 and its

Implementation Plan guide sustainable forest management. The Forestry Act 2014 provides legal frameworks for forest conservation.

- *Monitoring and Early Warning System:* Forecasting and weather warnings are in place to predict and respond to climate impacts. Climate-resilient reforestation schemes are designed to enhance forest resilience.

Resistance

- *Community Engagement and Education:* Grants for forest species diversity and native woodland conservation promote community involvement. Continuous cover forestry practices are encouraged as an effective way to ensure healthier Forests.
- *Research and Development:* Ongoing research supports the development of climate-resilient forestry practices.

Recovery and Response

- DAFM Biodiversity and Plant Health Strategy: DAFM is leading the development of strategies and measures to mitigate the effects of plant pests and pathogens on our natural environment, while also balancing international commitments with the socio-economic needs of citizens.

Redundancy

- Forestry Programme 2023–2027: May facilitate the restoration of forest land and forest ecosystems following significant damage by natural causes.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

3.3.3.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

3.3.4 B04 Risk of damage to forests due to wildfire

3.3.4.1 Risk Summary

Table 3.5: B04 Risk of damage to forests due to wildfire.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage to forests due to wildfire	Substantial	Substantial	Substantial	Substantial	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Low					
Consequence Confidence	Low					

Changing climate conditions, i.e., changes in precipitation, drought conditions, will potentially result in conditions suitable for wildfire occurring more frequently. Wildfires pose a significant threat to forests in Ireland, with the potential to cause extensive damage to forest stands, biodiversity, and the broader ecosystem. Forests are at risk of wildfire damage due to fuel build up (e.g., dead wood and leaves), dense vegetation, and human activity.

3.3.4.2 Exposure and Vulnerability

The Fire Weather Index (FWI) is a meteorologically based index used worldwide to estimate fire danger. It is developed by the Canadian Forestry Service to estimate forest fire ignition and spread conditions based on several weather variables (temperature, precipitation, relative humidity, and wind speed). At the NUTS2 region level, the projected FWI (from 1980-2010) shows the Southern region is projected to experience the largest increase in FWI in both 2050 (RCP4.5:0.27, RCP8.5: 0.62) and 2100 (RCP4.5:0.62, RCP8.5: 0.95).

Land cover data indicates that forests are present across all eight NUTS3 regions, including broadleaved forest, coniferous forest, mixed forest, and transitional forest. Forests total 808,848 hectares of land area in Ireland (National Forest Inventory 2022). Based on OSi Prime2 data, 592,525 hectares of

managed woodlands are spread across all eight NUTS3 Regions. The largest volumes of managed woodlands are located in the West Region (approximately 119,000 hectares) and South-West Region (approximately 113,000 hectares).

Ireland's Forest Strategy (2023-2030) sets an ambition of 18% forest cover nationally by 2050. This will entail the planting of an additional 450,000 hectares of new forests over the next 25 years, increasing the size and potentially broadening the distribution of this exposure.

3.3.4.3 Consequence

- **Damage:** The disturbance and loss to the forestry industry, which is worth €2.1 bn to the economy and supports 9,423 jobs (DAFM, 2023) is potentially substantial, becoming critical by 2100.
- **System Functionality:** The change in climate conditions can ultimately lead to temporary and long-term disturbances in this system with major impact on forestry extent.
- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent with the potential to affect all forestry type.
- **Cascading Effects:** There are temporary to long-term cascading effects on the Social System, meaning damage to forests could not only impact the biodiversity but also have negative impacts on the economy sector and jobs e.g., decline in timber resulting in higher prices due to limited supply.
- **Change through time**: In both scenarios, the changing climate conditions will continually become more suitable for wildfire occurrence. There is also likely to be an increase in exposure due to the expansion in forested area as outlined in Ireland's Forest Strategy (2023-2030). RCP8.5 will see the greatest change resulting in a Critical level consequence by 2100.

3.3.4.4 Confidence

Hazard Confidence: There is a Low level of confidence that wildfires will increase in frequency and severity in the future as there are limited climate projections available related to the changes in fire weather for Ireland, with no national scale projections, therefore European scale projections (EURO-CORDEX) have been used.

Consequence Confidence: Wildfires already occur within Ireland, however, there is limited information on the local scale variability, i.e., impact of terrain, fuel availability, potential sources of ignition, and how these may change in the future therefore confidence in the consequence is Medium.

3.3.4.5 Adaptation

There are several adaptation measures in place which address the risk of damage to managed forests due to wildfire:

Reliability

- *Monitoring and Early Warning Systems:* Forecasting and weather warnings to provide timely information, and Forest Fire Danger Notices inform the public and relevant stakeholders about the fire risk levels.
- *Community Engagement and Education:* Public awareness campaigns, such as Public Guidance on Wildfire Prevention, help communities understand the importance of fire safety and actions to reduce wildfire risks.
- *Policy and Governance:* The Forestry Act 2014 and the Forestry Programme 2023-2027 establish legal and policy frameworks for forest management and protection. Fire Management Plans implementation is also crucial.

Resistance

- *Forest Management Practices:* The Prescribed Burning Code provides guidelines for conducting controlled burns safely and effectively. The Forestry Strategy supports sustainable forest management.
- *Research and Development:* The FAO Voluntary Fire Management Guidelines provide a framework for developing and implementing effective fire management strategies.

Recovery and Response

- Fire Prevention and Management Guidance: DAFM's fire prevention and fire management guidance outlines recovery and response measures, detailing coordinated emergency response actions and post-incident recovery strategies.

Redundancy

- Restoration Measures: The Forestry Programme 2023–2027 may facilitate the restoration of forest land and forest ecosystems following significant damage by natural causes.

Adaptation Effectiveness

Based on the secondary research and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

3.3.4.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

3.3.5 B05 Risk of reduced yields from managed forests due to phenological changes

3.3.5.1 Risk Summary

Table 3.6: B05 Risk of reduced yields from managed forests due to phenological changes.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of reduced yields from managed forests due to phenological changes	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Low					

Climate change may impact phenology (seasonal timing of biological activity), which could lead to increased tree mortality and changes in competitive interrelationships in forest ecosystems. Tree species have the potential to acclimatise, adapt, and migrate; however, in many cases, the rate and magnitude of future climate change may significantly exceed the ability of tree species to naturally adjust. Tree species may, therefore, become increasingly maladapted (that is the local environment to which species are adapted begins to change at a rate beyond that which they can accommodate)

3.3.5.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C (0.6-1.7°C) by 2050, and 1.5°C (1.1-2.2°C) by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C (1.1-1.9°C) by 2050, and 2.7°C (2.0-3.3°C) by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100) scenarios.

Land cover data illustrates that forests are present across all eight of the NUTS3 regions. Forests include broadleaved forest and woodland, coniferous forest,

mixed forest, and transitional forest. The total area encompassed by forests in Ireland is 808,848 hectares (National Forest Inventory 2022). Based on OSi Prime 2 data, managed forests cover 592,525 hectares of land across Ireland. The largest volumes of managed forests are located in the West Region (approximately 119,000 hectares) and the South-West Region (approximately 113,000 hectares).

Ireland's Forest Strategy (2023-2030) sets an ambition of 18% forest cover nationally by 2050. This will entail the planting of an additional 450,000 hectares of new forests over the next 25 years, increasing the size and potentially broadening the distribution of this exposure.

3.3.5.3 Consequence

- **Damage:** The disturbance and loss to the forestry industry, which is worth €2.1 bn to the economy and supports 9,423 jobs (DAFM, 2023) is potentially substantial, becoming critical by 2100.
- **System Functionality:** The change in climate conditions and related phenological changes can ultimately lead to temporary and long-term disturbances in this system with major impact on forestry.
- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions and related phenological changes, this risk has potential to occur across a large extent with the potential to affect all forestry.
- **Cascading Effects:** There are temporary to long-term cascading effects on the Social System, meaning damage to forests could not only impact the biodiversity but also have negative impacts on the economy sector and jobs e.g., decline in timber resulting in higher prices due to limited supply.
- **Change through time**: In both scenarios, the changing climate conditions will continually alter the phenological cycles. There is also likely to be an increase in exposure due to the expansion in forested area as outlined in Ireland's Forest Strategy (2023-2030). RCP8.5 will see the greatest change resulting in a Critical level consequence by 2100.

3.3.5.4 Confidence

Hazard Confidence: There is a medium level of confidence that phenological changes will occur due to changing climate conditions. There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for the direction and degree of change. However, there is more confidence in the temperature related climate projections, in both the direction and degree of change. The Growing Season Length and Growing Season Start within the national TRANSLATE projections, the 90th percentile shows a different trend to the ensemble mean, and the 10th percentile. Both of these variables are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is low confidence in the consequence as changing phenological changes can result in both positive and negative impacts upon forestry therefore there is low confidence how phenological changes will impact upon forestry.

3.3.5.5 Adaptation

To address the risk of reduced yields from managed forests due to phenological changes, several adaptation measures have been implemented:

Reliability

- *Policy and Governance:* The Forest Strategy 2023-2030 and the Forestry Programme align forest management practices with national adaptation goals.
- *Monitoring and Early Warning Systems:* Climate risk assessments help identify vulnerabilities and inform adaptive strategies.

Resistance

- *Community Engagement and Education:* The Plant Health and Biosecurity Strategy raises awareness and builds community resilience.
- *Practices in Place:* The Forestry Strategy 2023-2030 and the Forestry Programme outline comprehensive measures to enhance forest resilience.

- *Research and Development:* The Forestry Programme 2023-2027 introduces measures to enhance forest resilience. Research is ongoing to determine how climate change will impact on tree species and provide guidance on suitable tree selection for climate scenario projections.

Recovery and Response

- *Emergency Response Planning:* Tree species diversity is a key measure of ensuring that forests have the adaptive capacity to respond to climate change

Redundancy

- *Restoration Measures:* The Forestry Programme 2023–2027 may facilitate the restoration of forest land and forest ecosystems following significant damage by natural causes.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

3.3.5.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

3.3.6 B06 Risk of damage to forests due to extreme wind

3.3.6.1 Risk Summary

Table 3.7: B06 Risk of damage to forests due to extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage to managed forests due to extreme wind	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Very Low					
Consequence Confidence	High					

Extreme wind poses a significant risk to forest ecosystems, managed forests, and tree species in Ireland. Extreme winds lead to damage primarily through windblow, where trees are uprooted, and windsnap, where trunks or branches break. Factors like tree species, soil type, and drainage affect vulnerability of forests to wind damage. Additionally, preceding weather conditions, like heavy rainfall or prolonged high winds, significantly impact the extent of forest damage.

3.3.6.2 Exposure and Vulnerability

For RCP4.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.32 days, 2100: -0.47) from the 1981-2010 baseline. For RCP8.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.61 days, 2100: -0.44) from the 1981-2010 baseline.

Land cover data illustrates that forests are present across all eight of the NUTS3 regions. Forests include broadleaved forest and woodland, coniferous forest, mixed forest, and transitional forest. The total area encompassed by forests in Ireland is 808,848 hectares (National Forest Inventory 2022). Based on OSi Prime 2 data, managed forests cover 592,525 hectares of land across Ireland.

The largest volumes of managed forests are located in the West Region (approximately 119,000 hectares) and the South-West Region (approximately 113,000 hectares).

3.3.6.3 Consequence

- **Damage:** Extreme wind can cause substantial losses to buildings. Ireland already experiences impacts from this risk, for instance:
  - Storm Darwin in 2014 caused over 8,000 hectares of forest damage in Ireland. This included approximately 6,000 hectares of state forests and an additional 2,000 hectares of privately owned forests (DAFM, 2019).
  - Storm Éowyn is estimated to have damaged 23,652 (17,744 – 29,950) hectares (3.3%) of forestry with an estimated ca. 10 million m^3 of growing stock were affected, predominantly in spruce plantations older than 20 years of age, resulted in the windthrow of 2.3 times the volume of timber that is normally harvested (Department of Agriculture, Food and the Marine, 2025).
- **System Functionality**: Extreme wind can cause moderate disturbances to the Biodiversity and Ecosystem System, leading to temporary and long-term impacts, particularly affecting forestry.
- **Extent and Pervasiveness**: The impact of extreme wind events is widespread, affecting a large number of forest ecosystems, managed forests, and tree species across extensive areas, indicating a moderate extent and pervasiveness.
- **Change through time**: Projections show no change in hazard (although with very low levels of confidence). There is also likely to be an increase in exposure due to the expansion in forested area as outlined in Ireland's Forest Strategy (2023-2030). However, the risk is currently assessed as a Substantial consequence, and this current level of risk is expected to continue into the future.

3.3.6.4 Confidence

Hazard Confidence: There is a Very Low level of confidence that extreme wind frequency and severity will not change in the future. There are limited

global, regional, and national scale projections available related to the changes in extreme wind for Ireland. National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used at the NUTS2 level, with national scale data for average wind speed used as an alternative proxy.

Consequence Confidence: There is High confidence in the consequence as the impacts of this risk have already been observed and will likely continue in the future.

3.3.6.5 Adaptation

To address the risk of damage to forests due to extreme wind, several adaptation measures are in place:

Reliability

- *Policy and Governance:* The Forest Strategy and Forestry Act ensure coordinated efforts in forest management and adaptation.
- *Practices in Place:* Climate Risk Assessments and the Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan are implemented to evaluate and mitigate risks. The Forest Strategy 2023-2030 and its Implementation Plan guide sustainable forest management. The Forestry Act 2014 provides legal frameworks for forest conservation.
- *Monitoring and Early Warning System:* Forecasting and weather warnings are in place to predict and respond to climate impacts. Climate-resilient reforestation schemes are designed to enhance forest resilience.

Resistance

- *Community Engagement and Education: The Plant Health and Biosecurity Strategy raises awareness and builds community resilience.*
- *Practices in Place: The Forestry Strategy 2023-2030 and the Forestry Programme outline comprehensive measures to enhance forest resilience.*

- *Research and Development: The Forestry Programme 2023-2027 introduces measures to enhance forest resilience. Research is ongoing to determine how climate change will impact on tree species and provide guidance on suitable tree selection for climate scenario projections.*

Recovery and Response

- *Emergency Response Planning:* Tree species diversity is a key measure of ensuring that forests have the adaptive capacity to respond to climate change.

Redundancy

- *Restoration Measures:* The Forestry Programme 2023–2027 may facilitate the restoration of forest land and forest ecosystems following significant damage by natural causes.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

3.3.6.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is Further Investigation.

3.3.7 B07 Risk of deterioration of freshwater quality due to overland flows as a result of flooding (fluvial, surface water, and groundwater)

3.3.7.1 Risk Summary

Table 3.8: B07 Risk of deterioration of freshwater quality due to overland flows as a result of flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of deterioration of freshwater quality due to overland flows as a result of flooding (fluvial, surface water, and groundwater)	Substantial	Substantial	Critical	Substantial	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Freshwater quality deterioration is significantly heightened by overland flows resulting from various types of flooding, including fluvial, surface water, and groundwater flooding. These events can cause substantial runoff from agricultural lands, carrying sediments, nutrients, and contaminants into freshwater systems. The resultant pollution can degrade water quality, impacting ecosystems, human health, and agricultural productivity.

3.3.7.2 Exposure and Vulnerability

Under RCP4.5, the 1 in 100-year event (1% Annual Exceedance Probability) puts 1.7% (CFRAM) to 2.3% (NIFM) of the total land area of Ireland at risk of fluvial flooding by 2100. In this context, the Midlands Region is most at risk, with 3.1% (NIFM) to 3.36% (CFRAM) of the total land area of the region impacted. Under RCP8.5, the 1 in 100-year event (1% Annual Exceedance Probability) puts 2.0% (CFRAM) to 2.4% (NIFM) of the total land area of Ireland at risk of fluvial flooding by 2100. Again, the Midlands Region is most at risk, with 3.1% (NIFM) to 3.94% (CFRAM) of the total land area of the region impacted.

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5.0 % (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios..

Land cover data shows that freshwater habitats exist across all eight NUTS3 regions. Freshwater includes rivers, streams, lakes, ponds, and artificial water bodies. The total area encompassed by freshwater is 191,827 hectares.

3.3.7.3 Consequence

- **Damage:** There is potential for intermediate to major impacts on freshwater environments, and associated ecosystem services resulting in potentially critical levels of damage by 2100.
- **System Functionality:** The decreased freshwater quality can lead to temporary and long-term disturbances in this system.
- **Extent and Pervasiveness:** Due to all NUTS3 regions exposed to flooding, and the presence of freshwater habitats in all NUTS3 regions, this risk has potential to occur across a large extent with the potential to affect all freshwater ecosystems.
- **Cascading Effects:** There are temporary to long-term cascading effects on the Water Security System, overland flows can cause pollution of water resources for drinking and for industrial use, Health System, the physical health of individuals can be impacted, and Energy System, overland flows can impact access to water and result in inability to discharge water.
- **Change through time**: In both scenarios, the changing climate conditions will continually increase the frequency and severity of flooding events. RCP8.5 will see the greatest change resulting in a Critical level consequence by 2100.

3.3.7.4 *Confidence*

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020).

Consequence Confidence: There is high confidence in the consequence as the impacts of this risk have already been observed and will likely increase in frequency and severity in the future.

3.3.7.5 *Adaptation*

To address the risk of deterioration of freshwater quality due to overland flows from flooding (fluvial, surface water, and groundwater), several adaptation measures have been implemented:

Reliability

- Policy and Governance: Farming for Water EIP and Waters for LIFE EIP provide the policy support for sustainable land management practices.
- Practices in Place: The Farming for Water EIP and Waters for LIFE EIP initiatives focus on sustainable agricultural practices that reduce runoff and improve water quality.

Resistance

- *Community Engagement and Education:* The Farming for Water EIP and Waters for LIFE EIP include raise awareness of water quality issues.

- *Research and Development:* The Farming for Water EIP and Waters for LIFE EIP support research into sustainable land management practices and their effectiveness in reducing runoff and improving water quality.

Recovery and Response

- *Knowledge Transfer and Training:* The adaptation actions include elements of knowledge transfer and training, particularly through the initiatives under the Farming for Water EIP and Waters for LIFE EIP.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

3.3.7.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

3.3.8 B08 Risk of alteration of freshwater flora and fauna due to changes in freshwater temperature

3.3.8.1 Risk Summary

Table 3.9: B08 Risk of alteration of freshwater flora and fauna due to changes in freshwater temperature.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of alteration of freshwater flora and fauna due to changes in freshwater temperature	Limited	Substantial	Critical	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	High					

Changing climate conditions are expected to significantly alter freshwater temperatures, posing a substantial risk to the flora and fauna within these ecosystems. Increasing air and water temperatures will magnify existing problems of nutrient enrichment and algal blooms, thereby putting greater pressure on species of invertebrates, fish, and plants. Water quality, i.e., dissolved oxygen, may also reduce and water stratification process affected. Species that are unable to adapt to these changes may become stressed or even extinct. These shifts can disrupt food webs and ecosystem stability, affecting biodiversity and water quality.

3.3.8.2 Exposure and Vulnerability

There are a number of drivers and factors that control freshwater temperature and includes atmospheric temperature. Therefore, increasing air temperature can drive increases in freshwater temperature and all NUTS3 regions are projected to experience increasing air temperatures. Specifically, the Mid-East and South-East regions are the most affected by increases in air temperature under both the RCP4.5 (1.5°C (1.1-2.2°C) 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100).

Land cover data shows that freshwater habitats exist across all eight NUTS3 regions. Freshwater includes rivers, streams, lakes, ponds, and artificial water bodies. The total area encompassed by freshwater is 191,827 hectares.

3.3.8.3 Consequence

- **Damage:** There is potential for intermediate to major impacts on freshwater environments, and associated ecosystem services resulting in potentially critical levels of damage by 2100.
- **System Functionality:** The increases in freshwater temperature can lead to temporary and long-term disturbances in this system.
- **Extent and Pervasiveness:** Due to all NUTS3 regions exposed to increases in air temperature and the presence of freshwater habitats in all NUTS3 regions, this risk has potential to occur across a large extent with the potential to affect all freshwater ecosystems.
- **Cascading Effects:** There are temporary to long-term cascading effects on the Water Security System, meaning alterations of freshwater flora and fauna can cause a decrease in water quality in water resources for drinking and for industrial use.
- **Change through time**: In both scenarios, there is increasing annual and seasonal air temperatures. There are limited differences between the hazard in RCP4.5 and RCP8.5 scenarios therefore, the level of consequence is Critical in both scenarios by 2100.

3.3.8.4 Confidence

Hazard Confidence: There is a medium level of confidence that increasing temperatures will increase freshwater temperatures. Although the atmospheric temperature can influence freshwater temperatures, other factors, such as groundwater input, water mixing, shading, water levels, can also influence temperature.

Air temperature projections are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is high confidence in the consequence as some of these impacts of this risk have already been observed at a local and short-term/temporary term basis.

3.3.8.5 Adaptation

To address the risk of alteration of freshwater flora and fauna due to changes in freshwater temperature, several practices have been implemented.

Reliability

- *Policy and Governance:* The National Nature-based Solutions Implementation Strategy and the Nature Restoration Law provide support for implementing nature-based solutions and habitat restoration measures.
- *Practices in Place:* The Water Framework Directive status and risks assessment, as well as the Water Action Plan, are key to addressing this risk. Integrated catchment management also guides actions on water quality.

Resistance

- *Community Engagement and Education:* The Farming for Water EIP and Waters for LIFE EIP raises awareness and builds community resilience.
- *Research and Development:* The Farming for Water EIP and Waters for LIFE EIP support research into sustainable land and water management practices.

Recovery and Response

- *Knowledge Transfer and Training:* Knowledge transfer and training is conducted through the Farming for Water EIP and Waters for LIFE EIP.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

3.3.8.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

3.3.9 B09 Risk of decreased freshwater quality due to reduced water flows as a result of drought conditions

3.3.9.1 Risk Summary

Table 3.10: B09 Risk of decreased freshwater quality due to reduced water flows as a result of drought conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of decreased freshwater quality due to reduced water flows as a result of drought conditions	Substantial	Substantial	Critical	Substantial	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Drought conditions are increasingly projected to impact freshwater quality due to reduced water flows. When water levels drop, the concentration of pollutants rises, leading to higher salinity and nutrient levels. Reduced water levels can also lead to hydromorphological changes resulting in sediment resuspension, increasing turbidity and releasing trapped nutrients. This can cause harmful algal blooms and lower dissolved oxygen, negatively impacting freshwater quality. Prolonged droughts may result in blackwater events, where decomposing organic matter releases harmful substances like ammonia and sulphides. These changes put significant stress on freshwater wildlife, affecting their health and biodiversity, and create issues for water security affecting water supply for drinking and industrial use.

3.3.9.2 Exposure and Vulnerability

In an RCP4.5 scenario, nationally the mean annual number of wet days is expected to decrease of 2.4% (-6.52 - 1.53%) by 2050 and 2.2 (-6.63 – -1.63%) by 2100, with the East region experiencing the largest decrease (2050: 3.2%, 2100: 2.8%). The same trend occurs in RCP8.5 with a decrease of 2.6% ((-6.21

– 1.11%) by 2050 and 4.1% (-9.71 – 0.47%) by 2100, with the East region experiencing the largest decrease (2050: 3.3%, 2100: 5.1%)

For RCP4.5 and RCP8.5 compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season for both 2050 and 2100.

Land cover data shows that freshwater habitats exist across all eight NUTS3 regions. Freshwater includes rivers, streams, lakes, ponds, and artificial water bodies. The total area encompassed by freshwater is 191,827 hectares.

3.3.9.3 Consequence

- **Damage:** There is potential for intermediate to major impacts on freshwater environments, and associated ecosystem services resulting in potentially critical levels of damage by 2100.
- **System Functionality:** The increase in freshwater temperature and associated decrease in water quality can lead to temporary and long-term disturbances in this system.
- **Extent and Pervasiveness:** Due to all NUTS3 regions exposed to increases in air temperature and the presence of freshwater habitats in all NUTS3 regions, this risk has potential to occur across a large extent with the potential to affect all freshwater ecosystems.
- **Cascading Effects:** There are temporary to long-term cascading effects on the Water Security System, meaning freshwater quality can cause disruption to water resources for drinking and for industrial use, and Energy system, meaning decreased freshwater quality can pose issues on access to water and inability to discharge water.
- **Change through time**: In both scenarios, there is a decrease in precipitation and an increase in drought conditions. There are limited differences between the hazard in RCP4.5 and RCP8.5 scenarios therefore, the level of consequence is Critical in both scenarios by 2100.

3.3.9.4 *Confidence*

Hazard Confidence: There is a medium level of confidence that drought conditions will increase in the future. Changes in the number of wet days have been used from national downscaled projections (TRANSLATE) which were produced by the national meteorological agency, and peer-reviewed research has been used for SPEI-3, however, further research and variables, i.e., SPEI-6, SPEI-12 are needed to better inform confidence in this hazard.

Consequence Confidence: There is high confidence in the consequence as some of these impacts of this risk have already been observed at a local and short-term/temporary term basis.

3.3.9.5 *Adaptation*

To address the risk of decreased freshwater quality due to reduced water flows from drought conditions, several practices have been implemented.

Reliability

- *Policy and Governance:* The National Nature-based Solutions Implementation Strategy and the National Resource Water Plan provide policy support for nature-based solutions and sustainable water management.
- *Practices in Place:* The Water Action Plan outlines measures to improve water quality, including sustainable licensing of abstraction, impoundment, and discharges, based on integrated catchment management. This is supported by the Water Environment (Abstractions and Associated Impoundments) Act 2022.
- *Monitoring and Early Warning System:* Water reservoir and river level monitoring provide real-time data. The National Catchment Management Plans monitor water flows and quality.

Resistance

- *Community Engagement and Education:* The National Resource Water Plan raises awareness and builds community resilience.
- *Research and Development:* The Water Scarcity Action Plan supports research into sustainable water management practices.

Recovery and Response

- *Knowledge Transfer and Training:* Knowledge transfer and training is enabled through the National Resource Water Plan and the Water Scarcity Action Plan.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

3.3.9.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

3.3.10 B10 Risk of degradation/loss of peatland ecosystems and habitats due to extreme heat and drought conditions

3.3.10.1 Risk Summary

Table 3.11: B10 Risk of degradation/loss of peatland ecosystems and habitats due to extreme heat and drought conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of degradation/loss of peatland ecosystems and habitats due to extreme heat and drought conditions	Substantial	Substantial	Critical	Substantial	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Peatlands are facing significant risks of degradation and loss due to extreme heat and drought conditions. These conditions dry out peatlands, leading to carbon release, increased fire risk, vegetation loss, erosion, and altered hydrology. Higher temperatures can exacerbate these effects by increasing evaporation rates and further drying out the peat. Additionally, prolonged droughts reduce the capacity of peatlands to absorb carbon dioxide, diminishing their role as carbon sinks. The loss of vegetation and altered hydrology can also lead to habitat loss for many species, further impacting biodiversity.

3.3.10.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38))

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2))

In an RCP4.5 scenario, nationally the mean annual number of wet days is expected to decrease of 2.4%(-6.52 – 1.53%) by 2050 and 2.2 (-6.63 – -1.63%) by 2100, with the East region experiencing the largest decrease (2050: 3.2%, 2100: 2.8%). The same trend occurs in RCP8.5 with a decrease of 2.6% ((-6.21 – 1.11%) by 2050 and 4.1% (-9.71 – 0.47%) by 2100, with the East region experiencing the largest decrease (2050: 3.3%, 2100: 5.1%).

For RCP4.5 and RCP8.5 compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season for both 2050 and 2100.

Land cover data shows that peatland is present across all eight NUTS3 regions. Peatland covers 462,102 hectares of blanket bog, cutover bog, fens, raised bog, and bare peat. The largest volumes of peatland are located in the West Region (approximately 206,000 hectares) and the Border Region (approximately 111,000 hectares).

3.3.10.3 Consequence

- **Damage:** There is potential for intermediate to major impacts on peatlands, and associated ecosystem services resulting in potentially critical levels of damage by 2100.
- **System Functionality:** The degradation and/or loss of peatlands can lead to temporary and long-term disturbances in this system.
- **Extent and Pervasiveness:** Due to all NUTS3 regions exposed to increases in extreme heat and drought conditions and the presence of peatland habitats

in all NUTS3 regions, this risk has potential to occur across a large extent with the potential to affect all peatland ecosystems.

- **Cascading Effects:** There are temporary to long-term cascading effects on the Water Security System, meaning the degradation/loss of peatland ecosystems can cause disruption to water resources for drinking and for industrial use.

- **Change through time**: In both scenarios, there is a potential increase in both extreme heat and drought conditions. There are limited differences between the hazard in RCP4.5 and RCP8.5 scenarios therefore, the level of consequence is Critical in both scenarios by 2100.

3.3.10.4 Confidence

Hazard Confidence: For extreme heat there is high confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). There is a medium level of confidence that drought conditions will increase in the future. Changes in the number of wet days have been used from national downscaled projections (TRANSLATE) which were produced by the national meteorological agency, and peer-reviewed research has been used for SPEI-3, however, further research and variables, i.e., SPEI-6, SPEI-12 are needed to better inform confidence in this hazard. Overall, the hazard confidence is considered Medium.

Consequence Confidence: There is medium confidence in the consequence as some of the impacts of peatland loss have already been observed at a local and long-term term basis, however, the driver for this loss has not been associated with extreme heat or drought, and there is uncertainty if the severity of extreme heat or droughts will lead to long term damage to peatlands.

3.3.10.5 Adaptation

To address the risk of degradation and loss of peatland ecosystems and habitats due to extreme heat and drought conditions, several practices have been implemented.

Reliability

- *Policy and Governance:* The National Nature-based Solutions Implementation Strategy and the Nature Restoration Law provide support for nature-based solutions and habitat restoration measures.
- *Practices in Place:* The National Biodiversity Action Plan, Peatlands Climate Action Scheme, LIFE IP Peatlands and People, and the Land Use Review, describe measures and policies for the protection and restoration of peatland. Vegetation management reduces wildfire impact by managing plant cover to minimise wildfire risk and severity. Special Areas of Conservation cover peatland areas and set out conservation objectives for these sites.
- *Monitoring and Early Warning System:* Climate Risk Assessments identify vulnerabilities and inform adaptive strategies. Forecasting and weather warnings provide timely information enabling proactive management.

Resistance

- *Community Engagement and Education:* The Biodiversity Climate Change Sectoral Adaptation Plan raises awareness and build community resilience.
- *Research and* Development**:** Research into rewetting and vegetation management practices informs adaptation efforts.

Recovery and Response

- *Knowledge Transfer and Training:* Adaptation actions include knowledge transfer and training through the Biodiversity Climate Change Sectoral Adaptation Plan.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

3.3.10.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

3.3.11 B11 Risk of degradation and loss of terrestrial ecosystems due to extreme cold

Table 3.12: B11 Risk of degradation and loss of terrestrial ecosystems due to extreme cold.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of degradation and loss of terrestrial ecosystems due to extreme cold	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	High					
Consequence Confidence	Low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

3.3.12 B12 Risk of increased landslide susceptibility due to the degradation of terrestrial ecosystems as a result of changes in climate conditions

Table 3.13:B12 Risk of increased landslide susceptibility due to the degradation of terrestrial ecosystems as a result of changes in climate conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased landslide susceptibility due to the degradation of terrestrial ecosystems as a result of changes in climate conditions	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

3.3.13 B13 Risk of degradation and loss of terrestrial habitats due to flooding (fluvial, surface water, and groundwater)

Table 3.14: B13 Risk of degradation and loss of terrestrial habitats due to flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of degradation and loss of terrestrial habitats due to flooding (fluvial, surface water, and groundwater)	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

3.3.14 B14 Risk of degradation and loss of terrestrial habitats due to extreme heat and drought conditions

3.3.14.1 Risk Summary

Table 3.15: B14 Risk of degradation and loss of terrestrial habitats due to extreme heat and drought conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of degradation and loss of terrestrial habitats due to extreme heat and drought conditions	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Extreme heat and drought conditions cause a lack of moisture in soil, weakening its structure and making it prone to erosion by wind and water. This degradation can lead to significant soil loss and reduced agricultural productivity. Additionally, fauna struggle to survive without adequate water, leading to widespread die-offs. The lack of moisture also affects soil microbial communities, disrupting nutrient cycling and further degrading soil health. These combined effects can have long-term impacts on ecosystems and biodiversity.

3.3.14.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38)).

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2))

In an RCP4.5 scenario, nationally the mean annual number of wet days is expected to decrease of 2.4%(-6.52 — 1.53%) by 2050 and 2.2 (-6.63 — -1.63%) by 2100, with the East region experiencing the largest decrease (2050: 3.2%, 2100: 2.8%). The same trend occurs in RCP8.5 with a decrease of 2.6% ((-6.21 – 1.11%) by 2050 and 4.1% (-9.71 – 0.47%) by 2100, with the East region experiencing the largest decrease (2050: 3.3%, 2100: 5.1%).

For RCP4.5 and RCP8.5 compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season for both 2050 and 2100.

Terrestrial habitats are located within all NUTS3 regions.

3.3.14.3 Consequence

- **Damage:** There is potential for intermediate to major impacts on terrestrial habitats, and associated ecosystem services resulting in potentially critical levels of damage by 2100.
- **System Functionality:** The degradation and/or loss of terrestrial habitats can lead to temporary and long-term disturbances in this system.
- **Extent and Pervasiveness:** Due to all NUTS3 regions exposed to increases in extreme heat and drought conditions and the presence of terrestrial habitats in all NUTS3 regions, this risk has potential to occur across a large extent with the potential to affect all peatland ecosystems.

- **Cascading Effects:** There are temporary to long-term cascading effects on the Water Security System, meaning the degradation and loss of terrestrial habitats can affect water flow and maintenance of water quality and Food Production and Supply Chain, meaning the degradation and loss of terrestrial habitats can lead to soil degradation and loss of pollinators.

- **Change through time**: In both scenarios, there is a potential increase in both extreme heat and drought conditions. There are limited differences between the hazard in RCP4.5 and RCP8.5 scenarios therefore, the level of consequence is Critical in both scenarios by 2100.

3.3.14.4 Confidence

Hazard Confidence: For extreme heat there is high confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). There is a medium level of confidence that drought conditions will increase in the future. Changes in the number of wet days have been used from national downscaled projections (TRANSLATE) which were produced by the national meteorological agency, and peer-reviewed research has been used for SPEI-3, however, further research and variables, i.e., SPEI-6, SPEI-12 are needed to better inform confidence in this hazard. Overall, the hazard confidence is considered Medium.

Consequence Confidence: There is medium confidence in the consequence as some of the impacts of terrestrial habitat loss have already been observed at a local and long-term term basis, however, the driver for this loss has not been associated with extreme heat or drought, and there is uncertainty if the severity of extreme heat or droughts will lead to long term damage to terrestrial habitats.

3.3.14.5 Adaptation

To address the risk of degradation and loss of terrestrial habitats due to extreme heat and drought conditions, several practices have been implemented.

Reliability

- *Policy and Governance:* The National Nature-based Solutions Implementation Strategy and the Nature Restoration Law provide policy support for nature-based solutions and habitat restoration measures. The CAP Eco-scheme and the Horticulture Exceptional Payment Scheme further support climate resilience and adaptation efforts.
- *Practices in Place:* The National Biodiversity Action Plan set out actions for the conservation and restoration of biodiversity in Ireland. The National Nature-based Solutions Implementation Strategy promotes natural processes to enhance resilience. The Nature Restoration Law provides a legal framework for restoring and protecting natural habitats.

Resistance

- *Habitat Restoration and Conservation:* Rewetting of cutaway peatland and vegetation management to reduce wildfire impact help maintain and restore natural habitats. The use of multi-species grass swards and post-wildfire Molinia management also contribute to habitat conservation and resilience.
- *Practices in Place:* The Forestry Programme 2023-2027 and the climate resilient reforestation scheme support the establishment of diverse and resilient forest stands.
- *Research and Development:* The investigation of alternative warmer climate crop use and the exploration of research into tree species adaptability under a changing climate .

Recovery and Response

- *Knowledge Transfer and Training:* Adaptation actions include knowledge transfer and training through ACRES.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

3.3.14.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

3.3.15 B15 Risk of terrestrial ecosystem and habitat disturbance as a result of increased outdoor recreation due to increases in average temperature

3.3.15.1 Risk Summary

Table 3.16 B15 Risk of terrestrial ecosystem and habitat disturbance as a result of increased outdoor recreation due to increases in average temperature.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of terrestrial ecosystem and habitat disturbance as a result of increased outdoor recreation due to increases in average temperature	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Increasing average temperatures due to climate change are likely to increase outdoor recreational activities. While this can have positive effects on public health and well-being, it also poses significant risks to terrestrial ecosystems and habitats (Sardar and Islam, 2025). Increased foot traffic and recreational activities can lead to soil compaction, vegetation damage, and disturbance to wildlife. Sensitive habitats, such as bogs and heathlands, are particularly vulnerable. Soil compaction reduces water infiltration and root growth, while vegetation damage can lead to erosion and loss of plant diversity. Wildlife disturbance can disrupt breeding and feeding patterns, leading to population declines. Additionally, the introduction of invasive species through recreational activities can further threaten native ecosystems.

3.3.15.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C (0.6-1.7°C) by 2050, and 1.5°C (1.1-2.2°C) by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C (1.1-1.9°C) by 2050, and 2.7°C (2.0-3.3°C) by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100) scenarios.

Terrestrial habitats are located within all NUTS3 regions. Levels of outdoor recreation and foot traffic can be expected to increase with a larger population. Based on projections prepared by ESRI in 2024, under a baseline scenario the national population is anticipated to increase by c.922,000 between 2022 and 2024, resulting in a population of 6.106 million people. Under a scenario accounting for higher rates in inward migration, the population is anticipated to increase by 1.124 million by 2040, resulting in a population of 6.308 million people. While all regions are expected to experience population growth, relatively higher growth is anticipated in the east and midlands, concentrated in Dublin and the Mid-East NUTS3 regions.

3.3.15.3 Consequence

- **Damage:** There is potential for minor to intermediate impacts on terrestrial habitats, and associated ecosystem services resulting in potentially substantial levels of damage by 2100.
- **System Functionality:** The degradation and/or loss of terrestrial habitats can lead to temporary and moderate disturbances in this system.
- **Extent and Pervasiveness:** All NUTS3 regions exposed to increases in air temperature and the presence of terrestrial habitats in all NUTS3 regions, however, the areas affected by outdoor recreated are likely to be a limited proportion of the terrestrial habitat area.

- **Cascading Effects:** There are temporary cascading effects on the Water Security System, meaning terrestrial ecosystem and habitat disturbance can impact water flow and the maintenance of water quality.

- **Change through time**: In both scenarios, there is a potential increase in both extreme heat and drought conditions. There are limited differences between the hazard in RCP4.5 and RCP8.5 scenarios therefore, the level of consequence is Critical in both scenarios by 2100.

3.3.15.4 Confidence

Hazard Confidence: There is a High-level confidence in the increasing temperature projections, which are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is a medium level of confidence that terrestrial habitats will be affected by an increase in outdoor recreation. It is likely that increase outdoor recreation will affect terrestrial habitats at the local scale, there is uncertainty as to whether it could lead to major impacts at the national scale. There is also uncertainty whether the increase in temperature would equate to a commensurate increase in outdoor recreational activity, and if there are significant spatial differences, i.e., does outdoor recreational activity increase in habitats closer to urban centres.

3.3.15.5 Adaptation

To address the risk of terrestrial ecosystem and habitat disturbance resulting from increased outdoor recreation due to rising average temperatures, several practices have been implemented.

Reliability

- *Policy and Governance:* Strong policy and governance frameworks support adaptation actions. The Biodiversity Climate Change Sectoral Adaptation Plan

and Local Authority Climate Adaptation Plans provide support for sustainable recreation and habitat protection measures.

- *Practices in Place:* The Biodiversity Climate Change Sectoral Adaptation Plan provides a framework for managing increased recreation impacts. Planning regulations minimise environmental disturbance from recreation.

Resistance

- *Community Engagement and Education***:** Collaboration between NPWS and the Department of Tourism raises awareness and promotes responsible recreation, ensuring visitors minimise their impact on natural habitats.
- *Research and Development:* Research into sustainable tourism practices informs adaptive management practices, supported by the Biodiversity Climate Change Sectoral Adaptation Plan and cross-sectoral collaboration.

Recovery and Response

- No recovery and response measures identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

3.3.15.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

3.3.16 B16 Risk of increases in occurrence of invasive species resulting in habitat disturbance due to changes in climate conditions

3.3.16.1 Risk Summary

Table 3.17: B16 Risk of increases in occurrence of invasive species resulting in habitat disturbance due to changes in climate conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increases in occurrence of invasive species resulting in habitat disturbance due to changes in climate conditions	Limited	Substantial	Critical	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Climate change is altering environmental conditions, making Ireland more susceptible to the introduction and spread of invasive species (animals, plants or pathogens that would not naturally occur in Ireland (National Biodiversity Data Centre. (n.d.)). Rising temperatures create favourable conditions for invasive species to thrive. Milder winters and warmer summers can allow non-native species to establish and spread more easily. These species can disrupt local ecosystems, outcompete native flora and fauna, and cause significant habitat disturbances. For example, non-native deer species like sika and muntjac are expected to increase in number and spread across Ireland, further stressing native plant species (O'Mahony et al., 2023).

3.3.16.2 Exposure and Vulnerability

All NUTS3 regions will experience changing climate conditions, including increasing air temperatures with the Mid-East and South-East regions the most affected by increases in air temperature under both the RCP4.5 (1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100)(Increases in annual precipitation, winter precipitation, five-day precipitation, and very wet days are also projected with the Mid-East and Dublin regions expected to experience the

highest increase in annual precipitation across both RCP4.5 (5.0 % (0.0 - 9.9%)by 2100) and RCP8.5 (8.9% (1.2-16.0%)by 2100) scenarios. The winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) to 20.9% (10.0-33.0%) (RCP8.5) and the summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) to -7.3% (-21.8 — -6.6%) (RCP8.5).

Terrestrial ecosystems are located within all NUTS3 regions.

3.3.16.3 Consequence

- **Damage:** There is potential for intermediate to major impacts on terrestrial habitats, and associated ecosystem services resulting in potentially critical levels of damage by 2100. Ireland has experienced impacts of this risk, with 4 48 species ranked as possibly having a risk of High Impact (Kelly et al., 2013)

- **System Functionality:** The change in climate conditions can ultimately lead to long-term disturbances in this system with major impact or loss of species.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent with the potential to affect all terrestrial habitat types.

- **Cascading Effects:** There are temporary to long-term cascading effects on the Water Security System, meaning increases in occurrence of invasive species can affect water flow and the maintenance of water quality and Food Production and Supply Chain, increases in occurrence of invasive species can affect water flow and the maintenance of water quality.

- **Change through time**: In both scenarios, the changing climate conditions will continually become more suitable for the dispersal and survival of pests and diseases. RCP8.5 will see the greatest change, however, even in an RCP4.5 scenario major damage could result, therefore a Critical level consequence is potentially reached by 2100 in both scenarios.

3.3.16.4 Confidence

Hazard Confidence: There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for the direction and degree of change. However, there is more confidence in the temperature related climate projections, in both the direction and degree of change. Therefore, an overall confidence of medium is assigned to this hazard.

Consequence Confidence: There is medium confidence in the consequence as this risk has and is already occurring within Europe.

3.3.16.5 Adaptation

To address the risk of increased occurrence of invasive species resulting in habitat disturbance due to changes in climate conditions, several practices have been implemented.

Reliability

- *Policy and Governance:* The National Biodiversity Action Plan sets out measures to accelerate adaptation responses to invasive species. The Plant Health and Biosecurity Strategy plans for priority pests provide policy support for biosecurity measures and managing invasive species.
- *Practices in Place:* The National Biodiversity Action Plan establishes a dedicated unit within NPWS to monitor and respond to invasive species and commits to the implementation of EU regulations on invasive species.
- *Monitoring and Early Warning System:* The Plant Science Division's Pest Risk Analysis Unit conducts horizon scanning and Pest Risk Assessments to identify potential threats. Pest vigilance and controls at ports ensure invasive species are detected and managed at entry points.

Resistance

- *Research and Development*: Forest adaptation research investigates how changing climate conditions affect the spread and impact of invasive species.

Recovery and Response

- *Emergency Response Planning:* Emergency response plans for pathogen outbreaks ensure clear protocols and plans are in place.
- *Knowledge Transfer and Training:* Adaptation actions include knowledge transfer and training through the Plant Science Division's Pest Risk Analysis Unit and stakeholder communication, involving capacity-building initiatives.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

3.3.16.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

3.3.17 B17 Risk of degradation and loss of terrestrial ecosystems and habitats due to phenological changes

3.3.17.1 Risk Summary

Table 3.18: B17 Risk of degradation and loss of terrestrial ecosystems and habitats due to phenological changes.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of degradation and loss of terrestrial ecosystems and habitats due to phenological changes	Limited	Substantial	Critical	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

3.3.17.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C (0.6-1.7°C) by 2050, and 1.5°C (1.1-2.2°C) by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C (1.1-1.9°C) by 2050, and 2.7°C (2.0-3.3°C) by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100) scenarios.

Terrestrial ecosystems are located within all NUTS3 regions.

3.3.17.3 Consequence

- **Damage:** There is potential for intermediate to major impacts on terrestrial habitats, and associated ecosystem services resulting in potentially critical levels of damage by 2100.

- **System Functionality:** The change in climate conditions and related phenological changes can ultimately lead to temporary and long-term disturbances in this system with major impact on terrestrial ecosystems.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent with the potential to affect all terrestrial habitat types.

- **Cascading Effects:** There are temporary to long-term cascading effects on the Water Security System, meaning the degradation and loss of terrestrial ecosystems and habitats can affect water flow and the maintenance of water quality and Food Production and Supply Chain, meaning the degradation and loss of terrestrial ecosystems and habitats can lead to soil degradation and the loss of pollinators.

- **Change through time**: In both scenarios, the changing climate conditions will continually alter phenological cycles. RCP8.5 will see the greatest change, however, even in an RCP4.5 scenario major damage could result; therefore, a Critical level consequence is potentially reached by 2100 in both scenarios.

3.3.17.4 Confidence

Hazard Confidence: There is a medium level of confidence that phenological changes will occur due to changing climate conditions. There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for the direction and degree of change. However, there is more confidence in the temperature related climate projections, in both the direction and degree of change. The Growing Season Length and Growing Season Start within the national TRANSLATE projections, the 90th percentile shows a different trend to the ensemble mean, and the 10th percentile. Both of these variables are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is low confidence in the consequence as changing phenological changes can result in both positive and negative impacts upon terrestrial ecosystems therefore there is low confidence how phenological changes will impact upon terrestrial ecosystems habitats.

3.3.17.5 Adaptation

To address the risk of degradation and loss of terrestrial ecosystems and habitats due to phenological changes, several practices have been implemented.

Reliability

- *Policy and Governance:* The Plant Health and Biosecurity Strategy plans for priority pests provide policy support for biosecurity measures and managing phenological changes.
- *Practices in Place:* The National Biodiversity Action Plan addresses habitat destruction, ensuring systematic approaches to managing habitat loss.
- *Monitoring and Early Warning System:* The Plant Science Division's Pest Risk Analysis Unit conducts horizon scanning and Pest Risk Assessments to identify potential threats. Pest vigilance and controls at ports ensure invasive species are detected and managed at entry points.

Resistance

- *Research and Development:* Forest adaptation research investigates how changing climate conditions affect phenological patterns and ecosystem health.

Recovery and Response

- *Emergency Response Planning:* Emergency response plans for pathogen outbreaks ensure clear protocols.
- *Knowledge Transfer and Training:* Adaptation actions include knowledge transfer and training through the Plant Science Division's Pest Risk Analysis Unit and stakeholder communication, involving capacity-building initiatives.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

3.3.17.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4 Built Environment

4.1 System Description

The Built Environment encompasses human-made structures and systems supporting daily life. The Built Environment's subsystems include buildings, cultural heritage, transport infrastructure, recreational, communication, and water services infrastructure.

Within each sub-system of the Built Environment, there are multiple elements at risk from climate change. Under buildings, elements at risk are residential buildings and non-residential buildings.[5] These buildings provide employment, education, healthcare, administration, state services, defence and security, airports, transport hubs, pumping stations, and data storage.

Within cultural heritage, elements at risk include archaeological monuments and sites, historic buildings and settlements, underwater cultural heritage, cultural landscapes, contents and collections, and intangible cultural heritage. Damage or loss of historic buildings and archaeological sites is often irreversible. In addition to the damage to the cultural heritage itself, there can be impacts on social value, sense of place, and wellbeing.

Elements at risk from climate change within the communication subsystem are underground infrastructure, and communication infrastructure. The recreational sub-system consists of elements at risk such as water sports amenities, golf courses, campsites and caravan parks, and outdoor activity tourism. Finally, elements at risk within the water services infrastructure are dam/reservoir infrastructure, stormwater infrastructure, potable water treatment, wastewater treatment, and pipelines.

The Built Environment system has important relevance to various policy sectors for adaptation, especially since it includes both residential and non-residential

[5] The assessment of risk to buildings has been based upon the location and number of the existing building stock in Ireland as of September 2023. The ESRI suggest potential for a population increase of approximately 922.000 people between 2022 and 2040 (ESRI, Population projects the flow of new households and structural housing demand, July 2024). In the context of increased population, the consequence of flooding risks may be higher where the building stock remains in areas at risk of flooding.

buildings. The sub-systems and elements at risk within the Built Environment system are particularly relevant for the adaptation sectors of Communication Networks, Flood Risk Management, Built Environment and Planning, Transport Infrastructure Water Quality, Water Services Infrastructure, Built and Archaeological Heritage, and Health.

The Built Environment system also has importance for the Economy and Finance System. Climate change risks have the potential to impact the built environment, and by extension, the services that buildings and infrastructure provide to their users and wider society. Damage to the built environment from climate risks can ultimately result in disruption to the production and distribution of goods and services.

4.2 Summary of Climate Change Risks

Table 4.1 shows a summary of the consequences for the risks identified to the Built Environment System under both RCP4.5 and RCP8.5 scenarios across three-time horizons (2030, 2050, and 2100).

Table 4.1: Summary of Climate Change Risks in the Built Environment System. Lim = Limited, Sub = Substantial, Cri = Critical, Cat = Catastrophic.

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
BE01	Risk of damage and loss of buildings due to sea level rise, coastal erosion, and coastal flooding	Sub	Cri	Cat	Sub	Cri	Cat
BE02	Risk of damage to buildings due to extreme cold	Sub	Sub	Sub	Sub	Sub	Sub
BE03	Risk of damage and loss of buildings due to extreme precipitation and flooding (fluvial, surface water, and groundwater)	Sub	Cri	Cat	Sub	Cri	Cat
BE04	Risk of overheating within buildings due to extreme heat	Lim	Sub	Sub	Lim	Sub	Cri
BE05	Risk of damage and loss of buildings due to wildfire	Lim	Lim	Sub	Lim	Lim	Sub
BE06	Risk of damage to buildings due to extreme wind	Sub	Sub	Sub	Sub	Sub	Sub
BE07	Risk of disruption and damage to communication infrastructure due to sea level rise, coastal erosion, and coastal flooding	Lim	Sub	Sub	Lim	Sub	Sub
BE08	Risk of disruption and damage to communication infrastructure due to flooding (fluvial, surface water, and groundwater)	Lim	Sub	Sub	Lim	Sub	Cri
BE09	Risk of disruption and damage to communication infrastructure due to ground movement as a result of drought conditions	Lim	Lim	Sub	Lim	Lim	Sub

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
BE10	Risk of disruption and damage to communication infrastructure due to overheating as a result of extreme heat	Lim	Lim	Sub	Lim	Sub	Sub
BE11	Risks of disruption and damage to communication infrastructure due to extreme wind	Cri	Cri	Cri	Cri	Cri	Cri
BE12	Risk of damage and loss of underwater cultural heritage (built and archaeological heritage) due to changes in ocean conditions	Lim	Lim	Lim	Lim	Lim	Lim
BE13	Risk of damage and loss of cultural heritage sites (built and archaeological heritage) due to sea level rise, coastal erosion, and coastal flooding	Lim	Sub	Sub	Lim	Sub	Sub
BE14	Risk of structural damage, deterioration, and subsidence of protected structures and sites (built and archaeological heritage) due to changes in precipitation	Lim	Lim	Lim	Lim	Lim	Lim
BE15	Risk of structural damage and deterioration of protected structures and sites (built and archaeological heritage) due to flooding (fluvial, surface water and groundwater)	Sub	Sub	Sub	Sub	Sub	Sub
BE16	Risk of damage and loss of cultural heritage sites (built and archaeological heritage) due to wildfire	Lim	Lim	Lim	Lim	Lim	Lim
BE17	Risk of structural damage, biological growth and subsidence of protected structures and sites (built and archaeological heritage) due to changes in average temperature	Lim	Lim	Lim	Lim	Lim	Lim
BE18	Risk of structural damage and deterioration of protected structures and sites (built and archaeological heritage) due to extreme wind	Sub	Sub	Sub	Sub	Sub	Sub
BE19	Risk of disruption and damage to recreational amenities due to coastal flooding	Lim	Lim	Lim	Lim	Lim	Lim
BE20	Risks of disruption and damage of recreational amenities due to extreme precipitation and driving rain	Lim	Lim	Lim	Lim	Lim	Lim
BE21	Risks of disruption and damage to recreational assets due to extreme wind	Lim	Lim	Lim	Lim	Lim	Lim
BE22	Risk of disruption to port operations and facilities due to sea level rise and extreme winds and waves	Sub	Sub	Sub	Sub	Sub	Sub
BE23	Risk of disruption, damage, and loss of transport infrastructure due to sea level rise, coastal erosion, and coastal flooding	Sub	Cri	Cat	Sub	Cri	Cat
BE24	Risks of disruption and damage to transport infrastructure due to extreme cold	Sub	Sub	Sub	Sub	Sub	Sub
BE25	Risks of instability of railway cuttings and embankments due to extreme precipitation	Lim	Lim	Lim	Lim	Lim	Lim
BE26	Risks of disruption and damage to transport infrastructure due to extreme precipitation and flooding (fluvial, surface water, and groundwater)	Sub	Cri	Cat	Sub	Cri	Cat
BE27	Risk of disruption and damage to transport infrastructure due to extreme heat	Lim	Sub	Cri	Lim	Sub	Cri
BE28	Risk of disruption, damage, and loss of railway infrastructure due to wildfire	Lim	Lim	Sub	Lim	Lim	Sub
BE29	Risk of disruption and damage to transport infrastructure due to extreme wind	Sub	Sub	Sub	Sub	Sub	Sub
BE30	Risks of disruption and damage to water services infrastructure due to coastal flooding	Lim	Lim	Sub	Lim	Lim	Sub
BE31	Risks of disruption and damage to water services infrastructure due to extreme cold	Sub	Sub	Sub	Sub	Sub	Sub

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
BE32	Risk of disruption and damage to water services infrastructure due to flooding (fluvial, surface water, and groundwater)	Sub	Sub	Cri	Sub	Sub	Cri
BE33	Risks of disruption and damage to water services infrastructure due to ground movement as a result of drought conditions	Lim	Lim	Sub	Lim	Lim	Sub
BE34	Risk of operational issues (i.e. changes to water treatment operations) for water services infrastructure due to increases in average temperature	Lim	Sub	Sub	Lim	Sub	Cri
BE35	Risk of stress on dam/reservoir infrastructure due to drought conditions	Lim	Lim	Sub	Lim	Lim	Sub
BE36	Risk of operational issues due to inability to discharge water into depleted water bodies (i.e., low assimilative capacity, low levels of dissolved oxygen) as a result of drought conditions	Lim	Sub	Sub	Lim	Sub	Sub
BE37	Risks of disruption and damage to water services infrastructure due to extreme wind	Sub	Sub	Sub	Sub	Sub	Sub

4.3 Risks

4.3.1 BE01 Risk of damage and loss of buildings due to sea level rise, coastal erosion, and coastal flooding

4.3.1.1 Risk Summary

Table 4.2: BE01 Risk of damage and loss of buildings due to sea level rise, coastal erosion, and coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage and loss of buildings due to sea level rise, coastal erosion, and coastal flooding	Substantial	Critical	Catastrophic	Substantial	Critical	Catastrophic
Urgency	More Action Needed					
Hazard Confidence	High					
Consequence Confidence	Medium					

Ireland's coastal regions are increasingly exposed to the impacts of sea level rise, coastal erosion, and coastal flooding, which pose significant risks to buildings and infrastructure. Rising sea levels cause more frequent and severe flooding, leading to structural damage to buildings through water damage and corrosion of building materials. Rising sea levels are also a driver for coastal erosion which can weaken foundations and damage buildings.

4.3.1.2 Exposure and Vulnerability

Using the OPW National Coastal Flood Hazard Mapping (NCFHM), for a 1 in 100-year event (1% Annual Exceedance Probability) under RCP4.5, 1.68% of buildings [6] in Ireland (based on the current total number and location of buildings) are at risk of coastal flooding by 2050. Similarly, for a 1 in 100-year event under RCP8.5, 1.68% of buildings are at risk of coastal flooding. By 2100, 1.98% of buildings in Ireland are at risk of coastal flooding for a 1 in 100-year event under RCP4.5, whereas under RCP8.5, 2.26% of buildings are at risk of coastal flooding for a 1 in 100-year event by 2100.

[6] The term 'Buildings' is defined as the entire buildings layer from the OSi Prime2 dataset.

Of the eight NUTS3 regions, seven are affected by coastal flooding. The Midlands region has no coastline and is therefore not exposed. The Mid-East and South-West Region being the most affected regions (Figure 4.1 and Figure 4.2). The Midlands Region is the only of the eight NUTS3 regions which is not impacted by coastal flooding, given its geographic location.

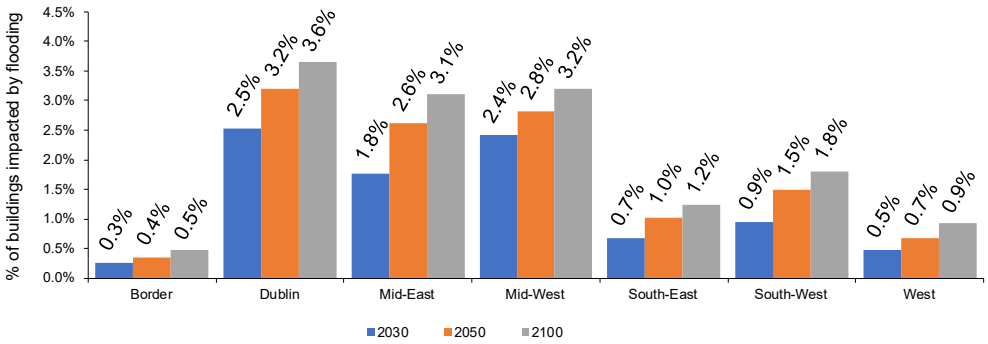


Figure 4.1: The proportion of buildings (OSi PRIME2) impacted by coastal flooding (1% AEP, RCP4.5, NCFHM). Note that the Midlands region is not shown.

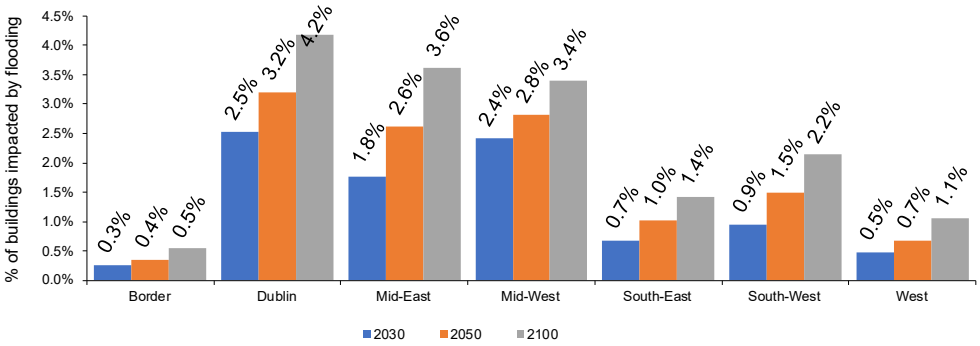


Figure 4.2: The proportion of buildings (OSi PRIME2) impacted by coastal flooding (1% AEP, RCP 8.5, NCFHM). Note that the Midlands region is not shown.

The South-West Region is expected to experience the highest sea-level rise across all scenarios and time periods. The South-West Region is projected to experience sea level rise under an RCP4.5 scenario of 0.24 m by 2050, and 0.51 m by 2100, and 0.26 m by 2050, and 0.65 m by 2100 under an RCP8.5 scenario. Sea level rise drives the exposure to coastal flooding, meaning that the South-West Region is particularly exposed to coastal flooding. The Border Region meanwhile will see the lowest increase in sea level rise.

The length of coastline projected to be at risk of coastal erosion in Ireland by 2050 is 328 km. The South-West (85 km) and South-East (46 km) regions are most at

risk, however, the effects of climate change were not included within this assessment.

4.3.1.3 Consequence

- **Damage:** There is potential for very large and frequent impacts on buildings resulting in potentially Catastrophic levels of damage by 2100.

- **System Functionality:** The impacts of sea level rise, coastal flooding and coastal erosion can lead to temporary to long-term disturbances, and potentially irreversible losses in this system with severe impacts on both residential and commercial buildings.

- **Extent and Pervasiveness:** The whole Irish coastline is exposed to sea level rise, with exposure to coastal flooding and coastal erosion dependent upon local conditions, i.e., elevation, lithology. The largest impacts will occur in areas that have concentrations of buildings close to the coast, however, all NUTS3 regions (apart from the Midlands) are exposed to this risk to varying degrees of severity.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Health System, i.e., damage to healthcare infrastructure, leading to costly repairs and reconstruction, business interruption due to the unavailability of healthcare services, affecting employee health and productivity, the Biodiversity and Ecosystem System, i.e., flooding can lead to the release of hazardous materials from facilities, contaminating water bodies and ecosystems, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, i.e., temporary use of accommodation to rehouse people can reduce supply of accommodation for tourism purposes.

- **Change through time**: In both scenarios, sea level rise will increase at similar rates to 2050, however, beyond this point RCP8.5 has a higher sea level by the end of the century compared to RCP4.5. Nevertheless, the spatial analysis

shows only minor differences in the number of buildings exposed to this risk. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the number of buildings (residential and commercial) is possible. Therefore, a Catastrophic level of consequence is potentially reached by 2100 in both scenarios.

4.3.1.4 Confidence

Hazard Confidence: There is high confidence that sea level rise, coastal flooding, and coastal erosion will increase in frequency and severity in the future. Global projections, including those from the IPCC Assessment Report 6, have been used to inform sea level rise, while national projections for coastal change (erosion or accretion) are unavailable, with extrapolation of current erosion rates for 2050 used instead. Coastal flood extent and frequency changes have been assessed by the OPW using rigorous models, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used. There is less confidence in the spatial distribution of coastal erosion in the future due to limited assessment of future coastal change that includes the consideration of climate change.

Consequence Confidence: The impacts of coastal flooding and coastal erosion are already affecting Ireland and this impact will increase in the future. However, the spatial distribution of these impacts related to coastal erosion is still uncertain. Therefore, a Medium level of confidence is assigned to the consequence of this risk.

4.3.1.5 Adaptation

To address the risk of damage and loss of buildings due to sea level rise, coastal erosion, and coastal flooding, several adaptation measures are in place:

Reliability

- *Policy and Governance:* The Planning and Development Act, Section 28 Guidelines, and the National Catchment Flood Risk Assessment and

Management Programme (CFRAM) provide a regulatory framework for adaptation. Notably, the Preliminary Flood Risk Assessment (PFRA) is reviewed every six years, as mandated by the EU Floods Directive, to ensure up-to-date flood risk management strategies. The Flood Risk Management Sectoral Adaptation Plan also supports management of this risk.

- *Monitoring and Early Warning Systems*: Continuous monitoring of physical coastal changes and national-scale coastal hazard mapping and risk assessments are conducted. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Sector-Specific Adaptation Actions:* The Office of Public Works (OPW) implements various schemes, including the Capital Flood Relief Scheme, Minor Flood Mitigation Works, and the Coastal Protection Scheme, to address coastal risks. Assessments of management options for coastal change risks and long-term planning are also in place.
- *Research and Development:* The Coastal Change Research Programme and the National Marine Research and Innovation Strategy support ongoing research to understand and mitigate coastal risks. The PFRA is reviewed every six years under the EU Floods Directive, ensuring that assessments of future flood risks remain current and relevant.
- *Practices in Place*: The National Adaptation Framework, Built & Archaeological Heritage Climate Change Adaptation Plan, and Local Authority Climate Action Plans guide adaptation efforts. The Flood Risk Management Climate Change Sectoral Adaptation Plan and Climate Risk Assessments identify vulnerabilities and inform planning.

Recovery and Response

- *Emergency Response:* The Major Emergency Management (MEM) Framework provides structured emergency response protocols for flood events. This framework ensures coordinated actions among relevant agencies during emergencies.

- *Humanitarian Aid Schemes:* Post-flooding, humanitarian aid schemes are available to support affected individuals and communities, facilitating recovery and rebuilding efforts.

Redundancy

- *Future Strategies:* While explicit redundancy measures have not yet been implemented, the ongoing work by the Inter-Departmental Group on Managing Coastal Change Strategy is anticipated to inform future strategies. This may include the development of redundant systems to enhance resilience against coastal risks.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Effective for managing this risk.

4.3.1.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is More Action Needed.

4.3.2 BE02 Risk of damage to buildings due to extreme cold

4.3.2.1 Risk Summary

Table 4.3: BE02 Risk of damage to buildings due to extreme cold.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage to buildings due to extreme cold	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	High					

Extreme cold in Ireland can pose significant risks to buildings and infrastructure. Cold temperatures cause materials like concrete and metal to contract, leading to cracks and structural weaknesses. This can compromise the integrity of buildings, making them more susceptible to damage. Heavy snowfall can add significant weight to roofs, potentially causing collapses if buildings are not designed to handle such loads. Additionally, frozen pipes can burst, leading to water damage and costly repairs. The accumulation of snow and ice can also block gutters and drainage systems, causing water to back up and damage roofs and walls.

4.3.2.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience a decrease in the number of frost days and a decrease in the number of icing days. Under RCP4.5, the number of frost days is expected to decrease by 21.1 days (-27.2 — -15.0) by 2100 with the Border region experiencing the largest decrease (-24.5 days (-31.4 — -17.6)). In an RCP8.5 scenario, number of frost days are expected to decrease by 31.4 days (-37.0- -24.7), with the Border region experiencing the largest decrease (-36.5 days (-43.3 - -28.9)

Under RCP4.5, regions are estimated to experience 0.30 (-0.4 — -0.2) fewer icing days by 2100 with the Mid-East region experiencing the largest decrease (-0.4

days). In an RCP8.5 scenario, there is projected to be 0.36 (-0.4 ─ -0.3) fewer icing days, with the Mid-East region experiencing the largest decrease (-0.5 days)

There are a total of 3.1 million buildings which will be exposed to extreme cold across the NUTS3 regions.

4.3.2.3 Consequence

- **Damage**: Extreme cold can cause moderate damage to buildings in 2030 and 2050, such as cracked foundations, burst pipes, and structural weaknesses. By 2100, even though the hazard frequency and severity decreases, due to an increase in exposure the consequence remains Substantial.

- **System Functionality**: Across all time periods, extreme cold can lead to temporary or moderate disturbances.

- **Extent and Pervasiveness**: The impact is substantial across all time periods, affecting a wide range of buildings and regions.

- **Cascading Effects**: This risk results in temporary cascading effects are possible. These cascading effects include the Health System, i.e., damage to buildings can result in increased emergency service demand as well as posing physical health risks, the Social System, i.e., economic disruption, and the Energy System, i.e., where damage to buildings can result in an increase in demand for energy.

- **Change through time**: The hazard is already a risk but will decrease in frequency and severity in the future, although the hazard will still occur. Impacts will reduce but not sufficiently to reach the Limited category, as there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the number of buildings (residential and commercial) is possible increasing exposure. There are only minor differences between the RCP4.5 and RCP8.5 scenarios, therefore the consequence is the same.

4.3.2.4 Confidence

Hazard Confidence: There is a High level of confidence that extreme cold events will decrease in the future with global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is a decreasing trend for the extreme cold variables (frost days and icing days). The national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform the extreme cold variables, using a robust and peer-reviewed modelling approach.

Consequence Confidence: The impacts of extreme cold are already affecting Ireland and this impact is expecting to decrease in the future. Therefore, the confidence in the consequence is High, with some uncertainty on the change of exposure in the future.

4.3.2.5 Adaptation

To address the risk of damage to buildings due to extreme cold, several adaptation measures are in place:

Reliability

- *Policy and Governance*: Workplace and health and safety regulations ensure buildings are safe and habitable during extreme cold.
- *Monitoring and Early Warning Systems:* Systems are in place to monitor building performance and energy usage during extreme cold events.
- *Practices in Place*: Building regulations mandate a minimum BER rating for new builds. Energy efficiency regulations and schemes are implemented to enhance building resilience.

Resistance

- *Sector-Specific Adaptation Actions:* Building refurbishment projects enhance comfort and energy efficiency.
- *Community Engagement and Education:* Public awareness campaigns educate communities on energy-saving practices a during cold weather.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the secondary research and stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

4.3.2.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.3 BE03 Risk of damage and loss of buildings due to extreme precipitation and flooding (fluvial, surface water, and groundwater)

4.3.3.1 Risk Summary

Table 4.4: BE03 Risk of damage and loss of buildings due to extreme precipitation and flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage and loss of buildings due to extreme precipitation and flooding (fluvial, surface water, and groundwater)	Substantial	Critical	Catastrophic	Substantial	Critical	Catastrophic
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	High					

The risk of damage and loss of buildings due to extreme precipitation and flooding is increasing due to changing climate conditions. Extreme precipitation and flooding can cause significant structural damage to buildings, water damage, promote mould growth, and create electrical hazards. Heavy rainfall can soften ground conditions, leading to foundation failure and structural collapse. Heavy rainfall can also overwhelm drainage systems, leading to water intrusion and prolonged dampness, which fosters mould growth and deteriorates indoor air quality. Flood waters can result in contamination of watercourses leading to issues for drinking water supply and water for industrial use.

4.3.3.2 Exposure and Vulnerability

Under the RCP4.5 scenario, 1.04% of buildings[7] (based on the current total number and location of buildings) across all NUTS3 regions are projected to be impacted by fluvial flooding by 2100, according to CFRAM data. As for the RCP8.5 scenario 1.62% of buildings are estimated to be affected by fluvial flooding (CFRAM) by 2100. Buildings in the Mid-East Region are the most

[7] The term 'Buildings' is defined as the entire buildings layer from the OSi Prime2 dataset.

exposed to fluvial flooding under both scenarios, with 2.08% of buildings impacted under RCP4.5 (Figure 4.3), and 4.9% of buildings affected under RCP8.5 (Figure 4.4).

In terms of NIFM data, all regions are projected to be affected by fluvial flooding by 2100. For the RCP4.5 scenario, 0.61% of buildings are exposed to fluvial flooding. Similarly, 0.66% of buildings are exposed to fluvial flooding across all NUTS3 regions. Buildings in the South-West Region are particularly exposed, with 0.86% affected by fluvial flooding for RCP4.5 (Figure 4.5), and 0.92% impacted under RCP8.5 (Figure 4.6).

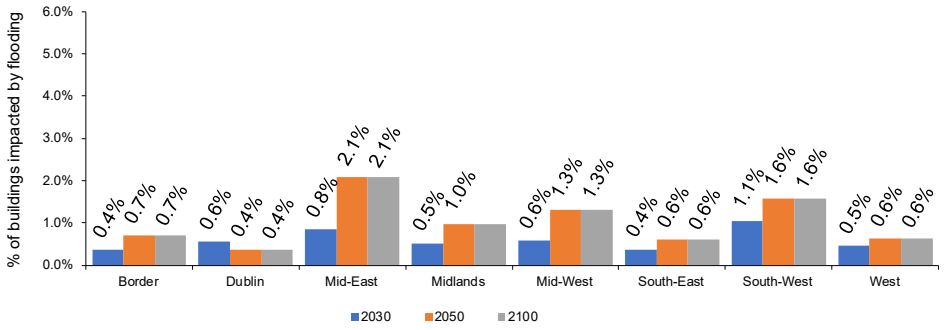


Figure 4.3: The proportion of buildings (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP4.5, CFRAM)

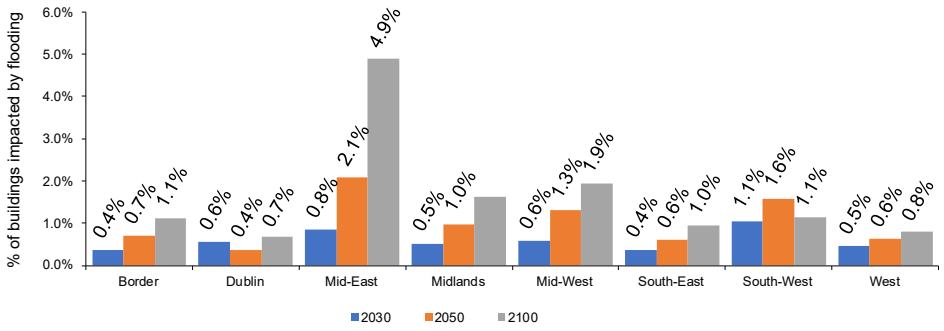


Figure 4.4: The proportion of buildings (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP8.5, CFRAM).

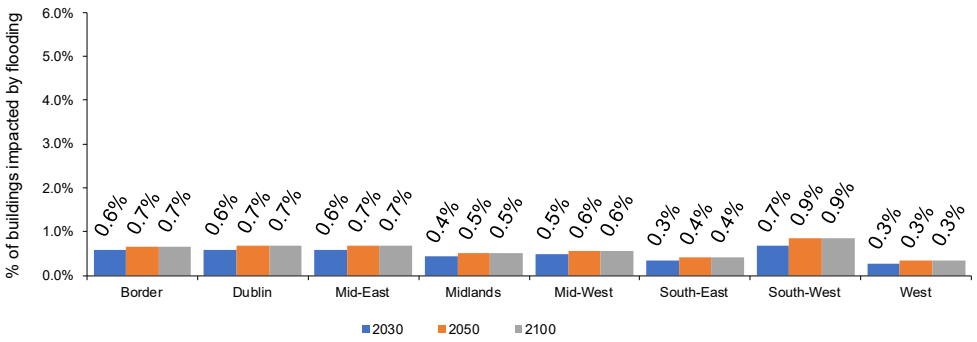


Figure 4.5: The proportion of buildings (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP4.5, NIFM)

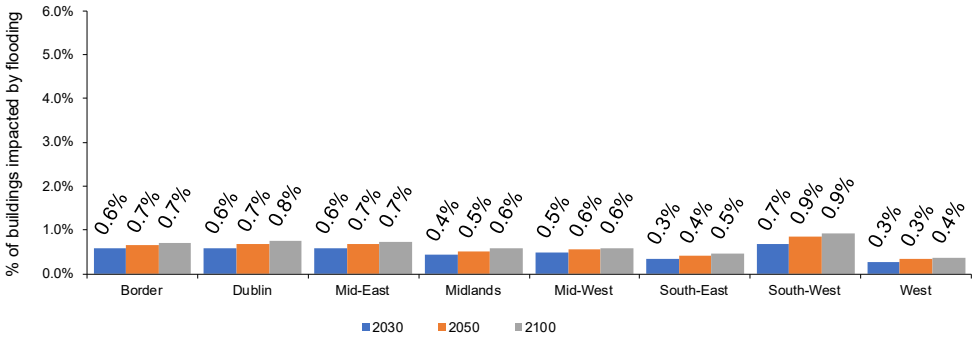


Figure 4.6: The proportion of buildings (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP 8.5, NIFM).

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5% by 2100) and RCP8.5 (8.9% by 2100) scenarios.

In terms of seasonality, the winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) and 20.9% (10.0-33.0%) (RCP8.5) by 2100. The summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) and -7.3% (-21.8 — -6.6%) (RCP8.5) by 2100. All NUTS3 regions are projected to experience an increase in five-day precipitation across both RCP4.5 (10.2% by 2100) and RCP8.5 (16.5% by 2100). Similarly, each region will see an increase in the number of very wet days under both RCP4.5 (an increase of 0.8 days by 2100) and RCP8.5 (an increase of 1.4 days by 2100).

4.3.3.3 Consequence

- **Damage:** Currently, buildings face substantial losses due to extreme precipitation and flooding (fluvial, surface water, and groundwater). Ireland already experiences impacts from this risk, for instance:
    - Between 2000 and 2014, total insured losses from flooding surpassed €1 billion, with the 2009 floods alone causing costs of over €244 million (Murphy et al., 2023).
    - In 2015, approximately 1,000 properties were flooded and thousands more at risk or cut-off nationally, with record flood levels in many parts of the country, particularly in the West (Office of Public Works (OPW), 2019).
    - Heavy rainfall occurred in Donegal in August 2017, with over 70 mm falling in 9 hours, causing significant damage to roads and bridges (Department of Housing, Local Government and Heritage, 2019).

  By 2050, large and frequent damage may occur, with very large and frequent damage by 2100 anticipated, as the intensity and frequency of extreme precipitation and flooding (fluvial, surface water, and groundwater) increases.

- **System Functionality:** Currently, flooding causes temporary or moderate disturbances to buildings. By 2050, long-term disturbances may occur, with irreversible losses by 2100 anticipated.

- **Extent and Pervasiveness:** Currently, impacts are of a moderate extent or pervasiveness. As extreme precipitation and flooding are projected to increase in frequency and intensity by 2050, these impacts will be more widespread, affecting larger areas and a greater number of buildings, with very large and pervasive impacts by 2100.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Health System, i.e., damage to healthcare infrastructure, leading to costly repairs and reconstruction, business interruption due to the unavailability of healthcare services, affecting employee health and productivity, the Biodiversity and Ecosystem System,

i.e., flooding can lead to the release of hazardous materials from healthcare facilities, contaminating water bodies and ecosystems, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, i.e., temporary use of accommodation to rehouse people can reduce supply of accommodation for tourism purposes.

- **Change through time**: In both scenarios, the changing climate conditions will continually increase the frequency and severity of flooding events. However, there are only minor differences between RCP4.5 and RCP8.5. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the number of buildings (residential and commercial) is possible, resulting in potential Catastrophic levels of risk by 2100.

4.3.3.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020).

Consequence Confidence: There is high confidence in the consequence as the impacts of this risk have already been observed and will likely increase in frequency and severity in the future.

4.3.3.5 Adaptation

To address the risk of damage and loss of buildings due to extreme precipitation and flooding (fluvial, surface water, and groundwater), several adaptation measures are in place:

Reliability

- *Policy and Governance:* Planning regulations, the Implementation of Planning and Development Act Section 28 Guidelines, and emergency response planning provide a regulatory framework for adaptation.
- *Practices in Place:* The Built & Archaeological Heritage Climate Change Sectoral Adaptation Plan and the Flood Risk Management Climate Change Sectoral Adaptation Plan guide adaptation effort. The National Catchment Flood Risk Assessment and Management Programme and the 3rd cycle of Flood Directive Implementation are key initiatives.
- *Monitoring and Early Warning Systems*: National flood forecasting and warning services are being established. Monitoring includes the review of Minor Flood Mitigation Works and the implementation of Flood Risk Management Plans. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Community Engagement and Education*: Public awareness campaigns and community resilience research are integral to adaptation efforts.
- *Research and Development:* Research focuses on advancing community resilience and developing infrastructure to upgrade surface water networks.
- *Sector-Specific Adaptation Actions:* The OPW Capital Flood Relief Scheme, OPW Minor Flood Mitigation Works address risks. Planning guidance and Scheme Climate Change Adaptation Plans are in place.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.3.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.4 BE04 Risk of overheating within buildings due to extreme heat

4.3.4.1 Risk Summary

Table 4.5: BE04 Risk of overheating within buildings due to extreme heat.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of overheating within buildings due to extreme heat	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	High					

With increasing temperatures, Ireland is experiencing more frequent and intense heatwaves, increasing the risk of overheating in buildings. Extreme heat can cause buildings to overheat, leading to uncomfortable and potentially dangerous indoor conditions. Prolonged exposure to high temperatures can cause the deterioration of building materials, such as the warping of wood, the expansion and cracking of concrete, and the degradation of insulation.

4.3.4.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38))

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-

0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2))

A total of 3.1 million buildings across all NUTS3 regions will be potentially exposed to extreme heat.

4.3.4.3 Consequence

- **Damage**: Limited or rare losses initially, with increased damage to large and frequent levels under an RCP8.5 scenario.
- **System Functionality**: Overheating can cause temporary or moderate disturbances in building operations; however, under an RCP8.5 scenario, these disturbances could become more chronic and therefore long-term if the frequency of extreme heat events increases.
- **Extent and Pervasiveness**: Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all building types.
- **Cascading Effects**: There are temporary cascading effects on Health System, meaning that the overheating in buildings can cause heat stress, especially within vulnerable populations such as the elderly and those with pre-existing health conditions, and the Energy System, where increased temperatures will increase energy use for cooling.
- **Change through time**: The risk is currently Limited but will increase significantly in the future, especially under the RCP8.5 scenario, leading to potential critical levels of damage with large and frequent impacts as extreme heat events become more common and severe. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the number of buildings (residential and commercial) is possible.

4.3.4.4 Confidence

Hazard Confidence: For extreme heat there is high confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: Overheating within buildings already occur within Ireland, and there are impacts of this already observed, therefore confidence in the consequence is High.

4.3.4.5 Adaptation

To address the risk of overheating within buildings due to extreme heat, several adaptation measures are in place:

Reliability

- *Policy and Governance:* Workplace regulations ensure safe working conditions during extreme heat. Planning regulations support the implementation of adaptation measures.
- *Practices in Place:* The Built & Archaeological Heritage Climate Change Adaptation Plan guide adaptation efforts. Building regulations mandate ventilation and cooling standards.
- *Monitoring and Early Warning Systems:* Forecasting and weather warnings are in place to alert communities about extreme heat events.

Resistance

- *Research and Development:* Research focuses on sustainable building design and improving temperature control systems.
- *Sector-Specific Adaptation Actions:* Sustainable building design and refurbishment projects enhance temperature control. Air conditioning is

installed in accommodation, catering, and recreational venues. Tree cover and urban greening initiatives reduce urban heat.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Ineffective for managing this risk.

4.3.4.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.5 BE05 Risk of damage and loss of buildings due to wildfire

4.3.5.1 Risk Summary

Table 4.6: BE05 Risk of damage and loss of buildings due to wildfire.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage and loss of buildings due to wildfire	Limited	Limited	Substantial	Limited	Limited	Substantial
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	Medium					

Changing climate conditions, such as changes in precipitation and drought conditions, will potentially result in conditions suitable for wildfires occurring more frequently. Wildfires can cause extensive damage, often resulting in total loss. Buildings located in the wildland-urban interface (WUI) are particularly

vulnerable to wildfires. This is where human development meets and intermingles with natural vegetation, creating a high-risk environment. In addition to direct flame and heat damage, embers carried by the wind can ignite structures far from the main fire1. Wildfires can also lead to secondary damage, such as smoke infiltration, which can degrade indoor air quality and cause long-term health issues.

4.3.5.2 Exposure and Vulnerability

The Fire Weather Index (FWI) is a meteorologically based index used worldwide to estimate fire danger. It is developed by the Canadian Forestry Service to estimate forest fire ignition and spread conditions based on several weather variables (temperature, precipitation, relative humidity, and wind speed). At the NUTS2 region level, the projected FWI (from 1980-2010) shows the Southern region is projected to experience the largest increase in FWI in both 2050 (RCP4.5:0.27, RCP8.5: 0.62) and 2100 (RCP4.5:0.62, RCP8.5: 0.95).

There are 3.1 m buildings national situated across all NUTS3 Regions that will be potentially exposed.

4.3.5.3 Consequence

- **Damage:** Initially, the risk of damage and loss of buildings due to wildfire is limited or rare. However, the risk increases to substantial under both RCP4.5 and RCP8.5 scenarios driven by the change in climate.

- **System Functionality:** Wildfires can cause temporary disturbances to the Built Environment. However, as the risk increases to substantial, these disturbances could become more pronounced, affecting the functionality of buildings for longer periods.

- **Extent and Pervasiveness:** Initially, the extent of damage is limited, but it will increase to a substantial extent under both scenarios. This indicates that while the initial impact might be confined to buildings in specific areas,

the impact will become more widespread as wildfires become more frequent and intense.

- **Cascading Effects:** The cascading effects of damage and loss of buildings due to wildfire include disruptions to the Health System, i.e., increase demand on health services due to physical injury to people, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, i.e. supply of temporary accommodation for people affected.

- **Change through time:** In both scenarios, the changing climate conditions will continually become more suitable for wildfire occurrence resulting in a Substantial level consequence by 2100 for both scenarios. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the number of buildings (residential and commercial) is possible.

4.3.5.4 Confidence

Hazard Confidence: There is a Low level of confidence that wildfires will increase in frequency and severity in the future as there are limited climate projections available related to the changes in fire weather for Ireland, with no national scale projections, therefore European scale projections (EURO-CORDEX) have been used.

Consequence Confidence: Wildfires already occur within Ireland, however, there is limited information on the local scale variability, i.e., impact of terrain, fuel availability, potential sources of ignition, and how these may change in the future therefore confidence in the consequence is Medium.

4.3.5.5 Adaptation

To address the risk of damage and loss of buildings due to wildfire, several adaptation measures are in place:

Reliability

- *Policy and Governance:* The Prescribed Burning Code and Forest Fire Danger Notices provide information for wildfire management.
- *Practices in Place:* Climate Risk Assessments identify vulnerabilities and inform planning. The Built & Archaeological Heritage Climate Change Adaptation Plan guides specific sectoral actions.
- *Monitoring and Early Warning Systems:* Forecasting and weather warnings are in place to alert communities about wildfire risks.

Resistance

- *Community Engagement and Education*: Public guidance on wildfire prevention educates communities on risk reduction practices.
- *Research and Development:* Research focuses on effective fire management strategies and improving wildfire resilience.
- *Sector-Specific Adaptation Actions:* Fire management plans are developed and encouraged to mitigate wildfire risks.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.5.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is a Watching Brief.

4.3.6 BE06 Risk of damage to buildings due to extreme wind

4.3.6.1 Risk Summary

Table 4.7: BE06 Risk of damage and loss of buildings due to extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage and loss of buildings due to wildfire	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Very Low					
Consequence Confidence	High					

Extreme wind poses a significant risk to buildings in Ireland, particularly as climate change increases the frequency and intensity of such events. Extreme winds can lead to damage such as roof detachment, tear off exterior cladding, broken windows, and compromises structural integrity and expose interiors to further damage from rain and debris. These damages can result in significant repair costs and potentially hazardous conditions for occupants. Additionally, wind-driven rain can penetrate buildings, causing water damage and promoting mould growth. Wind-driven rain can infiltrate buildings through gaps and cracks, leading to water damage that affects walls, ceilings, and insulation, promoting mould growth and deteriorating indoor air quality. Repeated exposure to high winds can cause long-term wear and tear on building materials, reducing their lifespan and increasing maintenance costs.

4.3.6.2 Exposure and Vulnerability

For RCP4.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.32 days, 2100: -0.47) from the 1981-2010 baseline. For RCP8.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region

showing the largest decrease (2050: -0.61 days, 2100: -0.44) from the 1981-2010 baseline.

For RCP4.5, there is a projected small decrease in the 10-m wind speed of 1.0–2.7% (mean 1.8%) compared to the 1981-2000 baseline by 2050. For RCP8.5, there is a 1.6–3.3% (2.6%) decrease.

Nationally, across all NUTS3 regions, there are 3.1 million buildings which will be potentially exposed to extreme wind.

4.3.6.3 Consequence

- **Damage**: Extreme wind can cause substantial losses to buildings. Ireland already experiences impacts from this risk, for instance:
    - Storm Ophelia, caused €70 million in damages, resulting from significant wind damage, including roofs blown off, trees felled, and buildings damaged (Department of Housing, Local Government and Heritage, 2019).
    - Ireland experienced severe winds due to Storm Darwin in February 2014, with maximum sustained speeds of 120 km/h and gusts up to 160 km/h. The storm caused considerable damage to housing and other buildings, leaving more than 215,000 homes without power (Department of Housing, Local Government and Heritage, 2019).
- **System Functionality**: Extreme wind can cause moderate disturbances to the Built Environment system, affecting the functionality and safety of the structures
- **Extent and Pervasiveness**: The impact of extreme wind events is widespread, affecting a large number of buildings, and building types, across extensive areas, indicating a large extent and pervasiveness.
- **Cascading Effects**: There are temporary cascading effects, due to the closure of buildings during and after an event. Depending on the type of buildings that are closed, this could lead to impacts on the Health System,

the damage to buildings can impact access to healthcare facilities, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, whereby it can result in business closure and service disruption.

- **Change through time**: Projections show no change in hazard (although with very low levels of confidence). There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the number of buildings (residential and commercial) is possible. However, the risk is currently assessed as a Substantial consequence, and this current level of risk is expected to continue into the future.

4.3.6.4 Confidence

Hazard Confidence: There is a Very Low level of confidence that extreme wind frequency and severity will not change in the future. There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used at the NUTS2 level, with national scale data for average wind speed used as an alternative proxy.

Consequence Confidence: There is High confidence in the consequence as the impacts of this risk have already been observed and will likely continue in the future.

4.3.6.5 Adaptation

To address the risk of damage to buildings due to extreme wind, several adaptation measures are in place:

Reliability

- *Policy and Governance:* Centrally managed and locally delivered responses to severe weather ensure coordinated action. Health and safety assessments are conducted to ensure building resilience.
- *Practices in Place:* Climate risk assessments identify vulnerabilities and inform planning. Building regulations ensure structures can withstand extreme wind.
- *Monitoring and Early Warning Systems:* Weather forecasting and severe weather warnings alert communities about impending extreme wind events.

Resistance

- *Sector-Specific Adaptation Actions:* Emergency repair work is carried out to address damage caused by extreme wind.
- *Community Engagement and Education:* Public awareness campaigns educate communities on preparedness and safety measures during extreme wind events.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.6.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is Further Investigation.

4.3.7 BE07 Risk of disruption and damage to communication infrastructure due to sea level rise, coastal erosion, and coastal flooding

4.3.7.1 Risk Summary

Table 4.8: BE07 Risk of disruption and damage to communication infrastructure due to sea level rise, coastal erosion, and coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to communication infrastructure due to sea level rise, coastal erosion, and coastal flooding	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Sustain Current Action					
Hazard Confidence	High					
Consequence Confidence	Low					

Coastal erosion and flooding pose a risk to communication infrastructure located in coastal areas. These hazards can damage physical assets such as cables, towers, and data centres, leading to service disruptions and increased maintenance costs. Coastal erosion can undermine the foundations of towers and other structures, causing them to become unstable or collapse. Coastal flooding can inundate underground cables and data centres, leading to water damage and corrosion. Additionally, saltwater intrusion from flooding can accelerate the deterioration of metal components, further compromising the integrity of communication infrastructure.

4.3.7.2 Exposure and Vulnerability

Using the OPW National Coastal Flood Hazard Mapping (NCFHM), for a 1 in 100-year event (1% Annual Exceedance Probability) for communication buildings [8], projections under RCP4.5 and RCP8.5 scenarios show that across all NUTS3 regions 5.9% communication buildings, will be impacted by coastal flooding by 2100 (NCHFM).

[8] The term 'Communication buildings' is defined as the following OSi Prime2 category: Telecommunication (buildings).

In terms of communication structures[9] in the NUTS3 regions, the RCP4.5 scenario estimates that 5.45% of communication structures will be impacted by coastal flooding by 2100. The RCP8.5 scenario on the other hand projects 7.27% communication structures will be impacted by coastal flooding by 2100.

The South-West Region is expected to experience the highest sea-level rise across all scenarios and time periods. The South-West Region is projected to experience sea level rise under an RCP4.5 scenario of 0.24 m by 2050, and 0.51 m by 2100, and 0.26 m by 2050, and 0.65 m by 2100 under an RCP8.5 scenario. Sea level rise drives the exposure to coastal flooding, meaning that the South-West Region is particularly exposed to coastal flooding. The Border Region meanwhile will see the lowest increase in sea level rise.

The length of coastline projected to be at risk of coastal erosion in Ireland by 2050 is 328 km. The South-West (85 km) and South-East (46 km) regions are most at risk, however, the effects of climate change were not included within this assessment.

4.3.7.3 Consequence

- **Damage**: Initially, the risk of damage to communication infrastructure due to sea level rise, coastal erosion, and coastal flooding is limited. However, this risk increases to substantial for both 2050 and 2100 under both scenarios.

- **System Functionality:** Coastal erosion and flooding currently cause limited or rare losses to communication infrastructure. The risk could increase to substantial over time, as these disturbances could become temporary or cause moderate disturbances, affecting the reliability of communication networks.

- **Extent and Pervasiveness:** Initially, the extent of damage is limited, but it will increase to a moderate extent by 2050 and 2100 under both scenarios.

[9] The term 'Communication structures is defined as the following OSi Prime2 category: Telecommunication (structures).

- **Cascading Effects:** There are initially no cascading effects beyond system boundaries. However, for both 2050 and 2100 under both scenarios. temporary cascading effects are anticipated. These cascading effects include impacts on the Health System, meaning the disruption and damage to communication infrastructure can impact emergency response time, public safety and healthcare, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, where it can cause business disruption and impact social connectivity.

- **Change through time:** Projections show sea levels to rise around Ireland, causing coastal changes and increasing coastal flooding. The increased frequency and extent of coastal flooding and erosion will expose more communication infrastructure, increasing the consequence from Limited to Substantial by 2050 and 2100 under both scenarios.

4.3.7.4 Confidence

Hazard Confidence: There is high confidence that sea level rise, coastal flooding, and coastal erosion will increase in frequency and severity in the future. Global projections, including those from the IPCC Assessment Report 6, have been used to inform sea level rise, while national projections for coastal change (erosion or accretion) are unavailable, with extrapolation of current erosion rates for 2050 used instead. Coastal flood extent and frequency changes have been assessed by the OPW using rigorous models, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used. There is less confidence in the spatial distribution of coastal erosion in the future due to limited assessment of future coastal change that includes the consideration of climate change.

Consequence Confidence: The confidence in the consequence is Low as there is limited spatial information available to fully assess the number and

type of communication assets that are or could be exposed to these hazards currently and in the future.

4.3.7.5 Adaptation

To address the increased risk of disruption and damage to communication infrastructure due to coastal erosion and coastal flooding, several adaptation measures are in place. The following measures collectively aim to enhance resilience against coastal hazards and ensure the continuity of critical communications services:

Reliability

- *Policy and Governance:* Coastal risks are integrated into the National Adaptation Framework and the Communications Sectoral Climate Change Adaptation Plan. Governance structures ensure that coastal hazard assessments, including sea level rise and erosion trends, are incorporated into infrastructure planning and resource allocation.
- *Monitoring and Early Warning Systems:* Collaborative arrangements with meteorological agencies (e.g., Met Éireann) and coastal monitoring networks provide real-time alerts on sea level changes and flooding events. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.
- *Risk Assessment:* Regular assessments, using coastal vulnerability mapping and hazard analyses, identify areas of exposure, guiding targeted reinforcement and relocation strategies.

Resistance

- *Infrastructure Reinforcement:* Measures include elevating critical network assets, installing seawalls or protective barriers, and using corrosion-resistant materials to mitigate the effects of saltwater exposure.
- *Design Standards:* Communication infrastructure has ingress protection (IP) standards which if adopted and maintenance is performed as per specification the impact of flooding can be minimised.

- *Community Engagement and Education*: End-user reports and operator reports to ComReg ensure community involvement and regulatory compliance.
- *Research and Development:* Ongoing R&D focuses on innovative coastal protection solutions and resilient design practices to adapt existing infrastructure to long-term coastal change.

Recovery and Response

- *Emergency Response Planning:* Pre-established contingency plans ensure rapid repair and restoration of services after coastal flooding events. This includes pre-arranged repair contracts and backup power arrangements.
- *Knowledge Transfer and Training:* Regular training sessions for technical teams on coastal emergency protocols support swift recovery and minimize service disruption.

Redundancy

- *Backup Systems:* Redundant network routes and alternative communication nodes are maintained to ensure service continuity if coastal assets become compromised.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Effective for managing this risk.

4.3.7.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is to Sustain Current Action.

4.3.8 BE08 Risk of disruption and damage to communication infrastructure due to flooding (fluvial, surface water, and groundwater)

4.3.8.1 Risk Summary

Table 4.9: BE08 Risk of disruption and damage to communication infrastructure due to flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to communication infrastructure due to flooding (fluvial, surface water, and groundwater)	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Sustain Current Action					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Flooding (fluvial, surface water, and groundwater) poses a risk to communication infrastructure, a risk that is exacerbated by Ireland's changing climate. Flooding can lead to the interruption of communication services, affecting both residential and commercial users, while also causing physical damage to infrastructure such as telephone lines, internet cables, and mobile network towers. Floodwaters can inundate underground cables and data centres, leading to water damage and corrosion.

4.3.8.2 Exposure and Vulnerability

Based on CFRAM and NIFM data, for a 1 in 100-year event, the total land area that will be exposed to flooding by 2100 is 1.73% and 2.29% respectively, under the RCP4.5 scenario. The Midlands Region is the most exposed region, with between 3.06% (NIFM) to 3.36% (CFRAM) of the region's total land area impacted.

For the RCP8.5 scenario, between 1.95% (CFRAM) to 2.38% (NIFM) of the total national land area will be at risk of flooding by 2100. Similarly, the

Midlands Region is the most exposed region, with between 3.13% (NIFM) to 3.94% (CFRAM) of the region's total land area potentially affected.

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5.0 % (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios.

Communication related assets are present in all NUTS3 regions.

4.3.8.3 Consequence

- **Damage:** Initially, flooding can cause Limited loses to communication infrastructure. Under both scenarios, these damages are projected to be large and frequent by 2100.
- **System Functionality:** Flooding can lead to temporary disturbances in communication infrastructure. As the risk increases to Critical by 2100, these disturbances become long-term, impacting the reliability and efficiency of communication systems.
- **Extent and Pervasiveness:** The extent and pervasiveness of the impact are expected to be moderate initially (2030 and 2050), affecting specific regions and infrastructure components. However, as the risk increases to Critical by 2080, the impact will likely expand to a larger extent, affecting a broader range of areas and infrastructure, leading to high pervasiveness.
- **Cascading Effects:** Initially, the cascading effects of flooding on communication infrastructure are expected to be temporary, with some effects extending beyond the system boundaries. By 2100, as the risk becomes Critical, the cascading effects could become long-term. These cascading effects include impacts on the Health System, meaning the disruption and damage to communication infrastructure can impact emergency response time, public safety and healthcare, the Economy and

Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, where it can cause business disruption and impact social connectivity.

- **Change through time:** Projections show increased fluvial flood extent and frequency, with no current groundwater flooding projections available. Currently, the risk to communication infrastructure is already Substantial. Minimal changes are projected between 2030 and 2050, however, the total land area exposed to flooding increases by 2100 under both RCP4.5 and RCP8.5 scenarios, increasing the consequence to Critical by 2100.

4.3.8.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020).

Consequence Confidence: The confidence in the consequence is Low as there is limited spatial information available to fully assess the number and type of communication assets that are or could be exposed to these hazards currently and in the future.

4.3.8.5 Adaptation

To address the increased risk of disruption and damage due to inland flooding from fluvial, surface water, and groundwater sources, a comprehensive set of

adaptation measures has been implemented. These measures are designed to enhance flood resilience across communication networks:

Reliability

- *Policy and Governance:* Flood risk management frameworks are embedded in national adaptation policies, ensuring that flood hazards are factored into planning and investment decisions. This includes the Flood Risk Management Climate Change Sectoral Adaptation Plan.
- *Monitoring and Early Warning Systems*: Advanced flood forecasting tools and sensor networks provide timely alerts on rising water levels and potential inundation, drawing on meteorological and hydrological data. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.
- *Risk Assessment:* Vulnerability mapping—using tools such as APSFR assessments—identifies flood-prone areas, enabling targeted infrastructure upgrades and relocation where necessary.

Resistance

- *Infrastructure Fortification:* Adaptation actions include elevating equipment, waterproofing vulnerable installations, and improving drainage around network facilities.
- *Design Standards:* Communication infrastructure has ingress protection (IP) standards which if adopted and maintenance is performed as per specification the impact of flooding can be minimised.
- *Community Engagement:* Collaboration with local authorities ensures that communities and service providers share best practices on flood preparedness and mitigation.
- *Research and Development*: Investments in innovative flood-resistant materials and construction techniques support long-term infrastructure durability.

Recovery and Response

- *Emergency Response Plans:* Detailed protocols and rapid deployment teams are in place to restore communication services quickly after flooding incidents, supported by lessons from recent impact analyses.
- *Training and Knowledge Transfer:* Regular training programs ensure that maintenance and emergency teams are equipped to address flood-induced damages efficiently.

Redundancy

- *Redundant Network Paths:* Alternate routing and backup systems—including power supplies and communication nodes—are established to maintain service continuity during and after flooding events.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Effective for managing this risk.

4.3.8.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is to Sustain Current Action.

4.3.9 BE09 Risk of disruption and damage to communication infrastructure due to ground movement as a result of drought conditions

4.3.9.1 Risk Summary

Table 4.10: BE09 Risk of disruption and damage to communication infrastructure due to ground movement as a result of drought conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to communication infrastructure due to ground movement as a result of drought conditions	Limited	Limited	Substantial	Limited	Limited	Substantial
Urgency	Watching Brief					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Drought conditions can lead to ground movement, such as soil shrinkage and subsidence, which poses a risk to communication infrastructure. As the soil dries out, it can contract and shift, causing damage to underground cables, conduits, and foundations of communication towers. This ground movement can lead to the misalignment or breakage of cables, resulting in service disruptions for both residential and commercial users. Additionally, the structural integrity of communication towers and other infrastructure can be compromised, increasing the risk of collapse or failure.

4.3.9.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38))..

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2)).

n an RCP4.5 scenario, nationally the mean annual number of wet days is expected to decrease of 2.4%(-6.52 — 1.53%) by 2050 and 2.2 (-6.63 — -1.63%) by 2100, with the East region experiencing the largest decrease (2050: 3.2%, 2100: 2.8%). The same trend occurs in RCP8.5 with a decrease of 2.6% ((-6.21 – 1.11%) by 2050 and 4.1% (-9.71 – 0.47%) by 2100, with the East region experiencing the largest decrease (2050: 3.3%, 2100: 5.1%).

For RCP4.5 and RCP8.5 compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season for both 2050 and 2100.

Communication related assets are present in all NUTS3 regions.

4.3.9.3 Consequence

- **Damage:** Ground movement due to drought conditions can cause Limited damage to communication infrastructure, such as cracks and shifts in foundations. By 2100, the damage is projected to become Substantial under both scenarios, with substantial loses anticipated.

- **System Functionality:** Initially, communication infrastructure will experience no significant disturbances in 2030 and 2050. However, by 2100, temporary or moderate disturbances are anticipated, affecting communication services.

- **Extent and Pervasiveness:** The extent and pervasiveness of the impact are limited in 2030 and 2050, affecting specific regions. By 2100, the

impact will expand to a moderate extent, with higher pervasiveness across broader areas.

- **Cascading Effects:** Currently, there are no significant cascading effects beyond system boundaries. By 2100, temporary cascading effects are anticipated. These cascading effects include impacts on the Health System, meaning the disruption and damage to communication infrastructure can impact emergency response time, public safety and healthcare, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, where it can cause business disruption and impact social connectivity.

- **Change through time:** Drought predictions for Ireland indicate an increase in the frequency of drought conditions, particularly during the spring and summer months. Drought conditions will; be more prevalent by 2100, increasing the consequence to Substantial.

4.3.9.4 Confidence

Hazard Confidence: There is a medium level of confidence that drought conditions will increase in the future. Changes in the number of wet days have been used from national downscaled projections (TRANSLATE) which were produced by the national meteorological agency, and peer-reviewed research has been used for SPEI-3, however, further research and variables, i.e., SPEI-6, SPEI-12 are needed to better inform confidence in this hazard.

Consequence Confidence: The confidence in the consequence is Low as there is limited examples of this risk occurring currently, and there is limited spatial information available to fully assess the number and type of communication assets that are or could be exposed to this hazard currently and in the future.

4.3.9.5 Adaptation

To mitigate the risk of disruption from ground movement triggered by prolonged drought conditions, targeted adaptation measures have been adopted. These measures focus on minimizing infrastructure damage from subsidence and soil contraction:

Reliability

- *Policy and Governance:* Drought-related ground movement risks are incorporated into national adaptation policies and infrastructure planning guidelines, ensuring that long-term risk is addressed.
- *Monitoring and Early Warning Systems*: Soil moisture and geotechnical monitoring systems provide early indicators of ground movement, supporting proactive maintenance and repair decisions.
- *Risk Assessment:* Geological surveys and vulnerability mapping identify high-risk zones for drought-induced ground movement, guiding preventative measures and asset relocation where necessary.

Resistance

- *Infrastructure Design and Upgrade:* Networks are designed with flexible conduit systems and reinforced with advanced backfill and compaction techniques to absorb ground movement without compromising service continuity.
- Research and Development*:* Ongoing studies on soil behaviour under drought conditions inform improvements in installation and maintenance practices for underground cables and critical infrastructure.
- *Community Engagement:* Coordination with local planning authorities and land management bodies enhances overall resilience to drought impacts.

Recovery and Response

- *Rapid Response Protocols:* Emergency repair teams are equipped to address damage from ground movement swiftly, including realignment and re-burial of affected cables.

- *Knowledge Transfer and Training:* Technical staff receive regular training on recognizing early signs of ground movement and applying corrective measures.

Redundancy

- *Alternate Routing:* Redundant network pathways and backup nodes ensure that, even if sections of the network are compromised by ground movement, service disruption is minimized.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Effective for managing this risk.

4.3.9.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is a Watching Brief.

4.3.10 BE10 Risk of disruption and damage to communication infrastructure due to overheating as a result of extreme heat

4.3.10.1 Risk Summary

Table 4.11: BE10 Risk of disruption and communication infrastructure due to overheating as a result of extreme heat.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to communication infrastructure due to overheating as a result of extreme heat	Limited	Limited	Substantial	Limited	Substantial	Substantial
Urgency	Sustain Current Action					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Extreme heat poses a risk to communication infrastructure, primarily due to overheating. Overheating can cause servers in data centres to fail, leading to data loss and service outages. Towers and antennas may experience reduced efficiency or complete failure, disrupting mobile and internet services. Underground cables can suffer from material degradation, resulting in signal loss or interruptions. Prolonged exposure to extreme heat can degrade materials in cables and other infrastructure, leading to physical damage and service disruptions.

4.3.10.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-

East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38)).

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2)).

Communication related assets are present in all NUTS3 regions. Communication technology present are designed to work within operational temperatures (and limits) of the current Irish climate.

4.3.10.3 Consequence

- **Damage:** Initially, overheating due to extreme heat can cause limited damage to communication infrastructure, such as equipment failures and degradation. By 2050 and 2100, the damage is projected to become substantial, with more substantial losses.

- **System Functionality:** Communications infrastructure will experience no significant disturbances in 2030. However, by 2050 and 2100, temporary or moderate disturbances are anticipated.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all communication infrastructure types.

- **Cascading Effects:** Currently, there are no significant cascading effects beyond system boundaries. By 2050 and 2100, temporary cascading effects are expected, potentially affecting other critical systems and services, for instance, the Energy System, meaning the disruption and damage to communication infrastructure can result in increased demand

for cooling systems during heatwaves which can strain the power supply, the Health System, where emergency response time, public safety, and healthcare are all impacted, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, resulting in business disruption and impacting social connectivity.

- **Change through time:** Projections show increased extreme heat extent and frequency. The consequence increases to Substantial by 2050, as the projected increase in frequency and severity of summer days and heatwave events increases. However, communication technology will evolve in the future (approximately every 7 years), therefore if, the environmental considerations regarding temperature changes happen, suppliers may offer technology and infrastructure that is better suited to the operating climate.

4.3.10.4 Confidence

Hazard Confidence: For extreme heat there is high confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: The confidence in the consequence is Low as there is limited examples of this risk occurring currently, and there is limited spatial information available to fully assess the number and type of communication assets that are or could be exposed to this hazard currently and in the future.

4.3.10.5 Adaptation

To address the increased risk of disruption from overheating caused by extreme heat, a series of adaptation measures have been introduced. These measures focus on maintaining the integrity and performance of network equipment under high-temperature conditions.

Reliability

- *Policy and Governance:* Thermal risk assessments are integrated into the national adaptation and Communications Sectoral Climate Change Adaptation Plan, ensuring that overheating risks are addressed at the policy level.
- *Monitoring and Early Warning Systems*: Temperature sensors and automated monitoring systems track ambient conditions and equipment performance to provide early warnings of overheating.
- *Risk Assessment:* Periodic audits and risk mapping identify equipment and sites most vulnerable to extreme heat, informing targeted upgrade initiatives.

Resistance

- *Infrastructure Upgrades:* Investments in enhanced cooling systems, improved ventilation, and the installation of heat-resistant components help reduce the risk of overheating.
- Research and Development*:* Ongoing R&D into alternative cooling technologies and materials aims to further increase the resilience of network infrastructure to high-temperature conditions.
- *Community Engagement:* Stakeholder consultations ensure that end users are informed of planned measures to mitigate heat-related risks.

Recovery and Response

- *Rapid Response Measures:* Emergency protocols enable the swift replacement or repair of overheated components, including the activation of backup cooling systems where needed.

- *Training and Knowledge Transfer:* Capacity-building initiatives ensure that technical teams are adept at diagnosing and managing heat-induced failures in network equipment.

Redundancy

- *Backup Systems:* Redundant power supplies and alternative network routes are established to maintain service continuity in the event that overheating damages key components.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Effective for managing this risk.

4.3.10.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is to Sustain Current Action.

4.3.11 BE11 Risk of disruption and damage to communication infrastructure due to extreme wind

4.3.11.1 Risk Summary

Table 4.12: BE11 Risk of disruption and damage to communication infrastructure due to extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to communication infrastructure due to extreme wind	Critical	Critical	Critical	Critical	Critical	Critical
Urgency	More Action Needed					
Hazard Confidence	Very Low					
Consequence Confidence	Medium					

Extreme wind events can impact communication infrastructure by toppling communication towers, snapping utility poles, and damaging satellite dishes. Additionally, high winds can cause trees to fall onto overhead lines, leading to further disruptions in internet, telephone, and other communication services. This damage leads to disruptions in internet, telephone, and other communication services, which can hinder emergency response efforts, disrupt business operations, and isolate communities. Repairing and replacing damaged infrastructure can be costly and time-consuming.

4.3.11.2 Exposure and Vulnerability

For RCP4.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.32 days, 2100: -0.47) from the 1981-2010 baseline. For RCP8.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.61 days, 2100: -0.44) from the 1981-2010 baseline.

For RCP4.5, there is a projected small decrease in the 10-m wind speed of 1.0–2.7% (mean 1.8%) compared to the 1981-2000 baseline by 2050. For RCP8.5, there is a 1.6–3.3% (2.6%) decrease.

Communication technology present are designed to work within operational temperatures (and limits) of the current Irish climate.

4.3.11.3 Consequence

- **Damage:** Extreme wind can cause critical levels of damage to communication infrastructure, such as downed cables, damaged towers, and broken equipment resulting in loss of communications for a large number of people. Ireland has already experienced the impact of this risk, for instance:
    - During Storm Darragh on 6-7 December 2024, overhead fixed fibre networks belonging to several providers suffered considerable damage.
    - During Storm Éowyn, the estimated effect on the national telecommunications userbase was the largest in ComReg's recording history. Peak loss of fixed services was 10% of users without service. Peak impact to mobile service was 35% of users experiencing some level of degradation.
- **System Functionality:** Under both scenarios, communication infrastructure will experience temporary or moderate disturbances due to extreme wind events across all time horizons, affecting communication services.
- **Extent and Pervasiveness:** The impacts caused by extreme wind will be large in extent and pervasiveness, affecting multiple regions.
- **Cascading Effects:** Temporary cascading effects are possible, potentially affecting other critical systems and services beyond the Built Environment system. These cascading effects include impacts on the Health System, meaning the disruption and damage to communication infrastructure can impact emergency response, public safety, and healthcare, the Energy system, i.e., disruption of generation and transmission/distribution operations,

the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, where it can cause significant business disruption and impact social connectivity leading to isolation.

- **Change through time:** Projections show no change in hazard (although with very low levels of confidence). However, the risk is currently assessed as a Critical consequence, and this current level of risk is expected to continue into the future.

4.3.11.4 Confidence

Hazard Confidence: There is a Very Low level of confidence that extreme wind frequency and severity will not change in the future. There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used at the NUTS2 level, with national scale data for average wind speed used as an alternative proxy.

Consequence Confidence: The confidence in the consequence is Medium as already impacts Ireland, however, there is limited spatial information available to fully assess the number and type of communication assets that are or could be exposed to this hazard currently and in the future.

4.3.11.5 Adaptation

To address the increased risk of disruption due to extreme wind, a comprehensive set of adaptation measures is in place. These measures are designed to ensure that communication infrastructure remains resilient under highwind conditions.

Reliability

- *Policy and Governance*: Extreme wind risk is incorporated into the national adaptation strategy and network design standards, ensuring that policies address wind-related vulnerabilities.
- *Monitoring and Early Warning Systems*: Wind speed and storm tracking systems—supported by data from meteorological agencies—provide timely alerts to operators, enabling proactive measures before severe events occur.
- *Risk Assessment:* Vulnerability mapping identifies areas and infrastructure elements most at risk from extreme wind, guiding reinforcement and protective actions.

Resistance

- *Infrastructure Fortification:* Adaptation measures include reinforcing towers, masts, and overhead cabling; implementing regular maintenance (such as vegetation trimming); and upgrading materials to withstand high wind loads.
- *Community Engagement and Education:* Joint initiatives with local authorities and emergency services ensure that communities are aware of wind risks and the measures in place to mitigate them.
- *Research and Development:* Investment in wind-resilient design innovations supports continuous improvements in infrastructure durability.

Recovery and Response

- *Emergency Response Protocols:* Detailed procedures and rapid repair teams are in place to restore network functionality quickly after windinduced damage, drawing on best practices identified in recent impact assessments.
- *Training and Capacity Building:* Ongoing training programmes equip technical staff with the skills to manage and repair wind-related damage safely and effectively.

Redundancy

- *Alternate Network Routes:* Redundant configurations and backup power systems ensure that, should key infrastructure be compromised by extreme wind, communication services continue uninterrupted.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.11.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is More Action Needed.

4.3.13 BE12 Risk of damage and loss of underwater cultural heritage (built and archaeological heritage) due to changes in ocean conditions

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

Table 4.13: BE12 Risk of damage and loss of underwater cultural heritage (built and archaeological heritage) due to changes in ocean conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage and loss of underwater cultural heritage (built and archaeological heritage) due to changes in ocean conditions	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	Low					

4.3.14 BE13 Risk of damage and loss of cultural heritage sites (built and archaeological heritage) due to sea level rise, coastal erosion, and coastal flooding

4.3.14.1 Risk Summary

Table 4.14: BE13 Risk of damage and loss of cultural heritage sites (built and archaeological heritage) due to sea level rise, coastal erosion, and coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage and loss of cultural heritage sites (built and archaeological heritage) due to sea level rise, coastal erosion, and coastal flooding	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	More Action Needed					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Cultural heritage sites, encompassing both built and archaeological heritage, face risk of damage and loss due to coastal erosion and flooding. Coastal erosion can undermine foundations and structural integrity of built heritage sites, such as historic buildings, monuments, and fortifications. This process can lead to partial or complete collapse of the build heritage site, resulting in the loss of culturally and historically significant structures. Coastal flooding can have immediate effects, inundating built heritage sites and causing water damage to materials such as wood, stone, and metal, which can weaken the structures over time. For archaeological sites, coastal flooding can wash away or submerge artifacts and remains, leading to the loss of irreplaceable historical information and context. The subsystems of buildings and cultural heritage are interconnected through their shared built heritage. Sea level rise, coastal erosion, and coastal flooding also pose risks of damage and loss of buildings (i.e., BE01).

4.3.14.2 Exposure and Vulnerability

Between 7.9% (RCP4.5) and 9.0% (RCP8.5) of National Inventory of Architectural Heritage (NIAH) sites are projected to be impacted by coastal

flooding by 2100. The South-West Region is anticipated to be the most exposed region to coastal flooding.

For sites listed in the Sites and Monuments Record (SMR), between 1.2% (RCP4.5) and 1.3% (RCP8.5) of sites are projected to be exposed to coastal flooding by 2100. Again, the South-West Region is anticipated to be the most exposed region to coastal flooding.

The South-West Region is expected to experience the highest sea-level rise across all scenarios and time periods. The South-West Region is projected to experience sea level rise under an RCP4.5 scenario of 0.24 m by 2050, and 0.51 m by 2100, and 0.26 m by 2050, and 0.65 m by 2100 under an RCP8.5 scenario. Sea level rise drives the exposure to coastal flooding, meaning that the South-West Region is particularly exposed to coastal flooding. The Border Region meanwhile will see the lowest increase in sea level rise.

The length of coastline projected to be at risk of coastal erosion in Ireland by 2050 is 328 km. The South-West (85 km) and South-East (46 km) regions are most at risk, however, the effects of climate change were not included within this assessment.

4.3.14.3 Consequence

- **Damage:** Initially, the risk of damage to cultural heritage sites due to sea level rise, coastal erosion, and coastal flooding is limited. However, there are examples of impacts from this risk, for instance:

    - Dunbeg Fort has faced significant coastal erosion since the mid-19th century, with rates increasing notably over the past decade. In January 2014, a storm caused part of the western cliff to collapse. Between December 2017 and January 2018, Storm Eleanor caused a 10-meter section of the internal drystone rampart, including the entranceway, to fall into the sea (Department of Housing, Local Government and Heritage, 2019). The damage from this risk increases to substantial for both 2050 and 2100 under both scenarios, due to the change in hazard frequency

and severity with some locations experiencing major or irreversible damage.

- **System Functionality:** Under both scenarios, the Built Environment will experience predominantly temporary or moderate disturbances due to sea level rise, coastal erosion, and coastal flooding.
- **Extent and Pervasiveness:** Initially, the extent of damage is limited, but it will increase to a moderate extent by 2050 and 2100 under both scenarios.
- **Cascading Effects:** Temporary to long-term cascading effects are possible, potentially affecting other critical systems and services beyond the Built Environment system. These cascading effects include impacts on Social System, meaning the damage and loss of cultural heritage sites can result in business interruption and impacts on local and regional tourism and hospitality. Further impacts on the Social System occur when coastal erosion and coastal flooding remove, severely damage, or expose ancient burial grounds. These burial grounds or historic graveyards have very strong social value for the communities who have family buried at these locations and there is an acute sense of loss when these types of cultural sites are threatened or damaged. the impact may be catastrophic for certain communities.
- **Change through time:** In both scenarios, sea level rise will increase at similar rates to 2050, however, beyond this point RCP8.5 has a higher sea level by the end of the century compared to RCP4.5. Nevertheless, the spatial analysis shows only minor differences in the number of buildings exposed to this risk.

4.3.14.4 Confidence

Hazard Confidence: There is high confidence that sea level rise, coastal flooding, and coastal erosion will increase in frequency and severity in the future. Global projections, including those from the IPCC Assessment Report 6, have been used to inform sea level rise, while national projections for coastal change (erosion or accretion) are unavailable, with extrapolation of current erosion rates for 2050 used instead. Coastal flood extent and frequency changes have been

assessed by the OPW using rigorous models, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used. There is less confidence in the spatial distribution of coastal erosion in the future due to limited assessment of future coastal change that includes the consideration of climate change.

Consequence Confidence: The impacts of coastal flooding and coastal erosion are already affecting Ireland and this impact will increase in the future. However, the spatial distribution of these impacts related to coastal erosion is still uncertain. Therefore, a Medium level of confidence is assigned to the consequence of this risk.

4.3.14.5 Adaptation

To address the risk of damage and loss of cultural heritage sites (built and archaeological heritage) due to sea level rise, coastal erosion, and coastal flooding, several adaptation measures are in place:

Reliability

- *Policy and Governance*: Integration of heritage issues into national and local policy and planning, and the integration of climate change adaptation into sectoral policy and conservation planning, provide a regulatory framework for adaptation.
- *Practices in Place:* The Built & Archaeological Heritage Climate Change Sectoral Adaptation Plan, the National Adaptation Framework, and Local Area Climate Action Plans guide adaptation efforts.
- *Monitoring and Early Warning Systems*: Monitoring of climate change and its impacts on heritage sites is conducted. Risks and vulnerability assessments identify at-risk heritage assets. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Community Engagement and Education:* Public awareness campaigns and skills and capacity building policies educate communities on heritage preservation.
- *Research and Development*: Increased research and rescue excavations in high-risk areas enhance understanding and protection of heritage sites.
- *Sector-Specific Adaptation Actions*: Heritage disaster risk management includes resilience policies, adaptation guidance, and surveys of high-risk assets to prioritise protection efforts.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.14.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is that More Action is required.

4.3.15 BE14 Risk of structural damage, deterioration, and subsidence of protected structures and sites (built and archaeological heritage) due to changes in precipitation

4.3.15.1 Risk Summary

Table 4.15: BE14 Risk of structural damage, deterioration, and subsidence of protected structures and sites (built and archaeological heritage) due to changes in precipitation.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of structural damage, deterioration, and subsidence of protected structures and sites (built and archaeological heritage) due to changes in precipitation	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	High					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios. However, the subsystems of buildings and cultural heritage are interconnected through their shared built heritage. Extreme precipitation and flooding (fluvial, surface water, and groundwater) also pose risks of damage and loss of buildings (i.e., BE03).

4.3.16 BE15 Risk of structural damage and deterioration of protected structures and sites (built and archaeological heritage) due to flooding (fluvial, surface water and groundwater)

4.3.16.1 Risk Summary

Table 4.16: BE15 Risk of structural damage and deterioration of protected structures and sites (built and archaeological heritage) due to flooding (fluvial, surface water and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of structural damage and deterioration of protected structures and sites (built and archaeological heritage) due to flooding (fluvial, surface water and groundwater)	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	High					

Flooding (fluvial, surface water and groundwater) in Ireland poses a risk to protected structures and archaeological sites, which can lead to structural damage and weakening of foundations, walls, and roofs, potentially leading to partial or complete collapse. It can also lead to material deterioration, such as the erosion of stone or the rotting of wood, can compromise the integrity of heritage structures, and water ingress can cause significant internal damage, affecting both the structure and its contents. Mould growth, resulting from prolonged damp conditions, can further degrade materials. Significant historic finishes, contents and collections may be damaged or destroyed.

The subsystems of buildings and cultural heritage are interconnected through their shared built heritage. Extreme precipitation and flooding (fluvial, surface water, and groundwater) also pose risks of damage and loss of buildings (i.e., BE03).

4.3.16.2 Exposure and Vulnerability

Based on CFRAM data, a total of 2,246 and 2,475 Sites and Monuments Record (SMR), sites across all NUTS3 regions are projected to be exposed to fluvial flooding by 2100 under RCP4.5 and RCP8.5 scenarios respectively. The West Region is the most exposed with 544 SMR sites anticipated to be impacted in a RCP8.5 scenario, and 522 SMR sites in a RCP4.5 scenario.

Based on NIFM data, a total of 2,322 and 2,412 SMR sites across all NUTS3 regions are projected to be exposed to fluvial flooding by 2100 under RCP4.5 and RCP8.5 scenarios respectively. The West Region is the most exposed with 485 SMR sites anticipated to be impacted in a RCP8.5 scenario, and 489 SMR sites in a RCP4.5 scenario.

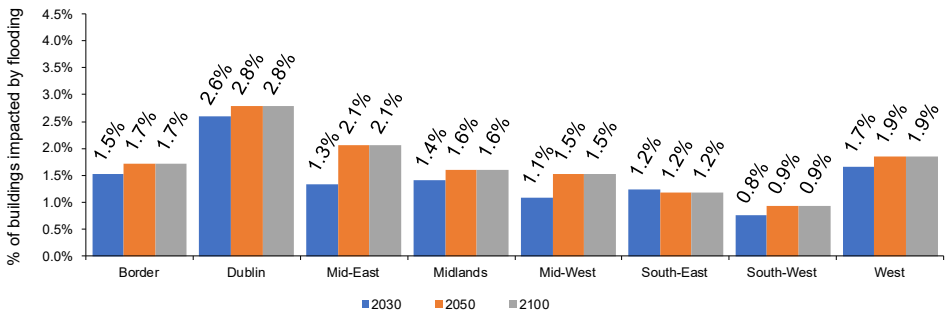


Figure 4.7: The proportion of Sites and Monuments Record (SMR), Sites impacted by fluvial flooding (1% AEP, RCP4.5, CFRAM).

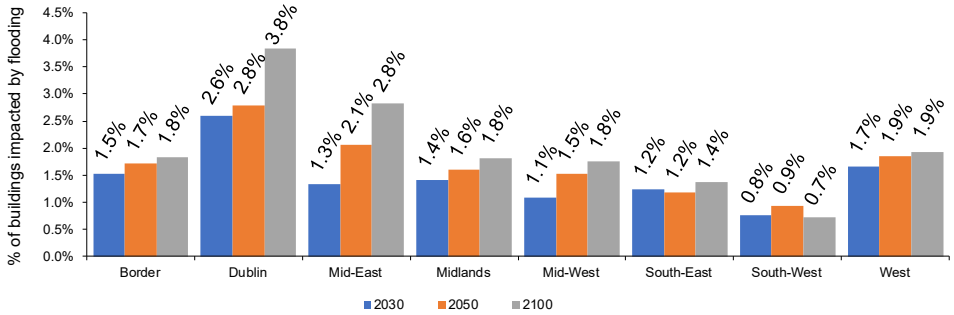


Figure 4.8: The proportion of Sites and Monuments Record (SMR), Sites impacted by fluvial flooding (1% AEP, RCP 8.5, CFRAM).

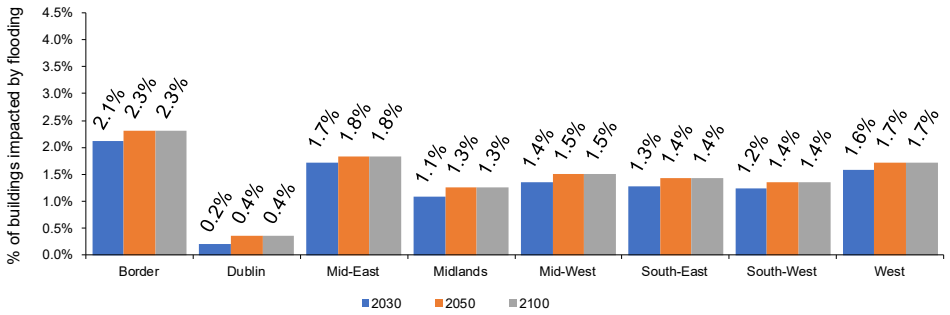


Figure 4.9: The proportion of Sites and Monuments Record (SMR), Sites impacted by fluvial flooding (1% AEP, RCP4.5, NIFM).

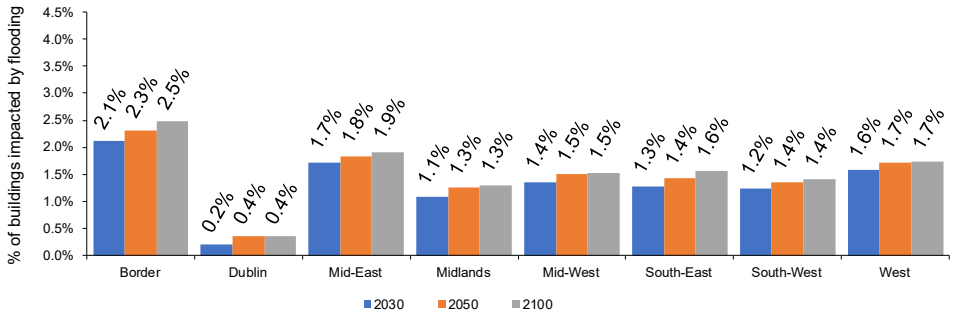


Figure 4.10: The proportion of Sites and Monuments Record (SMR), Sites impacted by fluvial flooding (1% AEP, RCP 8.5, NIFM).

4.3.16.3 Consequence

- **Damage:** There is potential for substantial losses to protected structures and sites, with this risk present occurring in Ireland. For instance:

  - In November 2009, the basement of the Lewis Glucksman Gallery at University College Cork was flooded with over ten feet of water after the River Lee burst its banks. A total of 187 pieces of art were submerged (Department of Housing, Local Government and Heritage, 2019).

  - The Old Mill Bridge in Buncrana, County Donegal, was destroyed in the floods caused by heavy precipitation in 2017 (Department of Housing, Local Government and Heritage, 2019).

  - Storm Gert brought fluvial and flash flooding and landslides during August 2017, causing severe damage to Buncrana Castle Bridge. The bridge was one of the many infrastructures severely impacted by the storm (Department of Housing, Local Government and Heritage, 2019).

- **System Functionality:** Under both scenarios, the Built Environment will experience predominantly temporary or moderate disturbances due to flooding.

- **Extent and Pervasiveness:** All NUTS3 Regions are exposed to flooding and there is exposure of SMR sites in all regions. Therefore, the extent of this risk is large extent with all SMR site types potentially impacted in 2030, 2050 and 2100 under both scenarios.

- **Cascading Effects:** Temporary to long-term cascading effects are possible, potentially affecting other critical systems and services beyond the Built Environment system. These cascading effects include impacts on Social System, meaning the structural damage and deterioration of protected structures and sites can cause business disruptions and impact local and regional tourism and hospitality.

- **Change through time:** Projections show increased fluvial flood extent and frequency, with no current groundwater flooding projections available. Currently, the risk to protected structures and sites is already Substantial, there is likely to be limited changes in exposure through time. Therefore, minimal changes in consequence are projected between 2030, 2050, and 2100, and the consequence in RCP4.5 and RCP8.5 scenarios is deemed to be Substantial across all time periods.

4.3.16.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and

Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020).

Consequence Confidence: The impacts of flooding are already affecting Ireland, however, limited changes are expected in the future due to limited changes in exposure. Therefore, a High level of confidence is assigned to the consequence of this risk.

4.3.16.5 Adaptation

To address the risk of structural damage and deterioration of protected structures and sites (built and archaeological heritage) due to flooding (fluvial, surface water, and groundwater), several adaptation measures are in place:

Reliability

- *Policy and Governance*: Integration of heritage issues into national and local policy and planning, and of climate change adaptation into sectoral policy and conservation planning, provide a regulatory framework for adaptation.
- *Practices in Place*: The Built & Archaeological Heritage Climate Change Sectoral Adaptation Plan, the National Adaptation Framework, and Local Area Climate Action Plans guide adaptation efforts.
- *Monitoring and Early Warning Systems*: Monitoring of climate change and its impacts on heritage sites is conducted. Risks and vulnerability assessments identify at-risk heritage assets. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Community Engagement and Education*: Public awareness campaigns and skills and capacity building policies educate communities on heritage preservation.
- *Research and Development*: Increased research and rescue excavations in high-risk areas enhance understanding and protection of heritage sites.

- *Sector-Specific Adaptation Actions*: Heritage disaster risk management includes resilience policies, adaptation guidance, and surveys of high-risk assets to prioritise protection efforts.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.16.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is that More Action is required.

4.3.17 BE16 Risk of damage and loss of cultural heritage sites (built and archaeological heritage) due to wildfire

Table 4.17: BE16 Risk of damage and loss of cultural heritage sites (built and archaeological heritage) due to wildfire.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage and loss of cultural heritage sites (built and archaeological heritage) due to wildfire	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	Medium					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios. However, the subsystems of buildings and cultural heritage are interconnected through their shared built heritage. Wildfire also poses a risk of damage and loss of buildings (i.e., BE05).

4.3.18 BE17 Risk of structural damage, biological growth and subsidence of protected structures and sites (built and archaeological heritage) due to changes in average temperature

Table 4.18:BE17 Risk of structural damage, biological growth and subsidence of protected structures and sites (built and archaeological heritage) due to changes in average temperature.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of structural damage, biological growth and subsidence of protected structures and sites (built and archaeological heritage) due to changes in average temperature	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Very low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios. However, the subsystems of buildings and cultural heritage are interconnected through their shared built heritage. Heat-related hazards, such as extreme heat, also pose risks to buildings (i.e., BE04).

4.3.19 BE18 Risk of structural damage and deterioration of protected structures and sites (built and archaeological heritage) due to extreme wind

4.3.19.1 Risk Summary

Table 4.19: BE18 Risk of structural damage and deterioration of protected structures and sites (built and archaeological heritage) due to extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of structural damage and deterioration of protected structures and sites (built and archaeological heritage) due to extreme wind	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Very low					
Consequence Confidence	High					

Extreme wind poses a risk to the structural integrity and preservation of protected structures and sites, including both built and archaeological heritage. High winds can cause partial collapse and catastrophic collapse to above ground archaeological structures and sites such as medieval castles, towers, buildings and churches. For archaeological sites, extreme winds can expose remains to environmental damage and displace artifacts from their original context, leading to the loss of valuable historical information.

The subsystems of buildings and cultural heritage are interconnected through their shared built heritage. Extreme wind also poses risks of damage of buildings (i.e., BE06).

4.3.19.2 Exposure and Vulnerability

For RCP4.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.32 days, 2100: -0.47) from the 1981-2010 baseline.

For RCP8.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.61 days, 2100: -0.44) from the 1981-2010 baseline.

For RCP4.5, there is a projected small decrease in the 10-m wind speed of 1.0–2.7% (mean 1.8%) compared to the 1981-2000 baseline by 2050. For RCP8.5, there is a 1.6–3.3% (2.6%) decrease.

There is a total of 146,757 SMR sites and 48,202 NIAH sites in Ireland. These sites are distributed evenly across the country and NUTS3 Regions. As each NUTS3 region is exposed, all of these sites could potentially be impacted by extreme wind.

4.3.19.3 Consequence

- **Damage:** Extreme wind can cause substantial losses to buildings. Ireland already experiences impacts from this risk, for instance:
    - The east wall of the tower house at Croom Castle collapsed during Storm Darwin due to a combination of strong winds, heavy rainfall, and vegetation growth that had weakened the stability of the castle walls (Department of Housing, Local Government and Heritage, 2019).
- **System Functionality:** Under both scenarios, the Built Environment will experience predominantly temporary or moderate disturbances due extreme wind.
- **Extent and Pervasiveness:** The impact of extreme wind events is widespread, affecting a large number of protected structure and site types, indicating a large extent and pervasiveness.
- **Cascading Effects:** Temporary to long-term cascading effects are possible, potentially affecting other critical systems and services beyond the Built Environment system. These cascading effects include impacts on Social System, structural damage and deterioration of protected structures and sites resulting in business interruption and impacts local and regional tourism and

hospitality. Further impacts on the social system occur when the collapse of above-ground archaeological monuments, whether partial or catastrophic, results in damage to well-being and the individual and community sense of place. These monuments hold significant value for custodians and communities in terms of their sense of identity and as cultural heritage landmarks in the landscape.

- **Change through time:** projections show no change in hazard (although with very low levels of confidence). However, the risk is currently assessed as a Substantial consequence, and this current level of risk is expected to continue into the future.

4.3.19.4 Confidence

Hazard Confidence: There is a Very Low level of confidence that extreme wind frequency and severity will not change in the future. There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used at the NUTS2 level, with national scale data for average wind speed used as an alternative proxy.

Consequence Confidence: There is High confidence in the consequence as the impacts of this risk have already been observed and will likely continue in the future.

4.3.19.5 Adaptation

To address the risk of structural damage and deterioration of protected structures and sites (built and archaeological heritage) due to extreme wind, several adaptation measures are in place:

Reliability

- *Policy and Governance*: Integration of heritage issues into national and local policy and planning, and the addition of climate change adaptation into

sectoral policy and conservation planning, provide a regulatory framework for adaptation.

- *Practices in Place*: The Built & Archaeological Heritage Climate Change Sectoral Adaptation Plan, the National Adaptation Framework, and Local Area Climate Action Plans guide adaptation efforts.
- *Monitoring and Early Warning Systems*: Monitoring of climate change and its impacts on heritage sites is conducted. Risks and vulnerability assessments identify at-risk heritage assets.

Resistance

- *Community Engagement and Education*: Public awareness campaigns and skills and capacity building policies educate communities on heritage preservation.
- *Research and Development:* Increased research and rescue excavations in high-risk areas enhance understanding and protection of heritage sites.
- *Sector-Specific Adaptation Actions*: Heritage disaster risk management includes resilience policies, adaptation guidance, and surveys of high-risk assets to prioritise protection efforts.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.19.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.20 BE19 Risk of disruption and damage to recreational amenities due to coastal flooding

Table 4.20: BE19 Risk of disruption and damage to recreational amenities due to coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to recreational amenities due to coastal flooding	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	High					
Consequence Confidence	Medium					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

4.3.21 BE20 Risks of disruption and damage of recreational amenities due to extreme precipitation and driving rain

Table 4.21: BE20 Risks of disruption and damage of recreational amenities due to extreme precipitation and driving rain.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risks of disruption and damage of recreational amenities due to extreme precipitation and driving rain	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	Medium					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

4.3.22 BE21 Risk of disruption and damage to recreational assets due to extreme wind

Table 4.22: BE21 Risk of disruption and damage to recreational assets due to extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to recreational assets due to extreme wind	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Very low					
Consequence Confidence	Medium					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

4.3.23 BE22 Risk of disruption to port operations and facilities due to sea level rise and extreme winds and waves

4.3.23.1 Risk Summary

Table 4.23: BE22 Risk of disruption to port operations and facilities due to sea level rise and extreme winds and waves.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption to port operations and facilities due to sea level rise and extreme winds and waves	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	High					

Ports face risks from sea level rise and extreme weather, leading to potential operational disruptions and infrastructure damage. Sea level rise can result in permanent inundation of infrastructure and cause significant damage to port facilities. Operational issues include delays in shipping schedules and disruptions in loading and unloading activities due to extreme winds and waves. Waves generated by extreme weather can damage port infrastructure and cause structural damage to docks and piers, and the displacement of protective barriers.

4.3.23.2 Exposure and Vulnerability

The South-West Region is expected to experience the highest sea-level rise across all scenarios and time periods. The South-West Region is projected to experience sea level rise under an RCP4.5 scenario of 0.24 m by 2050, and 0.51 m by 2100, and 0.26 m by 2050, and 0.65 m by 2100 under an RCP8.5 scenario. The Border Region meanwhile will see the lowest increase in sea level rise.

For RCP4.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.32 days, 2100: -0.47) from the 1981-2010 baseline. For RCP8.5, Ireland is projected to experience a small decrease in extreme wind

days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.61 days, 2100: -0.44) from the 1981-2010 baseline.

For RCP4.5, there is a projected small decrease in the 10-m wind speed of 1.0–2.7% (mean 1.8%) compared to the 1981-2000 baseline by 2050. For RCP8.5, there is a 1.6–3.3% (2.6%) decrease.

There are 99 ports and harbours in total (OSI Prime2) situated in all NUTS3 regions (apart from the Midlands), with 47 located within the South-West region.

4.3.23.3 Consequence

- **Damage:** Extreme wind can cause substantial losses and disturbance to port operations and facilities. Ireland already experiences the impacts of this risk, for instance:
    - At Dublin Port during Storm Emma in March 2018, high winds and waves damaged port infrastructure, including cranes and storage facilities, leading to delays in shipping schedules and disruptions in loading and unloading activities.
- **System Functionality:** Extreme winds and waves can cause temporary and moderate disturbances to the Built Environment System.
- **Extent and Pervasiveness:** All NUTS3 regions are exposed to extreme wind events and all but the Midlands region exposed to sea level rise. Consequently, all ports are exposed to this risk indicating a large extent and pervasiveness.
- **Cascading Effects:** There are both temporary to long-term cascading effects on Food Production and Supply Chain, meaning the disruption to port operations and facilities can result in supply chain disruption (both import and export), the Economy and Finance System, e.g., business interruption and a loss of revenue, and the Social System, whereby it can result in business disruption.

- **Change through time:** In both scenarios, sea level rise will increase at similar rates to 2050, however, beyond this point RCP8.5 has a higher sea level by the end of the century compared to RCP4.5. For extreme wind, projections show no change in hazard (although with very low levels of confidence). However, the risk is currently assessed as a Substantial consequence, and this current level of risk is expected to continue into the future.

4.3.23.4 Confidence

Hazard Confidence: There is high confidence that sea level rise, will increase in frequency and severity in the future. Global projections, including those from the IPCC Assessment Report 6, have been used to inform sea level rise.

There is a Very Low level of confidence that extreme wind frequency and severity will not change in the future. There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used at the NUTS2 level, with national scale data for average wind speed used as an alternative proxy.

Overall, the hazard confidence is considered Medium.

Consequence Confidence: There is High confidence in the consequence as the impacts of this risk have already been observed and will likely continue in the future.

4.3.23.5 Adaptation

To address the risk of disruption to port operations and facilities due to sea level rise and extreme winds and waves, several adaptation measures are in place:

Reliability

- *Policy and Governance:* Implementation of Planning and Development Act Section 28 Guidelines and the OPW Capital Flood Relief Scheme provide a regulatory framework for adaptation.

- *Practices in Place*: Climate Risk Assessments and planning regulations guide adaptation efforts. The National Catchment Flood Risk Assessment and Management Programme and Ocean Knowledge 2030 are key initiatives.
- *Monitoring and Early Warning Systems*: Monitoring of physical coastal change and national-scale coastal hazard mapping and risk assessment are conducted. Early warning systems are integrated into these monitoring efforts.

Resistance

- *Community Engagement and Education*: Public awareness campaigns and community engagement initiatives are part of the adaptation strategy, ensuring local communities are informed and involved.
- *Research and Development*: The Coastal Change Research Programme supports ongoing research to understand and mitigate coastal risks. Assessment of options for management of coastal change risks and long-term planning are also in place.
- *Sector-Specific Adaptation Actions:* Port gantry cranes are protected by operational and automatic safety limits. Sufficient quay wall height, surveys of navigational channels after storms, and secondary pilot boarding stations enhance port resilience.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

4.3.23.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.24 BE23 Risk of disruption, damage, and loss of transport infrastructure due to sea level rise, coastal erosion, and coastal flooding

4.3.24.1 Risk Summary

Table 4.24: BE23 Risk of disruption, damage, and loss of transport infrastructure due to sea level rise, coastal erosion, and coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption, damage, and loss of transport infrastructure due to sea level rise, coastal erosion, and coastal flooding	Substantial	Critical	Catastrophic	Substantial	Critical	Catastrophic
Urgency	More Action Needed					
Hazard Confidence	High					
Consequence Confidence	High					

Transport infrastructure located in coastal areas is at risk from the effects of sea level rise, coastal erosion, and coastal flooding. Coastal erosion leads to the loss of land which can lead to damage to foundations and infrastructure, potentially requiring permanent relocation of assets. Coastal flooding results in temporary disruptions, physical damage, saltwater corrosion, increased maintenance needs and significant economic impacts due to repair costs and disruption.

4.3.24.2 Exposure and Vulnerability

Transport infrastructure, including roads, railways, and train stations, exist across all of the eight NUTS3 regions. For the RCP4.5 scenario to 2050, 1.1% of all transport infrastructure will be exposed to a 1 in 100-year event. Under the same scenario to 2100, 1% of transport infrastructure is estimated to be exposed to a 1 in 100-year event. A 1 in 100-year event under the RCP8.5 scenario is projected to potentially impact 1.1% of transport infrastructure to 2050, and 1.4% to 2100.

The Dublin and South-East regions have the largest amount of infrastructure exposed to sea level rise, coastal erosion, and coastal flooding. Driving exposure, the South-West Region is expected to experience the highest sea level rise

across all scenarios and time periods. Conversely, the Border Region is anticipated to experience the lowers sea level rise across all scenarios and time periods.

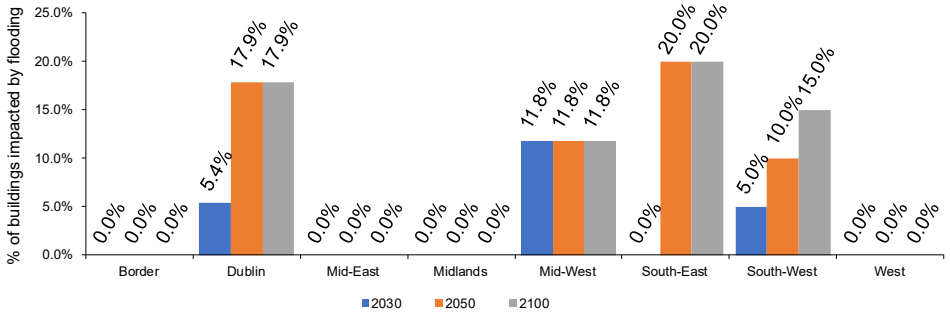


Figure 4.11: *Proportion of transport infrastructure buildings (OSi PRIME2) impacted by coastal flooding (1% AEP, RCP4.5, NCFHM)*

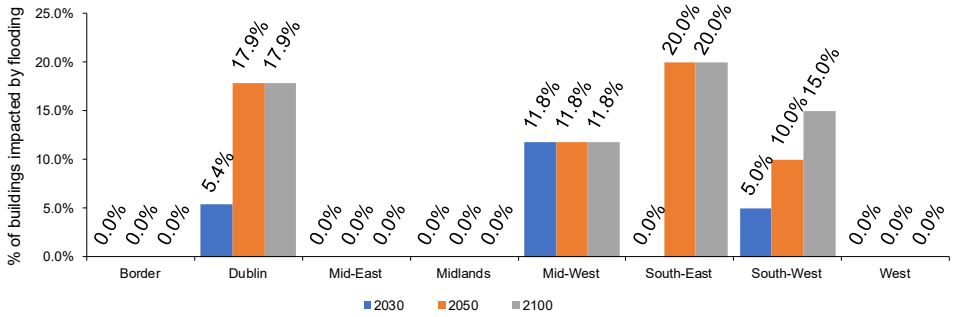


Figure 4.12: *Proportion of transport infrastructure buildings (OSi PRIME2) impacted by coastal flooding (1% AEP, RCP 8.5, NCFHM)*

For the RCP4.5 scenario in 2050, 3.6% of linear rail transport infrastructure [10] will be exposed to a 1 in 100-year event, rising to 4.2% by 2100. Dublin (2050: 10.5%, 2100: 12.2%) and South-East (2050: 9.8%, 2100: 10.9%) regions are the most exposed. For the RCP8.5 scenario in 2050, 3.7% of linear railway infrastructure will be exposed to a 1 in 100-year event, rising to 4.6% by 2100. Dublin (2050: 10.9%, 2100: 12.9%) and South-East (2050: 10.1%, 2100: 12.1%) regions are the most exposed.

For the RCP4.5 scenario in 2050, 1.1% of linear road infrastructure will be exposed to a 1 in 100-year event, rising to 1.3% by 2100. Dublin (2050: 3.0%, 2100: 3.5%) and Mid-West (2050: 1.8%, 2100: 2.0%) regions are the most exposed. For the RCP8.5 scenario in 2050, 1.1% of linear road infrastructure will

[10] The term 'linear rail transport infrastructure' is defined as the following OSi Prime2 category: Rail Network.

be exposed to a 1 in 100-year event, rising to 1.4% by 2100. Dublin (2050: 3.0%, 2100: 4.0%) and Mid-West (2050: 1.8%, 2100: 2.1%) regions are the most exposed.

Transport infrastructure, including roads, railways, stations, and airports, is present across all NUTS3 regions.

4.3.24.3 Consequence

- **Damage:** There is potential for substantial impacts to very large and frequent impacts on transport resulting in potentially Catastrophic levels of damage by 2100. Impacts of this risk are already occurring, for instance:
    - The coastal erosion rate along the Eastern Rail Corridor between Dublin and Rosslare, exacerbated by storms and rising sea levels, has accelerated from 1.4 m per year (1905-1990) to 2 m annually, potentially rendering the rail corridor unusable by 2030 (Department of Transport, 2019).
- **System Functionality:** The impacts of sea level rise, coastal flooding and coastal erosion can lead to temporary to long-term disturbances to the Built Environment system, and potentially irreversible losses.
- **Extent and Pervasiveness:** The whole Irish coastline is exposed to sea level rise, with exposure to coastal flooding and coastal erosion dependent upon local conditions, i.e., elevation, lithology. The largest impacts will occur in areas that have concentrations of transport infrastructure close to the coast, however, all NUTS3 regions (apart from the Midlands) are exposed to this risk to varying degrees of severity.
- **Cascading Effects:** There are both temporary to long-term cascading effects on the Food Supply and Supply Chain system, due to disruption, damage, and loss of transport infrastructure can result in logistics disruption, Health System, whereby it can cause difficulty in accessing healthcare, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance

coverage, and the Social System, whereby it can result in business disruption and disruption to education.

- **Change through time**: In both scenarios, sea level rise will increase at similar rates to 2050, however, beyond this point RCP8.5 has a higher sea level by the end of the century compared to RCP4.5. Nevertheless, the spatial analysis shows only minor differences in the number of transport infrastructure exposed to this risk. There is also a projected increase in population (increase of 1,953,300 (+41.2%) by 2051 (M1F1 Scenario, CSO (2021)), and therefore a possible commensurate increase in transport infrastructure is possible. Therefore, a Catastrophic level of consequence is potentially reached by 2100 in both scenarios.

4.3.24.4 Confidence

Hazard Confidence: There is high confidence that sea level rise, coastal flooding, and coastal erosion will increase in frequency and severity in the future. Global projections, including those from the IPCC Assessment Report 6, have been used to inform sea level rise, while national projections for coastal change (erosion or accretion) are unavailable, with extrapolation of current erosion rates for 2050 used instead. Coastal flood extent and frequency changes have been assessed by the OPW using rigorous models, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used. There is less confidence in the spatial distribution of coastal erosion in the future due to limited assessment of future coastal change that includes the consideration of climate change.

Consequence Confidence: The impacts of coastal flooding and coastal erosion are already affecting Ireland and this impact will increase in the future. However, the spatial distribution of these impacts related to coastal erosion is still uncertain. Therefore, a High level of confidence is assigned to the consequence of this risk.

4.3.24.5 Adaptation

To address the risk of disruption, damage, and loss of transport infrastructure due to sea level rise, coastal erosion, and coastal flooding, several adaptation measures are in place:

Reliability

- *Policy and Governance:* Implementation of Planning and Development Act Section 28 Guidelines and the OPW Capital Flood Relief Scheme provide a regulatory framework for adaptation.
- *Practices in Place*: Deployment of coastal defences and Climate Risk Assessments guide adaptation efforts. The National Catchment Flood Risk Assessment and Management Programme and Ocean Knowledge 2030 are key initiatives.
- *Monitoring and Early Warning Systems:* Monitoring of physical coastal change and national-scale coastal hazard mapping and risk assessment are conducted. Early warning systems are integrated into these monitoring efforts. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Community Engagement and Education*: Public awareness campaigns and community engagement initiatives are part of the Transport Climate Change Sectoral Adaptation Plan, ensuring local communities are informed and involved.
- *Research and Development*: The Coastal Change Research Programme supports ongoing research to understand and mitigate coastal risks. Assessment of options for management of coastal change risks and long-term planning are also in place.
- *Sector-Specific Adaptation Actions:* Transport resilience is enhanced by monitoring coastal railway assets, reinforcing Shannon Airport embankments, upgrading coastal defences, and designing East Coast Railway Protection

Projects. Port gantry cranes have safety limits, quay walls are sufficient, and navigational channels are surveyed post-storm with secondary pilot boarding stations implemented.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

4.3.24.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is that More Action is required.

4.3.25 BE24 Risks of disruption and damage to transport infrastructure due to extreme cold

4.3.25.1 Risk Summary

Table 4.25: BE24 Risks of disruption and damage to transport infrastructure due to extreme cold.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risks of disruption and damage to transport infrastructure due to extreme cold	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	High					

Extreme cold weather poses significant risks to transport infrastructure, leading to disruptions and damage across various modes of transportation. Ice and snow make roads hazardous, causing accidents and delays. Rail tracks can separate, and switches can fail, disrupting train services. Airports face flight cancellations, delays, and aircraft system damage due to ice on equipment and runways, and the requirement to deice aircraft. Extreme cold can also cause roads to crack and develop potholes, bridges, and overpasses to suffer structural strain, and rail tracks to separate and switches to freeze.

4.3.25.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience a decrease in the number of frost days and a decrease in the number of icing days. Under RCP4.5, the number of frost days is expected to decrease by 21.1 days (-27.2 — -15.0) by 2100 with the Northern region experiencing the largest decrease (-24.5 days (-31.4 — -17.6)). In an RCP8.5 scenario, number of frost days are expected to decrease by 31.4 days (-37.0- -24.7) , with the Northern region experiencing the largest decrease (-36.5 days (-43.3 - -28.9)

Under RCP4.5, regions are estimated to experience 0.30 (-0.4 — -0.2) fewer icing days by 2100 with the Mid-East region experiencing the largest decrease (-0.4

days). In an RCP8.5 scenario, there is projected to be 0.36 (-0.4 ─ -0.3) fewer icing days, with the Mid-East region experiencing the largest decrease (-0.5 days)

Transport infrastructure, including roads, railways, stations, and airports, is present across all NUTS3 regions.

4.3.25.3 Consequence

- **Damage**: Extreme cold results in limited or rare losses. This risk already exists in Ireland, for instance:
    - In 2018, Storm Emma caused major disruptions, including flight cancellations and public transport suspensions. Driving conditions were extremely dangerous, with some major roads, like the M1 motorway, becoming impassable at times (Department of Transport, 2019).
    - Heavy snowfall and low temperatures caused severe disruption in Ireland in 2018. Travel infrastructure was heavily impacted, with over 70,000 air passengers stranded due to flight cancellations and the health service faced challenges as fire crews assisted ambulances, and key workers struggled to reach their workplaces (Department of Health, 2019).
- **System Functionality**: In 2030 and 2050, extreme cold can lead to temporary or moderate disturbances in. By 2100, to temporary or moderate disturbances however, on a less frequent basis.
- **Extent and Pervasiveness**: The impact is substantial in 2030 and 2050, affecting a moderate extent, and all types of transport. By 2100, the extent and pervasiveness of the impact will continue but on a less frequent basis.
- **Cascading Effects**: There are both temporary to long-term cascading effects on the Food Supply and Supply Chain, meaning disruption and damage of transport infrastructure can result in logistics disruption, the Health System, where it poses physical health risks and difficulty in accessing healthcare, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance

and insurance coverage, and the Social System, where it can result in business disruption and disruption to education. By 2100, these effects are reduced, with no significant cascading impacts beyond the immediate damage.

- **Change through time**: The hazard is already a risk but will decrease in frequency and severity in the future, although the hazard will still occur. Impacts will reduce but not sufficiently to reach the Limited category due to the high levels of exposure of the transport infrastructure. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in transport infrastructure is possible. There are only minor differences between the RCP4.5 and RCP8.5 scenarios, therefore the consequence is the same.

4.3.25.4 Confidence

Hazard Confidence: There is a High level of confidence that extreme cold events will decrease in the future with global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is a decreasing trend for the extreme cold variables (frost days and icing days). The national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform the extreme cold variables, using a robust and peer-reviewed modelling approach.

Consequence Confidence: The impacts of extreme cold are already affecting Ireland and this impact is expecting to decrease in the future. Therefore, the confidence in the consequence is High, with some uncertainty on the timing of the future decrease in consequence.

4.3.25.5 Adaptation

To address the risks of disruption and damage to transport infrastructure due to extreme cold, several adaptation measures are in place:

Reliability

- *Policy and Governance:* Gritting materials are provided at train stations and car parks. Point heaters are installed across the rail network. Increased rail maintenance staff patrol during extreme cold.
- *Practices in Place*: Climate Risk Assessments identify vulnerabilities. Building regulations mandate a minimum BER rating for new builds. Energy efficiency regulations and schemes enhance infrastructure resilience. Provision of PPE for staff ensures safety during extreme cold events.
- *Monitoring and Early Warning Systems:* Updated operations risk assessments and adjustment of grit stock levels ensure preparedness. Vehicles, de-icing agents, and personnel are stationed at airports.

Resistance

- *Sector-Specific Adaptation Actions*: Gritting of roads and storage areas in ports, and the deployment of vehicles and personnel at airports, enhance transport resilience.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

4.3.25.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.26 BE25 Risks of instability of road and railway cuttings and embankments due to extreme precipitation

Table 4.26: BE25 Risks of instability of railway cuttings and embankments due to extreme precipitation.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risks of disruption and damage to transport infrastructure due to extreme cold	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	High					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

4.3.27 BE26 Risks of disruption and damage to transport infrastructure due to extreme precipitation and flooding (fluvial, surface water, and groundwater)

4.3.27.1 Risk Summary

Table 4.27: BE26 Risks of disruption and damage to transport infrastructure due to extreme precipitation and flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risks of disruption and damage to transport infrastructure due to extreme precipitation and flooding (fluvial, surface water, and groundwater)	Substantial	Critical	Catastrophic	Substantial	Critical	Catastrophic
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	High					

Extreme precipitation and flooding (fluvial, surface water, and groundwater flooding) poses a risk to transport infrastructure. Flooded roads and railways can cause significant delays and diversions, while prolonged flooding can lead to extended closures of critical transport routes. Floodwaters can erode foundations, wash away road surfaces, and cause bridge collapses. Railway tracks can be undermined or washed away, leading to derailments and service interruptions. Extreme precipitation can compromise runway integrity and disrupt ground services at airports. Inadequate drainage system capacity can result in flooding of airport infrastructure or inundation of surface and underground infrastructure such as electrical systems. Flooded runways and taxiways can render an airport inoperable.

4.3.27.2 Exposure and Vulnerability

Across all NUTS3 Regions, 1.3% of transport infrastructure buildings[11] (i.e., railway stations, depots, service infrastructure; not linear infrastructure) are

[11] The term 'transport infrastructure buildings' is defined as the following OSi Prime2 categories: Railway Station, Railway Service Shed, Airport Terminal.

projected to be exposed fluvial flooding based on CFRAM data. This estimation is consistent across RCP4.5 to 2050 and 2100, and RCP8.5 to 2050. For RCP8.5 by 2100, 4.4% of transport infrastructure buildings are anticipated to be exposed by fluvial flooding. The NIFM fluvial flooding scenarios show no buildings being exposed within either the RCP4.5 or RCP8.5 time horizons to 2050 and 2100.

By 2050, under both the RCP4.5 and RCP8.5 scenarios in a 1 in 100-year event, 1.1% of linear road transport infrastructure [12] and 1.3% of linear rail transport infrastructure are at risk of fluvial flooding according to CFRAM [13]. By 2100, under the RCP4.5 scenario, the risk remains the same, but under the RCP8.5 scenario, the risk increases to 1.4% for road transport and 2.2% for rail transport.

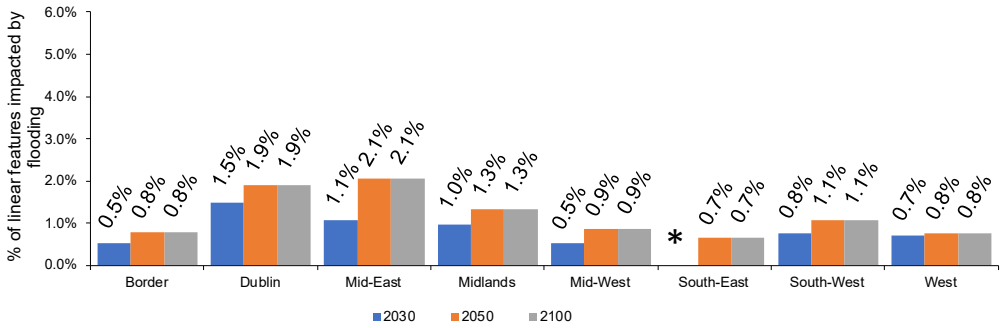


Figure 4.13: Proportion of linear road transport infrastructure (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP4.5, CFRAM).

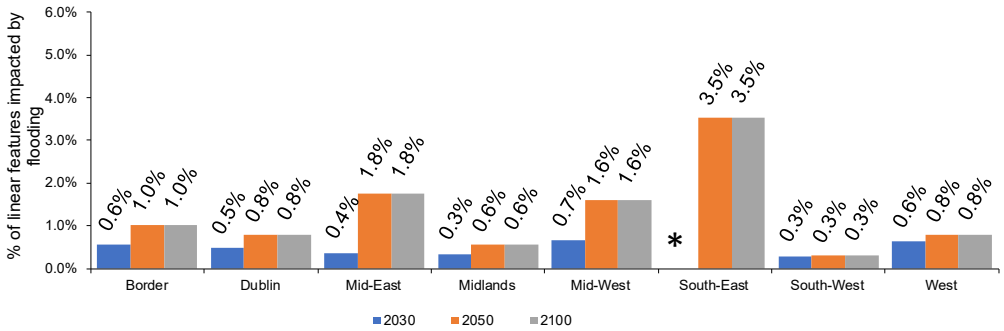


Figure 4.14: Proportion of linear rail transport infrastructure (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP4.5, CFRAM).

[12] The term 'linear road transport infrastructure' is defined as the following OSi Prime2 categories: Motorway, Dual Carriageway, Single Carriageway.
[13] Note that 2030 figures for the SE region have not been provided due to ongoing CFRAM data validation.

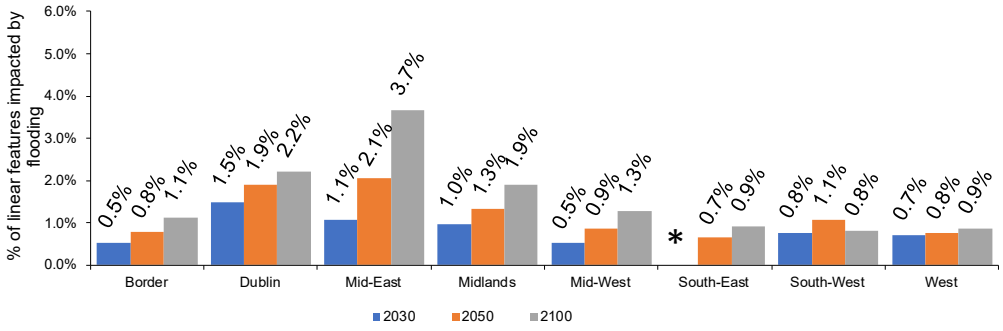


Figure 4.15: Proportion of linear road transport infrastructure (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP 8.5, CFRAM).

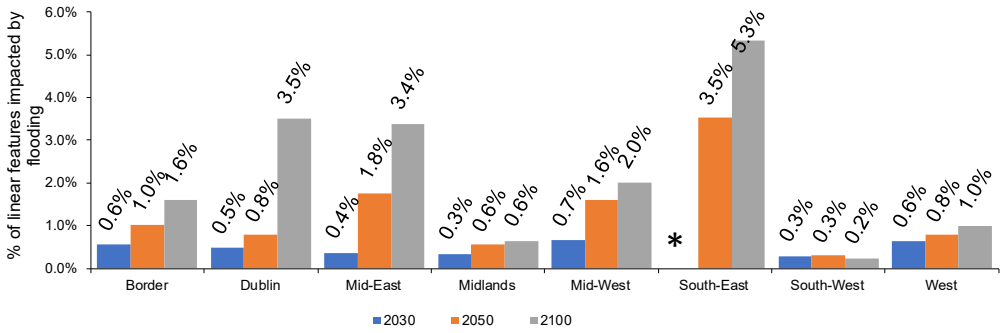


Figure 4.16: Proportion of linear rail transport infrastructure (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP 8.5, CFRAM).

Similarly, by 2050, under both the RCP4.5 and RCP8.5 scenarios with a 1 in 100-year event, 1.36% of linear road transport infrastructure and 1.1% of linear rail transport infrastructure are at risk of fluvial flooding according to NIFM. By 2100, under the RCP4.5 scenario, the risk remains the same, but under the RCP8.5 scenario, the risk increases to 1.4% for linear road transport and 1.2% for linear rail transport.

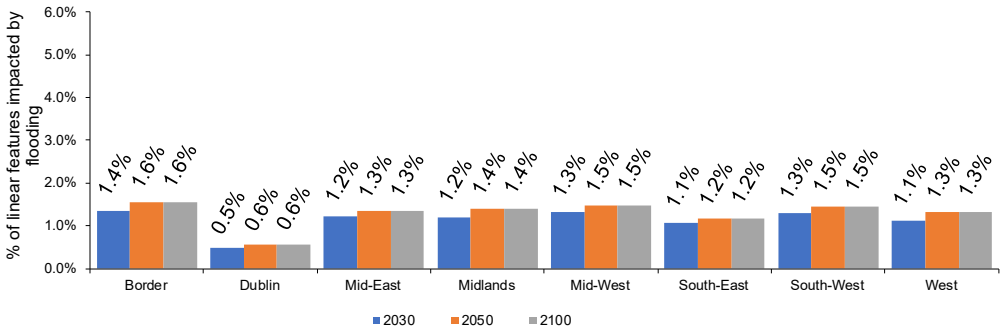


Figure 4.17: Proportion of linear road transport infrastructure (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP4.5, NIFM)

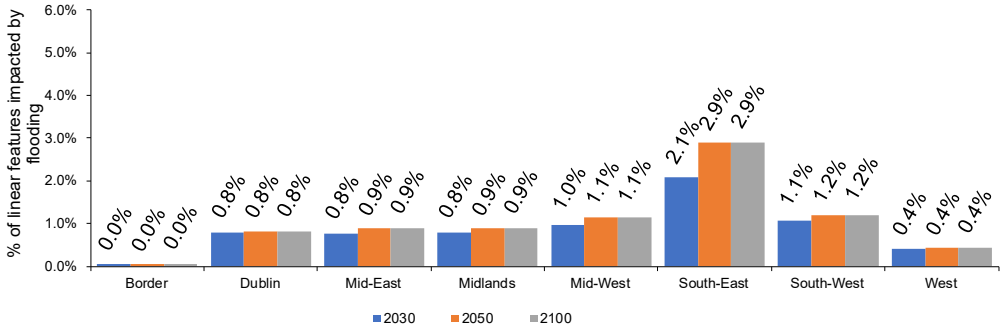


Figure 4.18: Proportion of linear rail transport infrastructure (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP4.5, NIFM)

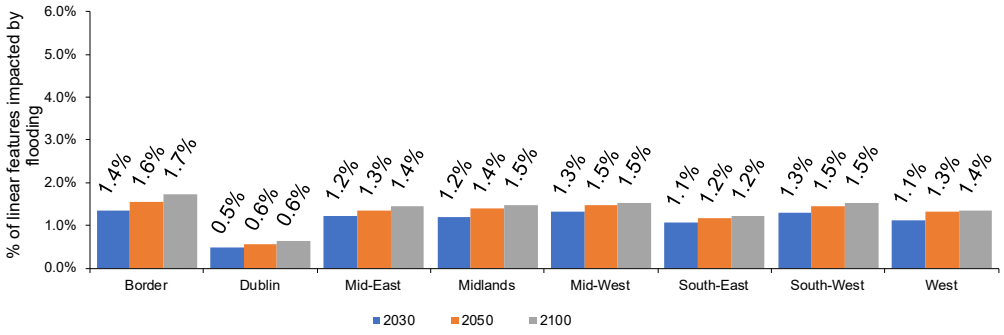


Figure 4.19: Proportion of linear road transport infrastructure (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP 8.5, NIFM).

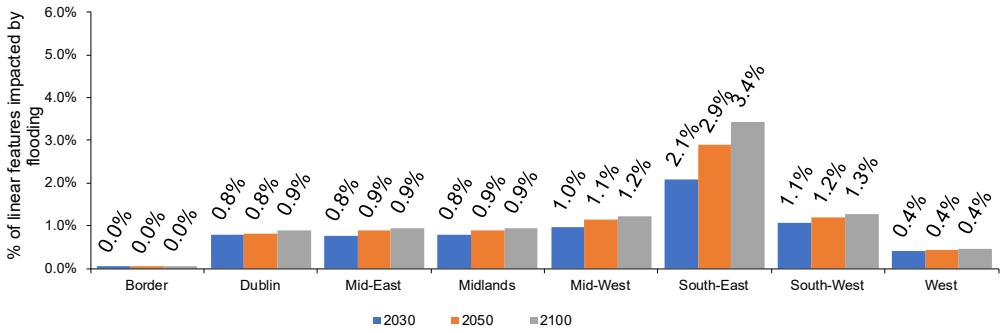


Figure 4.20: Proportion of linear rail transport infrastructure (OSi PRIME2) impacted by fluvial flooding (1% AEP, RCP 8.5, NIFM).

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5% by 2100) and RCP8.5 (8.9% by 2100) scenarios.

Transport infrastructure, including roads, railways, stations, and airports, is present across all NUTS3 regions.

4.3.27.3 Consequence

- **Damage:** Currently, transport infrastructure face substantial losses due to extreme precipitation and (fluvial, surface water, and groundwater). Ireland already experiences impacts from this risk, for instance:
    - In 2017, Hurricane Gert caused severe transport disruptions in the Inishowen Peninsula, County Donegal, damaging 1,500 km of roads, destroying six bridges, leaving some routes impassable for weeks, and trapping over 100 people in cars due to flash floods (Department of Transport, 2019).
    - The Old Mill Bridge in Buncrana, County Donegal, was destroyed in the floods caused by heavy precipitation in 2017 (Department of Housing, Local Government and Heritage, 2019).

By 2050, large and frequent damage may occur, with very large and frequent damage by 2100 anticipated, as the intensity and frequency of extreme precipitation and flooding (fluvial, surface water, and groundwater) increases.

- **System Functionality:** Currently, flooding causes temporary or moderate disturbances to buildings. By 2050, long-term disturbances may occur, with irreversible losses by 2100 anticipated.

- **Extent and Pervasiveness:** Currently, impacts are of a moderate extent or pervasiveness. As extreme precipitation and flooding are projected to increase in frequency and intensity, by 2050, these impacts will be more widespread, affecting larger areas and a greater number of transport infrastructure, with very large and pervasive impacts by 2100.

- **Cascading Effects:** There are both temporary to long-term cascading effects on the Food Supply and Supply Chain, whereby the disruption of damage and transport infrastructure can result in logistics disruption, the Health System, where it can cause difficulty accessing healthcare, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, where it may cause business disruption and disruption to education.

- **Changes through time:** In both scenarios, the changing climate conditions will continually increase the frequency and severity of flooding events. However, there are only minor differences between RCP4.5 and RCP8.5. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in transport infrastructure is possible, resulting in potential Catastrophic levels of risk by 2100.

4.3.27.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to

climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020).

Consequence Confidence: There is high confidence in the consequence as the impacts of this risk have already been observed and will likely increase in frequency and severity in the future.

4.3.27.5 Adaptation

To address the risks of disruption and damage to transport infrastructure due to extreme precipitation and flooding (fluvial, surface water, and groundwater), several adaptation measures are in place:

Reliability

- *Policy and Governance*: Planning regulations, the Implementation of Planning and Development Act Section 28 Guidelines, and emergency response planning provide a regulatory framework for adaptation.
- *Monitoring and Early Warning Systems:* National flood forecasting and warning services are being established. Monitoring includes the review of Minor Flood Mitigation Works and the implementation of Flood Risk Management Plans. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.
- *Practices in Place*: The Transport Climate Change Sectoral Adaptation Plan, and planning regulations guide adaptation efforts. The National Catchment Flood Risk Assessment and Management Programme and the 3rd cycle of Flood Directive Implementation are key initiatives.

Resistance

- *Community Engagement and Education*: Public awareness campaigns and community resilience research by the Department of Housing are integral to the Transport Climate Change Sectoral Adaptation Plan.
- *Research and Development*: Research focuses on advancing community resilience and developing infrastructure to upgrade surface water networks.
- *Sector-Specific Adaptation Actions*: Extreme storm protocols, storm water system maintenance plans, and monitoring of weather forecasts ensure preparedness. Resourcing of maintenance crews, new infrastructure designed for increased flooding, and improved drainage system maintenance enhance resilience. Port adaptation plans and airfield drainage projects address specific flooding issues.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.27.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.28 BE27 Risk of disruption and damage to transport infrastructure due to extreme heat

4.3.28.1 Risk Summary

Table 4.28: BE27 Risk of disruption and damage to transport infrastructure due to extreme heat.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to transport infrastructure due to extreme heat	Limited	Substantial	Critical	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	High					

Extreme heat poses a risk to transport infrastructure in Ireland, impacting roads, railways, and airports. High temperatures can cause road surfaces to soften and deform, leading to ruts and potholes, which increase maintenance costs. For railways, extreme heat can expand and buckle tracks, resulting in delays, speed restrictions, and derailments. Bridges are also affected, as thermal expansion stresses joints and bearings, potentially causing structural damage and compromising safety. High temperatures can cause runways to soften and deform, leading to surface damage that requires frequent maintenance and repairs. This can result in temporary closures and operational delays. Additionally, extreme heat can affect the performance of aircraft, reducing lift and requiring longer take-off distances, which can disrupt flight schedules. Ground operations, such as baggage handling and refuelling, can also be hampered by extreme heat, posing health risks to airport staff and potentially leading to slower turnaround times.

4.3.28.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events

per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38)).

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2)).

Transport infrastructure, including roads, railways, stations, and airports, is present across all NUTS3 regions.

4.3.28.3 Consequences

- **Damage:** Limited or rare losses initially, with increased damage to large and frequent levels under both RCP4.5 and RCP8.5 scenarios as temperatures increase. Ireland has experienced impacts from this previously, for instance:
    - During a heatwave in 2018, local councils had to grit roads due to high temperatures causing road surfaces to melt (Department of Transport, 2019).
    - In 2018, the high road temperatures led to road closures (Department of Housing, Local Government and Heritage, 2019).
- **System Functionality:** Extreme heat can cause temporary disturbances and short-term disruptions to transport infrastructure; however, under both RCP4.5 and RCP8.5 scenarios, these disturbances could become more chronic and therefore long-term if the frequency of extreme heat events increases.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all building types.

- **Cascading Effects:** There are both temporary to long-term cascading effects on the Food Supply and Supply Chain, whereby the disruption of damage and transport infrastructure can result in logistics disruption, the Health System, where it can cause difficulty accessing healthcare, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, where it may cause business disruption and disruption to education and an increase in emergency response time.

- **Changes through time:** The risk is currently Limited but will increase significantly in the future, especially under the RCP8.5 scenario, leading to potential Catastrophic levels of damage by 2100 with large and frequent impacts as extreme heat events become more common and severe. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in transport infrastructure is possible.

4.3.28.4 Confidence

Hazard Confidence: For extreme heat there is High confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: The impacts of this risk already occurs within Ireland, and there are impacts of this already observed, therefore confidence in the consequence is High.

4.3.28.5 Adaptation

To address the risk of disruption and damage to transport infrastructure due to extreme heat, several adaptation measures are in place:

Reliability

- *Policy and Governance:* Policies ensure emergency water supplies are available and infrastructure is monitored for heat-related hazards.
- *Monitoring and Early Warning Systems*: Forecasting and weather warnings provide timely alerts about extreme heat events.
- *Practices in Place*: The Transport Climate Change Sectoral Adaptation Plan and Climate Risk Assessments guide adaptation efforts.

Resistance

- *Community Engagement and Education*: Public awareness campaigns educate communities on heat mitigation practices and infrastructure maintenance.
- *Research and Development*: Examination of alternative materials and coordination on rail line exposure to higher temperatures enhance infrastructure resilience.
- *Sector-Specific Adaptation Actions*: Iarnród Éireann monitors for rail buckling hazards. Emergency water supplies are coordinated to ensure availability during extreme heat.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

4.3.28.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.29 BE28 Risk of disruption, damage, and loss of transport infrastructure due to wildfire

4.3.29.1 Risk Summary

Table 4.29: Summary for BE28 Risk of disruption, damage, and loss of railway infrastructure due to wildfire.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption, damage, and loss of transport infrastructure due to wildfire	Limited	Limited	Substantial	Limited	Limited	Substantial
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	Medium					

Changing climate conditions, such as changes in precipitation and drought, will potentially result in conditions suitable for wildfires occurring more frequently. Wildfires can cause direct damage to railway tracks, leading to buckling or warping due to intense heat, resulting in service disruptions and extensive repairs. Wildfires can also destroy signalling equipment and communication lines, further disrupting rail services. Railway tracks near vegetation are particularly vulnerable due to the proximity to flammable materials. Roads can become impassable due to fire damage or debris, hindering evacuation efforts and emergency response. The intense heat can cause asphalt to melt, necessitating repairs. Smoke from wildfires can reduce visibility, increasing the risk of accidents. Airports are affected by smoke and ash which can reduce visibility, leading to flight delays and cancellations. The heat can damage airport infrastructure, including runways and terminals. Additionally, wildfires can disrupt air traffic control systems and communication lines, complicating airport operations. The health risks posed by smoke and heat can affect staff and passengers, potentially leading to evacuations and service suspension.

4.3.29.2 Exposure and Vulnerability

The Fire Weather Index (FWI) is a meteorologically based index used worldwide to estimate fire danger. It is developed by the Canadian Forestry Service to estimate forest fire ignition and spread conditions based on several weather variables (temperature, precipitation, relative humidity, and wind speed). At the NUTS2 region level, the projected FWI (from 1980-2010) shows the Southern region is projected to experience the largest increase in FWI in both 2050 (RCP4.5:0.27, RCP8.5: 0.62) and 2100 (RCP4.5:0.62, RCP8.5: 0.95).

Transport infrastructure, including roads, railways, stations, and airports, is present across all NUTS3 regions.

4.3.29.3 Consequence

- **Damage:** Initially, the risk of damage and loss of transport infrastructure due to wildfire is limited or rare, however, it has already occurred in Ireland, for instance:
    - Drought conditions in 2018 caused a gorse fire on Bray Head, damaging infrastructure and halting DART services for nearly two days. Vulnerable individuals, such as pregnant women, infants, and the elderly, faced thermal discomfort due to rising cabin temperatures (Department of Transport, 2019).
- **System Functionality:** Wildfires can cause temporary disturbances to transport infrastructure, leading to short-term disruptions. However, as the risk increases to substantial, these disturbances could become more pronounced, affecting the functionality of the transport operations for longer periods.
- **Extent and Pervasiveness:** Initially, the extent of damage is limited, but it will increase to a substantial extent under both scenarios. This indicates that while the initial impact might be confined to buildings in specific areas, the impact will become more widespread as wildfires become more frequent and intense.
- **Cascading Effects:** There are both temporary to long-term cascading effects on the Food Supply and Supply Chain, meaning disruption, damage and loss

of railway infrastructure can result in logistics disruption., Health System, where it can impact emergency response time, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Social System, where it can cause business disruption.

- **Change through time:** In both scenarios, the changing climate conditions will continually become more suitable for wildfire occurrence resulting in a Substantial level consequence by 2100 for both scenarios. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in transport infrastructure is possible.

4.3.29.4 Confidence

Hazard Confidence: There is a Low level of confidence that wildfires will increase in frequency and severity in the future as there are limited climate projections available related to the changes in fire weather for Ireland, with no national scale projections, therefore European scale projections (EURO-CORDEX) have been used.

Consequence Confidence: Wildfires already occur within Ireland, however, there is limited information on the local scale variability, i.e., impact of terrain, fuel availability, potential sources of ignition, and how these may change in the future therefore confidence in the consequence is Medium.

4.3.29.5 Adaptation

To address the risk of disruption, damage, and loss of railway infrastructure due to wildfire, several adaptation measures are in place:

Reliability

- *Policy and Governance:* Policies ensure continuous monitoring and adaptation of railway infrastructure to mitigate wildfire risks.

- *Monitoring and Early Warning Systems*: Forecasting and weather warnings provide timely alerts about wildfire risks.
- *Practices in Place*: The Transport Climate Change Sectoral Adaptation Plan and Climate Risk Assessments guide adaptation efforts.

Resistance

- *Research and Development*: Examination of alternative materials enhances infrastructure resilience against wildfires.
- *Sector-Specific Adaptation Actions*: Iarnród Éireann monitors for rail buckling hazards to ensure railway safety during wildfires.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

4.3.29.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is a Watching Brief.

4.3.30 BE29 Risk of disruption and damage to transport infrastructure due to extreme wind

4.3.30.1 Risk Summary

Table 4.30: BE29 Risk of disruption and damage to transport infrastructure due to extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to transport infrastructure due to extreme wind	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Very low					
Consequence Confidence	High					

Extreme wind events pose a risk to transport infrastructure, including roads, railways, and airports. High winds can cause substantial physical damage, such as structural damage to bridges, scatter debris and toppling trees on to the road and rail network. Rail services can be disrupted due to damaged tracks, misalignments, and fallen trees, while overhead power lines and signalling equipment can also be affected. Airports may suffer damage to facilities like terminals and control towers, and runways can be littered with debris, posing risks to aircraft. High winds can lead to flight delays and cancellations, as aircraft may be unable to take off or land safely. Ground operations can also be disrupted, with equipment and personnel safety being compromised. Extreme winds can result in significant disruptions, including traffic delays, rerouting, and service cancellations.

4.3.30.2 Exposure and Vulnerability

For RCP4.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.32 days, 2100: -0.47) from the 1981-2010 baseline. For RCP8.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.61 days, 2100: -0.44) from the 1981-2010 baseline.

For RCP4.5, there is a projected small decrease in the 10-m wind speed of 1.0–2.7% (mean 1.8%) compared to the 1981-2000 baseline by 2050. For RCP8.5, there is a 1.6–3.3% (2.6%) decrease.

Transport infrastructure, including roads, railways, and train stations etc., exists across all NUTS3 regions and are potentially exposed to extreme wind.

4.3.30.3 Consequence

- **Damage:** Extreme wind can cause substantial losses to transport infrastructure. Ireland already experiences impact from this risk, for instance:
    - During Storm Ophelia in 2017, all public transport was suspended, flights were disrupted, ferry sailings were cancelled, and roads were hazardous due to strong winds and debris (Department of Transport, 2019).
    - In September 2018, Storm Ali caused widespread strong winds and heavy rain resulting in significant damage in Ireland disrupting air travel, trains and ferries (Department of Housing, Local Government and Heritage, 2019).
- **System Functionality:** Extreme wind can cause temporary or moderate disturbances to the Built Environment system impacting a large number of people and business operations.
- **Extent and Pervasiveness:** The impact of extreme wind events is widespread, affecting a large amount of transport infrastructure, and types, across extensive areas, indicating a large extent and pervasiveness.
- **Cascading Effects:** There are both temporary to long-term cascading effects on the Food Supply and Supply Chain, meaning disruption and damage of transport infrastructure can result in logistics disruption, the Health System, where it can pose difficulty accessing healthcare and healthcare staff travelling to work, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential

difficulties in securing finance and insurance coverage, and the Social System, where it may cause business disruption and disruption to education.

- **Changes through time:** Projections show no change in hazard (although with very low levels of confidence). However, the risk is currently assessed as a Substantial consequence, and this current level of risk is expected to continue into the future.

4.3.30.4 Confidence

Hazard Confidence: There is a Very Low level of confidence that extreme wind frequency and severity will not change in the future. There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used at the NUTS2 level, with national scale data for average wind speed used as an alternative proxy.

Consequence Confidence: There is High confidence in the consequence as the impacts of this risk have already been observed and will likely continue in the future.

4.3.30.5 Adaptation

To address the risk of disruption and damage to transport infrastructure due to extreme wind, several adaptation measures are in place:

Reliability

- *Policy and Governance:* Centrally managed and locally delivered responses to severe weather ensure coordinated action. Operational limits for high winds and storm conditions are established.
- *Practices in Place*: Climate risk assessments identify vulnerabilities. Building regulations ensure structures can withstand extreme wind.

- *Monitoring and Early Warning Systems*: Weather forecasting and severe weather warnings provide timely alerts. Monitoring of weather forecasts and coordination with Met Éireann ensure preparedness.

Resistance

- *Community Engagement and Education*: Safety information during extreme weather events educates communities on preparedness and safety measures.
- *Research and Development*: New infrastructure is designed to account for wind loading. Examination of new layouts allows for all potential wind conditions.
- *Sector-Specific Adaptation Actions:* Wind speed devices determine safe airport operations. Current operational practices and adverse weather procedures are followed. Maintenance crews are resourced to respond to storm damage.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

4.3.30.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.31 BE30 Risk of disruption and damage to water services infrastructure due to coastal flooding

4.3.31.1 Risk Summary

Table 4.31: BE30 Risk of disruption and damage to water services infrastructure due to coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to water services infrastructure due to coastal flooding	Limited	Limited	Substantial	Limited	Limited	Substantial
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Medium					

Coastal flooding poses a risk to water services infrastructure and sewage systems. Coastal floodwaters can inundate treatment plants, leading to contamination of drinking water supplies and disruption of water purification processes. Sewage systems can be overwhelmed, causing overflows and the release of untreated wastewater into the environment. Additionally, coastal flooding can erode the foundations of water infrastructure, leading to structural damage and increased maintenance needs.

4.3.31.2 Exposure and Vulnerability

The South-West Region is expected to experience the highest sea-level rise across all scenarios and time periods. The South-West Region is projected to experience sea level rise under an RCP4.5 scenario of 0.24 m by 2050, and 0.51 m by 2100, and 0.26 m by 2050, and 0.65 m by 2100 under an RCP8.5 scenario. Sea level rise drives the exposure to coastal flooding, meaning that the South-West Region is particularly exposed to coastal flooding. The Border Region meanwhile will see the lowest increase in sea level rise.

By 2100 under the RCP4.5 scenario, 2.6% of discharge points (as recorded by the EPA) across NUTS3 regions will be impacted by coastal flooding according to the NCFHM. RCP8.5 on the other hand anticipates 3.5% of discharge points

to be affected by 2100. The South-West region is the most exposed region to coastal flooding.

There are 145 water treatment complexes in Ireland according to OSi Prime2 data. These facilities are located through the eight NUTS3 regions.

4.3.31.3 Consequence

- **Damage:** There is potential for limited to substantial impacts on water services infrastructure resulting in potentially Substantial levels of damage by 2100.
- **System Functionality:** The impacts of sea level rise and coastal flooding can lead to temporary to long-term disturbances, and potentially irreversible losses in this system.
- **Extent and Pervasiveness:** The whole Irish coastline is exposed to sea level rise, with exposure to coastal flooding upon local conditions, i.e., elevation. The largest impacts will occur in areas that have concentrations of water services infrastructure close to the coast, however, all NUTS3 regions (apart from the Midlands) are exposed to this risk to varying degrees of severity.
- **Cascading Effects:** There are both temporary to long-term cascading effects on the Biodiversity and Ecosystem System, meaning disruption and damage to water services infrastructure can result in decreases in water quality, the Health System, where it can impact the physical health of people, the Social System, where it can cause business disruption, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Water Security System, where it impacts access to water for drinking and for industrial use.
- **Change through time**: In both scenarios, sea level rise will increase at similar rates to 2050, however, beyond this point RCP8.5 has a higher sea level by the end of the century compared to RCP4.5. However, there is expected to be only minor differences in the water services infrastructure exposed to this risk. There is also a projected increase in population (increase of 1.124 million by

2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the amount of water services infrastructure. Consequently, a Substantial level of consequence is potentially reached by 2100 in both scenarios.

4.3.31.4 Confidence

Hazard Confidence: There is high confidence that sea level rise and coastal flooding will increase in frequency and severity in the future. Global projections, including those from the IPCC Assessment Report 6, have been used to inform sea level rise. Coastal flood extent and frequency changes have been assessed by the OPW using rigorous models, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used.

Consequence Confidence: The impacts of coastal flooding are already affecting Ireland and this impact will increase in the future, however, there is uncertainty of the spatial distribution of the water services infrastructure that would be exposed to this risk currently and in the future.

4.3.31.5 Adaptation

To address the risks of disruption and damage to water services infrastructure due to coastal flooding, several adaptation measures are in place.

Reliability

- *Policy and Governance:* Implementation of Planning and Development Act Section 28 Guidelines and the OPW Capital Flood Relief Scheme provide a regulatory framework for adaptation.
- *Monitoring and Early Warning Systems:* Monitoring of physical coastal change and national-scale coastal hazard mapping and risk assessment are conducted. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

- *Practices in Place:* Climate Risk Assessments and planning regulations guide adaptation efforts. The National Catchment Flood Risk Assessment and Management Programme and Ocean Knowledge 2030 are key initiatives.

Resistance

- *Research and Development:* The Coastal Change Research Programme supports ongoing research to understand and mitigate coastal risks. Assessment of options for management of coastal change risks and long-term planning are also in place.
- *Sector-Specific Adaptation Actions:* Uisce Éireann conducts emergency repair works to address immediate risks. The OPW Minor Flood Mitigation Works and Coastal Protection Scheme enhance infrastructure resilience.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.31.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.32 BE31 Risk of disruption and damage to water services infrastructure due to extreme cold

4.3.32.1 Risk Summary

Table 4.32: BE31 Risk of disruption and damage to water services infrastructure due to extreme cold.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to water services infrastructure due to extreme cold	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	High					

Extreme cold can impact water services infrastructure through pipes freezing and pipes bursting. These impacts can result in increased maintenance and disruption to operations. For stormwater infrastructure, extreme cold can block drains and inlets through snow and ice build-up. The melting of this snow and ice can then overload stormwater infrastructure, resulting in flooding. Extreme cold can impact water treatment infrastructure, including potable and wastewater treatment, by freezing and breaking pipes, and increasing the amount of water entering treatment systems through snowmelt.

4.3.32.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience a decrease in the number of frost days and a decrease in the number of icing days. Under RCP4.5, the number of frost days is expected to decrease by 21.1 days (-27.2 — -15.0) by 2100 with the Northern region experiencing the largest decrease (-24.5 days (-31.4 — -17.6)). In an RCP8.5 scenario, number of frost days are expected to decrease by 31.4 days (-37.0- -24.7) , with the Northern region experiencing the largest decrease (-36.5 days (-43.3 - -28.9).

Under RCP4.5, regions are estimated to experience 0.30 (-0.4 — -0.2) fewer icing days by 2100 with the Mid-East region experiencing the largest decrease (-0.4

days). In an RCP8.5 scenario, there is projected to be 0.36 (-0.4 ─ -0.3) fewer icing days, with the Mid-East region experiencing the largest decrease (-0.5 days)

There are 145 water treatment complexes in Ireland according to OSi Prime2 data. These facilities are located through the eight NUTS3 regions.

4.3.32.3 Consequence

- **Damage**: Extreme cold can result in substantial damage to water services infrastructure, and already impacts Ireland, for instance:
    - Widespread heavy snowfalls in early March 2018, with up to 69 cm in the Wicklow mountains, led to significant impacts in Ireland such as freezing temperatures causing burst water mains and high water usage along with pipe leaks and bursts. Operational issues at treatment plants included compromised disinfection systems, leading to Boil Water Notices (Department of Housing, Local Government and Heritage, 2019).
    - Heavy snowfall and low temperatures caused severe disruption in Ireland in 2018, with over 18,000 people left without water (Department of Health, 2019).

  By 2100, even though the hazard frequency and severity decreases, due to an increase in exposure the consequence remains Substantial.

- **System Functionality**: This risk can lead to temporary or moderate disturbances in the Built Environment system across all time periods.
- **Extent and Pervasiveness**: This risk can affect a wide range of water service infrastructure and types across all time periods.
- **Cascading Effects**: There are both temporary to long-term cascading effects on the Biodiversity and Ecosystem System, meaning disruption and damage to water services infrastructure can result in decreases in water quality, the Health System, where it can impact the physical health of people, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance

and insurance coverage, the Social System, where it can cause business disruption, and the Water Security System, where it impacts access to water for drinking and for industrial use.

- **Change through time**: The hazard is already a risk but will decrease in frequency and severity in the future, although the hazard will still occur. Impacts will reduce but not sufficiently to reach the Limited category until 2100. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the amount of water services infrastructure. There are only minor differences between the RCP4.5 and RCP8.5 scenarios, therefore the consequence is the same.

4.3.32.4 Confidence

Hazard Confidence: There is a High level of confidence that extreme cold events will decrease in the future with global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is a decreasing trend for the extreme cold variables (frost days and icing days). The national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform the extreme cold variables, using a robust and peer-reviewed modelling approach.

Consequence Confidence: The impacts of extreme cold are already affecting Ireland and this impact is expecting to decrease in the future. Therefore, the confidence in the consequence is High, with some uncertainty on the change of exposure in the future.

4.3.32.5 Adaptation

To address the risks of disruption and damage to water services infrastructure due to extreme cold, several adaptation measures are in place:

Reliability

- *Policy and Governance:* The Water Quality and Water Services Infrastructure Climate Change Sectoral Adaptation Plan ensures continuous monitoring and adaptation of water services infrastructure to mitigate cold-related risks.
- *Monitoring and Early Warning Systems*: Systems are in place to monitor infrastructure performance during extreme cold events.
- *Practices in Place*: Climate Risk Assessments identify vulnerabilities. The Nature Restoration Law and National Nature-based Solutions Implementation Strategy guide adaptation efforts. Subsidies for the elderly and disadvantaged to purchase heating fuel ensure community support and resilience.

Resistance

- *Research and Development*: Research focuses on nature-based solutions to enhance infrastructure resilience against extreme cold.

Recovery and Response

- *Sector-Specific Adaptation Actions*: Uisce Éireann conducts emergency repair works to address immediate risks.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.32.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.33 BE32 Risk of disruption and damage to water services infrastructure due to flooding (fluvial, surface water, and groundwater)

4.3.33.1 Risk Summary

Table 4.33: BE32 Risk of disruption and damage to water services infrastructure due to flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to water services infrastructure due to flooding (fluvial, surface water, and groundwater)	Substantial	Substantial	Critical	Substantial	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	High					

Ireland is susceptible to various types of flooding, including fluvial, surface water, and groundwater flooding, which can impact water services infrastructure. In terms of stormwater infrastructure, flooding can disrupt and damage pipelines, impacting the function and capacity of stormwater systems through inundation. Flooding can disrupt water treatment infrastructure (potable and wastewater) by submerging facilities, contaminating water supplies, and preventing maintenance access. Furthermore, flooding can damage water treatment infrastructure (potable and wastewater) by submerging and eroding facilities, breaking pipelines, and damaging equipment with debris and forceful water flow. Additionally, flooding can lead to significant economic costs due to the damage and disruption of water services infrastructure, including repair and replacement expenses and the economic impact of service interruptions.

4.3.33.2 Exposure and Vulnerability

Based on CFRAM and NIFM data, for a 1 in 100-year event, the total land area that will be exposed to flooding by 2100 is 1.73% and 2.29% respectively, under the RCP4.5 scenario. The Midlands Region is the most exposed region, with

between 3.06% (NIFM) to 3.36% (CFRAM) of the region's total land area impacted.

For the RCP8.5 scenario, between 1.95% (CFRAM) to 2.38% (NIFM) of the total national land area will be at risk of flooding by 2100. Similarly, the Midlands Region is the most exposed region, with between 3.13% (NIFM) to 3.94% (CFRAM) of the region's total land area potentially affected.

Based on CFRAM data for a 1 in 100 year-event, 36.1% (RCP4.5 by 2100) to 40.6% (RCP8.5 by 2100) of discharge points (as recorded by the EPA) will be exposed to fluvial flooding. The highest proportion of exposed discharge points is also estimated to be in the Dublin Region.

Based on NIFM data for a 1 in 100 year-event event, 27.1% (RCP4.5 and RCP8.5 by 2100) of discharge points will be exposed to fluvial flooding. The highest proportion of exposed discharge points is also estimated to be in the Border Region.

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios.

There are 145 water treatment complexes in Ireland according to OSi Prime2 data. These facilities are located through the eight NUTS3 regions.

4.3.33.3 Consequence

- **Damage:** There is potential for substantial to large and frequent damage to water services infrastructure resulting in potentially Critical levels of damage by 2100.
- **System Functionality:** The impacts flooding can lead to temporary to long-term disturbances in this system.

- **Extent and Pervasiveness:** Currently, impacts are of a moderate extent or pervasiveness. As extreme precipitation and flooding are projected to increase in frequency and intensity, these impacts will be more widespread, affecting larger areas and a greater number of buildings, with large and pervasive impacts by 2100.

- **Cascading Effects:** There are both temporary to long-term cascading effects on the Biodiversity and Ecosystem System, meaning disruption and damage to water services infrastructure can result in decreases in water quality, the Health System, where it can impact the physical health of people, the Social System, where it can cause business disruption, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Water Security System, where it impacts access to water for drinking and for industrial use.

- **Changes through time:** In both scenarios, the changing climate conditions will continually increase the frequency and severity of flooding events. Furthermore, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the amount of water services infrastructure is possible, resulting in potential Critical levels of risk by 2100.

4.3.33.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020). The

potential impact of peatland restoration, i.e., rewetting, on flood exposure are currently unknown.

Consequence Confidence: There is high confidence in the consequence as the impacts of this risk have already been observed and will likely increase in frequency and severity in the future.

4.3.33.5 Adaptation

To address the risk of disruption and damage to water services infrastructure due to flooding, several adaptation measures are in place:

Reliability

- *Policy and Governance:* Planning regulations, the Implementation of Planning and Development Act Section 28 Guidelines, and emergency response planning provide a regulatory framework for adaptation.
- *Monitoring and Early Warning Systems:* The development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.
- *Practices in Place*: The Water Quality and Water Services Infrastructure Climate Change Sectoral Adaptation Plan and planning regulations guide adaptation efforts. The National Catchment Flood Risk Assessment and Management Programme and the 3rd cycle of Flood Directive Implementation are key initiatives.

Resistance

- *Research and Development:* Research focuses on advancing community resilience and developing infrastructure to upgrade surface water networks. The Farming for Water EIP and Waters for LIFE EIP support these efforts.
- *Sector-Specific Adaptation Actions*: The OPW Capital Flood Relief Scheme, OPW Minor Flood Mitigation Works, and various flood protection schemes address specific risks.

Recovery and Response

- *Emergency response*: Uisce Éireann text alert systems for vulnerable customers enhance community resilience. Uisce Éireann conducts emergency repair works to address immediate threats. Water reservoir and river level monitoring and alarm triggers for loss of power at water treatment plants ensure preparedness.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.33.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.34 BE33 Risks of disruption and damage to water services infrastructure due to ground movement as a result of drought conditions

4.3.34.1 Risk Summary

Table 4.34: BE33 Risks of disruption and damage to water services infrastructure due to ground movement as a result of drought conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risks of disruption and damage to water services infrastructure due to ground movement as a result of drought conditions	Limited	Limited	Substantial	Limited	Limited	Substantial
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	High					

Ground movement due to drought conditions can impact water services infrastructure by breaking pipes and damaging the foundations of water services buildings. For stormwater infrastructure and potable water treatment, such ground movement can shift and break pipes, leading to leaks that reduce capacity and, in the case of potable water, create potential contamination risks. The inability to access alternative water sources due to high demand and competition from other users can further strain water resources.

4.3.34.2 Exposure and Vulnerability

In an RCP4.5 scenario, nationally the mean annual number of wet days is expected to decrease of 2.4%(-6.52 — 1.53%) by 2050 and 2.2 (-6.63 — -1.63%) by 2100, with the East region experiencing the largest decrease (2050: 3.2%, 2100: 2.8%). The same trend occurs in RCP8.5 with a decrease of 2.6% ((-6.21 – 1.11%) by 2050 and 4.1% (-9.71 – 0.47%) by 2100, with the East region experiencing the largest decrease (2050: 3.3%, 2100: 5.1%).

For RCP4.5 and RCP8.5 compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season for both 2050 and 2100.

4.3.34.3 Consequence

- **Damage:** There is potential for limited or rare losses to substantial losses to water services infrastructure by 2100.

- **System Functionality:** Drought conditions can cause temporary disturbances to the Built Environment. However, as the risk increases to substantial, these disturbances could become more pronounced, affecting the functionality of water service infrastructure for longer periods.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and however, the direct impacts will affect underground water service infrastructure predominantly.

- **Cascading Effects:** There are both temporary to long-term cascading effects on the Biodiversity and Ecosystem System, meaning disruption and damage to water services infrastructure can result in decreases in water quality, the Health System, where it can impact the physical health of people, the Social System, where it can cause business disruption, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Water Security System, where it impacts access to water for drinking and for industrial use.

- **Change through time:** In both scenarios, there is a decrease in precipitation and an increase in drought conditions. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the amount of water services infrastructure. There are limited differences between the

hazard in RCP4.5 and RCP8.5 scenarios therefore, the level of consequence is Substantial in both scenarios by 2100.

4.3.34.4 Confidence

Hazard Confidence: There is a medium level of confidence that drought conditions will increase in the future. Changes in the number of wet days have been used from national downscaled projections (TRANSLATE) which were produced by the national meteorological agency, and peer-reviewed research has been used for SPEI-3, however, further research and variables, i.e., SPEI-6, SPEI-12 are needed to better inform confidence in this hazard.

Consequence Confidence: There is high confidence in the consequence as some of these impacts of this risk have already been observed at a local and short-term/temporary term basis.

4.3.34.5 Adaptation

To address the risks of disruption and damage to water services infrastructure due to ground movement as a result of drought conditions, several adaptation measures are in place:

Reliability

- *Policy and Governance:* The Water Quality and Water Services Infrastructure Climate Change Sectoral Adaptation Plan and other policies ensure continuous monitoring and adaptation of water services infrastructure to mitigate drought-related risks.
- *Monitoring and Early Warning Systems:* Systems are in place to monitor infrastructure performance during drought conditions.
- *Practices in Place:* Climate Risk Assessments identify vulnerabilities and inform planning.

Resistance

- *Community Engagement and Education*: Public awareness campaigns educate communities on water conservation and infrastructure resilience.

- *Research and Development:* The National Nature-based Solutions Implementation Strategy supports research on enhancing infrastructure resilience against drought.

Recovery and Response

- *Emergency response*: Uisce Éireann conducts emergency repair works to address immediate threats.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.34.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is a Watching Brief.

4.3.35 BE34 Risk of operational issues (i.e., changes to water treatment operations) for water services infrastructure due to increases in average temperature

4.3.35.1 Risk Summary

Table 4.35: BE34 Risk of operational issues (i.e., changes to water treatment operations) for water services infrastructure due to increases in average temperature.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of operational issues (i.e. changes to water treatment operations) for water services infrastructure due to increases in average temperature	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Medium					

There is a risk to water services infrastructure due to increases in average temperature. Higher temperatures can cause operational issues by enhancing conditions for algal blooms, accelerating eutrophication, stressing infrastructure, and increasing evaporation. Additionally, higher temperatures can lead to increased corrosion and material degradation, reduced efficiency of treatment processes, thermal pollution, and increased risk of pathogen proliferation.

4.3.35.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C (0.6-1.7°C) by 2050, and 1.5°C (1.1-2.2°C) by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C (1.1-1.9°C) by 2050, and 2.7°C (2.0-3.3°C) by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100) scenarios.

There are 145 water treatment plants in Ireland according to OSi Prime2 data. These facilities are located through the eight NUTS3 regions.

4.3.35.3 Consequence

- **Damage:** Increasing temperatures result in limited or rate impacts in 2030, however, as temperatures increase this impact could results in substantial to large and frequent impacts.

- **System Functionality:** In 2030, increasing temperatures have no significant disturbance on the Built Environment System, however, as temperatures increase the impact may increase to temporary or moderate disturbances in the Built Environment System. In RCP8.5, by 2100, this could result in long term disturbances to the system.

- **Extent and Pervasiveness:** All NUTS3 regions will be exposed to increase temperatures, therefore there is a large extent affected by this risk, however, there is low pervasiveness as only certain types of water services infrastructure, i.e., water treatment plants. The extent and pervasiveness is therefore considered Substantial.

- **Cascading Effects:** There are both temporary to long-term cascading effects on the Biodiversity and Ecosystem System, operational issues (i.e. changes to water treatment operations) for water services infrastructure can result in decreases in water quality, the Health System, where it can impact the physical health of people, the Social System, where it may cause business disruption, and the Water Security System, where it can impact access to water for consumption and water for industrial use.

- **Changes through time:** The risk is currently Limited but will increase significantly in the future, especially under the RCP8.5 scenario, leading to potential critical levels of damage with large and frequent impacts as temperatures increase. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)),

and therefore a possible commensurate increase in the amount of water services infrastructure.

4.3.35.4 Confidence

Hazard Confidence: For increasing temperatures there is High confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: The impacts of this risk will increase in the future, however, there is uncertainty with regards to the timing of these future impacts, therefore confidence in the consequence is Medium.

4.3.35.5 Adaptation

To address the risk of operational issues for water services infrastructure due to increases in average temperature, several adaptation measures are in place:

Reliability

- *Policy and Governance*: The Water Quality and Water Services Infrastructure Climate Change Sectoral Adaptation Plan and other policies ensure continuous monitoring and adaptation of water services infrastructure to mitigate temperature-related risks.
- *Monitoring and Early Warning Systems*: Systems are in place to monitor infrastructure performance during temperature increases.
- *Practices in Place*: Climate Risk Assessments identify vulnerabilities and inform planning.

Resistance

- *Community Engagement and Education*: Public awareness campaigns educate communities on water conservation.
- *Research and Development*: The National Nature-based Solutions Implementation Strategy supports research on enhancing infrastructure resilience against temperature increases.

Recovery and Response

- *Emergency response*: Uisce Éireann conducts emergency repair works to address immediate operational issues.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.35.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.36 BE35 Risk of stress on dam/reservoir infrastructure due to drought conditions

4.3.36.1 Risk Summary

Table 4.36: BE35 Risk of stress on dam/reservoir infrastructure due to drought conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of stress on dam/reservoir infrastructure due to drought conditions	Limited	Limited	Substantial	Limited	Limited	Substantial
Urgency	Watching Brief					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Drought conditions can stress dam and reservoir infrastructure by reducing water levels, which can compromise structural integrity and reduce the capacity for water storage and supply. Lower water levels can increase the risk of cracks and other structural issues in dams, while also reducing the hydrostatic pressure that helps maintain their stability. This could result in increased downtime and/or maintenance costs. Additionally, prolonged droughts can lead to sedimentation issues, further impacting the functionality and safety of reservoirs.

4.3.36.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38)).

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing

the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2))

In an RCP4.5 scenario, nationally the mean annual number of wet days is expected to decrease of 2.4%(-6.52 – 1.53%) by 2050 and 2.2 (-6.63 – -1.63%) by 2100, with the East region experiencing the largest decrease (2050: 3.2%, 2100: 2.8%). The same trend occurs in RCP8.5 with a decrease of 2.6% ((-6.21 – 1.11%) by 2050 and 4.1% (-9.71 – 0.47%) by 2100, with the East region experiencing the largest decrease (2050: 3.3%, 2100: 5.1%).

For RCP4.5 and RCP8.5 compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season for both 2050 and 2100.

There are 1,344 reservoirs in Ireland which store water as part of Uisce Éireann's water supply network, located in all NUTS3 regions (Uisce Éireann, Dec.2023) The largest numbers are located in the South-West (327 locations) and Border (244 locations) regions.

4.3.36.3 Consequence

- **Damage:** The damage ide (Department of Housing, Local Government and Heritage, 2019).
- **System Functionality:** In 2030 and 2050, this risk can result in no significant disturbance to the functionality of the Built Environment system, however, as drought conditions potential increase in frequency and severity by 2100, temporary or moderate disturbance to the system is possible.
- **Extent and Pervasiveness:** The extent and pervasiveness of the impacts are moderate to large as even though the direct impacts of this hazard will be in

regions where dams/reservoirs are located, the impacts of this risk may occur over a wider extent.

- **Cascading Effects:** There are both temporary to long-term cascading effects if dams/reservoirs require repairs or operational changes. This could affect the Energy System, Stress on dam/reservoir infrastructure can result in an inability to produce hydroelectric power, and the Water Security System, where it can affect access to drinking water and access to water for industrial use.

- **Changes through time:** Drought projections for Ireland indicate an increase in the frequency of drought conditions, particularly during the spring and summer months. Drought conditions will; be more prevalent by 2100, increasing the consequence to Substantial.

4.3.36.4 Confidence

Hazard Confidence: There is a medium level of confidence that drought conditions will increase in the future. Changes in the number of wet days have been used from national downscaled projections (TRANSLATE) which were produced by the national meteorological agency, and peer-reviewed research has been used for SPEI-3, however, further research and variables, i.e., SPEI-6, SPEI-12 are needed to better inform confidence in this hazard.

Consequence Confidence: The confidence in the consequence is Low as there is limited examples of this risk occurring currently and there is uncertainty of the timing of the future increase in the consequence of this risk.

4.3.36.5 Adaptation

To address the risk of stress on dam/reservoir infrastructure due to drought conditions, several adaptation measures are in place:

Reliability

- *Policy and Governance:* The Water Quality and Water Services Infrastructure Climate Change Sectoral Adaptation Plan and other policies ensure

continuous monitoring and adaptation of dam and reservoir infrastructure to mitigate drought-related risks.

- *Monitoring and Early Warning Systems*: Systems are in place to monitor infrastructure performance during drought conditions.
- *Practices in Place*: Climate Risk Assessments identify vulnerabilities and inform planning.

Resistance

- *Community Engagement and Education*: Public awareness campaigns educate communities on water conservation and infrastructure resilience.
- *Research and Development:* The National Nature-based Solutions Implementation Strategy supports research on enhancing infrastructure resilience against drought.

Recovery and Response

- *Emergency Response*: Uisce Éireann conducts emergency repair works to address immediate threats.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

4.3.36.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is a Watching Brief.

4.3.37 BE36 Risk of operational issues due to inability to discharge water into depleted water bodies (i.e., low assimilative capacity, low levels of dissolved oxygen) as a result of drought conditions

4.3.37.1 Risk Summary

Table 4.37: BE36 Risk of operational issues due to inability to discharge water into depleted water bodies (i.e., low assimilative capacity, low levels of dissolved oxygen) as a result of drought conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of operational issues due to inability to discharge water into depleted water bodies (i.e., low assimilative capacity, low levels of dissolved oxygen) as a result of drought conditions	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Drought conditions significantly impact water bodies by reducing their assimilative capacity and levels of dissolved oxygen, which in turn hampers water utilities' ability to discharge treated wastewater. This leads to operational bottlenecks, increased costs for additional treatment or storage, and potential regulatory compliance issues. Reduced stream flows and higher water temperatures exacerbate these issues by concentrating pollutants and decreasing the natural dilution and oxygenation processes. Additionally, drought can lead to increased concentrations of pollutants, such as nutrients and heavy metals, which can further degrade water quality. Consequently, water utilities must adopt more stringent treatment measures and explore alternative discharge strategies to maintain compliance and protect water quality.

4.3.37.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38)).

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2))

In an RCP4.5 scenario, nationally the mean annual number of wet days is expected to decrease of 2.4%(-6.52 — 1.53%) by 2050 and 2.2 (-6.63 — -1.63%) by 2100, with the East region experiencing the largest decrease (2050: 3.2%, 2100: 2.8%). The same trend occurs in RCP8.5 with a decrease of 2.6% ((-6.21 – 1.11%) by 2050 and 4.1% (-9.71 – 0.47%) by 2100, with the East region experiencing the largest decrease (2050: 3.3%, 2100: 5.1%)..

For RCP4.5 and RCP8.5 compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season for both 2050 and 2100.

Water discharge points and freshwater courses are present across all NUTS3 regions.

4.3.37.3 Consequence

- **Damage:** There will be Limited levels of damage in 2030 due to this risk, however, as drought conditions increase in frequency and severity, there will potentially be an increase to substantial losses.

- **System Functionality:** There is no significant disturbances in 2030 anticipated, However, by 2050, temporary or moderate disturbances are anticipated, potentially rising to long term disturbances by 2100.

- **Extent and Pervasiveness:** The extent and pervasiveness of the impacts are moderate to large as there are discharge points located across all NUTS3 regions, however, the type of impacts will depend upon local conditions and characteristics.

- **Cascading Effects:** Currently, there are no significant cascading effects beyond system boundaries. By 2100, temporary cascading effects are anticipated. These effects include impacts on the Biodiversity and Ecosystem System, meaning operational issues due to inability to discharge water into depleted water bodies (i.e, low assimilative capacity, low levels of dissolved oxygen) can result in decreases in water quality, the Health System, where it can impact the physical health of people, the Social System, where it can cause business interruption, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Water Security System, where it can impact access to drinking water and access to water for industrial use.

- **Change through time:** Drought projections for Ireland indicate an increase in the frequency of drought conditions, particularly during the spring and summer months. Drought conditions will be more prevalent by 2100, increasing the consequence to Substantial.

4.3.37.4 Confidence

Hazard Confidence: There is a medium level of confidence that drought conditions will increase in the future. Changes in the number of wet days have been used from national downscaled projections (TRANSLATE) which were produced by the national meteorological agency, and peer-reviewed research has been used for SPEI-3, however, further research and variables, i.e., SPEI-6, SPEI-12 are needed to better inform confidence in this hazard.

Consequence Confidence: The confidence in the consequence is Low as there is limited examples of this risk occurring currently and there is uncertainty of the timing of the future increase in the consequence of this risk.

4.3.37.5 Adaptation

Specific adaptation measures for this risk have not been identified.

4.3.37.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

4.3.38 BE37 Risk of disruption and damage to water services infrastructure due to extreme wind

4.3.38.1 Risk Summary

Table 4.38: BE37 Risk of disruption and damage to water services infrastructure due to extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to water services infrastructure due to extreme wind	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Very Low					
Consequence Confidence	High					

Extreme wind can disrupt and damage water services infrastructure by blocking drains and inlets and damaging physical infrastructure. Stormwater infrastructure can be blocked by debris blown from extreme winds. These blockages can reduce the capacity of stormwater infrastructure, potentially leading to flooding. Water treatment infrastructure, including potable and wastewater treatment, can be impacted by physical damage from extreme winds, which subsequently affects operations.

4.3.38.2 Exposure and Vulnerability

For RCP4.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.32 days, 2100: -0.47) from the 1981-2010 baseline. For RCP8.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.61 days, 2100: -0.44) from the 1981-2010 baseline.

For RCP4.5, there is a projected small decrease in the 10-m wind speed of 1.0–2.7% (mean 1.8%) compared to the 1981-2000 baseline by 2050. For RCP8.5, there is a 1.6–3.3% (2.6%) decrease.

There are 145 water treatment complexes in Ireland based on OSi PRIME2 data. These facilities are located throughout the eight NUTS3 regions.

4.3.38.3 Consequence

- **Damage**: This risk already occurs within Ireland, with damage considered Substantial due to the number of people that could be affected.
- **System Functionality**: Extreme wind can cause moderate disturbances to the Built Environment system.
- **Extent and Pervasiveness**: The impact of extreme wind events is widespread, affecting a large range water services infrastructure types, across extensive areas, indicating a large extent and pervasiveness.
- **Cascading Effects**: There are both temporary to long-term cascading effects on the Biodiversity and Ecosystem System, disruption and damage to water services infrastructure can result in decreases in water quality, the Health System, where it can impact the physical health of people, the Social System, where it may cause business disruption, the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and the Water Security System, where it can impact access to drinking water and access to water for industrial use.
- **Change through time**: Projections show no change in hazard (although with very low levels of confidence). There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the amount of water services infrastructure is possible. However, the risk is currently assessed as a Substantial consequence, and this current level of risk is expected to continue into the future.

4.3.38.4 Confidence

Hazard Confidence: There is a Very Low level of confidence that extreme wind frequency and severity will not change in the future. There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used at the NUTS2 level, with national scale data for average wind speed used as an alternative proxy.

Consequence Confidence: There is High confidence in the consequence as the impacts of this risk have already been observed and will likely continue in the future.

4.3.38.5 Adaptation

Specific adaptation measures for this risk have not been identified.

4.3.38.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

5 Economy and Finance

5.1 System Description

The Economy and Finance System encompasses the management of economic and financial activities to ensure stability and sustainable growth. Its subsystems include finance and insurance, and economic stability. The finance and insurance subsystem includes financial markets, insurance sectors, banking institutions, and investment mechanisms that facilitate capital allocation, manage financial risk, and support economic development. The economic stability subsystem focuses on maintaining macroeconomic balance through fiscal and monetary policy, inflation control, employment support, and emergency response mechanisms. Together, these subsystems form the foundation for a resilient and adaptive economy, particularly in the face of emerging systemic risks such as those driven by climate change.

The risks within the Economy and Finance System are largely the result of cascading and compounding impacts originating from other interconnected systems. As disruptions occur in other systems they can propagate through to the economy and finance system ultimately manifesting as financial and economic instability. These cross-system dependencies mean that the Economy and Finance System is particularly exposed to systemic shocks and relevant for all adaptation sectors. In this context, three significant risks have been identified within the system, each reflecting the broader, interconnected, and cascading nature of climate risks.

5.2 Summary of Climate Change Risks

Table 5.1 shows a summary of the consequences for the risks identified to the Economy and Finance System under both RCP4.5 and RCP8.5 scenarios across three-time horizons (2030, 2050, and 2100).

Table 5.1: Summary of Climate Change Risks in the Economy and Finance System. Lim = Limited, Sub = Substantial, Cri = Critical, Cat = Catastrophic.

ID	Risk	Consequence RCP4.5			Consequence RCP8.5		
		2030	2050	2100	2030	2050	2100
EC01	Risk of increased insurance claims and premia and widening protection gap due to climate change	Sub	Cri	Cri	Sub	Cri	Cat
EC02	Risk of increased probability of default and loss of asset value due to climate change	Sub	Cri	Cri	Sub	Cri	Cat
EC03	Risk of reduced tax revenues, increased government expenditure, lower credit ratings and increased cost of borrowing due to climate change	Sub	Cri	Cri	Sub	Cri	Cat

5.3 Risks

5.3.1 EC01 Risk of increased insurance claims and premia and widening protection gap due to climate change

5.3.1.1 Risk Summary

Table 5.2: EC01 Risk of increased insurance claims and premia and widening protection gap due to climate change

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased insurance claims and premia and widening protection gap due to climate change	Substantial	Critical	Critical	Substantial	Critical	Catastrophic
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Medium					

As climate change accelerates, Ireland will face more frequent and severe weather events, such as flooding, storms, and coastal erosion. These events will drive a sharp increase in insurance claims, placing sustained pressure on insurers. In response, providers will raise premiums, tighten underwriting criteria, or withdraw cover from high-risk areas, making insurance less accessible and affordable. This risk is a result of risks within other systems cascading into the Economy and Finance System.

A protection gap is typically defined as the shortfall between the economic losses arising from an event and insured losses from the same event. For flood insurance, an existing protection gap has been identified (Central Bank of Ireland, 2024). Climate change is expected to widen protection gaps, where more households, businesses, and communities will be left without adequate insurance cover. The financial burden of climate-related losses will increasingly fall on the uninsured, deepening social and regional inequalities and placing greater strain on public finances.

5.3.1.2 *Exposure and Vulnerability*

The change in mean temperature is used as an overall proxy for exposure to climate change and the necessity for adaptation. All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C by 2050, and 1.5°C by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C by 2050, and 2.7°C by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C by 2100) and RCP8.5 (2.7°C by 2100) scenarios.

Using the OPW National Coastal Flood Hazard Mapping (NCFHM), for a 1 in 100-year event (1% Annual Exceedance Probability) under RCP4.5, 1.68% of buildings [14] in Ireland (based on the current total number and location of buildings) are at risk of coastal flooding by 2050. Similarly, for a 1 in 100-year event under RCP8.5, 1.68% of buildings are at risk of coastal flooding. By 2100, 1.98% of buildings in Ireland are at risk of coastal flooding for a 1 in 100-year event under RCP4.5, whereas under RCP8.5, 2.26% of buildings are at risk of coastal flooding for a 1 in 100-year event by 2100.

For all NUTS3 regions for 1 in 100-year event scenario, 1.73% (CFRAM) to 2.29% (NIFM) of the total land area could be at risk of flooding by 2100 under RCP4.5. The Midlands region is the most at risk, with 3.06% (NIFM) to 3.36% (CFRAM) of the total land area impacted.

Under the RCP8.5 scenario, 1.95% (CFRAM) to 2.38% (NIFM) of the total land area of the regions could be at risk of flooding by 2100. The Midlands region is the most at risk, with 3.13% (NIFM) to 3.94% (CFRAM) of the total land area impacted.

All insurable assets are exposed to this risk, with all type of exposures, e.g., infrastructure, motor vehicles, buildings (residential and commercial), located across all NUTS3 Regions.

[14] The term 'Buildings' is defined as the entire buildings layer from the OSi Prime2 dataset.

5.3.1.3 Consequence

- **Damage:** Substantial losses initially with an increase to Critical losses by 2050 in both scenarios. It will remain to critical levels under a RCP4.5 by 2100, however, damage will potentially increase to a very large and frequent levels under a RCP8.5 scenario.

- **System Functionality:** Initially there will be a temporary or moderate disturbance on this system, however, as the impacts of climate change increase in the future, the Economy and Finance system will potentially face long-term disturbances.

- **Extent and Pervasiveness:** This risk will have a large extent and very high pervasiveness, with all parts of the Economy and Finance system impacted, especially within the RCP8.5 scenario.

- **Cascading Effects:** This risk is a result of risks within other systems cascading into the Economy and Finance System.

- **Changes through time**: As the impacts of climate change increase throughout the century in both scenarios there will be more frequent and severe extreme events increasing insurance premia and the protection gap. Furthermore, there is a projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) indicating an increase in the number of assets requiring insurance.

5.3.1.4 Confidence

Hazard Confidence: There is a High-level confidence in the increasing temperature projections, and therefore climate change, which are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is medium confidence in the consequence as there is uncertainty on the timing of the increase in consequence.

5.3.1.5 Adaptation

To address this risk, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* The Central Bank of Ireland has published guidance for (re)insurers on how to address climate change risks. This guidance clarifies expectations for how insurers should assess and manage their exposure to climate change, including developing risk management frameworks and incorporating climate change into their Risk Appetite Statements (RAS). Insurers are encouraged to identify additional data needs, develop tools for data management, and consider the impact of their own activities on the climate. The Central Bank also encourages insurers to incorporate climate change considerations into their investment strategies and assess the impact of climate change on their business models.

  The National Development Plan and County Development Plans support climate resilience by prioritising adaptation measures such as investing in flood defences, avoiding developments in at risk locations, i.e., flood zones, and enhancing ecosystem resilience to protect communities and infrastructure from climate impacts.

Resistance

- *Sector-Specific Adaptation Actions:* The Office of Public Works (OPW) supports insurance by implementing flood defence infrastructure and measures, as well as by providing valuable information to insurers on flood risks and resilience measures, aiding in accurate risk assessment and insurance coverage decisions for properties located in flood-prone areas.

Recovery and Response

- No recovery and response measures identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

5.3.1.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

5.3.3 EC02 Risk of increased probability of default and loss of asset value due to climate change

5.3.3.1 Risk Summary

Table 5.3: EC02 Risk of increased probability of default and loss of asset value due to climate change

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased probability of default and loss of asset value due to climate change	Substantial	Critical	Critical	Substantial	Critical	Catastrophic
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Low					

As climate change continues to intensify, the Irish economy will face growing financial risks linked to both acute and long-term climate impacts. Businesses and households exposed to climate-related impacts, such as flooding, heat stress, or supply chain interruptions, will be more likely to experience financial strain. This will increase the probability of default on loans with impacts for the Economy and Finance System. This risk is a result of risks within other systems cascading into the Economy and Finance System.

At the same time, asset values, including property, land, and infrastructure, will come under pressure in areas at risk. Properties in flood-prone areas or coastal zones may see reduced demand, falling valuations, and limited access to credit or insurance. These trends will affect the balance sheets of banks, investors, and pension funds, potentially leading to credit tightening, reduced lending, and market volatility. If left unaddressed, this risk will weaken financial resilience and could contribute to wider economic instability.

5.3.3.2 Exposure and Vulnerability

The change in mean temperature is used as an overall proxy for exposure to climate change and the necessity for adaptation. All NUTS3 regions are projected

to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C by 2050, and 1.5°C by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C by 2050, and 2.7°C by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C by 2100) and RCP8.5 (2.7°C by 2100) scenarios.

Using the OPW National Coastal Flood Hazard Mapping (NCFHM), for a 1 in 100-year event (1% Annual Exceedance Probability) under RCP4.5, 1.68% of buildings [15] in Ireland (based on the current total number and location of buildings) are at risk of coastal flooding by 2050. Similarly, for a 1 in 100-year event under RCP8.5, 1.68% of buildings are at risk of coastal flooding. By 2100, 1.98% of buildings in Ireland are at risk of coastal flooding for a 1 in 100-year event under RCP4.5, whereas under RCP8.5, 2.26% of buildings are at risk of coastal flooding for a 1 in 100-year event by 2100.

For all NUTS3 regions for 1 in 100-year event scenario, 1.73% (CFRAM) to 2.29% (NIFM) of the total land area could be at risk of flooding by 2100 under RCP4.5. The Midlands region is the most at risk, with 3.06% (NIFM) to 3.36% (CFRAM) of the total land area impacted.

Under the RCP8.5 scenario, 1.95% (CFRAM) to 2.38% (NIFM) of the total land area of the regions could be at risk of flooding by 2100. The Midlands region is the most at risk, with 3.13% (NIFM) to 3.94% (CFRAM) of the total land area impacted.

All assets with economic value are exposed to this risk, with all type of exposures, e.g., infrastructure, buildings (residential and commercial), located across all NUTS3 Regions.

5.3.3.3 Consequence

- **Damage:** Substantial losses initially with an increase to Critical losses by 2050 in both scenarios. It will remain to critical levels under a RCP4.5 by 2100,

[15] The term 'Buildings' is defined as the entire buildings layer from the OSi Prime2 dataset.

however, damage will potentially increase to a very large and frequent levels under a RCP8.5 scenario.

- **System Functionality:** Initially there will be a temporary or moderate disturbance on this system, however, as the impacts of climate change increase in the future, the Economy and Finance system will potentially face long-term disturbances.
- **Extent and Pervasiveness:** This risk will have a large extent and very high pervasiveness, with all parts of the Economy and Finance system impacted, especially within the RCP8.5 scenario.
- **Cascading Effects:** This risk is a result of risks within other systems cascading into the Economy and Finance System.
- **Changes through time**: As the impacts of climate change increase throughout the century in both scenarios there will be more frequent and severe extreme events potentially leading to increased probability of default and asset value loss.

5.3.3.4 Confidence

Hazard Confidence: There is a High-level confidence in the increasing temperature projections, and therefore climate change, which are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is medium confidence in the consequence as there is uncertainty on the timing of the increase in consequence.

5.3.3.5 *Adaptation*

To address this risk, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong policy frameworks and governance structures support adaptation (National Adaptation Framework, Climate Action Plan). The National Adaptation Framework, plus the associated sectoral adaptation plans, and local authority climate action plans address some of the financial risks and economic impacts of climate change by supporting the management of climate risks across society, which in turn supports the safeguarding asset values in exposed areas and promoting sustainable practices to enhance financial resilience and prevent economic instability.

  The National Development Plan and County Development Plans support climate resilience by prioritising adaptation measures such as investing in flood defences, avoiding developments in at risk locations, i.e., flood zones, and enhancing ecosystem resilience to protect communities and infrastructure from climate impacts.

Resistance

- *Sector-Specific Adaptation Actions:* The Office of Public Works (OPW) supports insurance by implementing flood defence infrastructure and measures, as well as by providing valuable information to insurers on flood risks and resilience measures, aiding in accurate risk assessment and insurance coverage decisions for properties located in flood-prone areas.

Recovery and Response

- No recovery and response measures identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

5.3.3.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

5.3.4 EC03 Risk of reduced tax revenues, increased government expenditure, lower credit ratings and increased cost of borrowing due to climate change

5.3.4.1 Risk Summary

Table 5.4: EC03 Risk of reduced tax revenues, increased government expenditure, lower credit ratings and increased cost of borrowing due to climate change

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of reduced tax revenues, increased government expenditure, lower credit ratings and increased cost of borrowing due to climate change	Substantial	Critical	Critical	Substantial	Critical	Catastrophic
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Low					

Climate change will place growing pressure on Ireland's public finances. As extreme weather events and long-term climate impacts increase, the State will face rising costs related to emergency response, infrastructure repair, healthcare, and social protection. At the same time, economic disruption will reduce tax revenues from income, consumption, and business activity. This risk is a result of risks within other systems cascading into the Economy and Finance System.

This imbalance between rising expenditure and falling revenue will widen the fiscal deficit, potentially leading to lower sovereign credit ratings. A downgrade in creditworthiness would increase the cost of borrowing for the State, making it more expensive to finance public services, invest in climate adaptation, or respond to future crises. Over time, this risk could limit Ireland's fiscal flexibility and reduce its ability to support vulnerable communities and sectors in the face of escalating climate impacts.

5.3.4.2 Exposure and Vulnerability

The change in mean temperature is used as an overall proxy for exposure to climate impacts and the necessity for adaptation. All NUTS3 regions are

projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C by 2050, and 1.5°C by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C by 2050, and 2.7°C by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C by 2100) and RCP8.5 (2.7°C by 2100) scenarios.

This risk is a result of risks within other systems cascading into the Economy and Finance System and therefore all of the assets within the eight other systems will be relevant exposures to this risk.

5.3.4.3 Consequence

- **Damage:** Substantial losses initially with an increase to Critical losses by 2050 in both scenarios. It will remain to critical levels under a RCP4.5 by 2100, however, damage will potentially increase to a very large and frequent levels under a RCP8.5 scenario.
- **System Functionality:** Initially there will be a temporary or moderate disturbance on this system, however, as the impacts of climate change increase in the future, the Economy and Finance system will potentially face long-term disturbances.
- **Extent and Pervasiveness:** This risk will have a large extent and very high pervasiveness, with all parts of the Economy and Finance system impacted, especially within the RCP8.5 scenario.
- **Cascading Effects:** This risk is a result of risks within other systems cascading into the Economy and Finance System.
- **Changes through time**: As the impacts of climate change increase throughout the century in both scenarios there will be more frequent and severe extreme events potentially leading to impacts on public finances.

5.3.4.4 Confidence

Hazard Confidence: There is a High-level confidence in the increasing temperature projections, and therefore climate change, which are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is medium confidence in the consequence as there is uncertainty on the timing of the increase in consequence.

5.3.4.5 Adaptation

To address this risk, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong policy frameworks and governance structures support adaptation (National Adaptation Framework, Climate Action Plan). The National Adaptation Framework, plus the associated sectoral adaptation plans, and local authority climate action plans address some of the financial risks and economic impacts of climate change by supporting the management of climate risks across society, which in turn supports the safeguarding asset values in exposed areas and promoting sustainable practices to enhance financial resilience and prevent economic instability.

Resistance

- No resistance measures identified.

Recovery and Response

- No recovery and response measures identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

5.3.4.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

6 Energy

6.1 System description

The Energy systems covers the production, conversion, and distribution of energy resources. Given this, Energy as a system is made up of two sub-systems – energy generation and conversion, and energy transmission and distribution infrastructure. The energy generation and conversion sub-system is made up of several elements at risk from climate change. These elements are energy generation infrastructure, the electricity network, hydropower, thermal power generation, and both onshore and offshore wind energy generation. The energy transmission and distribution sub-system consists of the electricity network and gas networks as the two key elements at risk.

The Energy system is of high importance for all adaptation sectors due to high dependency on the supply of electricity, in particularly Communication Networks, Electricity and Gas Networks, Flood Risk Management, Transport Infrastructure, Water Services Infrastructure, Health, Agriculture, Seafood, and Tourism.

6.2 Summary of Climate Change Risks

shows a summary of the consequences for the risks identified to the Energy System under both RCP4.5 and RCP8.5 scenarios across three-time horizons (2030, 2050, and 2100).

Table 6.1: Summary of Climate Change Risks in the Energy System. Lim = Limited, Sub = Substantial, Cri = Critical, Cat = Catastrophic.

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
E01	Risk of disruption and damage to energy generation and conversion infrastructure due to sea level rise and coastal flooding	Sub	Sub	Sub	Sub	Sub	Sub
E02	Risk of decreased generation of hydropower due to flood control measures during extreme precipitation events	Lim	Sub	Sub	Lim	Sub	Sub
E03	Risk of disruption and damage to energy generation and conversion infrastructure due to flooding (fluvial, surface water, and groundwater)	Sub	Sub	Sub	Sub	Sub	Sub
E04	Risk of increased demand (i.e., air conditioning) on energy generation and conversion infrastructure due to increases in temperature and extreme heat	Lim	Sub	Sub	Lim	Sub	Cri

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
E05	Risk of accelerated ageing of energy generation and conversion infrastructure due to increases in temperature	Lim	Sub	Sub	Lim	Sub	Sub
E06	Risk of reduced thermal power generation due to inability to discharge water into depleted water bodies (with low assimilative capacity) as a result of drought conditions and increased water temperature	Lim	Sub	Sub	Lim	Sub	Sub
E07	Risk of decreased wind energy generation and conversion due to changes in wind speed	Lim	Lim	Lim	Lim	Lim	Lim
E08	Risk of disruption and damage to energy transmission and distribution infrastructure due to sea level rise, coastal erosion, and coastal flooding	Lim	Sub	Sub	Lim	Sub	Sub
E09	Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme cold	Lim	Lim	Lim	Lim	Lim	Lim
E10	Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme precipitation and flooding (fluvial, surface water, and groundwater)	Sub	Sub	Sub	Sub	Sub	Sub
E11	Risk of degradation/accelerated ageing of energy transmission and distribution infrastructure due to increases in average temperature	Lim	Sub	Sub	Lim	Sub	Sub
E12	Risk of disruption and damage to underground energy transmission and distribution infrastructure due to ground movement as a result of drought conditions	Lim	Lim	Lim	Lim	Lim	Lim
E13	Risk of reduced efficiency of energy transmission and distribution infrastructure due to increases in temperature and extreme heat	Lim	Sub	Sub	Lim	Sub	Sub
E14	Risk of disruption and damage of energy transmission and distribution infrastructure due to lightning	Lim	Lim	Lim	Lim	Lim	Lim
E15	Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme wind	Cri	Cri	Cri	Cri	Cri	Cri

6.3 Risks

6.3.1 E01 Risk of disruption and damage to energy generation and conversion infrastructure due to sea level rise and coastal flooding

6.3.1.1 Risk Summary

Table 6.2: E01 Risk of disruption and damage to energy generation and conversion infrastructure due to sea level rise and coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to energy generation and conversion infrastructure due to sea level rise and coastal flooding	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Sustain Current Action					
Hazard Confidence	High					
Consequence Confidence	Medium					

Energy infrastructure faces significant risks from coastal flooding, which can cause direct physical damage to power plants, substations, and other energy generation and conversion infrastructure. The inundation of these facilities can lead to significant operational disruptions, including power outages and reduced efficiency in energy production and distribution. Additionally, the saltwater from coastal flooding can corrode equipment, leading to long-term maintenance challenges and increased costs.

6.3.1.2 Exposure and Vulnerability

The South-West Region is expected to experience the highest sea-level rise across all scenarios and time periods. The South-West Region is projected to experience sea level rise under an RCP4.5 scenario of 0.24 m by 2050, and 0.51 m by 2100, and 0.26 m by 2050, and 0.65 m by 2100 under an RCP8.5 scenario. Sea level rise drives the exposure to coastal flooding, meaning that the South-West Region is particularly exposed to coastal flooding. The Border Region meanwhile will see the lowest increase in sea level rise.

By 2100 under the RCP4.5 scenario, 2.6% of discharge points across NUTS3 regions will be impacted by coastal flooding according to the NCFHM. RCP8.5 on the other hand anticipates 3.5% of discharge points to be affected by 2100. The South-West region is the most exposed region to coastal flooding.

For the RCP4.5 scenario, 6.5% of energy generation and conversion sites and structures [16] (e.g., power station complexes, wind farms and hydroelectric dams) will be impacted by coastal flooding by 2100, across all NUTS3 regions. For RCP8.5, 6.5% of energy generation and conversion sites and structures are anticipated to be affected by coastal flooding by 2100. The South-East Region is particularly exposed, with 33.3% of energy generation and conversion sites and structures estimated to be affected by 2100 in both scenarios.

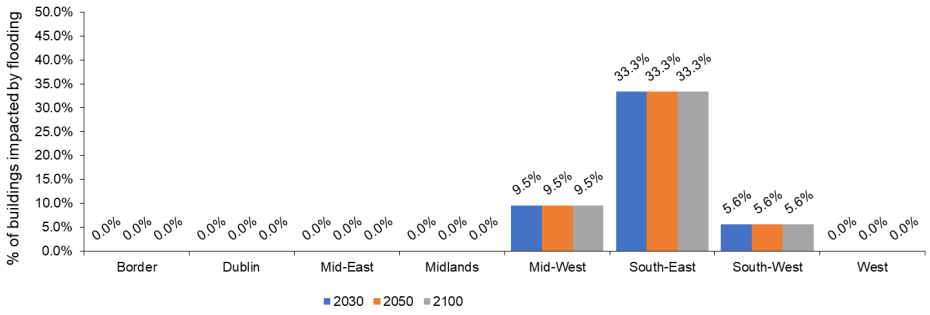


Figure 6.1: Proportion of energy generation and conversion sites and structures impacted by coastal flooding (1% AEP, RCP4.5, NCFHM).

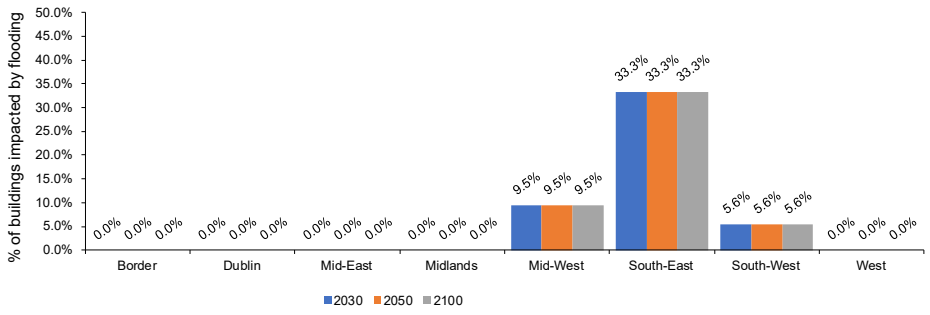


Figure 6.2: Proportion of energy generation and conversion sites and structures impacted by coastal flooding (1% AEP, RCP 8.5, NCFHM).

[16] The term 'Energy Generation' is defined as the following OSi Prime2 categories: Power Station Complex, Windfarm, Dam (Electricity Generation).

6.3.1.3 Consequence

- **Damage:** There is potential for limited to substantial impacts on energy generation and conversion resulting in potentially Substantial levels of damage by 2100.

- **System Functionality:** The impacts of sea level rise and coastal flooding can lead to temporary to long-term disturbances, and potentially irreversible losses in this system.

- **Extent and Pervasiveness:** The whole Irish coastline is exposed to sea level rise, with exposure to coastal flooding upon local conditions, i.e., elevation, and all NUTS3 regions (apart from the Midlands) are exposed to this risk to varying degrees of severity.

- **Cascading Effects:** There are both temporary and long-term cascading effects on all systems where electricity is critical to operations. The systems that will be impacted include:

    - The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security systems. Transport infrastructure, e.g., traffic lights and railway signals rely on electricity, and a power outage can cause traffic congestion and accidents. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting capabilities and public health. The loss of power in water treatment plants can lead to impacts on Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

    - The Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and loss of revenue.

- The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.

- The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may backup generators, however, patient care, may still be impacted. Furthermore, if there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.

- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Change through time**: In both scenarios, sea level rise will increase at similar rates to 2050, however, beyond this point RCP8.5 has a higher sea level by the end of the century compared to RCP4.5. However, the spatial analysis shows only minor differences in the energy generation and conversion infrastructure exposed to this risk. Additionally, in the future there will be developments that will result in increased baseline levels of energy demand. For instance, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps. Therefore, due to a high baseline level of energy demand in the future, loss of electricity will result in an amplification of the cascading effects related to this risk, such as heating failures and transportation disruptions. However, based on the minimal change in risk identified within the spatial analysis, a Substantial level of consequence is anticipated in 2100 in both scenarios.

6.3.1.4 Confidence

Hazard Confidence: There is High confidence that sea level rise and coastal flooding will increase in frequency and severity in the future. Global projections,

including those from the IPCC Assessment Report 6, have been used to inform sea level rise, while national projections for coastal change (erosion or accretion) are unavailable, with extrapolation of current erosion rates for 2050 used instead. Coastal flood extent and frequency changes have been assessed by the OPW using rigorous models, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used.

Consequence Confidence: There is Medium confidence in the consequence as the impacts of this risk have already been observed. The location new energy generation and conversion infrastructure that may be developed by 2100 is currently unknown.

6.3.1.5 Adaptation

To address the risk of coastal flooding, several measures have been implemented:

Reliability

- *Policy and Governance*: Planning regulations and Section 28 Guidelines ensure flood-resistant new developments. The OPW Capital Flood Relief Scheme and Minor Flood Mitigation Works support flood projects, while the Coastal Protection Scheme strengthens defences. Climate risk assessments identify coastal flooding vulnerabilities.
- *Monitoring and Early Warning Systems:* Continuous monitoring of coastal assets and the National Catchment Flood Risk Assessment and Management Programme inform mitigation strategies. The Coastal Change Research Programme aids in developing protective measures, while National-Scale Coastal Hazard Mapping identifies vulnerable areas for planning. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Research and Development*: Ocean Knowledge 2030 supports coastal protection research, while ongoing coastal change programmes enhance understanding and inform adaptation strategies.
- *Sector-Specific Adaptation Actions*: In the energy sector, actions include reviewing assets for vulnerabilities and replacing them with more resilient alternatives.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Effective for managing this risk.

6.3.1.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is to Sustain Current Action.

6.3.2 E02 Risk of decreased generation of hydropower due to flood control measures during extreme precipitation events

6.3.2.1 Risk Summary

Table 6.3: E02 Risk of decreased generation of hydropower due to flood control measures during extreme precipitation events.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of decreased generation of hydropower due to flood control measures during extreme precipitation events	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Low					
Consequence Confidence	Low					

Due to extreme precipitation events, there is a risk of decreased hydroelectric generation due to operational. During extreme precipitation events a large amount of water will enter water courses, requiring reservoirs to release water pre-emptively or maintain lower water levels, reducing the amount of water available for power generation. Furthermore, when rain events occur, reservoirs can be used to store or divert the large inflows of water to minimise the risk of flooding. This can lead to decreased energy production and potential disruptions in supply.

6.3.2.2 Exposure and Vulnerability

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios.

In terms of seasonality, the winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) and 20.9% (10.0-33.0%)

(RCP8.5) by 2100. The summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) and -7.3% (-21.8 — -6.6%) (RCP8.5) by 2100. All NUTS3 regions are projected to experience an increase in five-day precipitation across both RCP4.5 (10.2% (0.4 - 21.1%) by 2100) and RCP8.5 (16.5% (3.8 - 31.4%) by 2100). Similarly, each region will see an increase in the number of very wet days under both RCP4.5 (an increase of 0.8 days (0.3 - 1.3 days per year) by 2100) and RCP8.5 (an increase of 1.4 days (0.7-2.1 days per year) by 2100.

There are nine hydroelectric dams in Ireland are situated in four of the eight NUTS3 regions.

6.3.2.3 Consequence

- **Damage:** In 2030, there are limited or rare impacts due to this risk, however, as the hazard increase in the future, there is potential for this to increase to substantial levels of damage.

- **System Functionality:** There is temporary or moderate disturbances associated with this risk to the Energy system as disruption to hydropower generation will only be short-term and normal operations should resume once high-water levels have receded. However, there may be an increased demand placed upon other energy generation and conversion infrastructure during these periods.

- **Extent and Pervasiveness:** The extent and pervasiveness of the impacts are moderate to large as even though the direct impacts of this hazard will be in regions where dams/reservoirs are located, the impacts of this risk may occur over a wider extent.

- **Cascading Effects:** During an event, it may not be possible to meet the energy demand at that time. If this were to occur, there would be potential loss of power which could impact:

    - The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security systems. Transport infrastructure, e.g., traffic lights and railway signals rely

on electricity, and a power outage can cause traffic congestion and accidents. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting capabilities and public health. The loss of power in water treatment plants can lead to impacts on Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

- The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.

- The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may backup generators, however, patient care, may still be impacted. Furthermore, if there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.

- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Change through time:** In both scenarios, the changing climate conditions will continually increase the frequency and severity of extreme precipitation and flooding events. However, there are only minor differences in exposure between RCP4.5 and RCP8.5. Additionally, in the future there will be developments that will result in increased baseline levels of energy demand. For instance, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps. Therefore, due to a high baseline level of energy demand in the future, there will be an amplification of the cascading effects related to this risk compared to today if there is a loss of electricity, such as heating failures and transportation disruptions.

6.3.2.4 *Confidence*

Hazard Confidence: For extreme precipitation there is Low confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: The confidence in the consequence is Low. There is uncertainty to the timing of future impacts, and if the frequency and severity of extreme precipitation events will sufficiently increase to result is a risk consequence level greater than Limited.

6.3.2.5 *Adaptation*

To address the risk of increased flood risks, several adaptation actions have been implemented:

Reliability

- *Policy and Governance:* Section 28 Guidelines and planning regulations provide a robust legal framework for flood risk management. The OPW Capital Flood Relief Scheme and Minor Flood Mitigation Works support flood projects, while the National Catchment Flood Risk Assessment and Management Programme manages flood risks effectively.
- *Monitoring and Early Warning Systems:* Continuous review of Minor Flood Mitigation Works and Flood Risk Management Plans ensures effective flood control, supported by supplementary planning guidance and Scheme Climate Change Adaptation Plans.

Resistance

- *Sector-Specific Adaptation Actions*: In the energy sector, actions include visual inspection of assets after flooding to assess damage and implementation of adaptation measures to enhance resilience.

Recovery and response

- *Emergency response*: The Major Emergency Management Framework and "A Guide to Flood Emergencies 2013" offer guidelines for emergency response planning.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

6.3.2.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

6.3.3 E03 Risk of disruption and damage to energy generation and conversion infrastructure due to flooding (fluvial, surface water, and groundwater)

6.3.3.1 Risk Summary

Table 6.4: E03 Risk of disruption and damage to energy generation and conversion infrastructure due to flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to energy generation and conversion infrastructure due to flooding (fluvial, surface water, and groundwater)	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	High					

Flooding poses significant risks to energy generation and conversion infrastructure in Ireland. It can cause physical damage to infrastructure, such as erosion of foundations and inundation of electrical components. Additionally, flooding can lead to operational disruptions due to the need for emergency shutdowns and repairs. The presence of floodwaters can also result in the contamination of fuel supplies and the corrosion of metal components, further complicating recovery efforts. Flooding can disrupt supply chains, making it difficult to transport essential materials and equipment needed for repairs and maintenance. Prolonged flooding can also lead to soil instability, which can undermine the structural integrity of energy facilities.

6.3.3.2 Exposure and Vulnerability

For all NUTS3 regions for 1 in 100-year event scenario, 1.73% (CFRAM) to 2.29% (NIFM) of the total land area could be at risk of flooding by 2100 under RCP4.5. The Midlands region is the most at risk, with 3.06% (NIFM) to 3.36% (CFRAM) of the total land area impacted.

Under the RCP8.5 scenario, 1.95% (CFRAM) to 2.38% (NIFM) of the total land area of the regions could be at risk of flooding by 2100. The Midlands region is the most at risk, with 3.13% (NIFM) to 3.94% (CFRAM) of the total land area impacted.

Currently, 0.28% of energy production and conversion structures exposed to a 1 in a 100-year event for both CFRAM and NIFM flood extents. For an RCP4.5 scenario, this increases in 2050 to 3.1% of structures across five NUTS3 Regions, with the South-East region the most exposed (CFRAM). This exposure remains constant to 2100. When using NIFM data, 0.28% of structures are exposed across all time horizons. Under the RCP8.5 scenario, 3.1% of structures are exposed in 2050, with an increase to 7.5% by 2100 with the Mid-West region most exposed (CFRAM). When using NIFM data, 0.28% of structures are exposed across all time horizons.

Currently, 1% of energy production and conversion buildings are exposed to a 1 in a 100-year event for both CFRAM and NIFM flood extents. For an RCP4.5 scenario, this increases in 2050 to 2.0% of buildings across five NUTS3 Regions (CFRAM). This exposure remains constant to 2100. When using NIFM data, 0.28% of structures are exposed across all time horizons.

Under the RCP8.5 scenario, 2.0% of structures are exposed in 2050, with an increase to 3.2% by 2100 across six NUTS3 regions with the Mid-West and South-East regions most exposed (CFRAM). When using NIFM data, 1% of structures are exposed across all time horizons within two NUTS3 regions.

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios.

6.3.3.3 *Consequence*

- **Damage:** There is potential for substantial damage to energy generation and conversion infrastructure across all time horizons.

- **System Functionality:** The impacts flooding can lead to temporary or moderate disturbances in this system.

- **Extent and Pervasiveness:** Currently, impacts are of a moderate extent or pervasiveness. As extreme precipitation and flooding are projected to increase in frequency and intensity, by 2050, these impacts will be more widespread, affecting larger areas and an increased number of energy generation and conversion infrastructure.

- **Cascading Effects:** There are both temporary and long-term cascading effects on all systems where a loss of electricity would result in impacts such as:

    - The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security systems. Transport infrastructure, e.g., traffic lights and railway signals rely on electricity, and a power outage can cause traffic congestion and accidents. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting capabilities and public health. The loss of power in water treatment plants can lead to impacts on Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

    - The Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and loss of revenue.

    - The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.

- The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may backup generators, however, patient care, may still be impacted. Furthermore, if there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.

- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Changes through time:** There is only a minor increase in the number of energy production and conversion infrastructure that will be exposed to flooding. However, in the future there will be developments that will result in increased baseline levels of energy demand. For instance, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps. Therefore, due to a high baseline level of energy demand in the future, there will be an amplification of the cascading effects related to this risk compared to today if there is a loss of electricity, such as heating failures and transportation disruptions.

6.3.3.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020). The

potential impact of peatland restoration, i.e., rewetting, on flood exposure are currently unknown.

Consequence Confidence: There is high confidence in the consequence as the impacts of this risk have already been observed, however, the exposure of new energy generation and conversion infrastructure is unknown.

6.3.3.5 Adaptation

To address the risk of increased flood risks, several adaptation actions have been implemented. These measures enhance resilience and mitigate risks.

Reliability

- *Policy and Governance:* Section 28 Guidelines and planning regulations provide a robust legal framework for flood risk management. The OPW Capital Flood Relief Scheme and Minor Flood Mitigation Works support flood projects, while the National Catchment Flood Risk Assessment and Management Programme manages flood risks effectively.
- *Monitoring and Early Warning Systems:* Continuous review of Minor Flood Mitigation Works and Flood Risk Management Plans ensures effective flood control, supported by supplementary planning guidance and Scheme Climate Change Adaptation Plans. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Sector-Specific Adaptation Actions*: In the energy sector, actions include visual inspection of assets after flooding to assess damage and implementation of adaptation measures to enhance resilience.

Recovery and response

- *Emergency response*: The Major Emergency Management Framework and “A Guide to Flood Emergencies 2013” offer guidelines for emergency response planning.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

6.3.3.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

6.3.4 E04 Risk of increased cooling demand (i.e., air conditioning) on energy generation and conversion infrastructure due to increases in temperature and extreme heat

6.3.4.1 Risk Summary

Table 6.5: E04 Risk of increased demand (i.e., air conditioning) on energy generation and conversion infrastructure due to increases in temperature and extreme heat.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased demand (i.e., air conditioning) on energy generation and conversion infrastructure due to increases in temperature and extreme heat	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Medium					

Increases in temperature and extreme heat is a risk for energy generation and conversion infrastructure due to the rising demand for cooling, such as air conditioning. As temperatures rise, the demand for air conditioning increases, leading to higher energy consumption, especially during peak hours, which can strain power grids and increase the risk of blackouts.

6.3.4.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38))

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2))

Energy generation and conversion infrastructure are located in all NUTS3 regions.

6.3.4.3 Consequence

- **Damage:** There is potential for limited to substantial impacts on energy generation and conversion infrastructure resulting in potentially Critical levels of disruption and damage by 2100 within an RCP8.5 scenario.
- **System Functionality:** The impacts of extreme heat can lead to temporary to long-term disturbances, and potentially irreversible losses in this system.
- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent.
- **Cascading Effects:** There are both temporary and long-term cascading effects on all systems where a loss of electricity would result in impacts. This includes:
    - The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security systems. Transport infrastructure, e.g., traffic lights and railway signals rely on electricity, and a power outage can cause traffic congestion and accidents. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting

capabilities and public health. The loss of power in water treatment plants can lead to impacts on Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

- The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.

- The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may backup generators, however, patient care, may still be impacted. Furthermore, if there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.

- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Changes through time:** As the frequency and severity of summer days and extreme heat events increase, there will be an increased level of consequence due to this risk. There is potential within an RCP8.5 scenario for consequence to reach Critical by 2100. Furthermore, in the future there will be developments that will result in increased baseline levels of energy demand. For instance, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps. Consequently, due to a high baseline level of energy demand, short term increases in energy demand due to extreme heat may be more difficult to meet, and the cascading effects related to this risk could be amplified, such as heating failures and transportation disruptions.

6.3.4.4 *Confidence*

Hazard Confidence: For extreme heat there is high confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). There is a medium level of confidence that drought conditions will increase in the future. Changes in the number of wet days have been used from national downscaled projections (TRANSLATE) which were produced by the national meteorological agency, and peer-reviewed research has been used for SPEI-3, however, further research and variables, i.e., SPEI-6, SPEI-12 are needed to better inform confidence in this hazard. Overall, the hazard confidence is considered Medium.

Consequence Confidence: There is medium confidence in the consequence as some of the impacts of this risk have been observed in Ireland already, however, there is uncertainty on the timing of the increase in consequence, and whether sufficiently energy generation and conversion infrastructure will be developed that will provide sufficient capacity to meet the future short- and long-term increase in energy demand.

6.3.4.5 *Adaptation*

To address the risk of increased demand due to increases in temperature and extreme heat, several adaptation actions have been implemented. These measures enhance resilience and mitigate risks.

Reliability

- *Policy and Governance:* Climate risk assessment and the Electricity & Gas Networks Sector Climate Change Adaptation Plan are important to identify risks and inform adaptation planning.
- *Monitoring:* forecasting and weather warnings can provide advanced warning of extreme heat conditions.

Resistance

- *Practices in Place:* review of heat resistance ratings of existing equipment.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- Procurement of replacement equipment in case of failure.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

6.3.4.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

6.3.5 E05 Risk of accelerated ageing of energy generation and conversion infrastructure due to increases in temperature

6.3.5.1 Risk Summary

Table 6.6: E05 Risk of accelerated ageing of energy generation and conversion infrastructure due to increases in temperature.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of accelerated ageing of energy generation and conversion infrastructure due to increases in temperature	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Low					

Accelerated aging of energy generation and conversion infrastructure is a can occur as higher temperatures can cause thermal stress on power generation and conversion infrastructure, such as turbines and generators, leading to increased wear and tear. Thermal power plants rely heavily on water for cooling and steam generation, and with higher temperatures there is an increase the water's thermal load making it less effective for cooling purposes. This wear and tear can accelerate the aging of energy generation and conversion infrastructure, resulting in reduced efficiency, higher maintenance needs, and a greater risk of failures.

6.3.5.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C (0.6-1.7°C) by 2050, and 1.5°C (1.1-2.2°C) by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C (1.1-1.9°C) by 2050, and 2.7°C (2.0-3.3°C) by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100).

6.3.5.3 Consequence

- **Damage:** There is potential for limited to substantial impacts on energy generation and conversion infrastructure resulting in potentially Substantial levels of disruption and damage by 2100 within an both scenarios.

- **System Functionality:** The impacts of accelerated ageing of energy generation and conversion infrastructure can lead to temporary to long-term disturbances in this system.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent affecting all types of energy generation and conversion infrastructure.

- **Cascading Effects:** There are both temporary and long-term cascading effects on all systems where electricity is critical to operations. The systems that will be impacted include:

    - The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security systems. Transport infrastructure, e.g., traffic lights and railway signals rely on electricity, and a power outage can cause traffic congestion and accidents. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting capabilities and public health. The loss of power in water treatment plants can lead to impacts on Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

    - The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.

    - The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may backup generators, however, patient care, may still be impacted. Furthermore, if

there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.

- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Changes through time:** As air temperature increase, there will be an increased level of consequence of this risk. There is potential within both scenarios for consequence to reach Substantial by 2100. Furthermore, in the future there will be developments that will result in increased baseline levels of energy demand. For instance, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps. Consequently, due to a high baseline level of energy demand, there could be additional stress on the energy generation and conversion infrastructure.

6.3.5.4 Confidence

Hazard Confidence: There is a High-level confidence in the increasing temperature projections, which are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is low confidence in the consequence as there is uncertainty on the timing of the increase in consequence, and whether existing design standards of energy generation and conversion infrastructure are sufficiently robust to cope with the change in climate conditions.

6.3.5.5 *Adaptation*

To address the risk of increased temperatures, several measures have been implemented. These actions enhance resilience and mitigate risks.

Reliability

- *Policy and Governance:* Building regulations for ventilation and cooling ensure new constructions withstand higher temperatures, while the Electricity & Gas Networks Sector Climate Change Adaptation Plan strategically manages temperature impacts.
- *Monitoring and Early Warning Systems*: Forecasting and weather warnings provide timely information about upcoming heatwaves, allowing for proactive measures to be taken.

Resistance

- *Sector-Specific Adaptation Actions*: In the energy sector, actions include the, the review of equipment ratings for heat to ensure existing infrastructure can operate efficiently under extreme heat conditions.

Recovery and Response

- No redundancy measures were identified.

Redundancy

- Procurement of replacement equipment in case of failure.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

6.3.5.6 *Decision Urgency*

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

6.3.6 E06 Risk of reduced thermal power generation due to inability to discharge water into depleted water bodies (with low assimilative capacity) as a result of drought conditions and increased water temperature

6.3.6.1 Risk Summary

Table 6.7: E06 Risk of reduced thermal power generation due to inability to discharge water into depleted water bodies (with low assimilative capacity) as a result of drought conditions and increased water temperature.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of reduced thermal power generation due to inability to discharge water into depleted water bodies (with low assimilative capacity) as a result of drought conditions and increased water temperature	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Thermal power generation faces risks due to the inability to discharge water into depleted water bodies with low assimilative capacity, especially during drought conditions and increased water temperatures. Power plants rely heavily on water for cooling and steam generation, and when water bodies are depleted or too warm, the efficiency and capacity of these plants can be severely impacted. Drought conditions reduce water levels in freshwater systems, potential causing discharge thresholds to be exceeded due to the potential for ecological and pollution. Discharging heated water into already stressed ecosystems can lead to thermal pollution, which degrades water quality and harms aquatic life. This can result in regulatory restrictions and force thermal power plants to reduce output or temporarily shut down to prevent environmental damage, resulting in energy generation reduction and operational issues at the site.

6.3.6.2 *Exposure and Vulnerability*

In an RCP4.5 scenario, nationally the mean annual number of wet days is expected to decrease of 2.4%(-6.52 – 1.53%) by 2050 and 2.2 (-6.63 – -1.63%) by 2100, with the East region experiencing the largest decrease (2050: 3.2%, 2100: 2.8%). The same trend occurs in RCP8.5 with a decrease of 2.6% ((-6.21 – 1.11%) by 2050 and 4.1% (-9.71 – 0.47%) by 2100, with the East region experiencing the largest decrease (2050: 3.3%, 2100: 5.1%).

For RCP4.5 and RCP8.5 compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season for both 2050 and 2100.

Energy generation and conversion infrastructure are located in all NUTS3 regions and water discharge points and freshwater courses are also present across all NUTS3 regions.

6.3.6.3 *Consequence*

- **Damage:** Currently, there are Limited level of damage associate with this risk, with potential for substantial damage to energy generation and conversion infrastructure resulting by 2100.
- **System Functionality:** This risk could lead temporary or moderate disturbances within this system.
- **Extent and Pervasiveness:** The extent and pervasiveness of the impacts are moderate to large as even though the direct impacts of this risk will be confined to the thermal power infrastructure, the indirect impacts will affect a larger area.
- **Cascading Effects:** There are both temporary and long-term cascading effects on all systems where a loss of electricity would result in impacts. This includes:
    - The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security

systems. Transport infrastructure, e.g., traffic lights and railway signals rely on electricity, and a power outage can cause traffic congestion and accidents. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting capabilities and public health. The loss of power in water treatment plants can lead to impacts on Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

- The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.

- The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may backup generators, however, patient care, may still be impacted. Furthermore, if there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.

- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Changes through time:** Drought projections for Ireland indicate an increase in the frequency of drought conditions, particularly during the spring and summer months. Drought conditions will be more prevalent by 2100, increasing the consequence to Substantial. Additionally, in the future there will be developments that will result in increased baseline levels of energy demand. For instance, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps. Therefore, due to a high baseline level of energy demand in the future, there will be an amplification of the cascading effects

related to this risk compared to today if there is a loss of electricity, such as heating failures and transportation disruptions.

6.3.6.4 Confidence

Hazard Confidence: There is a medium level of confidence that drought conditions will increase in the future. Changes in the number of wet days have been used from national downscaled projections (TRANSLATE) which were produced by the national meteorological agency, and peer-reviewed research has been used for SPEI-3, however, further research and variables, i.e., SPEI-6, SPEI-12 are needed to better inform confidence in this hazard.

Consequence Confidence: The confidence in the consequence is Medium as this risk is currently managed through regulation, however, there is uncertainty of the timing of the future increase in the frequency and consequence of this risk.

6.3.6.5 Adaptation

To address the risk of drought on thermal power generation, several measures have been implemented. These actions enhance resilience and mitigate risks.

Reliability

- *Policy and Governance:* Building regulations for ventilation and cooling ensure new constructions withstand higher temperatures, while the Electricity & Gas Networks Sector Climate Change Adaptation Plan strategically manages temperature impacts.
- *Monitoring and Early Warning Systems*: Forecasting and weather warnings provide timely information about upcoming heatwaves, allowing for proactive measures to be taken.

Resistance

- *Sector-Specific Adaptation Actions*: In the energy sector, actions include the, the review of equipment ratings for heat to ensure existing infrastructure can operate efficiently under extreme heat conditions.

Recovery and Response

- No redundancy measures were identified.

Redundancy

- Procurement of replacement equipment in case of failure.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

6.3.6.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

6.3.7 E07 Risk of decreased wind energy generation and conversion due to changes wind speed

Table 6.8: E07 Risk of decreased wind energy generation and conversion due to changes wind speed.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of decreased wind energy generation and conversion due to changes wind speed	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Very Low					
Consequence Confidence	High					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

6.3.8 E08 Risk of disruption and damage to energy transmission and distribution infrastructure due to sea level rise, coastal erosion, and coastal flooding

6.3.8.1 Risk Summary

Table 6.9: E08 Risk of disruption and damage to energy generation and conversion grid due to sea level rise, coastal erosion, and coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to energy transmission and distribution infrastructure due to sea level rise, coastal erosion, and coastal flooding	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Sustain Current Action					
Hazard Confidence	High					
Consequence Confidence	Medium					

Ireland's coastal regions are increasingly exposed to the impacts of sea level rise, coastal erosion, and coastal flooding, which pose significant risks to energy transmission and distribution infrastructure, e.g., power lines, substations, transformers, batteries, gas pipelines. Rising sea levels cause more frequent and severe flooding, leading to structural damage to energy transmission and distribution infrastructure through water damage and corrosion of materials. Rising sea levels are also a driver for coastal erosion which can weaken foundations and damage energy transmission and distribution infrastructure.

6.3.8.2 Exposure and Vulnerability

In terms of energy transmission and distribution infrastructure buildings [17] across NUTS3 regions, 4.42% or 18 of 407 will be impacted by coastal flooding by 2100 under the RCP4.5 scenario. For RCP8.5, 4.91% of buildings are anticipated to be exposed by coastal flooding by 2100. The South-West Region is particularly

[17] The term 'Energy Transmission is defined as the following OSi Prime2 categories: Utility Box (Electricity Distribution), and Electricity Station.

exposed, with 8.2% (RCP4.5) to 9.84% (RCP8.5) of energy transmission and distribution infrastructure buildings estimated to be exposed by 2100.

As for energy transmission and distribution infrastructure structures, 7.24% will be exposed by coastal flooding by 2100 under the RCP4.5 scenario. For RCP8.5, 8.08% or 29 of 359 structures are anticipated to be exposed by coastal flooding by 2100. The Mid-West Region is particularly exposed, with 12.6% (RCP4.5) to 13.6% (RCP8.5) of structures in the region estimated to be exposed by 2100.

The South-West Region is expected to experience the highest sea-level rise across all scenarios and time periods. The South-West Region is projected to experience sea level rise under an RCP4.5 scenario of 0.24 m by 2050, and 0.51 m by 2100, and 0.26 m by 2050, and 0.65 m by 2100 under an RCP8.5 scenario. Sea level rise drives the exposure to coastal flooding, meaning that the South-West Region is particularly exposed to coastal flooding. The Border Region meanwhile will see the lowest increase in sea level rise.

The length of coastline projected to be at risk of coastal erosion in Ireland by 2050 is 328 km. The South-West (85 km) and South-East (46 km) regions are most at risk, however, the effects of climate change were not included within this assessment.

6.3.8.3 Consequence

- **Damage:** There is potential for substantial impacts to very large and frequent impacts on buildings resulting in potentially Substantial levels of damage by 2100 for both scenarios.
- **System Functionality:** The impacts of sea level rise, coastal flooding and coastal erosion can lead to temporary to long-term disturbances, and potentially irreversible losses in this system.
- **Extent and Pervasiveness:** The whole Irish coastline is exposed to sea level rise, with exposure to coastal flooding and coastal erosion dependent upon local conditions, i.e., elevation, lithology. The largest impacts will occur in areas that have concentrations of energy transmission and distribution infrastructure close

to the coast, however, all NUTS3 regions (apart from the Midlands) are exposed to this risk to varying degrees of severity. However, only a very small proportion energy the transportation and distribution grid infrastructure is exposed to this risk, resulting in a limited extent at risk.

- **Cascading Effects:** There are both temporary and long-term cascading effects on all systems where a loss of electricity would result in impacts. This includes:

    - The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security systems. Transport infrastructure, e.g., traffic lights and railway signals rely on electricity, and a power outage can cause traffic congestion and accidents. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting capabilities and public health. The loss of power in water treatment plants can lead to impacts on Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

    - The Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and loss of revenue.

    - The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.

    - The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may backup generators, however, patient care, may still be impacted. Furthermore, if there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.

- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Changes through time:** As sea levels increase, there will be an increased level of consequence of this risk. There is potential within both scenarios for consequence to reach Substantial by 2100. Furthermore, in the future there will be developments that will result in increased baseline levels of energy demand. For instance, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps, and increased number of buildings. Consequently, there will be a commensurate increase in energy generation and conversion infrastructure, and therefore an increase in energy transport and distribution infrastructure.

6.3.8.4 Confidence

Hazard Confidence: There is high confidence that sea level rise, coastal flooding, and coastal erosion will increase in frequency and severity in the future. Global projections, including those from the IPCC Assessment Report 6, have been used to inform sea level rise, while national projections for coastal change (erosion or accretion) are unavailable, with extrapolation of current erosion rates for 2050 used instead. Coastal flood extent and frequency changes have been assessed by the OPW using rigorous models, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used. There is less confidence in the spatial distribution of coastal erosion in the future due to limited assessment of future coastal change that includes the consideration of climate change.

Consequence Confidence: The impacts of coastal flooding and coastal erosion are already affecting Ireland and this impact will increase in the future. However, the spatial distribution of these impacts related to coastal erosion is still uncertain. Furthermore, the location new energy transmission and distribution infrastructure

that may be developed by 2100 is currently unknown. Therefore, a Medium level of confidence is assigned to the consequence of this risk.

6.3.8.5 Adaptation

To address the risk of coastal erosion and flooding, several measures have been implemented. These actions enhance resilience and mitigate risks.

Reliability

- *Policy and Governance*: Section 28 Guidelines and planning regulations ensure flood-resistant new developments. The OPW Capital Flood Relief Scheme and Minor Flood Mitigation Works support flood projects, while the Coastal Protection Scheme strengthens defences. Climate risk assessments identify coastal flooding vulnerabilities.
- *Monitoring and Early Warning Systems*: Continuous monitoring of coastal assets and the National Catchment Flood Risk Assessment and Management Programme inform mitigation strategies. The Coastal Change Research Programme aids in developing protective measures, while National-Scale Coastal Hazard Mapping identifies vulnerable areas for planning. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Research and Development*: Ocean Knowledge 2030 supports research for coastal protection. Ongoing coastal change research programmes contribute to understanding coastal dynamics and inform adaptation strategies.
- *Community Engagement and Education*: Research on advancing community resilience involves local communities in adaptation efforts.
- *Sector-Specific Adaptation Actions*: In the energy sector, actions include reviewing assets for vulnerabilities, replacing them with resilient alternatives, and continuously monitoring coastal assets to address emerging risks.
- *Coastal Defences*: Deployed to protect vulnerable areas from flooding.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Effective for managing this risk.

6.3.8.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is to Sustain Current Action.

6.3.9 E09 Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme cold

Table 6.10: E09 Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme cold.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme cold	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Sustain Current Action					
Hazard Confidence	High					
Consequence Confidence	High					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

6.3.10 E10 Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme precipitation and flooding (fluvial, surface water, and groundwater)

6.3.10.1 Risk Summary

Table 6.11: E10 Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme precipitation and flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme precipitation and flooding (fluvial, surface water, and groundwater)	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Extreme precipitation and flooding, including fluvial, surface water, and groundwater flooding, pose a risk to energy transmission and distribution infrastructure. These hazards can cause short circuits and equipment failures, leading to power outages. Additionally, flooding can erode foundations, damage underground cables, and submerge critical components, making repairs difficult and costly. The increased moisture can also accelerate the corrosion of metal parts, further compromising the integrity of the infrastructure. Moreover, access to affected areas can be hindered, delaying restoration efforts and exacerbating the impact on energy supply. Flooding can also disrupt fuel supply chains, damage gas pipelines, and impair the functionality of control systems and substations, leading to prolonged service interruptions.

6.3.10.2 Exposure and Vulnerability

In terms of energy transmission and distribution infrastructure buildings across NUTS3 regions, 0.98% (CFRAM) and 0.98% (NIFM) will be impacted by fluvial flooding under the Current Scenario. By 2100 under the RCP4.5 scenario,1.97%

(CFRAM) to 0.98% (NIFM) will be impacted by fluvial flooding. For RCP8.5, 5.65% (CFRAM) to 0.98% (NIFM) buildings are anticipated to be exposed to fluvial flooding by 2100.

As for energy transmission and distribution infrastructure structures across NUTS3 regions, 3.06% (CFRAM) to 0.28% (NIFM) will be impacted by fluvial flooding by 2100 under the RCP4.5 scenario. For RCP8.5, 7.52% (CFRAM) to 0.28% (NIFM) structures are anticipated to be exposed to fluvial flooding by 2100.

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9%(1.2-16.0%) by 2100) scenarios.

In terms of seasonality, the winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) and 20.9% (10.0-33.0%) (RCP8.5) by 2100. The summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) and -7.3% (-21.8 — -6.6%). (RCP8.5) by 2100. All NUTS3 regions are projected to experience an increase in five-day precipitation across both RCP4.5 (10.2% (0.4 - 21.1%) by 2100) and RCP8.5 (16.5% (3.8 - 31.4%) by 2100). Similarly, each region will see an increase in the number of very wet days under both RCP4.5 (an increase of 0.8 days (0.3 - 1.3 days per year) by 2100) and RCP8.5 (an increase of 1.4 days (0.7-2.1 days per year) by 2100).

6.3.10.3 Consequence

Damage: Currently, energy transmission and distribution infrastructure face substantial losses due to extreme precipitation and (fluvial, surface water, and groundwater). The spatial analysis shows minor increases in exposure, with limited differences between the two scenarios.

System Functionality: Currently, flooding causes temporary or moderate disturbances to energy transmission and distribution infrastructure. By 2050, long-term disturbances may occur.

Extent and Pervasiveness: Currently, impacts are of a moderate extent or pervasiveness. As extreme precipitation and flooding are projected to increase in frequency and intensity, by 2050, these impacts will be more widespread, affecting larger areas and a greater number of energy transmission and distribution infrastructure.

Cascading Effects: There are both temporary and long-term cascading effects on all systems where electricity is critical to operations. The systems that will be impacted include:

- The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security systems. Transport infrastructure, e.g., traffic lights and railway signals rely on electricity, and a power outage can cause traffic congestion and accidents. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting capabilities and public health. The loss of power in water treatment plants can lead to impacts on Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

- The Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and loss of revenue.

- The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.

- The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may backup

generators, however, patient care, may still be impacted. Furthermore, if there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.

- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Changes through time:** As sea levels increase, there will be an increased level of consequence of this risk. There is potential within both scenarios for consequence to reach Substantial by 2100. Furthermore, in the future there will be developments that will result in increased baseline levels of energy demand. For instance, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps, and increased number of buildings. Consequently, there will be a commensurate increase in energy generation and conversion infrastructure, and therefore an increase in energy transport and distribution infrastructure.

6.3.10.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020).

Consequence Confidence: There is medium confidence in the consequence as the impacts of this risk have already been observed with spatial analysis showing minor increases in exposure, however, the location new energy transmission and distribution infrastructure that may be developed by 2100 is currently unknown.

6.3.10.5 Adaptation

To address the risk of extreme precipitation and flooding, several measures have been implemented:

Reliability

- *Policy and Governance:* The Planning and Development Act Section 28 Guidelines and regulations support flood risk management, while the OPW Capital Flood Relief Scheme and Minor Flood Mitigation Works provide financial and logistical aid. The National Catchment Flood Risk Assessment and Management Programme aims to manage flood risks effectively.
- *Monitoring and Early Warning Systems:* Regular reviews of Minor Flood Mitigation Works and Flood Risk Management Plans ensure effective, up-to-date flood control, supported by supplementary planning guidance and Climate Change Adaptation Plans. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Sector-Specific Adaptation Actions*: In the energy sector, actions include visual inspection of assets after flooding to assess damage and implementation of adaptation measures to enhance resilience.

Recovery and response

- *Emergency response*: The Major Emergency Management Framework and “A Guide to Flood Emergencies 2013” offer guidelines for emergency response planning.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

6.3.10.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is that Further Investigation is required.

6.3.12 E11 Risk of accelerated ageing of energy transmission and distribution infrastructure due to increases in average temperature

6.3.12.1 Risk Summary

Table 6.12: E11 Risk of degradation/accelerated ageing of energy transmission and distribution infrastructure due to increases in average temperature.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of accelerated ageing of energy transmission and distribution infrastructure due to increases in average temperature	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Medium					

Increases in average temperature can lead to the accelerated ageing and degradation of energy transmission and distribution infrastructure. This degradation includes the breakdown of insulation materials, increased corrosion rates, and mechanical stress on components such as power lines and transformers. Additionally, higher temperatures can reduce the efficiency of cooling systems, leading to overheating and potential failures.

6.3.12.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C (0.6-1.7°C) by 2050, and 1.5°C (1.1-2.2°C) by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C (1.1-1.9°C) by 2050, and 2.7°C (2.0-3.3°C) by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100) scenarios..

6.3.12.3 Consequence

- **Damage:** There is potential for limited to substantial impacts on energy transmission and distribution infrastructure resulting in potentially Substantial levels of disruption and damage by 2100 within an both scenarios.

- **System Functionality:** The impacts of accelerated ageing of energy generation and conversion infrastructure can lead to temporary to long-term disturbances in this system.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent affecting all types of energy transmission and distribution infrastructure.

- **Cascading Effects:** There are both temporary and long-term cascading effects on all systems where electricity is critical to operations. The systems that will be impacted include:

    - The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security systems. Transport infrastructure, e.g., traffic lights and railway signals rely on electricity, and a power outage can cause traffic congestion and accidents. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting capabilities and public health. The loss of power in water treatment plants can lead to impacts on Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

    - The Economy and Finance System, e.g., increased expenditure, such as repairs and maintenance.

    - The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.

- The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may backup generators, however, patient care, may still be impacted. Furthermore, if there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.

- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Changes through time:** As temperatures increase, there will be an increased level of consequence of this risk. There is potential within both scenarios for consequence to reach Substantial by 2100. Furthermore, in the future there will be developments that will result in increased baseline levels of energy demand. For instance, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps, and increased number of buildings. Consequently, there will be a commensurate increase in energy generation and conversion infrastructure, and therefore an increase in energy transport and distribution infrastructure.

6.3.12.4 Confidence

Hazard Confidence: There is a High-level confidence in the increasing temperature projections, which are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is medium confidence in the consequence as there is uncertainty on the timing of the increase in consequence, and whether existing design standards of energy transmission and distribution infrastructure are sufficiently robust to cope with the change in climate conditions.

6.3.12.5 Adaptation

To address the risk of increased temperatures, several measures have been implemented. These actions enhance resilience and mitigate risks.

Reliability

- *Policy and Governance:* Building regulations for ventilation and cooling ensure new constructions withstand higher temperatures, while the Electricity & Gas Networks Sector Climate Change Adaptation Plan strategically manages temperature impacts.
- *Monitoring and Early Warning Systems*: Forecasting and weather warnings provide timely information about upcoming heatwaves, allowing for proactive measures to be taken.

Resistance

- *Sector-Specific Adaptation Actions*: In the energy sector, actions include the, the review of equipment ratings for heat to ensure existing infrastructure can operate efficiently under extreme heat conditions.

Recovery and Response

- No redundancy measures were identified.

Redundancy

- Procurement of replacement equipment in case of failure.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

6.3.12.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

6.3.13 E12 Risk of disruption and damage to underground energy transmission and distribution infrastructure due to ground movement as a result of drought conditions

Table 6.13: E12 Risk of disruption and damage to underground energy transmission and distribution infrastructure due to ground movement as a result of drought conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to underground energy transmission and distribution infrastructure due to ground movement as a result of drought conditions	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	Low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

6.3.14 E13 Risk of reduced efficiency of energy transmission and distribution infrastructure due to increases in temperature and extreme heat

6.3.14.1 Risk Summary

Table 6.14: E13 Risk of reduced efficiency of energy transmission and distribution infrastructure due to increases in temperature and extreme heat.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of reduced efficiency of energy transmission and distribution infrastructure due to increases in temperature and extreme heat	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Medium					

Increased temperatures and extreme heat pose a risk to the efficiency and reliability of energy transmission and distribution infrastructure. Higher temperatures reduce the efficiency of power transmission lines due to increased electrical resistance, resulting in greater energy loss and higher operational costs. Additionally, sagging lines can experience increased electrical resistance, which results in greater energy loss during transmission.

6.3.14.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38))

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing

the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2))

6.3.14.3 Consequence

- **Damage:** Limited or rare losses initially, with increased damage to large and frequent levels under both RCP4.5 and RCP8.5 scenarios as temperatures increase.

- **System Functionality:** Extreme heat can cause temporary or moderate disturbances to energy transmission and distribution infrastructure; however, under both RCP4.5 and RCP8.5 scenarios, these disturbances could become more chronic and therefore long-term if average temperatures increase and frequency of extreme heat events increases.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all building types.

Cascading Effects: There are both temporary and long-term cascading effects on all systems where electricity is critical to operations. The systems that will be impacted include:

- The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security systems. Transport infrastructure, e.g., traffic lights and railway signals rely on electricity, and a power outage can cause traffic congestion and accidents. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting capabilities and public health. The loss of power in water treatment plants

can lead to impacts on Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

- The Economy and Finance System, e.g., increased expenditure, such as repairs and maintenance.
- The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.
- The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may backup generators, however, patient care, may still be impacted. Furthermore, if there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.
- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Changes through time:** As temperatures increase and heatwave frequency and severity increase, there will be an increased level of consequence of this risk. There is potential within both scenarios for consequence to reach Substantial by 2100. Furthermore, in the future there will be developments that will result in increased baseline levels of energy demand. For instance, there is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps, and increased number of buildings. Consequently, there will be a commensurate increase in energy generation and conversion infrastructure, and therefore an increase in energy transport and distribution infrastructure.

6.3.14.4 Confidence

Hazard Confidence: For extreme heat there is high confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: There is medium confidence in the consequence as there is uncertainty on the timing of the increase in consequence, and whether existing design standards of energy transmission and distribution infrastructure are sufficiently robust to cope with the change in climate conditions.

6.3.14.5 Adaptation

To address the risk of increased temperatures on energy infrastructure, several measures have been implemented. These actions enhance resilience and mitigate risks.

Reliability

- *Policy and Governance:* Building regulations for ventilation and cooling ensure new constructions withstand higher temperatures, while the Electricity & Gas Networks Sector Climate Change Adaptation Plan strategically manages temperature impacts.
- *Monitoring and Early Warning Systems*: Forecasting and weather warnings provide timely information about upcoming heatwaves, allowing for proactive measures to be taken.

Resistance

- *Sector-Specific Adaptation Actions*: In the energy sector, actions include the, the review of equipment ratings for heat to ensure existing infrastructure can operate efficiently under extreme heat conditions.

Recovery and Response

- No redundancy measures were identified.

Redundancy

- Procurement of replacement equipment in case of failure.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

6.3.14.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

6.3.15 E14 Risk of disruption and damage of energy transmission and distribution infrastructure due to lightning

Table 6.15: E14 Risk of disruption and damage of energy transmission and distribution infrastructure due to lightning.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage of energy transmission and distribution infrastructure due to lightning	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Very Low					
Consequence Confidence	High					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

6.3.16 E15 Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme wind

6.3.16.1 Risk Summary

Table 6.16: E15 Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to energy transmission and distribution infrastructure due to extreme wind	Critical	Critical	Critical	Critical	Critical	Critical
Urgency	More Action Needed					
Hazard Confidence	Very low					
Consequence Confidence	High					

Extreme winds pose a risk to energy transmission and distribution infrastructure, leading to potential damage and disruptions. Extreme wind can damage energy transmission and distribution infrastructure by knocking down power lines and causing structural failures in transmission towers. Additionally, debris carried by strong winds can damage critical components. This damage can lead to disruptions in the energy supply, resulting in power outages and significant repair costs.

6.3.16.2 Exposure and Vulnerability

For RCP4.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.32 days, 2100: -0.47) from the 1981-2010 baseline. For RCP8.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.61 days, 2100: -0.44) from the 1981-2010 baseline.

For RCP4.5, there is a projected small decrease in the 10-m wind speed of 1.0–2.7% (mean 1.8%) compared to the 1981-2000 baseline by 2050. For RCP8.5, there is a 1.6–3.3% (2.6%) decrease.

6.3.16.3 Consequence

- **Damage:** Extreme wind can cause large and frequent losses and disturbance Ireland is already experiencing impacts from this risk, for instance:
    - In February 2014, Storm Darwin caused over €110 million in damages, with more than 260,000 homes were left without power (Murphy et al., 2023). Significant damage was caused by Storm Darwin to the electricity distribution network, highlighting the vulnerability of overhead lines to falling trees and severe weather (Department of the Environment, Climate and Communications, 2019).
    - In September 2018, Storm Ali caused widespread strong winds and heavy rain resulting in significant damage in Ireland. High winds, with gusts up to 90 mph at Mace Head, led to power outages affecting over 180,000 customers (Department of Housing, Local Government and Heritage, 2019).
    - A windstorm in October 2017 brought gales and strong winds across Ireland, with Cork experiencing violent storm-force winds. Over 100,000 customers lost water due to power outages affecting treatment plants and pumping stations (Department of Housing, Local Government and Heritage, 2019).
    - In 2017, Storm Ophelia caused significant disruption to infrastructure and services. It led to power outages affecting 300,000 households and 385,000 premises in total (Department of Health, 2019).
    - In 2025, Storm Éowyn across Ireland, 768,000 premises were left without power. ESB reported that it took 19 days to fully restore all connections (CCAC, 2025).
- **System Functionality:** Extreme wind can cause temporary and moderate disturbances to the Energy System.
- **Extent and Pervasiveness:** The impact of extreme wind events is widespread, affecting overground energy transmission and distribution

infrastructure types, across extensive areas, indicating a large extent and pervasiveness.

- **Cascading Effects:** There are both temporary and long-term cascading effects on all systems where electricity is critical to operations. The systems that will be impacted include:

  - The Built Environment System, where a loss of power to buildings, e.g., heating, ventilation, and air conditioning (HVAC) systems, and security systems. Transport infrastructure, e.g., traffic lights and railway signals rely on electricity, and a power outage can cause traffic congestion and accidents. Communications infrastructure, e.g., loss of broadband connectivity, loss of mobile communications. Water services infrastructure and water security systems, e.g., electricity is essential for pumping and distributing water. A power outage can lead to a loss of water supply and pressure, affecting firefighting capabilities and public health. The loss of power in water treatment plants can lead to impacts on the Health System if sufficient drinking water is not provided, and the Biodiversity and Ecosystems System if there is a subsequent decrease in water quality.

  - The Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage, and loss of revenue.

  - The Food Production and Supply Chain System, where electricity is used for irrigation, refrigeration, and processing, and a power outage can result in crop losses and spoilage of perishable goods.

  - The Health System, as hospitals depend on electricity for life-saving equipment, lighting, and electronic health records. Hospitals may have backup generators, however, patient care, may still be impacted. Those with health-related equipment in their own homes that require electricity will be severely impacted as backup generators are unlikely to be in place. Furthermore, if there is a loss of power to water services infrastructure, loss of water may also jeopardise patient care.

- The Social System, where a loss of communications can occur resulting in loss of internet, phone systems, and data centres, leading to significant disruption to people and businesses.

- **Changes through time:** Climate projections show no change in extreme winds in the future, however, there is very low confidence associated with these projections. However, there will be an increase in exposure in the future, due a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), increased adoption of electric vehicles (EVs), increase in high energy consumption infrastructure, i.e., data centres., increased use of electricity for heating, i.e., heat pumps, and increased number of buildings. Consequently, there will be a commensurate increase in energy generation and conversion infrastructure, and therefore an increase in energy transport and distribution infrastructure. This increase in exposure results in an increase in the consequence level from 2050 onwards for RCP4.5 and RCP8.5.

6.3.16.4 Confidence

Hazard Confidence: There is a Very Low level of confidence that extreme wind frequency and severity will not change in the future. There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used at the NUTS2 level, with national scale data for average wind speed used as an alternative proxy.

Consequence Confidence: There is High confidence in the consequence as the impacts of this risk have already been observed and will likely continue in the future.

6.3.16.5 Adaptation

To address the risk of extreme wind on energy infrastructure, several measures have been implemented. These actions enhance resilience and mitigate risks.

Reliability

- *Policy and Governance*: Building regulations ensure new constructions are designed to withstand high wind speeds. Climate risk assessments also allow identification of vulnerabilities to extreme wind.
- *Monitoring and Early Warning Systems:* Weather forecasting and severe weather warnings provide timely alerts about potential high wind events, helping to prepare for and minimise the effects on energy infrastructure.

Resistance

- *Sector-Specific Adaptation Actions:* In the energy sector, actions include designing networks to withstand high wind hazards.

Recovery and Response

- *Emergency response:* Centrally managed and locally delivered responses to severe weather ensure coordinated and effective action during extreme wind events.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Effective for managing this risk.

6.3.16.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is More Action Needed.

7 Food Production and Supply Chain

7.1 System Description

The Food Production and Supply Chain system involves the processes and systems for growing and distributing food. The core sub-system of food production is food production. There are various elements at risk from climate change within the food production sub-system. These elements at risks include crops, livestock, soils, fisheries, and aquaculture.

The Food Production and Supply Chain system has important relevance to various policy sectors for adaptation. The food production subsystem is particularly relevant for the adaptation sectors of Biodiversity, Water Quality, Agriculture, and Seafood. The food supply chain sub-system on the other hand has some degree of relevance the Agriculture, Flood Risk Management, Transport, and Seafood sectors.

7.2 Summary of Climate Change Risks

Table .1 shows a summary of the consequences for the risks identified to the Food Production and Supply Chain under both RCP4.5 and RCP8.5 scenarios across three-time horizons (2030, 2050, and 2100).

Table 7.1: Summary of Climate Change Risks in the Food Production and Supply Chain System. Lim = Limited, Sub = Substantial, Cri = Critical, Cat = Catastrophic.

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
F01	Risk of reduced aquaculture yields as a result of extreme winds and waves	Lim	Lim	Lim	Lim	Lim	Lim
F02	Risk of decreased fish stocks as a result of changes in ocean conditions	Lim	Sub	Sub	Lim	Sub	Sub
F03	Risk of reduced crop yields due to changes in climate conditions	Sub	Sub	Cri	Sub	Sub	Cri
F04	Risk of reduced agricultural yield as a result of loss of nutrients (i.e., nitrogen, phosphorous) and sediment due to extreme precipitation	Lim	Lim	Sub	Lim	Lim	Sub

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
F05	Risk of increased activity and transmission rates of vector-borne diseases among livestock due to flooding (fluvial, surface water, and groundwater)	Lim	Sub	Sub	Lim	Sub	Sub
F06	Risk of heat stress to livestock due to extreme heat	Lim	Sub	Sub	Lim	Sub	Sub
F07	Risk of damage and loss of crops due to wildfire	Lim	Lim	Lim	Lim	Lim	Lim
F08	Risk of increased input costs (e.g., irrigation, fertilisers, animal feed) due to changes in climate conditions	Lim	Sub	Sub	Lim	Sub	Sub
F09	Risk of damage and loss of crops due to lightning	Lim	Lim	Lim	Lim	Lim	Lim
F10	Risk of livestock mortality due to lightning	Lim	Lim	Lim	Lim	Lim	Lim
F11	Risk of damage and loss of crops due to extreme wind	Lim	Lim	Lim	Lim	Lim	Lim

7.3 Risks

7.3.1 F01 Risk of reduced aquaculture yields as a result of extreme winds and waves

Table 7.2: F01 Risk of reduced aquaculture yields as a result of extreme winds and waves.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of reduced aquaculture yields as a result of extreme winds and waves	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Very low					
Consequence Confidence	Low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

7.3.2 F02 Risk of decreased commercial fish stocks as a result of changes in ocean conditions

7.3.2.1 Risk Summary

Table 7.3: F02 Risk of decreased fish stocks as a result of changes in ocean conditions

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of decreased commercial fish stocks as a result of changes in ocean conditions	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Climate change impacts fish in several ways, including their growth, recruitment, and distribution. Rising ocean temperatures can affect fish metabolism and growth rates, with warmer waters potentially increasing metabolic rates and leading to faster growth in some species, while causing stress and reduced growth in others due to lower oxygen levels. Changes in temperature and salinity can alter spawning seasons and locations, affecting the survival rates of fish larvae and juveniles, and leading to shifts in recruitment patterns with some species experiencing reduced reproductive success. Additionally, as ocean temperatures rise, many fish species migrate to cooler waters, often moving poleward or to deeper depths, resulting in a mismatch between fish and their traditional habitats, which affects local ecosystems and fisheries.

7.3.2.2 Exposure and Vulnerability

Sea surface temperature is projected to increase by between 0.4°C(0.3-0.8°C) in 2050 to 0.9°C (0.8-1.5°C) in 2100 under an RCP4.5 scenario and 0.7°C(0.5-1.1°C) in 2050 to 1.9°C (1.5-2.5°C) in 2100 under RCP8.5 scenario within the Irish Exclusive Economic Zone (EEZ) (IPCC AR6).

Additionally, sea surface pH level is estimated to decrease (increase in acidity) by 0.12 in 2050 and 0.13 by 2100 under an RCP4.5 scenario and 0.16 in 2050 and 0.17 in 2100 under an RCP8.5 scenario within the Irish EEZ.

Commercial fish stocks such as Atlantic Mackerel, Cod, Hake, Horse Mackerel, Blue Whiting, and Norway Lobster are exposed to this risk (Nolan et al., 2023).

7.3.2.3 Consequence

- **Damage:** Limited or rare losses initially, with increased substantial losses by 2050 and 2100 under both scenarios. Around €382M worth of quota fish and shellfish species are caught in the Irish Exclusive Economic Zone (EEZ) annually (Nolan et al., 2023).

- **System Functionality:** Ocean temperatures and changes in salinity can cause temporary or moderate disturbances in this system by 2050 and 2100 under both scenarios.

- **Extent and Pervasiveness:** All of the Irish EEZ will be exposed to changing oceanic chemistry, affecting a wide range of marine species, resulting in a large extent and high pervasiveness of this risk.

- **Cascading Effects:** There is potential for cascading effects on the Marine and Coastal Ecosystems system, i.e., a loss of local biodiversity, disruption to marine food webs, the Biodiversity and Ecosystem System, i.e., disruption of the natural food webs and ecological balance. the System Social System, i.e., loss of commercial fishing industry could negatively impact the economy and jobs that coastal communities depend on, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erode cultural identities and traditions.

- **Changes through time:** Currently, there is a mixture of stock trajectories within the Irish EEZ, with some stocks rebuilding well following overexploitation by fisheries. Average overall fishing mortality rates have declined in the Celtic Seas ecoregion since around the year 2000 with subsequent increases in spawning stock biomasses. Some stocks remain at

levels of exploitation above current scientific advice. Declines in over-exploited fish stocks may be exacerbated by climate change.

7.3.2.4 Confidence

Hazard Confidence: There is medium confidence that ocean conditions will change in the future. Global projections have been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6, however, national downscaled projections that align with the climate scenarios (RCP4.5 and RCP8.5) and future time periods (~2050, ~2100) used within the NCCRA are not available for variables such as sea surface temperature, near-bottom temperature, sea surface salinity, and near bottom salinity.

Consequence Confidence: Confidence in the consequence of this risk is low, as disentangling long-term anthropogenic activities, such as fishing, from the impacts of climate change is difficult. Climate change cannot be examined in isolation of these effects (Nolan et al., 2023)

7.3.2.5 Adaptation

To address the risk of decreased fish stocks resulting from rising ocean temperatures and changes in salinity, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* The Fishery Harbour Centre and Coastal Infrastructure Development Programme enhances coastal infrastructure resilience for sustainable fisheries, while the ACRES Scorecard for Coastal Ecosystems assesses ecosystem health to guide policy and management.
- *Practices in Place:* The Historical Marine Data Review and the Irish Ocean Climate and Ecosystem Status Report 2023 offer insights into past and current marine conditions, informing future trend predictions and management strategies.

- *Monitoring and Early Warning Systems:* Marine Institute Research monitors ocean temperatures and salinity, providing timely data to understand and potentially mitigate climate changes impacts.

Resistance

- *Community Engagement and Education:* Initiatives now focus on raising awareness about climate-driven changes—such as ocean warming, acidification, and shifts in ocean chemistry—that directly threaten commercial fish stocks. Through targeted educational programs and stakeholder outreach, the community is informed about how these climatic changes can reduce fish stock abundance and disrupt marine ecosystems, while promoting adaptive strategies to safeguard fisheries.
- *Research and Development:* Marine Institute Research tackles climate change challenges by studying ocean temperature and salinity impacts on fish stocks, that can inform the development of innovative solutions and adaptive strategies.

Recovery and Response

- *Additional Measures:* The Brexit Reserve Adjustment Funding provides financial support to the seafood sector to adapt to new market conditions and regulatory changes post-Brexit, ensuring resilience against climate change pressures.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

7.3.2.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

7.3.3 F03 Risk of reduced crop yields due to changes in climate conditions

7.3.3.1 *Risk Summary*

Table 7.4: F03 Risk of reduced crop yields due to changes in climate conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of reduced crop yields due to changes in climate conditions	Substantial	Substantial	Critical	Substantial	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Changes in climate conditions pose significant risks to crop yields. Higher temperatures can stress crops, leading to reduced growth and lower yields. Heat stress can affect photosynthesis, nutrient uptake, and water use efficiency, ultimately reducing the overall productivity of crops. Additionally, changing climate conditions can alter rainfall patterns, resulting in droughts or excessive rainfall. Droughts can lead to water scarcity, soil degradation, and increased vulnerability to pests and diseases, while excessive rainfall can cause flooding, soil erosion, waterlogging of soils, and nutrient leaching. Both extremes can harm crops, disrupting planting and harvesting schedules, and reducing the quality and quantity of agricultural produce. These impacts can threaten food security, increase food prices, and affect the livelihoods of farmers and communities dependent on agriculture.

7.3.3.2 Exposure and Vulnerability

All NUTS3 regions will experience changing climate conditions, including increasing air temperatures with the Mid-East and South-East regions the most affected by increases in air temperature under both the RCP4.5 (1.5 °C (1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100). Increases in annual precipitation, winter precipitation, five-day precipitation, and very wet days are also projected with the Mid-East and Dublin regions expected to experience the

highest increase in annual precipitation across both RCP4.5 (5.0% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0% by 2100) scenarios.

The winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) to 20.9% (10.0-33.0) (RCP8.5) and the summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) to -7.3% (-21.8 — -6.6%) (RCP8.5).

According to the National Land Cover Map, there cultivated land exists in all NUTS3 regions, with the highest proportion found in the South-East (29% of cultivated land) and Mid-East (28%) regions.

7.3.3.3 Consequence

- **Damage:** Substantial losses initially by 2050, increasing to large and frequent levels of damage by 2100 under both scenarios. Ireland is already experienced impacts from this risk, for instance:
    - In 2018, Storm Emma resulted in the prevention of grazing due to snow, high rainfall, and grass supply for farmers livestock. This resulted in farmers having to have adequate stock of conserved fodder and sufficient slurry storage in place to manage and cope with the event (Department of Agriculture, Food and the Marine, 2019.)
    - Extreme heat in 2018 caused an extended dry period which impacted grassland growth rates, resulting in a requirement for significant supplementation to offset the poor grass growth. Dairy cattle were particularly susceptible to the heat stress caused by the high temperatures and humidity, which affects growth, milk production and fertility (Department of Agriculture, Food and the Marine, 2019.)
    - Due to these adverse effects of both Storm Emma and the heatwave in 2018, an overall decrease of 3 tons of dry matter per hectare of grass was produced (Department of Agriculture, Food and the Marine, 2019.)

- **System Functionality:** Changes in climate conditions can cause temporary or moderate disturbances in this system by 2050, with an increase to long-term disturbances by 2100 in both scenarios.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent with the potential to affect all agriculture types.

- **Cascading Effects:** There is potential for temporary and long-term cascading effects on the System Social System, i.e., loss of agriculture industry could negatively impact the economy and jobs, especially within rural communities, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erode cultural identities and traditions.

- **Changes through time:** In both scenarios, the changing climate conditions will continually alter agriculture. RCP8.5 will see the greatest change, however, even in an RCP4.5 scenario major damage could result; therefore, a critical level consequence is potentially reached by 2100 in both scenarios.

7.3.3.4 Confidence

Hazard Confidence: There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for the direction and degree of change. However, there is more confidence in the temperature related climate projections, in both the direction and degree of change. Therefore, an overall confidence of medium is assigned to this hazard.

Consequence Confidence: Confidence in the consequence is low as there are complex interactions between climate variables and agricultural systems that increase the uncertainty of future risk.

7.3.3.5 Adaptation

To address the risk of reduced crop yields caused by changing climate conditions, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong policy frameworks like the CAP Eco-Scheme, ACRES, Straw Incorporation Measure, and Mandatory Post-Harvest Stubble Cultivation support sustainable agricultural practices and climate adaptation, while retaining hedgerows and land drains preserves essential landscape features.
- *Practices in Place:* The Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan and Climate Risk Assessments address agricultural vulnerabilities, while Forecasting and Weather Warnings enable farmers to make informed decisions and prepare for adverse weather.
- *Monitoring and Early Warning Systems:* The Teagasc National Climate Centre provides timely climate warnings, while Value for Cultivation and Use Trials ensure resilient crop selection under varying climate scenarios.

Resistance

- *Community Engagement and Education:* The Public Policy Strategic Research Call on Adaptation Actions educates and involves communities in sustainable agriculture, building resilience to climate risks and ensuring stakeholders are well-prepared.
- *Research and Development:* Research on alternative crops and no-till systems, supported by the Teagasc Climate Action Strategy, develops innovative solutions and resilient forages to mitigate climate impacts on agriculture.

Recovery and Response

- *Additional Measures:* The Bailing Assistance Payment 2024, forage stock advice, and support schemes ensure resource availability, while irrigation

and multi-species swards enhance resilience, addressing seasonal and post-disaster needs.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

7.3.3.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

7.3.4 F04 Risk of reduced agricultural yield as a result of loss of nutrients (i.e., nitrogen, phosphorous) and sediment due to extreme precipitation

7.3.4.1 Risk Summary

Table 7.5: F04 Risk of reduced agricultural yield as a result of loss of nutrients (i.e., nitrogen, phosphorous) and sediment due to extreme precipitation.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of reduced agricultural yield as a result of loss of nutrients (i.e., nitrogen, phosphorous) and sediment due to extreme precipitation	Limited	Limited	Substantial	Limited	Limited	Substantial
Urgency	Watching Brief					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Extreme precipitation events pose a significant risk to agricultural yields due to the loss of essential nutrients and sediment. Heavy rainfall can cause runoff, which washes away vital nutrients like nitrogen and phosphorus from the soil, reducing its fertility. This nutrient loss can lead to lower crop productivity and diminished yields. Additionally, sediment loss due to erosion can degrade soil structure and reduce its ability to retain water and nutrients. These combined effects can severely impact crop growth and agricultural output, threatening food security and the livelihoods of farmers.

7.3.4.2 Exposure and Vulnerability

Increases in annual precipitation, winter precipitation, five-day precipitation, and very wet days are also projected with the Mid-East and Dublin regions expected to experience the highest increase in annual precipitation across both RCP4.5 (5.0% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios. The winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) to 20.9% (10.0-33.0%) (RCP8.5) and the

summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%)1 (RCP4.5) to -7.3% (-21.8 — -6.6%) (RCP8.5).

According to the National Land Cover Map, there cultivated land exists in all NUTS3 regions, with the highest proportion found in the South-East (29% of cultivated land) and Mid-East (28%) regions.

7.3.4.3 Consequence

- **Damage:** Limited or rare losses by 2050, with an increase to substantial losses by 2100 under both scenarios.
- **System Functionality:** Extreme precipitation is likely to cause no significant disturbance by 2050 in this system however, it may cause temporary or moderate disturbances in this system by 2100 under both scenarios.
- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent with the potential to affect all agriculture types.
- **Cascading Effects:** This risk would have cascading effects on the Biodiversity and Ecosystem System, i.e., nutrients entering water bodies may reduce water quality leading to eutrophication and harming aquatic life, the Water Security System, i.e., contamination of water resources, the Health System, i.e., increase the risk of harmful algal blooms (HABs).
- **Changes through time:** In both scenarios, the changing climate conditions will continually alter agriculture. RCP8.5 will see the greatest change, however, even in an RCP4.5 scenario substantial losses could result; therefore, a substantial consequence is potentially reached by 2100 in both scenarios.

7.3.4.4 Confidence

Hazard Confidence: There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for

the direction and degree of change. However, there is more confidence in the temperature related climate projections, in both the direction and degree of change. Therefore, an overall confidence of medium is assigned to this hazard.

Consequence Confidence: Confidence in the consequence is low as there are complex interactions between climate variables and agricultural systems that increase the uncertainty of future risk.

7.3.4.5 Adaptation

To address the risk of reduced agricultural yield due to nutrient and sediment loss from extreme precipitation, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* The CAP Strategic Plan, ACRES Actions, and coordinated flood risk management align agricultural practices with climate adaptation goals, supported by strong policy frameworks.
- *Practices in Place:* The Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan and Planning Regulations align agriculture with climate goals, while flood risk programs manage nutrient and sediment loss.
- *Monitoring and Early Warning Systems:* Nutrient management plans maximize uptake and reduce run-off, ensuring compliance with the Nitrates Action Programme, while the Teagasc Climate Action Strategy develops resilient grasses and forages for extreme weather.

Resistance

- *Community Engagement and Education:* The Department of Housing Research on Advancing Community Resilience educates and involves communities in sustainable agriculture, building resilience to climate risks and ensuring stakeholders are well-prepared.
- *Research and Development:* Research on Fodder Reserves, Land Drainage, and Diversity Swards, supported by the Signpost Programme, develops solutions for extreme precipitation impacts, while the Nitrates

Action Programme and Multi-Species Sward Measure maintain soil health and reduce nutrient loss.

Recovery and Response

- *Additional Measures:* Flood relief schemes and targeted support protect agricultural lands, while peatland maintenance and no-till practices conserve soil and manage water effectively.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

7.3.4.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is a Watching Brief.

7.3.5 F05 Risk of increased activity and transmission rates of vector-borne diseases among livestock due to flooding (fluvial, surface water, and groundwater)

7.3.5.1 Risk Summary

Table 7.6: F05 Risk of increased activity and transmission rates of vector-borne diseases among livestock due to flooding (fluvial, surface water, and groundwater.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased activity and transmission rates of vector-borne diseases among livestock due to flooding (fluvial, surface water, and groundwater)	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Flooding, whether from fluvial, surface water, or groundwater sources, can increase the risk of vector-borne diseases among livestock. Flooding creates numerous stagnant water bodies, which serve as ideal breeding grounds for vectors. Flooding often displaces livestock. This stress can weaken the animals' immune systems, making them more susceptible to infections. Additionally, floodwaters can carry pathogens and contaminated materials over large areas, spreading diseases to new regions and increasing the overall risk of outbreak.

7.3.5.2 Exposure and Vulnerability

For a 1 in 100-year event scenario under RCP4.5, 1.73% (CFRAM) to 2.29% (NIFM) of the total land area of Ireland could be at risk of flooding by 2100. In this context, the Midlands Region is most at risk, with 3.06% (NIFM) to 3.36% (CFRAM) of the total land area of the region impacted.

Under RCP8.5, the 1 in 100-year event scenario puts 1.95% (CFRAM) to 2.38% (NIFM) of the total land area at risk of flooding by 2100. Again, the Midlands

Region is most at risk, with 3.13% (NIFM) to 3.94% (CFRAM) of the total land area of the region impacted.

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios.

7.3.5.3 Consequence

- **Damage:** Limited or rare losses initially with an increase to substantial losses by 2050 under both scenarios.
- **System Functionality:** Flooding and vector-borne diseases are likely to cause no significant disturbance by 2050 in this system however, it may cause long term disturbances in this system by 2100 under both scenarios.
- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent with the potential to affect all agriculture types.
- **Cascading Effects:** There is potential for temporary and long-term cascading effects on the System Social System, i.e., disturbance or loss of the livestock industry could negatively impact the economy and jobs, especially within rural communities, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erode cultural identities and traditions.
- **Changes through time:** In both scenarios, the changing climate conditions will have an effect on vector-borne diseases. RCP8.5 will see the greatest change, however, even in an RCP4.5 scenario substantial losses could result; therefore, a substantial consequence is potentially reached by 2100 in both scenarios.

7.3.5.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020). The potential impact of peatland restoration, i.e., rewetting, on flood exposure are currently unknown.

Consequence Confidence: There is medium confidence in the consequences of this risk as interactions between flooding, climate change, and vector-borne diseases are complex and not fully understood.

7.3.5.5 Adaptation

To address the risk of increased activity and transmission rates of vector-borne diseases among livestock due to flooding, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* The CAP Strategic Plan, ACRES Actions, and coordinated flood risk management align agricultural practices with climate adaptation goals, supported by strong policy frameworks.
- *Practices in Place:* The Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan and Planning Regulations align agriculture with climate goals, while flood risk programs manage vector-borne disease risks.
- *Monitoring and Early Warning Systems:* The National Flood Forecasting and Warning Service alerts farmers to flooding, while the Teagasc Climate

Action Strategy develops resilient grasses and forages to mitigate livestock health impacts and reduce disease spread.

Resistance

- *Community Engagement and Education:* The Department of Housing Research on Advancing Community Resilience educates and involves communities in sustainable agriculture, building resilience to climate risks and ensuring stakeholders are well-prepared.
- *Research and Development:* Research on Fodder Reserves, Land Drainage, and Diversity Swards, supported by the Signpost Programme, develops solutions for livestock health during floods, while the Nitrates Action Programme and Multi-Species Sward Measure maintain soil health and reduce disease spread.

Recovery and Response

- *Additional Measures:* Flood relief schemes and targeted support protect agricultural lands, while peatland maintenance and no-till practices conserve soil and manage water effectively.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

7.3.5.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

7.3.6 F06 Risk of heat stress to livestock due to extreme heat

7.3.6.1 Risk Summary

Table 7.7: F06 Risk of heat stress to livestock due to extreme heat.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of heat stress to livestock due to extreme heat	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Medium					

Extreme heat poses a risk of heat stress to livestock, particularly cattle, due to their larger body mass and limited ability to dissipate heat effectively. High temperatures and humidity, direct solar radiation, and the heat generated by digestion all contribute to this issue.

7.3.6.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38))

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by

0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2))

7.3.6.3 Consequence

- **Damage:** Initially limited or rare losses with an increase to substantial losses by 2050 and 2100 under both scenarios. Ireland is already experiencing impacts from this risk, for instance:
    - Dairy cattle were particularly susceptible to the heat stress caused by the high temperatures and humidity during the Summer of 2018, with growth, milk production and fertility all affected (Department of Agriculture, Food and the Marine, 2019.)
- **System Functionality:** Extreme heat can cause temporary or moderate disturbances in this system by 2050 and 2100 under both scenarios.
- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all livestock.
- **Cascading Effects:** There is potential for temporary and long-term cascading effects on the System Social System, i.e., disturbance or loss of the livestock industry could negatively impact the economy and jobs, especially within rural communities, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erode cultural identities and traditions.
- **Changes through time:** The risk is currently Limited but will increase significantly in the future, leading to potential substantial losses.

7.3.6.4 Confidence

Hazard Confidence: For extreme heat there is high confidence in the trend of increasing frequency with the projections derived from the national downscaled

projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: Heat stress is already occurring within Ireland, and there are impacts of this already observed, therefore confidence in the consequence is High.

7.3.6.5 Adaptation

To address the risk of heat stress to livestock caused by extreme heat, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* The CAP Eco-Scheme, ACRES, and Targeted Agricultural Modernisation Schemes support sustainable practices and infrastructure resilience, while the Fodder Transport Support Scheme ensures resource availability during extreme heat.
- *Practices in Place:* Climate Risk Assessments identify livestock heat stress vulnerabilities, while Safety Statements and The Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan ensure farmers are prepared and manage these risks strategically.
- *Monitoring and Early Warning Systems:* The Teagasc National Climate Centre provides climate condition monitoring and warnings, while Media Notices disseminate heat risk information, enabling farmers to protect livestock.

Resistance

- *Community Engagement and Education:* The Public Policy Strategic Research Call on Adaptation Actions educates and involves communities in

sustainable agriculture, building resilience to climate risks and ensuring stakeholders are well-prepared.

- *Research and Development:* The Teagasc National Climate Centre studies heat stress impacts on livestock and develops solutions, while the Buffer Winter Forage Stock Advice and Fodder Support Scheme aids in managing forage stocks during heatwaves.

Recovery and Response

- *Additional Measures:* The Summer Fodder Support Schemes help farmers manage forage stocks during summer, ensuring livestock have adequate nutrition and are less susceptible to heat stress.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

7.3.6.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

7.3.7 F07 Risk of damage and loss of crops due to wildfire

Table 7.8: F07 Risk of damage and loss of crops due to wildfire.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage and loss of crops due to wildfire	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	Low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

7.3.8 F08 Risk of increased input costs (e.g., irrigation, fertilisers, animal feed) due to changes in climate conditions

7.3.8.1 Risk Summary

Table 7.9: F08 Risk of increased input costs (e.g., irrigation, fertilisers, animal feed) due to changes in climate conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased input costs (e.g., irrigation, fertilisers, animal feed) due to changes in climate conditions	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Extreme precipitation events pose a significant risk to agricultural yields due to the loss of essential nutrients and sediment (see F04). This can result in the requirement to use fertilisers to replace lost nutrients. Furthermore, due to changing precipitation, there may be a requirement for increased levels of irrigation. Increased fertiliser use can degrade soil health, lead to water pollution through runoff, and contribute to greenhouse gas emissions. Moreover, poor growing conditions can lead to fodder shortages reducing the availability of feed for livestock. This reduction in fodder availability can force farmers to purchase additional feed, and potentially impacting the health and productivity of their animals. The economic burden of irrigation, fertilisers, and animal feed costs can impact farmers, leading to market volatility and affecting food security.

7.3.8.2 Exposure and Vulnerability

In an RCP4.5 scenario, nationally the mean annual number of wet days is expected to decrease of 2.4%(-6.52 — 1.53%) by 2050 and 2.2 (-6.63 — -1.63%) by 2100, with the East region experiencing the largest decrease (2050: 3.2%, 2100: 2.8%). The same trend occurs in RCP8.5 with a decrease of 2.6%

((-6.21 – 1.11%) by 2050 and 4.1% (-9.71 – 0.47%) by 2100, with the East region experiencing the largest decrease (2050: 3.3%, 2100: 5.1%).

Increases in annual precipitation, winter precipitation, five-day precipitation, and very wet days are also projected with the Mid-East and Dublin regions expected to experience the highest increase in annual precipitation across both RCP4.5 (5.0% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios. The winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) to 20.9% (10.0-33.0%) (RCP8.5) and the summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) to -7.3% (-21.8 — -6.6%) (RCP8.5).

For RCP4.5 and RCP8.5 compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season for both 2050 and 2100.

According to the National Land Cover Map, there cultivated land exists in all NUTS3 regions, with the highest proportion found in the South-East (29% of cultivated land) and Mid-East (28%) regions.

7.3.8.3 Consequence

[Consequence criteria and description to be updated]

- **Damage:** Substantial losses expected under both scenarios across all time horizons. Ireland has already experienced impacts from this risk, for instance:
    - Extreme heat in 2018 caused an extended dry period which impacted grassland growth rates, resulting in a requirement for significant supplementation to offset the poor grass growth. Dairy cattle were particularly susceptible to the heat stress caused by the high temperatures and humidity, which affects growth, milk production and fertility.
- **System Functionality:** Changes in climate conditions can cause temporary or moderate disturbances in this system across all time horizons under both scenarios.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent with the potential to affect all agriculture types.

- **Cascading Effects:** Increased use of fertilisers would have cascading effects on the Biodiversity and Ecosystem System, i.e., nutrients entering water bodies may reduce water quality leading to eutrophication and harming aquatic life, the Water Security System, i.e., contamination of water resources, the Health System, i.e., increase the risk of harmful algal blooms (HABs). Increase use of irrigation would impact the Water Security System, i.e., increased demand for water. The System Social System will also be affected, i.e., disturbance or loss of the agricultural industry could negatively impact the economy and jobs, especially within rural communities, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erode cultural identities and traditions.

- **Changes through time:** In both scenarios, the changing climate conditions will continually alter agriculture. RCP8.5 will see the greatest change, however, even in an RCP4.5 scenario substantial losses could result; therefore, a substantial consequence is potentially reached by 2100 in both scenarios.

7.3.8.4 Confidence

Hazard Confidence: Medium

There is a Medium level of confidence that climate change will cause an increase in costs such as irrigation and fertilisers.

- Agreement: The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for this variable. The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

- Robustness: National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: Low

7.3.8.5 Adaptation

To address the risk of increased input costs such as irrigation and fertilizers due to changing climate conditions, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong policy frameworks, supported by National Genetic Conservation Strategies and Climate Risk Assessments, promote resilient crops and sustainable farming, managing input costs and ensuring long-term viability.
- *Practices in Place:* National Genetic Conservation Strategies preserve crop diversity for climate-resilient varieties, while Climate Risk Assessments and Severe Weather Warnings help farmers manage vulnerabilities and input costs.
- *Monitoring and Early Warning Systems:* Severe Weather Warnings help farmers make informed decisions about irrigation and fertilizer use, ensuring effective resource allocation and management during extreme weather events.

Resistance

- *Community Engagement and Education:* The Public Policy Strategic Research Call on Adaptation Actions educates and involves communities in sustainable agriculture, building resilience to climate risks and preparing stakeholders for financial impacts.
- *Research and Development:* Project 2023RP973 examines climate change impacts on clover-pollinator interactions to enhance soil health and reduce

fertilizer use. Research into crop variety selection aims to develop water- and nutrient-efficient crops, lowering irrigation and fertilizer costs.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

7.3.8.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

7.3.9 F09 Risk of damage and loss of crops due to lightning

Table 7.10: F09 Risk of damage and loss of crops due to lightning.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage and loss of crops due to lightning	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Very low					
Consequence Confidence	Very low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

7.3.10 F10 Risk of livestock mortality due to lightning

Table 7.11: F10 Risk of livestock mortality due to lightning.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of livestock mortality due to lightning	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Very low					
Consequence Confidence	Very low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

7.3.11 F11 Risk of damage and loss of crops due to extreme wind

Table 7.12: F11 Risk of damage and loss of crops due to extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of damage and loss of crops due to extreme wind	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Very low					
Consequence Confidence	Low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

8 Health

8.1 System Description

Health describes both the medical services as well overall human well-being. Based on this, the Health system is split into two sub-systems – healthcare and human health. The healthcare sub-system focuses on the risks from climate to change to healthcare services and infrastructure. Therefore, the main element at risks within this sub-system are medical and healthcare facilities. These medical and care facilities provide service delivery, and encompass information systems, medical products, and technologies.

Human health on the other hand relates to physical and mental wellbeing of people. Elements at risk from climate change under the human health subsystem therefore include public health in a broad sense, covering physical injury, mental health, and illness.

As a system, Health underlines many other policy sectors for adaptation. The Health system has high relevance for the Biodiversity, Water Quality, Communication Networks, Electricity and Gas Networks, Flood Risk Management, Built Environment and Planning, Health, Agriculture, Forestry, Seafood, and Tourism.

8.2 Summary of Climate Change Risks

Table .1 shows a summary of the consequences for the risks identified to the Health System under both RCP4.5 and RCP8.5 scenarios across three-time horizons (2030, 2050, and 2100).

Table 8.1: Summary of Climate Change Risks in the Health System. Lim = Limited, Sub = Substantial, Cri = Critical, Cat = Catastrophic.

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
H01	Risk of disruption and damage to healthcare services and facilities due to sea level rise and coastal flooding	Sub	Sub	Sub	Sub	Sub	Sub
H02	Risk of disruption and damage to healthcare services and facilities as a result of extreme cold	Lim	Lim	Lim	Lim	Lim	Lim

ID	Risk	Consequence (RCP4.5)			Consequence (RCP8.5)		
		2030	2050	2100	2030	2050	2100
H03	Risk of disruption and damage to healthcare services and facilities due to extreme precipitation and flooding (fluvial, surface water and groundwater)	Sub	Sub	Cri	Sub	Sub	Cri
H04	Risk of increased demand on healthcare services and facilities due to extreme heat	Lim	Sub	Sub	Sub	Sub	Cri
H05	Risk of overheating in healthcare services and facilities due to extreme heat	Lim	Lim	Sub	Lim	Sub	Cri
H06	Risk of increased antimicrobial resistance due to changes in climate conditions	Lim	Sub	Cri	Lim	Sub	Cri
H07	Risk of disruption and damage to healthcare services and facilities as a result of extreme wind	Sub	Sub	Sub	Sub	Sub	Sub
H08	Risk to human health (physical injury and mental health) due to sea level rise, coastal erosion, and coastal flooding	Lim	Sub	Sub	Lim	Sub	Sub
H09	Risk to human health (illness) as a result of harmful algal blooms (HABs) and pathogens in marine bathing waters	Lim	Sub	Sub	Lim	Sub	Sub
H10	Risk to human health (physical injury and cold-related illness) due to extreme cold	Lim	Lim	Lim	Lim	Lim	Lim
H11	Risk to human health (physical injury and mental health) due to increases in average precipitation, extreme precipitation, and flooding (fluvial, surface water, and groundwater)	Lim	Sub	Cat	Lim	Cri	Cat
H12	Risk of insufficient individual hygiene practices due to reduced water supply as a result of drought conditions	Lim	Lim	Lim	Lim	Lim	Lim
H13	Risk of respiratory health impacts as a result of wildfire	Lim	Lim	Lim	Lim	Lim	Lim
H14	Risk to human health due to increases in average temperature (e.g., increased aeroallergen levels, higher rates of skin cancer, and decreased indoor air quality)	Lim	Sub	Cri	Lim	Cri	Cri
H15	Risk to human health (physical and mental health) due to extreme heat	Lim	Sub	Cri	Lim	Cri	Cat
H16	Risk of increased vector-borne diseases due to changes in climate conditions	Lim	Sub	Sub	Lim	Sub	Cri
H17	Risk to human health (physical injury) due to extreme wind	Sub	Sub	Sub	Sub	Sub	Sub

8.3 Risks

8.3.1 H01 Risk of disruption and damage to healthcare services and facilities due to sea level rise and coastal flooding

8.3.1.1 Risk Summary

Table 8.2: H01 Risk of disruption and damage to healthcare services and facilities due to sea level rise and coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to healthcare services and facilities due to sea level rise and coastal flooding	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	More Action Needed					
Hazard Confidence	High					
Consequence Confidence	High					

Coastal flooding poses a risk to healthcare services and facilities, impacting their ability to function effectively during and after such events. Coastal flooding can block access routes, making it difficult for patients and healthcare workers to reach facilities. Floodwaters can cause significant structural damage to healthcare facilities, including hospitals and clinics. Medical equipment and supplies may be destroyed or rendered unusable due to water damage. Additionally, floodwaters can introduce contaminants and pathogens into healthcare facilities, posing health risks to patients and staff. Furthermore, flooding can interrupt the delivery of medical supplies and pharmaceuticals, leading to shortages. For patients, this means delayed treatment, increased risk of infections, and potential long-term mental health impacts due to the stress and anxiety caused by service disruptions. For healthcare staff, blocked access routes can jeopardise their safety, increase their workload, and expose them to

health risks from contaminated floodwaters. The operational challenges and stress from managing flood-related damages can also lead to burnout and fatigue among healthcare workers.

8.3.1.2 Exposure and Vulnerability

The South-West Region is expected to experience the highest sea-level rise across all scenarios and time periods. The South-West Region is projected to experience sea level rise under an RCP4.5 scenario of 0.24 m by 2050, and 0.51 m by 2100, and 0.26 m by 2050, and 0.65 m by 2100 under an RCP8.5 scenario. Sea level rise drives the exposure to coastal flooding, meaning that the South-West Region is particularly exposed to coastal flooding. The Border Region meanwhile will see the lowest increase in sea level rise.

Under RCP4.5 for a 1 in 100-year event, 1.3% of healthcare buildings [18] are projected to be exposed to coastal flooding by 2050 in the South-West, Mid-West, Dublin, and Mid-East NUST3 regions. By 2100, 1.7% of healthcare buildings are estimated to be exposed in these regions.

Similarly, under RCP8.5 for a 1 in 100-year event, 1.3% of healthcare buildings are anticipated to be exposed to coastal flooding by 2050. For 2100, 2.7% of health system buildings will be exposed given a 1 in 100-year event in the South-West, Mid-West, Dublin, and Mid-East NUTS3 regions.

There are 841 health system facilities nationally, situated across all 8 NUTS 3 Regions (Based on Prime2 assets: Hospitals - Childrens Hospital, Dental Hospital, Eye and Ear Hospital, General Hospital, Maternity Hospital, Psychiatric Hospital, Specialised Hospital, Community Hospital, District Hospital, Private Hospital, Health Centre, Ambulance Station). The West (20%) and Dublin (18%) NUTS3 Regions have the largest proportion of health system facilities.

[18] The term 'healthcare buidlings' is defined as the following OSi Prime2 categories: Hospitals (Children's Hospital, Dental Hospital, Eye and Ear Hospital, General Hospital, Maternity Hospital, Psychiatric Hospital, Specialised Hospital, Community Hospital, District Hospital, Private Hospital), Health Centre, Ambulance Station.

8.3.1.3 Consequence

- **Damage:** A low proportion of healthcare facilities are currently exposed to coastal flooding, and even in the RCP8.5 scenario there is only a minor increase in exposure. However, there is still potential for substantial levels of consequence on healthcare services and facilities.

- **System Functionality:** Given the low proportion of healthcare facilities exposed, the system will only be temporarily or moderately impacted by this risk.

- **Extent and Pervasiveness:** The whole Irish coastline is exposed to sea level rise, with exposure to coastal flooding dependent upon local conditions, i.e., elevation. The extent is exposed is moderate affecting all healthcare facility types. All NUTS3 regions (apart from the Midlands) are exposed to this risk to varying degrees of severity.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., damage to healthcare infrastructure, leading to costly repairs and reconstruction, business interruption due to the unavailability of healthcare services, affecting employee health and productivity, social isolation due to relocation, the Biodiversity and Ecosystem System, i.e., flooding can lead to the release of hazardous materials from healthcare facilities, contaminating water bodies and ecosystems, and the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage.

- **Changes through time:** Although sea level is projected to increase around Ireland, the spatial analysis shows very minor increases in the facilities exposed. The projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and the rise in the over-65 population will lead to a higher demand for healthcare services. Consequently, this will necessitate the development of new healthcare facilities, potentially increasing exposure risks depending on their locations.

8.3.1.4 Confidence

Hazard Confidence: There is High confidence that sea level rise and coastal flooding will increase in frequency and severity in the future. Global projections, including those from the IPCC Assessment Report 6, have been used to inform sea level rise, while national projections for coastal change (erosion or accretion) are unavailable, with extrapolation of current erosion rates for 2050 used instead. Coastal flood extent and frequency changes have been assessed by the OPW using rigorous models, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used.

Consequence Confidence: There is medium confidence in the consequence as the impacts of this risk have already been observed, however, the location new healthcare facilities that may be developed by 2100 is currently unknown.

8.3.1.5 Adaptation

To address the Risk of disruption and damage to healthcare services and facilities due to sea level rise and coastal flooding, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Planning regulations, flood relief schemes, and HSE-OPW collaboration ensure healthcare facilities are designed to withstand coastal flooding.
- *Practices in Place:* Climate risk assessments, coastal change monitoring, and hazard mapping identify vulnerabilities and prioritize protective measures for healthcare infrastructure.
- *Monitoring and Early Warning Systems:* National flood programs and services provide alerts, while surveys and reviews assess healthcare facilities' vulnerability to coastal flooding. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Research and Development:* Ocean Knowledge 2030 supports innovative projects for coastal infrastructure resilience, while assessments and long-term planning provide critical data and strategies for managing coastal change risks.

Recovery and Response

- *Additional Measures:* The OPW Coastal Protection Scheme addresses coastal erosion and flooding, while HSE emergency management ensures healthcare continuity during floods, and building requirements mandate resilience measures in healthcare facility design and operation.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed **Ineffective** for managing this risk.

8.3.1.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is More Action Needed.

8.3.2 H02 Risk of disruption and damage to healthcare services and facilities as a result of extreme cold

Table 8.3: H02 Risk of disruption and damage to healthcare services and facilities as a result of extreme cold.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to healthcare services and facilities as a result of extreme cold	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Medium					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

8.3.3 H03 Risk of disruption and damage to healthcare services and facilities due to extreme precipitation and flooding (fluvial, surface water and groundwater)

8.3.3.1 Risk Summary

Table 8.4: H03 Risk of disruption and damage to healthcare services and facilities due to extreme precipitation and flooding (fluvial, surface water and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to healthcare services and facilities due to extreme precipitation and flooding (fluvial, surface water and groundwater)	Substantial	Substantial	Critical	Substantial	Substantial	Critical
Urgency	More Action Needed					
Hazard Confidence	Medium					
Consequence Confidence	High					

Extreme precipitation and flooding (fluvial, surface water, and groundwater) pose significant risks to healthcare services and facilities. Floodwaters can cause damage to the physical structure of healthcare facilities, including walls, floors, and foundations. Medical equipment, devices, and supplies can also be damaged or contaminated by floodwaters. Additionally, floodwaters can introduce contaminants and pathogens into healthcare facilities, posing health risks to patients and staff. The stress and trauma associated with flooding can exacerbate mental health issues among patients and healthcare workers. Furthermore, flooding can interrupt the delivery of medical supplies and pharmaceuticals, leading to shortages. For patients, this means delayed treatment, increased risk of infections, and potential long-term mental health impacts due to the stress and anxiety caused by service disruptions. For healthcare staff, blocked access routes can jeopardise their safety, increase their workload, and expose them to health risks from contaminated floodwaters. The operational challenges and stress from managing flood-related damages can also lead to burnout and fatigue among healthcare workers.

8.3.3.2 *Exposure and Vulnerability*

Based on 1-in-100-year return period 1.3% of healthcare services and facilities buildings are exposed to fluvial flooding (CFRAM). Under the RCP4.5 and RCP8.5 scenario, 2.4% are exposed in 2050 and 2100. The South-East region is the most exposed area, with 8.8% of facilitates and services impacted.

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9%(1.2-16.0%) by 2100) scenarios.

In terms of seasonality, the winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) and 20.9% (10.0-33.0%) (RCP8.5) by 2100. The summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) and -7.3% (-21.8 — -6.6%) (RCP8.5) by 2100. All NUTS3 regions are projected to experience an increase in five-day precipitation across both RCP4.5 (10.2% (0.4 - 21.1%) by 2100) and RCP8.5 (16.5% (3.8 - 31.4%) by 2100). Similarly, each region will see an increase in the number of very wet days under both RCP4.5 (an increase of 0.8 days (0.3 - 1.3 days per year) by 2100) and RCP8.5 (an increase of 1.4 days (0.7-2.1 days per year) by 2100).

There are 841 health system facilities nationally, situated across all 8 NUTS 3 Regions (Based on Prime2 assets: Hospitals - Childrens Hospital, Dental Hospital, Eye and Ear Hospital, General Hospital, Maternity Hospital, Psychiatric Hospital, Specialised Hospital, Community Hospital, District Hospital, Private Hospital, Health Centre, Ambulance Station). The West (20%) and Dublin (18%) NUTS3 Regions have the largest proportion of health system facilities.

8.3.3.3 *Consequence*

- **Damage:** Currently, healthcare services and facilities face substantial losses due to extreme precipitation and flooding (fluvial, surface water, and

groundwater). Ireland is already experiences impacts from this risk, for instance:

- Flooding at Letterkenny General Hospital in 2014 caused significant disruption to healthcare services. The hospital lost 40% of its capacity, leading to the cancellation of elective surgeries and outpatient clinics, medical records were damaged which had indirect health impacts by disrupting patient care and continuity of service (Department of Health, 2019).

Due to an increase in the number of healthcare facilities by 2100 there is potential for large and frequent damage.

- **System Functionality:** Given the low proportion of healthcare facilities exposed, the system will only be temporarily or moderately impacted by this risk.

- **Extent and Pervasiveness:** Currently, impacts are of a moderate extent or pervasiveness. As extreme precipitation and flooding are projected to increase in frequency and intensity, however, the spatial analysis shows only minor increases in exposure by 2100, therefore, the extent and pervasiveness remains the same through the three time horizons.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., damage to healthcare infrastructure, leading to costly repairs and reconstruction, business interruption due to the unavailability of healthcare services, affecting employee health and productivity, the Biodiversity and Ecosystem System, i.e., flooding can lead to the release of hazardous materials from healthcare facilities, contaminating water bodies and ecosystems, and the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage.

- **Changes through time:** Although extreme precipitation and flooding are projected to increase around Ireland, the spatial analysis shows very minor increases in the facilities exposed. However, the projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and the rise in the over-65 population will lead to a higher demand for healthcare services. Consequently, this will necessitate the development of new healthcare facilities, potentially increasing exposure risks depending on their locations.

8.3.3.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020).

Consequence Confidence: There is high confidence in the consequence as the impacts of this risk have already been observed and will likely increase in frequency and severity in the future however, the location new healthcare facilities that may be developed by 2100 is currently unknown.

8.3.3.5 Adaptation

To address the risk of disruption and damage to healthcare services and facilities due to extreme precipitation and flooding, several practices have been implemented:

Reliability

- *Policy and Governance:* Planning regulations, flood relief schemes, and HSE-OPW collaboration ensure new healthcare facilities are flood-resistant and integrated into broader flood management.

- *Monitoring and Early Warning Systems:* The National Flood Forecasting and Warning Service provides alerts, and HSE severe weather planning guidance helps healthcare facilities prepare for extreme precipitation. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- The Health Climate Change Sectoral Adaptation Plan provides a strategic framework for managing climate risks in the healthcare sector.
- *Planning Regulations* ensure healthcare facilities are designed and built to withstand flooding.
- *National Catchment Flood Risk Assessment and Management Programme* focuses on managing flood risks to protect healthcare infrastructure.
- *Community Engagement and Education*: Public health advice initiatives educate local communities in flooding risks.
- *Research and Development:* Ocean Knowledge 2030 supports projects to enhance coastal infrastructure resilience. Assessment of options for management of coastal change risks provides data for long-term coastal management.

Recovery and Response

- *Additional Measures:* The OPW Coastal Protection Scheme addresses erosion and flooding, HSE emergency management ensures healthcare continuity during floods, building requirements mandate resilience measures, and CFRAM projections aid flood risk management planning.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed **Ineffective** for managing this risk.

8.3.3.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is that More Action is required.

8.3.4 H04 Risk of increased demand on healthcare services and facilities due to extreme heat

8.3.4.1 Risk Summary

Table 8.5: H04 Risk of increased demand on healthcare services and facilities due to extreme heat.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased demand on healthcare services and facilities due to extreme heat	Limited	Substantial	Substantial	Substantial	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Extreme heat poses a risk to healthcare services and facilities in Ireland due leading to increased demand and operational challenges. It can cause heat exhaustion, heatstroke, and dehydration, resulting in a surge in emergency department visits and hospital admissions. Vulnerable populations, such as the elderly, children, and those with pre-existing health conditions, are disproportionately affected, potentially leading to higher rates of morbidity and mortality. Additionally, extreme heat exacerbates chronic conditions, increasing the risk of hospitalisation. Extreme heat can exacerbate health disparities in rural and remote areas, where access to healthcare services may already be limited.

8.3.4.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -

0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38))

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2)).

There are 841 health system facilities nationally, situated across all 8 NUTS 3 Regions (Based on Prime2 assets: Hospitals - Childrens Hospital, Dental Hospital, Eye and Ear Hospital, General Hospital, Maternity Hospital, Psychiatric Hospital, Specialised Hospital, Community Hospital, District Hospital, Private Hospital, Health Centre, Ambulance Station). The West (20%) and Dublin (18%) NUTS3 Regions have the largest proportion of health system facilities.

Vulnerable populations, such as the elderly, children, and those with pre-existing health conditions, are disproportionately affected, potentially leading to higher rates of morbidity and mortality. Based on Census 2022, 776,315 people in Ireland are aged over 65. This means that 15.08% of the population are over 65. The highest proportion of over 65-year-olds are in the West (17.2%) and Border (17.2%) regions.

8.3.4.3 Consequence

- **Damage:** Limited or rare losses initially, however, as temperatures increase in both RCP4.5 and RCP8.5 scenarios, the damage increases to substantial. By 2100, under RCP8.5 scenario damage increases to large and frequent, with damage under an RCP4.5 scenario remaining at substantial levels.

- **System Functionality:** Extreme heat can cause temporary or moderate disturbances on healthcare services and facilities; however, under an RCP8.5 scenario, these disturbances could become more chronic and therefore long-term if the frequency of extreme heat events increases.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all healthcare facilities.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., business interruption due to the unavailability of healthcare services, affecting employee health and productivity, and the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage.

- **Changes through time:** The projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and the rise in the over-65 population will lead to a higher demand for healthcare services. Consequently, this will necessitate the development of new healthcare facilities, potentially increasing exposure risks depending on their locations, plus existing healthcare services and facilities servicing a larger population.

8.3.4.4 Confidence

Hazard Confidence: For extreme heat there is High confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: The confidence in the consequence is Low as there is uncertainty to the timing of future impacts, and the impact of the future increase in population will have on healthcare service demand.

8.3.4.5 Adaptation

To address the risk of increased demand on healthcare services and facilities due to extreme heat, several practices have been implemented:

Reliability

- *Policy and Governance:* Workplace regulations, HSE emergency management, and the Severe Weather Group ensure healthcare facilities operate safely during heatwaves.
- *Monitoring and Early Warning Systems:* Forecasting, weather warnings, and media notices protect infrastructure and inform about heat risks.

Resistance

- *Climate Risk Assessments* are essential for understanding the specific vulnerabilities of healthcare services to extreme heat.
- *Safety Statements Including Heat Risks* ensure healthcare facilities are aware of potential dangers and have plans to protect their operations.
- The Health Climate Change Sectoral Adaptation Plan provides a strategic framework for managing these risks across different sectors.
- *Community Engagement and Education:* Public health advice initiatives educate and involve local communities in understanding extreme heat risks and preparedness. The HSE Public Heatwave Plan provides specific guidelines for protecting public health during heatwaves.
- *Research and Development:* Dynamic simulation modelling of building design performance helps assess how healthcare facilities can be designed or retrofitted to better withstand extreme heat. Surveys of health infrastructure assess the current state of healthcare facilities and their vulnerability to heatwaves.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

8.3.4.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

8.3.5 H05 Risk of overheating in healthcare services and facilities due to extreme heat

8.3.5.1 Risk Summary

Table 8.6: H05 Risk of overheating in healthcare services and facilities due to extreme heat.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of overheating in healthcare services and facilities due to extreme heat	Limited	Limited	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Extreme heat poses a risk to healthcare services and facilities in Ireland, leading due to disruption to healthcare services plus damage to facilities. Healthcare staff are at risk of heat-related illnesses, which can cause staffing shortages and increased stress on the remaining staff. HVAC systems can become overburdened during extreme heat events, and continuous operation at maximum capacity can lead to system failures, leaving the facility without adequate cooling. Prolonged heat can damage healthcare infrastructure, causing wear and tear on buildings and equipment, and leading to increased maintenance costs. Furthermore, extreme heat can deteriorate the quality of medications and supplies that require specific storage conditions.

8.3.5.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -

0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38)).

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2))

There are 841 health system facilities nationally, situated across all 8 NUTS 3 Regions (Based on Prime2 assets: Hospitals - Childrens Hospital, Dental Hospital, Eye and Ear Hospital, General Hospital, Maternity Hospital, Psychiatric Hospital, Specialised Hospital, Community Hospital, District Hospital, Private Hospital, Health Centre, Ambulance Station). The West (20%) and Dublin (18%) NUTS3 Regions have the largest proportion of health system facilities.

8.3.5.3 Consequence

- **Damage:** Limited or rare losses initially, however, as temperatures increase in both RCP4.5 and RCP8.5 scenarios, the damage increases to substantial. By 2100, under RCP8.5 scenario damage increases to large and frequent, with damage under an RCP4.5 scenario remaining at substantial levels.

- **System Functionality:** Extreme heat can cause temporary or moderate disturbances on healthcare services and facilities; however, under an RCP8.5 scenario, these disturbances could become more chronic and therefore long-term if the frequency of extreme heat events increases.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all healthcare facilities.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., business interruption due to the unavailability of healthcare services, affecting employee health and productivity, and the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage.

- **Changes through time:** The projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and the rise in the over-65 population will lead to a higher demand for healthcare services. Consequently, this will necessitate the development of new healthcare facilities, potentially increasing exposure risks depending on their locations, plus existing healthcare services and facilities servicing a larger population.

8.3.5.4 Confidence

Hazard Confidence: For extreme heat there is High confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: The confidence in the consequence is Low as there is uncertainty to the timing of future impacts, and the impact of the future increase in population will have on healthcare service demand.

8.3.5.5 Adaptation

To address the risk of overheating in healthcare services and facilities due to extreme heat, several practices have been implemented:

Reliability

- *Policy and Governance:* Workplace regulations, HSE emergency management, and the Severe Weather Group ensure healthcare facilities operate safely during heatwaves.
- *Climate Risk Assessments:* Essential for understanding healthcare facilities' vulnerabilities to extreme heat.
- *Safety Statements Including Heat Risks:* Ensure awareness and plans to protect healthcare operations.
- Health Climate Change Sectoral Adaptation Plan provides a strategic framework for managing heat risks across the health sector.
- *Monitoring and Early Warning Systems:* Forecasting, weather warnings, and media notices protect infrastructure and inform about heat risks.

Resistance

- *Community Engagement and Education:* Public health advice initiatives and the HSE Public Heatwave Plan educate communities and provide guidelines for protecting public health during heatwaves.
- *Research and Development:* Dynamic simulation modelling and surveys assess healthcare facilities' design performance and vulnerability to extreme heat.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

8.3.5.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

8.3.6 H06 Risk of increased antimicrobial resistance due to changes in climate conditions

8.3.6.1 Risk Summary

Table 8.7: H06 Risk of increased antimicrobial resistance due to changes in climate conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased antimicrobial resistance due to changes in climate conditions	Limited	Substantial	Critical	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Very low					

C

8.3.6.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C (0.6-1.7°C) by 2050, and 1.5°C (1.1-2.2°C) by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C (1.1-1.9°C) by 2050, and 2.7°C (2.0-3.3°C) by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100) scenarios.

Vulnerable populations, such as the elderly, children, and those with pre-existing health conditions, are disproportionately affected, potentially leading to higher rates of morbidity and mortality.

8.3.6.3 Consequence

- **Damage**: In both scenarios, there are limited or rare losses initially, however, as temperatures increase in both RCP4.5 and RCP8.5 scenarios, the damage increases to substantial. By 2100, under both scenarios damage increases to large and frequent.

- **System Functionality**: As the damage increases through time, there is a similar increase in system functionality, with irreversible loss to the system if resistance reaches a level that it undermines the effectiveness of medicines.

- **Extent and Pervasiveness**: Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a very large extent and with high pensiveness.

- **Cascading Effects**: As a result of this risk, there is long-term cascading effects on the Food Production and Supply Chain System, i.e., livestock and crop production, leading to reduced agricultural productivity and food security issues, Biodiversity and Ecosystems System, i.e., contamination of water sources posing risks to both human and animal health, the Social System, i.e., increasing health care costs, business interruption due to the unavailability of healthcare services, employee health and productivity, and the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage.

- **Change through time**: Change climate conditions will increase levels of damage, plus the projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and the rise in the over-65 population will lead to a higher demand for healthcare services and therefore a decrease in the effectiveness of medicines and health care will have a greater exposure to public health in the future.

8.3.6.4 *Confidence*

Hazard Confidence: There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for the direction and degree of change. However, there is more confidence in the temperature related climate projections, in both the direction and degree of change. Therefore, an overall confidence of medium is assigned to this hazard.

Consequence Confidence: There is medium confidence in the consequence as this risk has and is already occurring within Europe.

Consequence Confidence: There is very low confidence in the consequence of this risk because the timing of the effect of climate change on antimicrobial resistance is uncertain, as is the potential degree to which AMR develops. The interplay between climate change and AMR is complex and not fully understood.

8.3.6.5 *Adaptation*

To address the risk of increased antimicrobial resistance (AMR) due to changes in climate conditions, several practices have been implemented:

Reliability

- *Policy and Governance:* The Health Climate Change Sectoral Adaptation Plan develops policies addressing climate change and AMR, including antimicrobial use regulations and infection control guidelines.
- *The Health Climate Change Sectoral Adaptation Plan* provides a strategic framework for managing climate risks in healthcare, including guidelines for monitoring and mitigating AMR impacts.
- *Monitoring and Early Warning Systems:* Climate risk assessments and severe weather warnings help monitor conditions influencing AMR, enabling proactive responses.

Resistance

- *Research and Development*: Focuses on understanding and mitigating climate change impacts on AMR, including studying how climate variables affect resistant pathogens and exploring new antimicrobial treatments and strategies.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

8.3.6.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

8.3.7 H07 Risk of disruption and damage to healthcare services and facilities as a result of extreme wind

8.3.7.1 Risk Summary

Table 8.8: H07 Risk of disruption and damage to healthcare services and facilities as a result of extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of disruption and damage to healthcare services and facilities as a result of extreme wind	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Very low					
Consequence Confidence	Medium					

Extreme wind events in Ireland can disrupt healthcare services by causing utility outages (power, water, communication) essential for medical operations and blocking roads with debris, which delays access to care and disrupts healthcare staff travelling to work. High winds can cause substantial damage to healthcare facilities, including structural harm to roofs, windows, and external structures. High winds can also damage communication infrastructure, leading to disruptions in phone and internet services, which are crucial for coordinating emergency responses and patient care. Strong winds can make it difficult to evacuate patients safely, especially those with mobility issues or those in critical condition. Additionally, extreme wind events can lead to an increase in injuries and accidents, putting additional strain on emergency services and healthcare facilities. High winds can also disrupt the supply chain, delaying the delivery of essential medical supplies and equipment.

8.3.7.2 Exposure and Vulnerability

For RCP4.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the

largest decrease (2050: -0.32 days, 2100: -0.47) from the 1981-2010 baseline. For RCP8.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.61 days, 2100: -0.44) from the 1981-2010 baseline.

For RCP4.5, there is a projected small decrease in the 10-m wind speed of 1.0–2.7% (mean 1.8%) compared to the 1981-2000 baseline by 2050. For RCP8.5, there is a 1.6–3.3% (2.6%) decrease.

There are 841 health system facilities nationally, situated across all 8 NUTS 3 Regions (Based on Prime2 assets: Hospitals - Childrens Hospital, Dental Hospital, Eye and Ear Hospital, General Hospital, Maternity Hospital, Psychiatric Hospital, Specialised Hospital, Community Hospital, District Hospital, Private Hospital, Health Centre, Ambulance Station). The West (20%) and Dublin (18%) NUTS3 Regions have the largest proportion of health system facilities.

8.3.7.3 Consequence

- **Damage:** Extreme wind can cause substantial losses to buildings. Ireland already experiences impacts from this risk, for instance:
    - In 2017, the health service experienced widespread disruption to outpatient services, hospital procedures, and discharges due to Storm Ophelia (Department of Health, 2019).
    - Storm Ophelia, caused €70 million in damages, resulting from significant wind damage, including roofs blown off, trees felled, and buildings damaged (Department of Housing, Local Government and Heritage, 2019).
    - Ireland experienced severe winds due to Storm Darwin in February 2014, with maximum sustained speeds of 120 km/h and gusts up to 160 km/h. The storm caused considerable damage to housing and other buildings, leaving more than 215,000 homes without power (Department of Housing, Local Government and Heritage, 2019).

- **System Functionality:** Extreme wind can cause temporary to moderate disturbances to the Health System.
- **Extent and Pervasiveness:** The impact of extreme wind events is widespread, affecting a large number of buildings, and building types, across extensive areas, indicating a large extent and pervasiveness.
- **Cascading Effects:** There are both temporary to long-term cascading effects on the Social System, i.e., business interruption due to the unavailability of healthcare services, affecting employee health and productivity, and the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, and potential difficulties in securing finance and insurance coverage.
- **Changes through time:** The projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and the rise in the over-65 population will lead to a higher demand for healthcare services. Consequently, this will necessitate the development of new healthcare facilities, potentially increasing exposure risks depending on their locations, plus existing healthcare services and facilities servicing a larger population.

8.3.7.4 Confidence

Hazard Confidence: There is a Very Low level of confidence that extreme wind frequency and severity will not change in the future. There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used at the NUTS2 level, with national scale data for average wind speed used as an alternative proxy.

Consequence Confidence: There is High confidence in the consequence as the impacts of this risk have already been observed and will likely continue in the future.

8.3.7.5 Adaptation

To address the risk of disruption and damage to healthcare services and facilities due to extreme wind, several practices have been implemented:

Reliability

- *Policy and Governance:* HSE building requirements, capital funding, and emergency management ensure healthcare facilities incorporate resilience measures and operate during extreme wind events.
- *Climate Risk Assessments:* Essential for understanding healthcare facilities' vulnerabilities to extreme wind.
- *Building Regulations:* Ensure healthcare infrastructure withstands high wind conditions, protecting buildings and services.
- *Centrally Managed and Locally Delivered Responses:* Provide a coordinated approach to managing extreme wind impacts.
- *Monitoring and Early Warning Systems:* Weather forecasting and warnings enable healthcare facilities to protect infrastructure and services from wind damage.

Resistance

- *Community Engagement and Education:* Public health advice initiatives educate communities about extreme wind risks.
- *Research and Development:* Dynamic simulation modelling and surveys assess healthcare facilities' design performance and vulnerability to wind damage.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

8.3.7.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

8.3.8 H08 Risk to human health (physical injury and mental health) due to sea level rise, coastal erosion, and coastal flooding

8.3.8.1 Risk Summary

Table 8.9: H08 Risk to human health (physical injury and mental health) due to sea level rise, coastal erosion, and coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk to human health (physical injury and mental health) due to sea level rise, coastal erosion, and coastal flooding	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Sea level rise, coastal erosion, and coastal flooding pose a risk to human health, both physically and mentally. Coastal erosion and flooding pose significant physical health risks, including injuries and fatalities from drowning, debris, and collapsing structures. Coastal erosion and flooding can result in the loss of homes, livelihoods, and community infrastructure, potentially leading to significant stress, anxiety, depression, grief, and solastalgia. Additionally, the displacement of communities due to coastal erosion can disrupt social networks and support systems, further exacerbating mental health issues. The contamination of water sources by floodwaters can also lead to waterborne diseases, posing additional health risks.

8.3.8.2 Exposure and Vulnerability

Of the approximate 1.8m residences in Ireland, 1.3% of these are within 100 metres of the coast according to Prime2 data. The South-West Region is particularly exposed, as it has the highest proportion of residences within 100 metres of the coast at 2.9%.

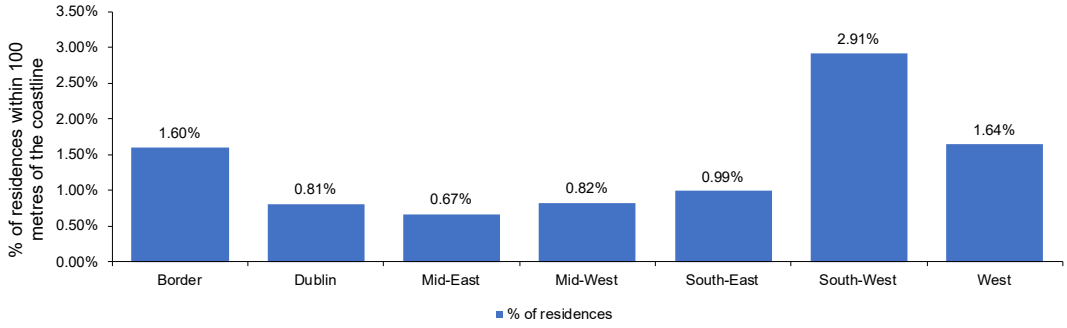


Figure 8.1: Proportion of residences (OSi PRIME2) within 100 metres of the coastline.

Using the OPW National Coastal Flood Hazard Mapping (NCFHM), for a 1 in 100-year event (1% Annual Exceedance Probability) under RCP4.5, 1.68% of buildings in Ireland (based on the current total number and location of buildings) are at risk of coastal flooding by 2050. Similarly, for a 1 in 100-year event under RCP8.5, 1.68% of buildings are at risk of coastal flooding. By 2100, 1.98% of buildings in Ireland are at risk of coastal flooding for a 1 in 100-year event under RCP4.5, whereas under RCP8.5, 2.26% of buildings are at risk of coastal flooding for a 1 in 100-year event by 2100.

Using the same NCFHM data, for a 1 in 100-year event (1% Annual Exceedance Probability) under RCP4.5, 2% of residences in Ireland (based on the current total number and location of residences) are at risk of coastal flooding by 2050. Similarly, for a 1 in 100-year event under RCP8.5, 2% of residences are also at risk of coastal flooding. By 2100, 2.34% of residences in Ireland are at risk of coastal flooding for a 1 in 100-year event under RCP4.5, whereas under RCP8.5, 2.66% of residences are at risk of coastal flooding for a 1 in 100-year event by 2100.

Of the eight NUTS3 regions, seven are affected by coastal flooding. The Midlands region has no coastline and is therefore not exposed. The Mid-East and South-West Region being the most affected regions. The Midlands Region is the only of the eight NUTS3 regions which is not impacted by coastal flooding, given its geographic location.

The South-West Region is expected to experience the highest sea-level rise across all scenarios and time periods. The South-West Region is projected to experience sea level rise under an RCP4.5 scenario of 0.24 m by 2050, and 0.51 m by 2100, and 0.26 m by 2050, and 0.65 m by 2100 under an RCP8.5 scenario. Sea level rise drives the exposure to coastal flooding, meaning that the South-West Region is particularly exposed to coastal flooding. The Border Region meanwhile will see the lowest increase in sea level rise.

The length of coastline projected to be at risk of coastal erosion in Ireland by 2050 is 328 km. The South-West (85 km) and South-East (46 km) regions are most at risk, however, the effects of climate change were not included within this assessment.

The impact of coastal flooding and coastal erosion is expected to grow in line with a larger population which may be exposed to those diseases. Based on projections prepared by ESRI in 2024, under a scenario accounting for higher rates in inward migration, the population is anticipated to increase by 1.124 million by 2040, resulting in a population of 6.308 million people. While all regions are expected to experience population growth, relatively higher growth is anticipated in the east and midlands, concentrated in Dublin and the Mid-East NUTS3 regions.

Vulnerable populations, such as the elderly, children, and those with pre-existing health conditions, are disproportionately affected, potentially leading to higher rates of morbidity and mortality. Based on Census 2022, 776,315 people in Ireland are aged over 65, accounting for 15.08% of the population, while 1,012,287 children are under 15, making up 23.6% of the total population. The highest proportion of over 65-year-olds are in the West (17.2%) and Border (17.2%) regions. The number of people aged over 65 is anticipated to double from 2022 (c.781,000) to 2042 (c.1.4 million), growing from 15% of the population to 23% (CSO 2024, M2 scenario). Under the high net migration scenario (M1), the children under 15 is projected to decline to 859,400 by 2042, a 15.3% decrease across the state. This decline varies by region, with the largest drop in the South-West (18.5%) and the smallest in the South-East (10.2%). In the 2022

Census, 22% of population reported experiencing at least one lasting condition or difficulties. The statistics show the prevalence of long-lasting conditions or difficulties increase with age in Ireland.

8.3.8.3 Consequence

- **Damage:** There is potential for substantial impacts to very large and frequent impacts on buildings, and therefore people, resulting in potentially substantial levels of damage by 2100 which will have associated impacts on human health.

- **System Functionality:** The impacts of sea level rise, coastal flooding and coastal erosion can lead to temporary to long-term disturbances on human health.

- **Extent and Pervasiveness:** The whole Irish coastline is exposed to sea level rise, with exposure to coastal flooding and coastal erosion dependent upon local conditions, i.e., elevation, lithology. The largest impacts will occur in areas that have concentrations of buildings close to the coast, however, all NUTS3 regions (apart from the Midlands) are exposed to this risk to varying degrees of severity.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., business interruption due to employee health and productivity, and the Economy and Finance System, e.g., increased healthcare expenditure.

Changes through time: In both scenarios, sea level rise will increase at similar rates to 2050, however, beyond this point RCP8.5 has a higher sea level by the end of the century compared to RCP4.5. Nevertheless, the spatial analysis shows only minor differences in the number of buildings exposed to this risk. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)), and therefore a possible commensurate increase in the number of buildings (residential and commercial) is possible, potential resulting in an increase in exposure of people.

8.3.8.4 *Confidence*

Hazard Confidence: There is high confidence that sea level rise, coastal flooding, and coastal erosion will increase in frequency and severity in the future. Global projections, including those from the IPCC Assessment Report 6, have been used to inform sea level rise, while national projections for coastal change (erosion or accretion) are unavailable, with extrapolation of current erosion rates for 2050 used instead. Coastal flood extent and frequency changes have been assessed by the OPW using rigorous models, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used. There is less confidence in the spatial distribution of coastal erosion in the future due to limited assessment of future coastal change that includes the consideration of climate change.

Consequence Confidence: There is high confidence in the consequence as the impacts of this risk have already been observed, however, the location of new buildings, and therefore people, that may be developed by 2100 is currently unknown.

8.3.8.5 *Adaptation*

To address the risk to human health (both physical injury and mental health) due to coastal erosion and coastal flooding, several practices have been implemented:

Reliability

- *Policy and Governance:* Planning regulations, flood relief schemes, and HSE requirements ensure new developments and healthcare facilities are resilient to coastal flooding, with emergency management ensuring continuity during floods.
- *Climate Risk Assessments:* Essential for understanding coastal area vulnerabilities.
- *Monitoring of Physical Coastal Change:* Provides critical data on coastal dynamics for mitigation strategies.

- *Coastal Change Research Programme:* Offers insights into coastal dynamics to aid protective measures.
- *National-Scale Coastal Hazard Mapping and Risk Assessment:* Identifies high-risk areas and prioritizes protective measures.
- *Monitoring and Early Warning Systems:* National flood programs and services provide timely alerts, with surveys assessing healthcare facilities' vulnerability to coastal flooding. Additionally, the development of the National Flood Forecasting and Warning Service (NFFWS) is underway to enhance early warning capabilities for flood events.

Resistance

- *Community Engagement and Education:* Public health advice initiatives and HSE-OPW collaboration educate communities on coastal flooding risks and integrate healthcare facilities into flood management.
- *Research and Development:* Ocean Knowledge 2030 supports projects for coastal infrastructure resilience, with assessments providing data for long-term coastal management strategies.

Recovery and Response

- *Humanitarian relief schemes* provide immediate support to affected communities.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed **Ineffective** for managing this risk.

8.3.8.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

8.3.9 H09 Risk to human health (illness) as a result of harmful algal blooms (HABs) and pathogens in marine bathing waters

8.3.9.1 Risk Summary

Table 8.10: H09 Risk to human health (illness) as a result of harmful algal blooms (HABs) and pathogens in marine bathing waters.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk to human health (illness) as a result of harmful algal blooms (HABs) and pathogens in marine bathing waters	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Low					
Consequence Confidence	Low					

Climate change can increase the risk of harmful algal blooms and pathogens in marine waters by warming ocean temperatures and altering rainfall patterns, which create favourable conditions for their growth. Harmful Algal Blooms (HABs) in marine waters can produce toxins that can cause respiratory problems, skin irritation, and gastrointestinal issues.

8.3.9.2 Exposure and Vulnerability

Sea surface temperature is projected to increase by between 0.4°C (0.3-0.8°C) in 2050 to 0.9°C 0.9°C (0.8-1.5°C) in 2100 under an RCP4.5 scenario and 0.7°C (0.5-1.1°C) in 2050 to 1.9°C (1.5-2.5°C) in 2100 under RCP8.5 scenario within the Irish Maritime Exclusive Economic Zone (IPCC AR6).

Additionally, sea surface pH level is estimated to decrease (increase in acidity) by 0.12 in 2050 and 0.13 by 2100 under an RCP4.5 scenario and 0.16 in 2050 and 0.17 in 2100 under an RCP8.5 scenario within the Irish Maritime Exclusive Economic Zone.

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9%(1.2-16.0%) by 2100) scenarios.

In terms of seasonality, the winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) and 20.9% (10.0-33.0%) (RCP8.5) by 2100. The summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) and -7.3% (-21.8 — -6.6%) (RCP8.5) by 2100. All NUTS3 regions are projected to experience an increase in five-day precipitation across both RCP4.5 (10.2% (0.4 - 21.1%) by 2100) and RCP8.5 (16.5% (3.8 - 31.4%) by 2100). Similarly, each region will see an increase in the number of very wet days under both RCP4.5 (an increase of 0.8 days (0.3 - 1.3 days per year) by 2100) and RCP8.5 (an increase of 1.4 days (0.7-2.1 days per year) by 2100).

There are 146 designated bathing sites nationally which could be exposed to an increased incidence of algal blooms and marine pathogens (noting that a small number of these bathing sites are in freshwater locations). The highest proportions of these bathing places are in the West (21%) and Border (19%) NUTS3 regions. Bathing waters sites that are situated close to rivers/streams are particularly vulnerable due to the in the increase in surface run-off during heavy precipitation events transporting contaminants and pathogens.

8.3.9.3 Consequence

- **Damage:** Currently, there is a limited or rare losses associated with this risk, however, with an increase in frequency and severity of HABs, this may increase to substantial losses by 2050 and 2100.
- **System Functionality:** Given the relatively low exposure of the public to this risk, there is expected to be no significant disturbance increasing to temporary to moderate disturbances to the Health System.

- **Extent and Pervasiveness:** The whole Irish coastline is exposed this risk, however, exposure is predominantly restricted to the designated bathing sites, indicating a limited extent, however, in the future this may increase to a moderate extent.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., business interruption due to the unavailability of healthcare services, affecting employee health and productivity, and the Economy and Finance System, e.g., increased healthcare expenditure.

- **Change through time:** Improved conditions for harmful algal blooms (HABs) are expected in the future, leading to a potential increase in damage. Additionally, with the projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and rising sea temperatures potentially increasing recreational use of marine bathing waters, an increase in exposure of this risk is possible.

8.3.9.4 Confidence

Hazard Confidence: There is low confidence that HABs will increase in frequency and severity in the future as there are limited climate projections available related to the changes in HABs for Ireland, with no national scale projections, therefore IPCC AR6 sea surface temperature and pH surface information have been used. There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for the direction and degree of change.

Consequence Confidence: There is very low confidence in the consequence of this risk because the timing of the effect of climate change on HABs is uncertain. Furthermore, it is uncertain whether an increase of exposure due to an increasing population and recreational activity will occur.

8.3.9.5 Adaptation

To address the risk to human health from algal blooms and pathogens in marine bathing waters, several practices have been implemented:

Reliability

- *Policy and Governance:* Planning regulations, flood relief schemes, and HSE requirements ensure new developments and healthcare facilities are resilient to coastal flooding and health risks, with emergency management ensuring continuity.
- *Monitoring and Early Warning Systems:* National flood programs and services provide alerts, with surveys assessing healthcare facilities' vulnerability to flooding, algal blooms, and pathogen spread.
- *Climate Risk Assessments:* Essential for understanding coastal area vulnerabilities to health risks.
- *Monitoring of Physical Coastal Change:* Provides critical data on coastal dynamics for mitigation strategies.
- *Coastal Change Research Programme:* Offers insights into coastal dynamics to aid protective measures.
- *National-Scale Coastal Hazard Mapping and Risk Assessment:* Identifies high-risk areas and prioritizes protective measures.

Resistance

- *Community Engagement and Education:* Public health advice initiatives and HSE-OPW collaboration educate communities on algal bloom and pathogen risks, integrating healthcare facilities into flood and coastal management.
- *Research and Development:* Ocean Knowledge 2030 supports innovative projects for coastal water resilience, with assessments providing data for long-term coastal management strategies.

Recovery and Response

- *Humanitarian relief schemes* provide immediate support to affected communities.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed **Ineffective** for managing this risk.

8.3.9.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

8.3.10 H10 Risk to human health (physical injury and cold-related illness) due to extreme cold

8.3.10.1 Risk Summary

Table 8.11: H10 Risk to human health (physical injury and cold-related illness) due to extreme cold.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk to human health (physical injury and cold-related illness) due to extreme cold	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Medium					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

8.3.11 H11 Risk to human health (physical injury and mental health) due to increases in average precipitation, extreme precipitation, and flooding (fluvial, surface water, and groundwater)

8.3.11.1 Risk Summary

Table 8.12: Risk summary of H11 Risk to human health (physical injury and mental health) due to increases in average precipitation, extreme precipitation, and flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk to human health (physical injury and mental health) due to increases in average precipitation, extreme precipitation, and flooding (fluvial, surface water, and groundwater)	Limited	Substantial	Catastrophic	Limited	Critical	Catastrophic
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	High					

Increases in average precipitation, extreme precipitation, and flooding (fluvial, surface water, and groundwater) in Ireland pose significant risks to human health, both physically and mentally. Flooding threatens physical health, leading to injuries and fatalities. Floodwaters can cause drowning, while physical injuries can result from debris and damaged structures.

Increased precipitation and flooding can have profound impacts on mental health. Individuals affected by flooding may experience post-traumatic stress disorder (PTSD), depression, and ongoing anxiety. The disruption of social networks and support systems due to displacement can exacerbate these mental health issues. Long-term displacement can also lead to chronic stress and a sense of insecurity, further impacting mental well-being. The psychological effects of flooding can persist for years, affecting overall quality of life and community resilience.

Furthermore, the increased frequency and severity of flooding can place significant pressure on healthcare services. The surge in emergency department

visits and hospital admissions during and after flood events can temporarily overwhelm healthcare facilities.

8.3.11.2 Exposure and Vulnerability

Under the RCP4.5 scenario, 1.04% of buildings (based on the current total number and location of buildings) across all NUTS3 regions are projected to be impacted by fluvial flooding by 2100, according to CFRAM data. As for the RCP8.5 scenario 1.62% of buildings are estimated to be affected by fluvial flooding (CFRAM) by 2100. Buildings in the Mid-East Region are the most exposed to fluvial flooding under both scenarios, with 2.08% of buildings impacted under RCP4.5 (Figure 4.3), and 4.9% of buildings affected under RCP8.5 (Figure 4.4).

In terms of NIFM data, all regions are projected to be affected by fluvial flooding by 2100. For the RCP4.5 scenario, 0.61% of buildings are exposed to fluvial flooding. Similarly, 0.66% of buildings are exposed to fluvial flooding across all NUTS3 regions. Buildings in the South-West Region are particularly exposed, with 0.86% affected by fluvial flooding for RCP4.5 (Figure 4.5), and 0.92% impacted under RCP8.5 (Figure 4.6).

All eight of the NUTS3 regions are projected to experience an increase in annual precipitation, winter precipitation, five-day precipitation, and very wet days, which drives this exposure. The Mid-East and Dublin regions are particularly exposed, as they register the highest increase in annual precipitation across both RCP4.5 (5% (0.0 - 9.9%) by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios.

In terms of seasonality, the winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) and 20.9% (10.0-33.0%) (RCP8.5) by 2100. The summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) and -7.3% (-21.8 — -6.6%) (RCP8.5) by 2100. All NUTS3 regions are projected to experience an increase in five-day precipitation across both RCP4.5 (10.2% (0.4 - 21.1%) by 2100) and RCP8.5 (16.5% (3.8 - 31.4%) by 2100). Similarly, each region will see an increase in the number of very wet days under both RCP4.5 (an increase of 0.8 days (0.3

- 1.3 days per year) by 2100) and RCP8.5 (an increase of 1.4 days (0.7-2.1 days per year) by 2100).

The impact of flooding is expected to grow in line with a larger population which may be exposed to those diseases. Based on projections prepared by ESRI in 2024, under a scenario accounting for higher rates in inward migration, the population is anticipated to increase by 1.124 million by 2040, resulting in a population of 6.308 million people. While all regions are expected to experience population growth, relatively higher growth is anticipated in the east and midlands, concentrated in Dublin and the Mid-East NUTS3 regions.

Vulnerable populations, such as the elderly, children, and those with pre-existing health conditions, are disproportionately affected, potentially leading to higher rates of morbidity and mortality. Based on Census 2022, 776,315 people in Ireland are aged over 65. This means that 15.08% of the population are over 65. The highest proportion of over 65-year-olds are in the West (17.2%) and Border (17.2%) regions. The number of people aged over 65 anticipated to double from 2022 (c.781,000) to 2042 (c.1.4 million), growing from 15% of the population to 23% (CSO 2024, M2 scenario).

8.3.11.3 Consequence

- **Damage:** Currently, buildings face substantial losses due to extreme precipitation and flooding (fluvial, surface water, and groundwater). Ireland already experiences impacts from this risk, for instance:
    - Due to flooding in 2011, there were 2 fatalities and nearly 1,700 properties flooded, with an approximate €130 million insured damages (Office of Public Works (OPW), 2019).
    - In 2015, there was a notable rise in boil water notices due to cryptosporidium contamination. This was a result of inadequate water treatment infrastructure being overwhelmed by flooding. The contamination posed significant public health risks, particularly for those relying on private water supplies (Department of Health, 2019).

As the frequency and severity of flooding increases and overall and vulnerable population, i.e., over-65, increases, and the vulnerable population there will be an increase in the level of damage associated with risk in both RCP4.5 and RCP8.5 scenarios.

- **System Functionality:** Initially there is temporary or moderate disturbances to the Health System, due to increase in demand during an event, however, as the risk increases in frequency and severity, plus the occurrence of more chronic impacts, i.e., mental health impacts, there will be an increase demand on healthcare services, potentially resulting in long-term disturbances under an RCP8.5 scenario by 2100.

- **Extent and Pervasiveness:** Currently, impacts are of a moderate extent or pervasiveness. As extreme precipitation and flooding are projected to increase in frequency and intensity by 2050, these impacts will be more widespread, affecting larger areas and a greater number of people, with very large and pervasive impacts by 2100.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., business interruption due to the unavailability of healthcare services, affecting employee health and productivity, social isolation due to relocation, and the Economy and Finance System, e.g., increased healthcare expenditure.

- **Changes through time:** In both scenarios, the changing climate conditions will continually increase the frequency and severity of flooding events. However, there are only minor differences between RCP4.5 and RCP8.5. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)) and therefore a possible commensurate increase in the number of residential properties. Furthermore, there will be an increase in the vulnerable population, i.e., over-65s, potentially increasing this risk to Catastrophic levels of risk by 2100.

8.3.11.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020). The potential impact of peatland restoration, i.e., rewetting, on flood exposure are currently unknown.

Consequence Confidence: There is high confidence in the consequence as the impacts of this risk have already been observed and will likely increase in frequency and severity in the future.

8.3.11.5 Adaptation

To address the risk to human health from physical injury and mental health issues due to increases in average precipitation, extreme precipitation, and flooding, several practices have been implemented.

Reliability

- *Policy and Governance:* Planning regulations, OPW schemes, HSE resilience measures, and CFRAM projections.
- *The Health Climate Change Sectoral Adaptation Plan* provides a strategic framework for climate risk management.
- *Planning Regulations:* Ensuring flood-resistant new developments.
- *National Catchment Flood Risk Assessment:* Managing flood risks to protect health.

- *Monitoring and Early Warning Systems:* National Flood Forecasting, HSE severe weather planning, and health infrastructure surveys.

Resistance

- *Community Engagement and Education:* Public health advice, community involvement, and HSE-OPW collaboration.
- *Research and Development:* National Marine Research projects, coastal resilience, and long-term planning data.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed **Ineffective** for managing this risk.

8.3.11.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

8.3.12 H12 Risk of insufficient hygiene practices due to reduced water supply as a result of drought conditions

8.3.12.1 Risk Summary

Table 8.13: H12 Risk of insufficient hygiene practices due to reduced water supply as a result of drought conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of insufficient individual hygiene practices due to reduced water supply as a result of drought conditions	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Further Investigation					
Hazard Confidence	Low					
Consequence Confidence	Low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

8.3.13 H13 Risk of respiratory health impacts as a result of wildfire (e.g., exacerbations of asthma, COPD, bronchitis)

8.3.13.1 Risk Summary

Table 8.14: H13 Risk of respiratory health impacts as a result of wildfire.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of respiratory health impacts as a result of wildfire	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	Low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

8.3.14 H14 Risk to human health due to increases in average temperature (e.g., increased aeroallergen levels, higher rates of skin cancer, and decreased indoor air quality)

8.3.14.1 Risk Summary

Table 8.15: H14 Risk to human health due to increases in average temperature (e.g., increased aeroallergen levels, higher rates of skin cancer, and decreased indoor air quality).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk to human health due to increases in average temperature (e.g., increased aeroallergen levels, higher rates of skin cancer, and decreased indoor air quality)	Limited	Substantial	Critical	Limited	Critical	Critical
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Low					

In Ireland, rising average temperatures pose several health risks. Increased aeroallergen levels due to longer pollen seasons can exacerbate respiratory conditions like asthma and allergies. Additionally, higher temperatures encourage more outdoor activities, resulting in greater exposure to ultraviolet (UV) radiation and potentially higher rates of skin cancer. Indoor air quality may also decline as warmer temperatures increase the concentration of pollutants and allergens, posing further respiratory challenges.

8.3.14.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C (0.6-1.7°C) by 2050, and 1.5°C (1.1-2.2°C) by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C (1.1-1.9°C) by 2050, and 2.7°C (2.0-3.3°C) by 2100. The Mid-East and South-East regions most affected

across both RCP4.5 (1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100) scenarios.

The impact of increasing average temperature is expected to grow in line with a larger population which may be exposed to those diseases. Based on projections prepared by ESRI in 2024, under a scenario accounting for higher rates in inward migration, the population is anticipated to increase by 1.124 million by 2040, resulting in a population of 6.308 million people. While all regions are expected to experience population growth, relatively higher growth is anticipated in the east and midlands, concentrated in Dublin and the Mid-East NUTS3 regions.

Vulnerable populations, such as the elderly, children, and those with pre-existing health conditions, are disproportionately affected, potentially leading to higher rates of morbidity and mortality. Based on Census 2022, 776,315 people in Ireland are aged over 65. This means that 15.08% of the population are over 65. The highest proportion of over 65-year-olds are in the West (17.2%) and Border (17.2%) regions. The number of people aged over 65 anticipated to double from 2022 (c.781,000) to 2042 (c.1.4 million), growing from 15% of the population to 23% (CSO 2024, M2 scenario).

8.3.14.3 Consequence

- **Damage:** Initially there would be limited or rare losses of this risk due to the minimal change in average temperatures. As temperatures increase in both scenarios, substantial losses would occur. Due to the increased level of warming within RCP8.5, critical levels of damage would be reached in 2050, whereas under an RCP4.5, this would be reached in 2100.

- **System Functionality:** Initially there are no significant disturbances, increasing to temporary or moderate disturbances to the Health System, due to increase in demand on healthcare services, however, as the risk increases in severity, plus the occurrence of more chronic impacts, there will be an increase demand on healthcare services, potentially resulting in long-term disturbances under an RCP8.5 scenario by 2100.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all types of healthcare facilities.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., business interruption due to the unavailability of healthcare services, affecting employee health and productivity, and the Economy and Finance System, e.g., increased healthcare expenditure.

- **Changes through time:** There will be an increase in the number of people exposed to this risk, as the projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and there will be an increase in the vulnerable population, i.e., over-65 population. Confidence

Hazard Confidence: There is a High-level confidence in the increasing temperature projections, which are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is low confidence in the consequences of this risk as e interactions between climate change, environmental factors, and human health are complex and not fully understood. Furthermore, the timing and levels of changes in population size and demographics over long time scales is unknown.

8.3.14.4 Adaptation

To address the risk to human health from increases in average temperature, several practices have been implemented:

Reliability

- *Policy and Governance:* Workplace and health regulations, HSE emergency measures, Severe Weather Group coordination, and staff warnings.
- *Climate Risk Assessments:* Understanding health vulnerabilities to rising temperatures.
- *Safety Statements:* Addressing heat risks and employee protection plans.
- *The Health Climate Change Sectoral Adaptation Plan* provides a strategic framework for managing health sector-specific risks.
- *Monitoring and Early Warning Systems:* Forecasting, weather warnings, and media notices for heat-related health risks.

Resistance

- *Community Engagement and Education:* Public health advice, community involvement, and Be Summer Ready campaign.
- *Research and Development:* Dynamic simulation modelling, building design performance, and health infrastructure surveys.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

8.3.14.5 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

8.3.15 H15 Risk to human health (physical and mental health) due to extreme heat

8.3.15.1 Risk Summary

Table 8.16: H15 Risk to human health (physical and mental health) due to extreme heat.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk to human health (physical and mental health) due to extreme heat	Limited	Substantial	Critical	Limited	Critical	Catastrophic
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Extreme heat in Ireland can pose a risk to human health, particularly to vulnerable groups such as older adults, children, and those with chronic illnesses. It can lead to serious conditions such as heat exhaustion and heat stroke. Extreme heat can further increase the risk of dehydration, affecting overall health, and can exacerbate symptoms of chronic diseases. Additionally, extreme heat can aggravate pre-existing health conditions, including cardiovascular, respiratory, cerebrovascular, and neurological disorders.

8.3.15.2 Exposure and Vulnerability

In RCP4.5, summer days are expected to increase by 3.0 days(0.9-5.3 days) by 2050 and 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (2050: 4.1 days per year (1.3-6.7 days), 2100: 5.6(per year (2.0-8.8 days) , with an increase in the number of heatwave events by 0.06 events per year(-0.05 — -0.21 per year) by 2050 and 0.11 events per year (-0.03 — -0.27 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.12 events per year (-0.01 — -0.32), 2100: 0.18 events per year (0.03-0.38))

In RCP8.5, summer days are expected to increase by 4.7 days (2.5-6.7 days) by 2050 and 11.0 days (6.5-16.8 days) by 2100 with the Midland region experiencing the largest increase (2050: 6.4 days (3.4-8.8 days) , 2100: 14.5 days (8.9-21.3 days)), with an increase in the number of heatwave events by 0.15 events per year (0.04-0.28 per year) by 2050 and 0.45 events per year (0.16-0.86 per year) by 2100 also projected. The South-East region is projected to experience largest increase (2050: 0.25 events per year(0.1-0.4), 2100: 0.68 events per year(0.3-1.2))

The impact of extreme heat is expected to grow in line with a larger population which may be exposed to those diseases. Based on projections prepared by ESRI in 2024, under a scenario accounting for higher rates in inward migration, the population is anticipated to increase by 1.124 million by 2040, resulting in a population of 6.308 million people. While all regions are expected to experience population growth, relatively higher growth is anticipated in the east and midlands, concentrated in Dublin and the Mid-East NUTS3 regions.

Vulnerable populations, such as the elderly, children, and those with pre-existing health conditions, are disproportionately affected, potentially leading to higher rates of morbidity and mortality. Based on Census 2022, 776,315 people in Ireland are aged over 65. This means that 15.08% of the population are over 65. The highest proportion of over 65-year-olds are in the West (17.2%) and Border (17.2%) regions. The number of people aged over 65 anticipated to double from 2022 (c.781,000) to 2042 (c.1.4 million), growing from 15% of the population to 23% (CSO 2024, M2 scenario). People who work outside will also be disproportionately affected.

8.3.15.3 Consequence

- **Damage**: Limited or rare losses initially, however, as heatwaves increase in both RCP4.5 and RCP8.5 scenarios and population increases, the damage increases to substantial under an RCP4.5 scenario and critical under an RCP8.5 scenario. This increase in consequence continues to 2100, reaching catastrophic levels of consequence by 2100 for the RCP8.5 scenario. Duffey

et al. (2024) estimate that additional deaths per annum in Ireland by 2100 due to heatwaves is 483 (RCP4.5) and 1,400 (RCP8.5).

- **System Functionality**: Extreme heat can cause temporary or moderate disturbances on healthcare services and facilities due to the increase in short term demand during an event; however, under an RCP8.5 scenario, these disturbances could become more chronic and therefore long-term if the frequency of extreme heat events increases.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all people, however the elderly, children, and those with pre-existing health conditions, people who work outside will be disproportionately affected.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., business interruption due to the unavailability of healthcare services, affecting employee health and productivity, and the Economy and Finance System, e.g., increased healthcare expenditure.

- **Changes through time**: The projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and the rise in the over-65 population will lead to a higher demand for healthcare services. Consequently, this will necessitate the development of new healthcare facilities, potentially increasing exposure risks depending on their locations, plus existing healthcare services and facilities servicing a larger population.

8.3.15.4 Confidence

Hazard Confidence: For extreme heat there is High confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the

90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: The confidence in the consequence is Low as there is uncertainty to the timing of future impacts, and the impact of the future increase in population will have on healthcare service demand.

8.3.15.5 Adaptation

To address the risk to human health from heat stress due to extreme heat, several practices have been implemented:

Reliability

- *Policy and Governance:* Workplace and health regulations, HSE emergency measures, Severe Weather Group coordination, and staff warnings.
- *Climate Risk Assessments:* Understanding health vulnerabilities to extreme heat.
- *Safety Statements:* Addressing heat risks and employee protection plans.
- *The Health Climate Change Sectoral Adaptation Plan* provides a strategic framework for managing health sector-specific risks.
- *Monitoring and Early Warning Systems:* Forecasting, weather warnings, and media notices for heat stress protection.

Resistance

- *Community Engagement and Education:* Public health advice, community involvement, and Be Summer Ready campaign.
- *Research and Development:* Dynamic simulation modelling, building design performance, and health infrastructure surveys.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

8.3.15.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

8.3.16 H16 Risk of increased vector-borne diseases (e.g., West Nile virus) due to changes in climate conditions

8.3.16.1 Risk Summary

Table 8.17: H16 Risk of increased vector-borne diseases due to changes in climate conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased vector-borne diseases due to changes in climate conditions	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Warmer temperatures expand the range of vectors and speed up their life cycles, increasing their populations. More rainfall creates breeding sites for mosquitoes, while droughts concentrate water sources, bringing vectors and hosts closer together. In Ireland, the public health impact includes a higher incidence of diseases like Lyme disease and West Nile virus, potentially straining healthcare services. Warmer climates extend the disease transmission season, and temperature changes can affect the behaviour of vectors, making them more active and increasing the likelihood of disease spread.

8.3.16.2 Exposure and Vulnerability

All NUTS3 regions will experience changing climate conditions, including increasing air temperatures with the Mid-East and South-East regions the most affected by increases in air temperature under both the RCP4.5 (1.5°C(1.1-2.2°C) by 2100) and RCP8.5 (2.8°C (2.0-3.5°C) by 2100). Increases in annual precipitation, winter precipitation, five-day precipitation, and very wet days are also projected with the Mid-East and Dublin regions expected to experience the highest increase in annual precipitation across both RCP4.5 (5.0% (0.0 - 9.9%)

by 2100) and RCP8.5 (8.9% (1.2-16.0%) by 2100) scenarios. The winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) to 20.9% (10.0-33.0%) (RCP8.5) and the summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) to -7.3% (-21.8 — -6.6%) (RCP8.5).

The impact of an increase in vector-borne diseases can be expected to grow in line with a larger population which may be exposed to those diseases. Based on projections prepared by ESRI in 2024, under a scenario accounting for higher rates in inward migration, the population is anticipated to increase by 1.124 million by 2040, resulting in a population of 6.308 million people. While all regions are expected to experience population growth, relatively higher growth is anticipated in the east and midlands, concentrated in Dublin and the Mid-East NUTS3 regions.

Moreover, the Irish population is aging. The number of people aged over 65 anticipated to double from 2022 (c.781,000) to 2042 (c.1.4 million), growing from 15% of the population to 23% (CSO 2024, M2 scenario). This increased number of older adults represents a population that are likely to be more vulnerable to vector-borne diseases.

8.3.16.3 Consequence

- **Damage**: Limited or rare losses initially, however, as climate conditions change in both RCP4.5 and RCP8.5 scenarios and the population increases, the damage increases to substantial. This increase in consequence continues to 2100 in the RCP8.5 scenario, reaching critical levels of consequence by 2100.

- **System Functionality**: An increase in vector-borne diseases can cause temporary or moderate disturbances on healthcare services and facilities however, as conditions change, these disturbances could become more chronic and therefore long-term.

- **Extent and Pervasiveness:** Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all people, however the elderly, children, and those with pre-existing health conditions, will be disproportionately affected.

- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., business interruption due to the unavailability of healthcare services, affecting employee health and productivity, and the Economy and Finance System, e.g., increased healthcare expenditure.

- **Changes through time**: The projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and the rise in the over-65 population will lead to a higher demand for healthcare services. Consequently, this will necessitate the development of new healthcare facilities, potentially increasing exposure risks depending on their locations, plus existing healthcare services and facilities servicing a larger population.

8.3.16.4 Confidence

Hazard Confidence: There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for the direction and degree of change. However, there is more confidence in the temperature related climate projections, in both the direction and degree of change. Therefore, an overall confidence of medium is assigned to this hazard.

Consequence Confidence: There is low confidence in the consequences of this risk as interactions between climate change, environmental factors, and human health are complex and not fully understood. Furthermore, the timing and levels of changes in population size and demographics over long time scales is unknown.

8.3.16.5 Adaptation

To address the risk of increased vector-borne diseases due to changes in climate conditions, several practices have been implemented.

Reliability

- *Policy and Governance:* Plant Health and Biosecurity Strategy, HSE emergency measures, and Severe Weather Group coordination.
- *Contingency Plans for Priority Pests:* Quick response strategies for outbreaks.
- *Enhanced Control of Invasive Species:* Preventing the spread of disease-carrying species.
- *Monitoring and Early Warning Systems:* Pest risk assessments, horizon scanning, forecasting, weather warnings, and staff alerts.

Resistance

- *Community Engagement and Education:* Public health advice, community involvement, and Be Summer Ready campaign.
- *Research and Development:* Dynamic simulation modelling, building design performance, and health infrastructure surveys.

Recovery and Response

- *Emergency Response Plans for Control and Management of Pathogen Outbreaks:* Provide frameworks for managing pathogen outbreaks effectively.
- *Pest Vigilance/Controls at Ports:* Help prevent the introduction and spread of vectors that can carry diseases.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

8.3.16.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

8.3.17 H17 Risk to human health (physical and mental health) due to extreme wind

8.3.17.1 Risk Summary

Table 8.18: H17 Risk to human health (physical and mental health) due to extreme wind.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk to human health (physical and mental health) due to extreme wind	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Very low					
Consequence Confidence	High					

Extreme wind events in Ireland pose significant risks to both physical and mental health. Extreme wind can cause direct physical harm through flying debris, falling trees, and structural damage. The unpredictability and severity of extreme wind events can lead to heightened stress and anxiety among affected populations. Additionally, the aftermath of extreme wind events, including loss of property and disruption of daily life (power, water, communication), can lead to negative mental impacts.

8.3.17.2 Exposure and Vulnerability

For RCP4.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.32 days, 2100: -0.47) from the 1981-2010 baseline. For RCP8.5, Ireland is projected to experience a small decrease in extreme wind days by 2050 and 2100, with the Northern and Western region showing the largest decrease (2050: -0.61 days, 2100: -0.44) from the 1981-2010 baseline.

For RCP4.5, there is a projected small decrease in the 10-m wind speed of 1.0–2.7% (mean 1.8%) compared to the 1981-2000 baseline by 2050. For RCP8.5, there is a 1.6–3.3% (2.6%) decrease.

The impact of extreme wind is expected to grow in line with a larger population which may be exposed to these events. Based on projections prepared by ESRI in 2024, under a scenario accounting for higher rates in inward migration, the population is anticipated to increase by 1.124 million by 2040, resulting in a population of 6.308 million people. While all regions are expected to experience population growth, relatively higher growth is anticipated in the east and midlands, concentrated in Dublin and the Mid-East NUTS3 regions.

Vulnerable populations, such as the elderly, children, and those with pre-existing health conditions, are disproportionately affected, potentially leading to higher rates of morbidity and mortality. Based on Census 2022, 776,315 people in Ireland are aged over 65. This means that 15.08% of the population are over 65. The highest proportion of over 65-year-olds are in the West (17.2%) and Border (17.2%) regions. The number of people aged over 65 anticipated to double from 2022 (c.781,000) to 2042 (c.1.4 million), growing from 15% of the population to 23% (CSO 2024, M2 scenario). People who work outside will also be disproportionately affected.

8.3.17.3 Consequence

- **Damage:** Extreme wind can cause substantial damage to human health (physical and mental health). Ireland already experiences impacts from this risk, for instance:
    - In 2017, Storm Ophelia led to the deaths of three individuals, severely disrupted road infrastructure and public services, and caused power outages affecting more than 300,000 homes nationwide. (Department of Health, 2019).
    - Storm Ophelia, caused €70 million in damages, resulting from significant wind damage, including roofs blown off, trees felled, and buildings damaged (Department of Housing, Local Government and Heritage, 2019).

- **System Functionality:** Extreme wind can cause temporary to moderate disturbances to the Health System.
- **Extent and Pervasiveness:** The impact of extreme wind events is widespread, affecting a large number of people, across extensive areas, indicating a large extent and pervasiveness.
- **Cascading Effects:** As a result of this risk, there is potentially temporary cascading effects on the Social System, i.e., business interruption due to the unavailability of healthcare services, affecting employee health and productivity, and the Economy and Finance System, e.g., increased healthcare expenditure.
- **Changes through time:** Projections show no change in hazard (although with very low levels of confidence). There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024. However, the risk is currently assessed as a Substantial consequence, and this current level of risk is expected to continue into the future.

8.3.17.4 Confidence

Hazard Confidence: There is a Very Low level of confidence that extreme wind frequency and severity will not change in the future. There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used at the NUTS2 level, with national scale data for average wind speed used as an alternative proxy.

Consequence Confidence: There is High confidence in the consequence as the impacts of this risk have already been observed and will likely continue in the future.

8.3.17.5 Adaptation

To address the risk of disruption and damage to healthcare services and facilities due to extreme wind, several practices have been implemented:

Reliability

- *Policy and Governance:* HSE building requirements, capital funding, and emergency management ensure healthcare facilities incorporate resilience measures and operate during extreme wind events.
- *Climate Risk Assessments:* Essential for understanding population's vulnerabilities to extreme wind.
- *Building Regulations:* Ensure infrastructure withstands high wind conditions, protecting patients and the public.
- *Centrally Managed and Locally Delivered Responses:* Provide a coordinated approach to managing extreme wind impacts.
- *Monitoring and Early Warning Systems:* Weather forecasting and warnings enable the public to take timely precautions against hazardous conditions.

Resistance

- *Community Engagement and Education:* Public health advice initiatives educate communities about extreme wind risks.
- *Research and Development:* Dynamic simulation modelling and surveys assess healthcare facilities' design performance and vulnerability to wind damage.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

8.3.17.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

9 Marine and Coastal Ecosystems

9.1 System description

Marine and Coastal Ecosystems relate to oceanic and coastal habitats and their biodiversity. Therefore, this system is split into two subsystems of marine ecosystems and coastal ecosystems. The marine ecosystem sub-system consists marine life as its key element at risk. Coastal ecosystems are the main element at risk from climate of the coastal ecosystem sub-system.

The Marine and Coastal Ecosystems system and sub-systems have significant relevance to the adaptation sectors of Biodiversity, Water Quality, Built and Archaeological Heritage, and Seafood sectors. The system also has some relevance to the flood risk management and tourism sectors.

9.2 Summary of Climate Change Risks

Table .1 shows a summary of the consequences for the risks identified to the Marine and Coastal Ecosystems System under both RCP4.5 and RCP8.5 scenarios across three-time horizons (2030, 2050, and 2100).

Table 9.1: Summary of Climate Change Risks in the Marine and Coastal Ecosystems System. Lim = Limited, Sub = Substantial, Cri = Critical, Cat = Catastrophic.

ID	Risk	Consequence RCP4.5			Consequence RCP8.5		
		2030	2050	2100	2030	2050	2100
M01	Risk of coastal ecosystem degradation/loss due to sea level rise, coastal erosion, and coastal flooding	Lim	Sub	Sub	Lim	Sub	Sub
M02	Risk of coastal ecosystem degradation/loss due to wildfire	Lim	Lim	Lim	Lim	Lim	Lim
M03	Risk of marine habitat and ecosystem disturbances due to changes in average ocean conditions	Lim	Sub	Sub	Lim	Sub	Cri
M04	Risk of decreases in reproduction rates of marine species due to changes in average ocean conditions	Lim	Sub	Sub	Lim	Sub	Cri
M05	Risk of seafood contamination due to harmful algal bloom (HABs) events and microbiological sources	Lim	Sub	Sub	Lim	Sub	Sub
M06	Risk of species distribution shifts and changes in marine ecosystem functioning due to	Lim	Sub	Sub	Lim	Sub	Cri

ID	Risk	Consequence RCP4.5			Consequence RCP8.5		
		2030	2050	2100	2030	2050	2100
	changes in average ocean conditions						
M07	Risk of increased mortality of cold-water coral reefs and shellfish due to ocean acidification	Lim	Sub	Sub	Lim	Sub	Cri
M08	Risk of degradation and loss of marine ecosystems and habitats due to phenological changes	Lim	Sub	Sub	Lim	Sub	Cri

9.3 Risks

9.3.1 M01 Risk of coastal ecosystem degradation/loss due to sea level rise, coastal erosion, and coastal flooding

9.3.1.1 Risk Summary

Table 9.2: M01 Risk of coastal ecosystem degradation/loss due to sea level rise, coastal erosion, and coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of coastal ecosystem degradation/loss due to sea level rise, coastal erosion, and coastal flooding	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Sustain Current Action					
Hazard Confidence	High					
Consequence Confidence	Medium					

Coastal ecosystem degradation and loss due to coastal erosion and flooding is a risk for Ireland. Coastal erosion and flooding degrade habitats by altering landscapes, introducing pollutants, and disrupting the natural balance, making it difficult for species to thrive. Coastal erosion and flooding (temporary and permanent) cause habitat loss by physically removing or submerging ecosystems like salt marshes and sand dunes, leading to their permanent disappearance. This not only affects biodiversity but also the services these ecosystems provide, such as coastal protection and carbon sequestration. For instance, salt marshes in Ireland are home to various plant species like sea lavender and glasswort, as well as bird species such as the redshank and curlew. Sand dunes support plants like marram grass and sea holly and are crucial for insects such as the sand dune tiger beetle. Birds like the little tern and skylark also rely on sand dunes for nesting. However, it should be noted that coastal erosion is a natural process that some habitats and ecosystems require. For example, salt marshes and sand

dunes rely on the natural movement of sediment to build and sustain their ecological functions and support diverse species.

9.3.1.2 Exposure and Vulnerability

Nationally, for a 1 in 100-year event, the National Coastal Flood Hazard Maps (NCFHM) projects between 1.04% (RCP4.5) and 1.20% (RCP8.5) of the total land area could be at risk of coastal flooding by 2100.

Under both scenarios, the Dublin Region is the most exposed to coastal flooding. In RCP4.5, 2.75% of the land is estimated to be at risk, while 3.45% is at risk in RCP8.5.

The South-West Region is expected to experience the highest sea-level rise across all scenarios and time periods. The South-West Region is projected to experience sea level rise under an RCP4.5 scenario of 0.24 m by 2050, and 0.51 m by 2100, and 0.26 m by 2050, and 0.65 m by 2100 under an RCP8.5 scenario. Sea level rise drives the exposure to coastal flooding, meaning that the South-West Region is particularly exposed to coastal flooding. The Border Region meanwhile will see the lowest increase in sea level rise.

The length of coastline projected to be at risk of coastal erosion in Ireland by 2050 is 328 km. The South-West (85 km) and South-East (46 km) regions are most at risk, however, the effects of climate change were not included within this assessment.

Coastal habitats and ecosystems are vulnerable to coastal squeeze, which occurs when rising sea levels trap these habitats between the sea and human infrastructure like seawalls and buildings. This prevents natural migration inland, leading to habitat loss, reduced biodiversity, and diminished ecological functions. Consequently, coastal squeeze exacerbates the impacts of coastal erosion and flooding. Intertidal soft sediments, such as mudflats and sandflats, are particularly vulnerable.

9.3.1.3 Consequence

- **Damage**: Limited or rare losses initially, with increased substantial losses by 2050 and 2100 under both scenarios.

- **System Functionality**: Sea level rise, coastal erosion, and coastal flooding can cause temporary disturbances and short-term disruptions to Marine and Coastal Ecosystem system; however, by 2050, these disturbances could become more long-term if the frequency and severity of events increases, and sea level increases to permanently inundate habitats.

- **Extent and Pervasiveness**: The whole Irish coastline is exposed to sea level rise, with exposure to coastal flooding and coastal erosion dependent upon local conditions, i.e., elevation, lithology, with all coastal ecosystems potentially impacted.

- **Cascading Effects**: Temporary cascading effects are possible, potentially affecting other critical systems and services beyond the Marine and Coastal Ecosystems system. By 2100, these effects are long-term, with significant cascading impacts beyond the immediate damage. These cascading effects include the Biodiversity and Ecosystems, i.e., loss of species and degradation of habitats. Coastal birds are very important in food webs and their decline due to coastal ecosystem degradation/loss. including the loss of seabird nesting, breeding, and feeding grounds, could have cascading impacts on the biodiversity and ecosystems system. Further cascading effects include the Built Environment, i.e., the loss of coastal protection ecosystem services may increase exposure of assets to coastal erosion and flooding, the Energy System, i.e., the loss of coastal protection ecosystem services may increase exposure of assets to coastal erosion and flooding, the Food Production and Supply Chain System, i.e., increased exposure of saline contamination of agricultural land, and habitat loss and change also impacts on aquaculture operations and production, the Health System, i.e., spread of waterborne diseases, solastalgia, the Water Security System, i.e., contamination of freshwater resources by saline water, and the Social System, i.e., degradation of important landscapes for tourism and

recreation, leading to economic losses for communities that rely on these activities.

- **Change through time**: In both scenarios, sea level rise will increase at similar rates to 2050, however, beyond this point RCP8.5 has a higher sea level by the end of the century compared to RCP4.5.

9.3.1.4 Confidence

Hazard Confidence: There is high confidence that coastal flooding and coastal erosion will increase in frequency and severity in the future. Global projections, including those from the IPCC Assessment Report 6, have been used to inform sea level rise, while national projections for coastal change (erosion or accretion) are unavailable, with extrapolation of current erosion rates for 2050 used instead. Coastal flood extent and frequency changes have been assessed by the OPW using rigorous models, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used. There is less confidence in the spatial distribution of coastal erosion in the future due to limited assessment of future coastal change that includes the consideration of climate change.

Consequence Confidence: The impacts of coastal flooding and coastal erosion are already affecting Ireland and this impact will increase in the future. However, the spatial distribution of these impacts related to coastal erosion is still uncertain. Therefore, a medium level of confidence is assigned to the consequence of this risk.

9.3.1.5 Adaptation

To address the risk of coastal ecosystem degradation due to coastal erosion and flooding, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong policy frameworks and governance structures support adaptation, with planning regulations and Section 28 Guidelines managing coastal risks, and OPW schemes supporting flood mitigation and coastal defences.
- *Practices in Place:* The National Coastal Change Management Strategy includes national data analysis, a Coastal Defence Asset Database, and ensures new developments consider coastal risks through planning regulations and the National Catchment Flood Risk Assessment and Management Programme.
- *Monitoring and Early Warning Systems*: The National Coastal Change Management Strategy supports Met Éireann's Coastal Flood Forecast Service, OPW's coastal change monitoring, and establishes a national flood forecasting and warning service for timely alerts.

Resistance

- *Community Engagement and Education*: Community engagement and education build awareness of coastal ecosystem degradation through public awareness campaigns, community-led monitoring, and initiatives like the National Dialogue on Climate Action and the National Youth Assembly.
- *Research and Development:* The National Coastal Change Management Strategy and Ocean Knowledge 2030 support research on coastal erosion, inter-tidal zone mapping, risk assessment, and innovative coastal protection solutions.

Recovery and Response

- *Sector-Specific Adaptation Actions:* Specific adaptation actions in coastal management include supplementary planning guidance, Scheme Climate Change Adaptation Plans, and regular reviews of the Coastal Protection Scheme to maintain ecosystem resilience and health.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Effective for managing this risk.

9.3.1.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is to Sustain Current Action.

9.3.2 M02 Risk of coastal ecosystem degradation/loss due to wildfire

9.3.2.1 Risk Summary

Table 9.3: M02 Risk of coastal ecosystem degradation/loss due to wildfire.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of coastal ecosystem degradation/loss due to wildfire	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	Low					
Consequence Confidence	Medium					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

9.3.3 M03 Risk of marine habitat and ecosystem disturbances due to changes in average ocean conditions

9.3.3.1 Risk Summary

Table 9.4: M03 Risk of increases in occurrence of invasive and non-native species resulting in habitat and ecosystem disturbance due to changes in ocean conditions

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increases in occurrence of invasive and non-native species resulting in habitat and ecosystem disturbance due to changes in average ocean conditions	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Changes in average ocean conditions, such as variations in temperature, pH, salinity, de-oxygenation, and circulation, can impact marine ecosystems. These changes can create favourable conditions for invasive and non-native species to thrive, leading to habitat and ecosystem disturbances. Warmer waters extend the range of warm-water species, disrupting ecosystems by outcompeting native species. Thermal stress on native species opens niches for invasive species. Lower pH weakens marine organisms' shells and skeletons, making them more vulnerable. Fluctuations in salinity stress native species and create opportunities for adaptable invasive species. De-oxygenation reduces the oxygen available for marine life, leading to hypoxic conditions that can cause significant ecological disruptions and disrupt food webs. Changes in ocean circulation can alter nutrient distribution and impact the migration patterns of marine species.

As a result of these combined factors, marine fauna are impacted by increase in stress levels and making them more susceptible to pests and diseases. Warmer waters around Ireland can expand the range of infectious agents, introducing diseases to new areas. Ocean acidification, caused by increased CO_2 absorption, affects the calcification process in marine organisms, weakening their shells and

skeletons (see M07). Additionally, changes in salinity can disrupt the ion balance in marine organisms.

9.3.3.2 *Exposure and Vulnerability*

Sea surface temperature is projected to increase by between 0.4°C (0.3-0.8°C) in 2050 to 0.9°C (0.8-1.5°C) in 2100 under an RCP4.5 scenario and 0.7°C (0.5-1.1°C) in 2050 to 1.9°C (1.5-2.5°C) in 2100 under RCP8.5 scenario within the Irish Exclusive Economic Zone (EEZ) (IPCC AR6).

Additionally, sea surface pH level is estimated to decrease (increase in acidity) by 0.12 in 2050 and 0.13 by 2100 under an RCP4.5 scenario and 0.16 in 2050 and 0.17 in 2100 under an RCP8.5 scenario within the Irish EEZ.

9.3.3.3 *Consequence*

- **Damage**: Limited or rare losses initially, with increased substantial losses by 2050 and with large and frequent damage possible by 2100 under both scenarios. Ireland already experiences impact from this risk, for instance:
    - Over the past decade, there has been a significant increase in the abundance, geographical range and growth season of certain phytoplankton species in Irish waters (Murphy et al., 2024, Nolan et al. 2023), particularly in inshore waters. Examples of species that could establish themselves in Irish waters include *Alexandrium catenella* and *Gymnodinium catenatum*, both producers of paralytic shellfish poison commonly found in Spanish waters, and *Ostreopsis spp*., a toxin-producing benthic dinoflagellate now known to have a European distribution beyond the Mediterranean causing impacts on human respiratory health and beach closures..
- **System Functionality**: Changes in ocean conditions can cause temporary disturbances and short-term disruptions to Marine and Coastal Ecosystem system; however, by 2050, these disturbances could become more long-term if ocean conditions continue to change. By 2100, there may be irreversible losses within the system.

- **Extent and Pervasiveness**: All of the Irish EEZ will be exposed to changing oceanic conditions, affecting a wide range of marine species, resulting in a large extent and high pervasiveness of this risk.

- **Cascading Effects**: Temporary cascading effects are possible, potentially affecting other critical systems and services beyond the Marine and Coastal Ecosystems system. These cascading effects include the Health System, i.e., spread of marine-borne diseases, Food Production and Supply Chain System, i.e., reduced commercial fish stocks as a result of weakening shells, Biodiversity and Ecosystems, i.e., disruption of the natural food webs and ecological balance, and the Social System, i.e., loss or changes of commercial fishing and aquaculture sectors could negatively impact the economy and jobs that coastal communities depend on, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erode cultural identities and traditions.

- **Change through time**: Across both scenarios there is an increase in sea surface temperature and a decrease in pH at the surface identified in all waters surrounding Ireland, however, RCP8.5 will see the greatest levels of change. There is an increase in consequence from Limited to Substantial by 2050 in both scenarios, and due to the irreversible losses that are possible, critical levels of consequence are reached by 2100 in RCP8.5.

9.3.3.4 Confidence

Hazard Confidence: There is medium confidence that ocean conditions will change in the future. Global projections have been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6, however, national downscaled projections that align with the climate scenarios (RCP4.5 and RCP8.5) and future time periods (~2050, ~2100) used within the NCCRA are not available for variables such as sea surface temperature, near-bottom temperature, sea surface salinity, and near bottom salinity.

Consequence Confidence: There is Low confidence in the consequence. the impacts of this risk have already been observed, however there is uncertainty over the timing of future changes in ocean conditions and if irreversible losses will occur.

9.3.3.5 Adaptation

To address the risk of habitat and ecosystem disturbance due to invasive and non-native species, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong policy frameworks and governance structures support adaptation, with cross-sectoral collaboration developing national policies, and the Common Agricultural Policy and Bioeconomy Action Plan managing invasive species impacts on marine ecosystems.
- *Practices in Place:* The Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan has actions focussed on building resilience within the sector, with cross-sectoral collaboration developing policies, and the Common Agricultural Policy and Bioeconomy Action Plan supporting sustainable marine practices.
- *Monitoring and Early Warning Systems:* Effective monitoring and early warning systems manage invasive species impacts, with climate impact tracking, essential research proposals, and periodic reviews ensuring effective adaptation strategies.

Resistance

- *Community Engagement and Education:* Community engagement and education can build awareness of the impacts of invasive species impacts through public awareness campaigns, community-led monitoring, and initiatives like the National Dialogue on Climate Action and the National Youth Assembly.

- *Research and Development:* Research and development, supported by the Sectoral Adaptation Plan, focus on innovative solutions for managing invasive species and improving marine ecosystem resilience.

Recovery and Response

- *Sector-Specific Adaptation Actions:* Specific adaptation actions in marine and agricultural sectors include tracking climate impacts and periodic reviews to maintain marine ecosystem resilience and health.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

9.3.3.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

9.3.4 M04 Risk of decreases in reproduction rates of marine species due to changes in average ocean conditions

9.3.4.1 Risk Summary

Table 9.5: M04 Risk of decreases in reproduction rates of marine species due to changes in average ocean conditions

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of decreases in reproduction rates of marine species due to changes in average ocean conditions	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Changes in average ocean conditions, including variations in temperature, pH, salinity, acidification, de-oxygenation, and circulation, can significantly impact the reproductive rates of marine species. Temperature changes can alter metabolic rates and cause thermal stress, affecting reproductive success. Lower pH levels can dissolve calcium carbonate structures and interfere with reproductive processes. Variations in salinity can disrupt osmoregulation and alter habitat suitability, impacting reproductive capabilities. De-oxygenation reduces the oxygen available for marine life, leading to hypoxic conditions that can cause significant ecological disruptions. Changes in ocean circulation can alter nutrient distribution and impact the migration patterns of marine species. Additionally, altered pH levels can impair sensory abilities, affecting food location, predator avoidance, and navigation. The collapse of key species can disrupt food webs, impacting dependent species.

9.3.4.2 Exposure and Vulnerability

Sea surface temperature is projected to increase by between 0.4°C (0.3-0.8°C) in 2050 to 0.9°C (0.8-1.5°C) in 2100 under an RCP4.5 scenario and 0.7°C (0.5-

1.1°C) in 2050 to 1.9°C (1.5-2.5°C) in 2100 under RCP8.5 scenario within the Irish Exclusive Economic Zone (EEZ) (IPCC AR6).

Additionally, sea surface pH level is estimated to decrease (increase in acidity) by 0.12 in 2050 and 0.13 by 2100 under an RCP4.5 scenario and 0.16 in 2050 and 0.17 in 2100 under an RCP8.5 scenario within the Irish EEZ.

9.3.4.3 Consequence

- **Damage**: Limited or rare losses initially, with increased substantial losses by 2050 and with large and frequent damage possible by 2100 under both scenarios.
- **System Functionality**: Changes in ocean conditions can cause temporary disturbances and short-term disruptions to Marine and Coastal Ecosystem system; however, by 2050, these disturbances could become more long-term if ocean conditions continue to change. By 2100, there may be irreversible losses within the system.
- **Extent and Pervasiveness**: All of the Irish EEZ will be exposed to changing oceanic conditions, affecting a wide range of marine species, resulting in a large extent and high pervasiveness of this risk.
- **Cascading Effects**: Temporary cascading effects are possible, potentially affecting other critical systems and services beyond the Marine and Coastal Ecosystems system. These cascading effects include the Food Production and Supply Chain System, i.e., reduced commercial fish stocks and shellfish aquaculture production, Biodiversity and Ecosystems, i.e., disruption of the natural food webs and ecological balance, and the Social System, i.e., loss of commercial fishing industry could negatively impact the economy and jobs that coastal communities depend on, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erode cultural identities and traditions.
- **Change through time**: Across both scenarios there is an increase in sea surface temperature and a decrease in pH at the surface identified in all waters surrounding Ireland, however, RCP8.5 will see the greatest levels of change.

There is an increase in consequence from Limited to Substantial by 2050 in both scenarios, and due to the irreversible losses that are possible, critical levels of consequence are reached by 2100 in RCP8.5.

9.3.4.4 Confidence

Hazard Confidence: There is medium confidence that ocean conditions will change in the future. Global projections have been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6, however, national downscaled projections that align with the climate scenarios (RCP4.5 and RCP8.5) and future time periods (~2050, ~2100) used within the NCCRA are not available for variables such as sea surface temperature, near-bottom temperature, marine heatwaves, sea surface salinity, and near bottom salinity.

Consequence Confidence: Confidence in the consequence of this risk is low, as disentangling long-term anthropogenic activities, such as fishing, from the impacts of climate change is difficult. Climate change cannot be examined in isolation of these effects (Nolan et al., 2023).

9.3.4.5 Adaptation

To address the risk of decreases in reproduction rates of marine species due to changes in ocean conditions, several practices can be implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong policy frameworks and cross-sectoral collaboration develop national mitigation and adaptation policies, with the Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan strategically managing ocean conditions impacts.
- *Monitoring and Early Warning Systems:* Effective monitoring and early warning systems manage ocean chemistry impacts on marine species

reproduction, with climate impact tracking and research proposals aiding early detection and mitigation.

Resistance

- *Community Engagement and Education:* Community engagement and education can build awareness of how changing ocean conditions will impact marine life through public awareness campaigns, community-led monitoring, and initiatives like the National Dialogue on Climate Action and the National Youth Assembly.
- *Research and Development:* Research and development, supported by sectoral adaptation plans, focus on research to understand how ocean conditions will effect spawning and reproduction rates of marine life, and improving ecosystem resilience.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

9.3.4.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

9.3.5 M05 Risk of seafood contamination due to harmful algal bloom (HABs) events and microbiological sources

9.3.5.1 Risk Summary

Table 9.6: M05 Risk of seafood contamination due to harmful algal bloom (HABs) events and microbiological sources

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of seafood contamination due to harmful algal bloom (HABs) events microbiological sources	Limited	Substantial	Substantial	Limited	Substantial	Substantial
Urgency	Further Investigation					
Hazard Confidence	Low					
Consequence Confidence	Low					

Harmful algal bloom (HAB) events pose a significant risk to seafood, particularly shellfish, in Ireland. These blooms occur when algae grow excessively, where some phytoplankton species produce toxins that can be harmful to fish, resulting in behaviour changes, stress or mortalities. These toxins also contaminate shellfish (bivalve molluscs), leading to serious health risks known as shellfish poisonings when consumed (i.e., amnesic, diarrhetic, azaspiracid and paralytic). In addition to the potential risk to the food chain supply and human safety, the economic impact on the seafood industry can be substantial, with prolonged closures of shellfish farms resulting in loss of income and increased monitoring costs.

Other impacts of HAB events, including non-toxin producing high biomass phytoplankton bloom species, can result in negative marine ecosystem effects and impacts such as anoxia, water discoloration, mucilage, and mechanical damage to fish gills.

Urban wastewater discharges, particularly untreated stormwater overflows, can cause significant microbial contamination of the marine environment. Bivalve

molluscs grown in impacted areas can become contaminated by human pathogens, presenting a public health risk for consumers.

9.3.5.2 *Exposure and Vulnerability*

Sea surface temperature is projected to increase by between 0.4°C (0.3-0.8°C) in 2050 to 0.9°C (0.8-1.5°C) in 2100 under an RCP4.5 scenario and 0.7°C (0.5-1.1°C) in 2050 to 1.9°C (1.5-2.5°C) in 2100 under RCP8.5 scenario within the Irish Maritime Exclusive Economic Zone (IPCC AR6).

In terms of seasonality, the winter season is projected to experience the highest increase in precipitation of 11.5% (3.8-19.2%) (RCP4.5) and 20.9% (10.0-33.0%) (RCP8.5) by 2100. The summer season is expected to see a decrease in precipitation of -2.0% (-12.9 — -6.8%) (RCP4.5) and -7.3% (-21.8 — -6.6%) (RCP8.5) by 2100. All NUTS3 regions are projected to experience an increase in five-day precipitation across both RCP4.5 (10.2% (0.4 - 21.1%) by 2100) and RCP8.5 (16.5% (3.8 - 31.4%) by 2100). Similarly, each region will see an increase in the number of very wet days under both RCP4.5 (an increase of 0.8 days (0.3 - 1.3 days per year) by 2100) and RCP8.5 (an increase of 1.4 days (0.7-2.1 days per year) by 2100).

In Ireland, aquaculture sites exist for salmon, mussels, oysters, scallops, and seaweed. Sites are primarily located along in the NUTS3 regions of the Border, West, South-West, and Mid-West. Sites that are situated close to rivers/streams are particularly vulnerable due to the in the increase in surface run-off during heavy precipitation events.

9.3.5.3 *Consequence*

- **Damage:** Limited or rare losses initially, with increased substantial losses by 2050 and 2100 under both scenarios.
    - In 2012, a harmful algal bloom (HAB) caused many fish deaths in Irish waters, including turbot, flounder, and scorpion fish. The north-west of Ireland was the most affected, with beaches in Rossnowlagh and Murvagh closed due to dead fish washing ashore (Murphy et al., 2023).

    - An expansion of the phytoplankton growth season (for some species) has already been observed over the last 20 years. Changing environmental conditions, driven in part by climate change, can result in multiple environmental stressors influencing HABs (Nolan et al., 2023).

- **System Functionality:** While most Harmful algal bloom events can cause temporary disturbances and short-term disruptions to Marine and Coastal Ecosystems, there are examples of HABs lasting for months. However, by 2050, these disturbances could become more long-term if the frequency and severity of events increases.

- **Extent and Pervasiveness:** All of the Irish EEZ will be exposed to changing oceanic conditions, affecting a wide range of marine species, resulting in a large extent and high pervasiveness of this risk. However, exposure is predominantly restricted to aquaculture sites, particularly, shellfish aquaculture and finfish aquaculture. A significant number of shellfish growing areas are currently impacted by urban wastewater discharges and extensive legislation and management controls are in place to mitigate the impacts.

- **Cascading Effects:** There are temporary cascading effects of this risk on the Food Production and Supply Chain System, i.e., reduction in seafood supply, the Health System, i.e., human health issues such as respiratory problems, skin irritation, and gastrointestinal issues, and the Social System, i.e., loss of aquaculture industry could negatively impact the economy and jobs that coastal communities depend on, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erode cultural identities and traditions. Additionally, there is potential for cascading effects on the Biodiversity and Ecosystems, i.e., disruption of food webs and ecological balance.

- **Change through time:** HABs are expected to increase in the future due to changing ocean conditions, leading to a potential increase in damage. There may be an increase in exposure if there is a growth in this industry as outlined in The National Strategic Plan for Sustainable Aquaculture Development 2030. Increasing frequency and intensity of rainfall events are also projected.

These are likely to lead to greater contamination of shellfish growing areas and an increased risk for shellfish consumers.

9.3.5.4 Confidence

Hazard Confidence: There is low confidence that HABs will increase in frequency and severity in the future as there are limited climate projections available related to the changes in HABs for Ireland, with no national scale projections, therefore IPCC AR6 sea surface temperature and pH surface information have been used. There is low confidence in the climate projections related to precipitation (annual precipitation, winter precipitation, five-day precipitation, and very wet days) as there are low agreement in the TRANSLATE ensemble for the direction and degree of change.

HABs are influenced by various factors, including eutrophication. More research is needed to understand how rainfall affects HABs. Agricultural runoff, which can carry high nutrient loads depending on farming practices, may contribute to high biomass blooms in coastal areas if the freshwater runoff contains significant nutrients.

Consequence Confidence: There is low confidence in the consequence of this risk because the timing of the effect of climate change on HABs is uncertain. Furthermore, the future growth of the aquaculture industry is uncertain and therefore the exposure to HABs is unknown..

9.3.5.5 Adaptation

To address the risk of seafood contamination due to HAB and microbiological contamination events, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong policy frameworks and cross-sectoral collaboration develop national mitigation and adaptation policies, with the

Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan highlighting HAB as a risk for the sector.

- *Practices in Place:* The Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan guides sectors in adapting to HABs, with cross-sectoral collaboration developing national policies for sustainable aquaculture management.
- *Monitoring and Early Warning Systems:* Effective monitoring and early warning systems, along with a climate network of sentinel sites in aquaculture areas and periodic reviews, are crucial for managing HAB impacts on seafood safety and ensuring adaptive strategies remain effective. Ongoing regulatory classification of shellfish harvesting areas based on bacterial levels is a key control to mitigate public health risks associated with microbiological contamination. However, this does not fully mitigate risks associated with human viruses.

Resistance

- *Community Engagement and Education:* Community engagement, education, public awareness campaigns, and initiatives like the National Dialogue on Climate Action and the National Youth Assembly are vital for building awareness of HAB impacts on seafood safety through monitoring, reporting, and public participation.
- *Research and Development:* Research and development, supported by the Sectoral Adaptation Plan and climate impact proposals, focus on innovative solutions to manage HABs and enhance aquaculture resilience for seafood safety.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

9.3.5.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

9.3.6 M06 Risk of species distribution shifts and changes in ecosystem dynamics due to changes in average ocean conditions

9.3.6.1 Risk Summary

Table 9.7: M06 Risk of species distribution shifts and changes in marine ecosystem functioning due to changes in average ocean conditions.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of species distribution shifts and changes in ecosystem dynamics due to changes in average ocean conditions	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Changes in average ocean conditions, particularly due to temperature, pH, salinity, acidification, de-oxygenation, and circulation changes, significantly impact species distribution and ecosystem dynamics. Hypoxia, or low oxygen levels, often accompanies acidification, causing mass die-offs and disrupting food webs. These changes force many marine species to migrate to more favourable environments, potentially altering community structures. Consequently, shifts in species distribution and abundance can have cascading effects on ecosystem dynamics, affecting nutrient cycling, habitat structure, food web dynamics, and overall productivity. Trophic guild dynamics, which involve the interactions and relationships among groups of species with similar feeding habits, are particularly affected. Alterations in the distribution and abundance of species within these guilds can disrupt the flow of energy and nutrients through the food web, leading to changes in the balance and interactions within the ecosystem.

9.3.6.2 Exposure and Vulnerability

Sea surface temperature is projected to increase by between 0.4°C (0.3-0.8°C) in 2050 to 0.9°C (0.8-1.5°C) in 2100 under an RCP4.5 scenario and 0.7°C (0.5-

1.1°C) in 2050 to1.9°C (1.5-2.5°C) in 2100 under RCP8.5 scenario within the Irish Exclusive Economic Zone (EEZ) (IPCC AR6).

Additionally, sea surface pH level is estimated to decrease (increase in acidity) by 0.12 in 2050 and 0.13 by 2100 under an RCP4.5 scenario and 0.16 in 2050 and 0.17 in 2100 under an RCP8.5 scenario within the Irish EEZ.

9.3.6.3 Consequence

- **Damage**: Limited or rare losses initially, with increased substantial losses by 2050 and with large and frequent damage possible by 2100 under both scenarios.
- **System Functionality:** Changes in ocean conditions can cause temporary disturbances and short-term disruptions to Marine and Coastal Ecosystem system; however, by 2050, these disturbances could become more long-term if ocean conditions continue to change. By 2100, there may be irreversible losses within the system.
- **Extent and Pervasiveness:** All of the Irish EEZ will be exposed to changes in ocean conditions, affecting a wide range of marine species, resulting in a large extent and high pervasiveness of this risk.
- **Cascading Effects:** There is potential for cascading effects on the Food Production and Supply Chain System, i.e., reduction or loss of commercial fisheries, and the System Social System, i.e., loss of commercial fishing industry could negatively impact the economy and jobs that coastal communities depend on, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erode cultural identities and traditions.
- **Changes through time:** Currently, there is a mixture of stock trajectories within the Irish EEZ, with some stocks rebuilding well following overexploitation by fisheries. Average overall fishing mortality rates have declined in the Celtic Seas ecoregion since around the year 2000 with subsequent increases in spawning stock biomasses. Some stocks remain at levels of exploitation above current scientific advice. Declines in over-exploited fish stocks may be exacerbated by climate change.

9.3.6.4 Confidence

Hazard Confidence: There is medium confidence that ocean conditions will change in the future. Global projections have been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6, however, national downscaled projections that align with the climate scenarios (RCP4.5 and RCP8.5) and future time periods (~2050, ~2100) used within the NCCRA are not available for variables such as sea surface temperature, near-bottom temperature, marine heatwaves, sea surface salinity, and near bottom salinity.

Consequence Confidence: Confidence in the consequence of this risk is low, as disentangling long-term anthropogenic activities, such as fishing, from the impacts of climate change is difficult. Climate change cannot be examined in isolation of these effects (Nolan et al., 2023).

9.3.6.5 Adaptation

To address the Risk of species distribution shifts and changes in ecosystem dynamics due to changes in ocean chemistry, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong frameworks and cross-sectoral collaboration develop national policies and the Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan for managing changes in ocean conditions.
- *Monitoring and Early Warning Systems:* Effective systems track climate impacts on species and ecosystems, aiding early detection and response, supported by research on climate change impacts.

Resistance

- *Community Engagement and Education:* Public awareness campaigns, community-led monitoring, and initiatives like the National Dialogue on

Climate Action and the National Youth Assembly build awareness of ocean chemistry changes.

- *Research and Development:* Supported by sectoral adaptation plans, ongoing research develops our understanding of how ocean conditions are changing, the impacts it will have on marine life and how marine ecosystem resilience could be enhanced. The Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan includes actions on developing research on the change and the distribution of fish and fisheries.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

9.3.6.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

9.3.7 M07 Risk of increased mortality of cold-water coral reefs and shellfish due to ocean acidification

9.3.7.1 Risk Summary

Table 9.8: M07 Risk of increased mortality of cold-water coral reefs and shellfish due to ocean acidification.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased mortality of cold-water coral reefs and shellfish due to ocean acidification	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Ocean acidification poses a significant risk of increased mortality for cold-water coral reefs and shellfish in Ireland. Acidic conditions weaken coral skeletons, making them more susceptible to erosion and collapse. Similarly, shellfish, such as oysters and mussels, struggle to build and maintain their calcium carbonate shells in more acidic waters, leading to higher mortality rates. This can lead to the decline of these vital ecosystems, which support a diverse range of marine life.

9.3.7.2 Exposure and Vulnerability

Sea surface pH level is estimated to decrease (increase in acidity) by 0.12 in 2050 and 0.13 by 2100 under an RCP4.5 scenario and 0.16 in 2050 and 0.17 in 2100 under an RCP8.5 scenario within the Irish EEZ.

Cold water coral reefs are found within 200–1600 m depth where the water temperature is 4–8ºC and the salinity is 32–36% and are generally located close to the continental shelf slope and on the Rockall Bank (National Parks and Wildlife Service, n.d.). Corals are also recorded on the Hatton Bank. The typical reef forming species are Lophelia pertusa and Madrepora oculate. Living

Lophelia pertusa and Madrepora oculate may be resilient to acidification. However, as water becomes undersaturated towards the end of the century under high scenarios, the reef structures will be at risk due to the tendency for dissolution.

9.3.7.3 Consequence

- **Damage:** Limited or rare losses initially with an increase to substantial losses by 2050 in both scenarios. It will maintain a substantial level under a RCP4.5 by 2100 increasing to a large and frequent level of damage under a RCP8.5 scenario

- **System Functionality:** Ocean acidification can cause temporary disturbances and short-term disruptions to Marine and Coastal Ecosystems; however, under a RCP8.5 Scenario, these disturbances could become more chronic and therefore long-term if the frequency of these events increases.

- **Extent and Pervasiveness:** All of the Irish EEZ will be exposed to changing oceanic conditions, affecting a wide range of marine species and plankton, resulting in a large extent and high pervasiveness of this risk.

- **Cascading Effects:** There is potential for cascading effects on the Food Production and Supply Chain System, i.e., reduction or loss of commercial fisheries, and the System Social System, i.e., loss of commercial fishing industry, e.g., shellfish aquaculture, could negatively impact the economy and jobs that coastal communities depend on, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erode cultural identities and traditions.

- **Changes through time:** Across both scenarios there is an increase in sea surface temperature and a decrease in pH at the surface identified in all waters surrounding Ireland, however, RCP8.5 will see the greatest levels of change. There is an increase in consequence from Limited to Substantial by 2050 in both scenarios, and due to the irreversible losses that are possible, critical levels of consequence are reached by 2100 in RCP8.5.

9.3.7.4 Confidence

Hazard Confidence: There is medium confidence that ocean chemistry will change in the future. Global projections have been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6, however, national downscaled projections that align with the climate scenarios (RCP4.5 and RCP8.5) and future time periods (~2050, ~2100) used within the NCCRA are not available for variables such as sea surface salinity, and near bottom salinity.

Consequence Confidence: There is Low confidence in the consequence as there is uncertainty over the timing of future changes in ocean chemistry and if irreversible losses will occur.

9.3.7.5 Adaptation

To address the risk of increased mortality of cold-water coral reefs and shellfish due to ocean acidification, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong frameworks and cross-sectoral collaboration develop national policies and the Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan for managing ocean acidification impacts.
- *Monitoring and Early Warning Systems:* Effective systems track ocean pH changes and manage impacts on coral reefs and shellfish, supported by research on climate change impacts.

Resistance

- *Community Engagement and Education:* Public awareness campaigns, community-led monitoring, and initiatives like the National Dialogue on Climate Action and the National Youth Assembly build awareness of ocean acidification impacts.

- *Research and Development:* Supported by sectoral adaptation plans, ongoing research develops innovative solutions to manage ocean acidification impacts and enhance marine ecosystem resilience.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

9.3.7.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

9.3.8 M08 Risk of degradation and loss of marine ecosystems and habitats due to phenological changes

9.3.8.1 Risk Summary

Table 9.9: M08 Risk of degradation and loss of marine ecosystems and habitats due to phenological changes.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of degradation and loss of marine ecosystems and habitats due to phenological changes	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Low					

Phenological changes, such as shifts in the timing of breeding, migration, and blooming, pose a significant risk of degradation and loss of marine ecosystems and habitats. These changes can disrupt the synchronisation between species and their environment, leading to mismatches in food availability, altered predator-prey relationships, and reduced reproductive success. Additionally, phenological changes can affect the timing of plankton blooms, which are crucial for the marine food web, impacting species that rely on them for food. These disruptions can cascade through the ecosystem, affecting biodiversity and the overall health of marine habitats. Key climate drivers in Ireland include rising sea temperatures, ocean acidification, sea-level rise, marine heatwaves, changes in salinity, cold spells, and hypoxia. These factors collectively contribute to the observed shifts in marine phenology and their cascading effects on marine ecosystems.

9.3.8.2 Exposure and Vulnerability

Sea surface temperature is projected to increase by between 0.4°C (0.3-0.8°C) in 2050 to 0.9°C (0.8-1.5°C) in 2100 under an RCP4.5 scenario and 0.7°C (0.5-

1.1°C) in 2050 to.9°C (1.5-2.5°C) in 2100 under RCP8.5 scenario within the Irish Exclusive Economic Zone (EEZ) (IPCC AR6).

Additionally, sea surface pH level is estimated to decrease (increase in acidity) by 0.12 in 2050 and 0.13 by 2100 under an RCP4.5 scenario and 0.16 in 2050 and 0.17 in 2100 under an RCP8.5 scenario within the Irish EEZ.

9.3.8.3 Consequence

- **Damage**: Limited or rare losses initially with an increase to substantial losses by 2050 in both scenarios. It will maintain a substantial level under a RCP4.5 by 2100 increasing to a large and frequent level of damage under a RCP8.5 scenario.

- **System Functionality:** Changes in ocean conditions can cause temporary disturbances and short-term disruptions to Marine and Coastal Ecosystem system. However, by 2050, these disturbances could become more long-term if phenological changes, such as shifts in the timing of biological events, continue. By 2100, there may be irreversible losses within the system in RCP8.5.

- **Extent and Pervasiveness:** It is estimated that all of the Irish EEZ will be exposed to changing ocean conditions, which could cause changes in phenological cycles, resulting in a large extent and high pervasiveness of this risk.

- **Cascading Effects:** There is potential for cascading effects on the Food Production and Supply Chain System, i.e., reduction or loss of commercial fisheries, and the System Social System, i.e., loss of commercial fishing industry could negatively impact the economy and jobs that coastal communities depend on, leading to economic instability, loss of livelihoods, and increased poverty in affected regions, and erosion of cultural identities and traditions. There is potential for cascading effects on the Biodiversity and Ecosystems, i.e., disruption of food webs and ecological balance.

- **Changes through time:** Across both scenarios there is an increase in sea surface temperature and a decrease in pH at the surface identified in all waters

surrounding Ireland which could potentially alter phenological cycles, however, RCP8.5 will see the greatest levels of change. There is an increase in consequence from Limited to Substantial by 2050 in both scenarios, and due to the irreversible losses that are possible, critical levels of consequence are reached by 2100 in RCP8.5.

9.3.8.4 Confidence

Hazard Confidence: There is medium confidence that ocean conditions will change in the future. Global projections have been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6, however, national downscaled projections that align with the climate scenarios (RCP4.5 and RCP8.5) and future time periods (~2050, ~2100) used within the NCCRA are not available for variables such as sea surface temperature, near-bottom temperature, marine heatwaves, sea surface salinity, and near bottom salinity.

Consequence Confidence: There is Low confidence in the consequence as there is uncertainty over the timing of future changes in ocean conditions and if irreversible losses will occur.

9.3.8.5 Adaptation

To address the risk of degradation and loss of marine ecosystems and habitats due to phenological changes, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Effective frameworks and cross-sectoral collaboration ensure comprehensive, inclusive, and updated policies for successful adaptation actions.
- *Practices in Place:* The Agriculture, Forest, and Seafood Climate Change Sectoral Adaptation Plan and cross-sectoral collaboration outline

measures for sectors to mitigate and adapt to climate impacts, ensuring sustainable marine ecosystem management.

- *Monitoring and Early Warning System:* Robust systems track climate impacts and invasive species, aiding early detection and timely interventions for marine ecosystem protection.

Resistance

- *Community Engagement and Education:* Awareness efforts, educational programs, and community initiatives foster stewardship and sustainable practices to address climate impacts on marine ecosystems.
- *Cross-Sectoral Collaboration:* Involving government, NGOs, and the private sector ensures robust adaptation actions through shared knowledge, resources, and best practices.

Recovery and Response

- No recovery and response measures were identified.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Slightly Effective for managing this risk.

9.3.8.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

10 Social

10.1 System Description

The Social system describes societal structures and governance systems. In this sense, the Social system refers to the way in which civil society and communities respond to climate change risks. It concerns community wellbeing, social cohesion, as well as trust and equality in society. The Social system is split into two sub-systems – governance and society.

In terms of governance, elements at risk include emergency services, social cohesion, and any and all governing and institutional systems. Within the society sub-system, elements at risk include community wellbeing, employment and financial wellbeing, equity, skills and education, and social welfare services.

The Social system cuts across all policy sectors for adaptation in terms of its relevance. The adaptation actions of each sector can support the Social system to be ready for and respond to the effects of climate change by ameliorating the impacts of risks on community wellbeing. Therefore, the Social system has a high level of interconnectedness with preparedness and response adaptation measures put in place by each sector.

10.2 Summary of Climate Change Risks

Table 10.1 shows a summary of the consequences for the risks identified to the Social System under both RCP4.5 and RCP8.5 scenarios across three-time horizons (2030, 2050, and 2100).

Table 10.1: Summary of Climate Change Risks in the Social System. Lim = Limited, Sub = Substantial, Cri = Critical, Cat = Catastrophic.

ID	Risk	Consequence RCP4.5			Consequence RCP8.5		
		2030	2050	2100	2030	2050	2100
S01	Risk of compromised emergency responses, loss of public trust in government, and exacerbation of social justice issues due to maladaptation to climate change	Limited	Substantial	Critical	Limited	Substantial	Catastrophic
S02	Risk of exacerbating societal inequalities as a result of impacts on community wellbeing, employment, education, and social services due to climate change	Limited	Substantial	Critical	Limited	Substantial	Critical

10.3 Risks

10.3.1 S01 Risk of compromised emergency responses, loss of public trust in government, and exacerbation of social justice issues due to maladaptation to climate change.

10.3.1.1 Risk Summary

Table 10.2: S01 Risk of compromised emergency responses, loss of public trust in government, and exacerbation of social justice issues due to maladaptation to climate change.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of compromised emergency responses, loss of public trust in government, and exacerbation of social justice issues due to maladaptation to climate change	Limited	Substantial	Critical	Limited	Substantial	Catastrophic
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Low					

Climate change maladaptation in Ireland may compromise emergency responses, eroding public trust in government. Ineffective adaptation strategies can exacerbate social justice issues, disproportionately affecting vulnerable communities. Vulnerable populations, including low-income communities, the elderly, people with disabilities, and marginalised groups, are most exposed to the risks. Delayed or inadequate emergency services during extreme weather events, can lead to increased casualties and property damage. Perceived or actual government inaction or ineffective policies can erode public confidence, leading to social unrest and decreased cooperation with authorities. Inequitable distribution of resources and support during climate crises can deepen existing inequalities, leaving vulnerable communities disproportionately affected. Ensuring equitable and effective climate policies is crucial to maintaining public confidence and safeguarding all citizens.

10.3.1.2 Exposure and Vulnerability

The change in mean temperature is used as an overall proxy for exposure to climate change and the necessity for adaptation. All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C by 2050, and 1.5°C by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C by 2050, and 2.7°C by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C by 2100) and RCP8.5 (2.7°C by 2100) scenarios.

The whole of Irish society is exposed to this risk. As of the Census 2021, the population in Ireland is 5,149,139 people. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)),

Vulnerable populations, such as the elderly, children, and those with pre-existing health conditions, are disproportionately affected, potentially leading to higher rates of morbidity and mortality. Based on Census 2021, 776,315 people in Ireland are aged over 65. This means that 15.08% of the population are over 65. The highest proportion of over 65-year-olds are in the West (17.2%) and Border (17.2%) regions. The number of people aged over 65 anticipated to double from 2022 (c.781,000) to 2042 (c.1.4 million), growing from 15% of the population to 23% (CSO 2024, M2 scenario).

10.3.1.3 Consequence

- **Damage:** Limited or rare losses initially with an increase to substantial losses by 2050 in both scenarios. It will increase to critical levels under a RCP4.5 by 2100, however, damage will potentially increase to a very large and frequent levels under a RCP8.5 scenario.

- **System Functionality:** Initially there will be a temporary or moderate disturbance on this system, however, as the impacts of climate change increase in the future, the Social system will potentially face long-term disturbances.

- **Extent and Pervasiveness:** This risk will have a large extent and very high pervasiveness, with all parts of society impacted, especially within the RCP8.5 scenario.

- **Cascading Effects:** If there is compromised emergency response, this could have temporary and long-term impacts on the Built Environment System, i.e., damage to buildings and infrastructure, the Health System, i.e., physical and mental health wellbeing, increase in healthcare service demand, and the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, emergency response, and welfare costs. The Social System is highly interconnected with all systems, meaning all risks could worsen if maladaptation occurs. This could lead to long-term and irreversible cascading effects across all systems, significantly impacting the Social System.

- **Changes through time**: As the impacts of climate change increase, there is potential for increased emergency response, government action, and adaptation. If these are not provided, or effective, there will be an increase in the impacts of this risk. Furthermore, there is a projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and the rise in the over-65 population, increasing exposure and vulnerability.

10.3.1.4 Confidence

Hazard Confidence: There is a High-level confidence in the increasing temperature projections, and therefore climate change, which are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is low confidence in the consequence as there is uncertainty on the timing of the increase in consequence, and the impact of the cascading risks from the other system will have on this system.

10.3.1.5 Adaptation

To address the risk of compromised emergency responses, loss of public trust in government, and exacerbation of social justice issues due to maladaptation to climate change, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong policy frameworks and governance structures support adaptation (National Adaptation Framework, Climate Action Plan), with coordinated severe weather responses, while building regulations and the National Broadband Plan enhance infrastructure resilience and connectivity.
- *Practices in Place:* The National Dialogue on Climate Action, "Climate Change in the Irish Mind" initiative, and National Youth Assembly engage diverse groups in climate discussions, while humanitarian relief schemes, media notices, and remote working strategies ensure resource availability and communication during extreme weather.
- *Monitoring and Early Warning Systems:* The National Incident Management System reports extreme weather events, circulates severe weather warnings to staff, and Uisce Éireann's text alerts and emergency water supplies support vulnerable customers during emergencies.

Resistance

- *Community Engagement and Education:* The National Dialogue on Climate Action and the National Youth Assembly promote public participation and awareness, while public health risk assessments and advice during air pollution events help communities respond to health risks, and the National Broadband Plan keeps remote and vulnerable communities connected.
- *Research and Development:* Initiatives like "Climate Change in the Irish Mind" offer insights into public perceptions and behaviours, informing climate adaptation strategies and policies.

Recovery and Response

- *Sector-Specific Adaptation Actions:* The Energy Interconnector from Ireland to France boosts energy security, while emergency response planning and HSE emergency management ensure health services and critical infrastructure remain operational during climate events.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

10.3.1.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

10.3.2 S02 Risk of exacerbating societal inequalities as a result of impacts on community wellbeing, employment, education, and social services due to climate change.

10.3.2.1 Risk Summary

Table 10.3: S02 Risk of exacerbating societal inequalities as a result of impacts on community wellbeing, employment, education, and social services due to climate change.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of exacerbating societal inequalities as a result of impacts on community wellbeing, employment, education, and social services due to climate change	Limited	Substantial	Critical	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	High					
Consequence Confidence	Low					

Climate change impacts in Ireland risk exacerbating societal inequalities by affecting community wellbeing, employment, education, and social services. Vulnerable populations may face heightened challenges, deepening existing disparities. Addressing these issues through inclusive and equitable adaptation strategies is essential to mitigate adverse effects and promote social cohesion. Vulnerable populations, including low-income households, the elderly, people with disabilities, and marginalised communities, are most exposed to the risks of exacerbated societal inequalities due to climate change impacts on community wellbeing, employment, education, and social services. A number of risks are involved including; An increase in mental health issues and reduced access to healthcare services in affected areas. Job losses in climate-sensitive sectors like agriculture and tourism, disproportionately affecting low-income workers. Disruptions to schooling due to extreme weather events, impacting students' learning and future opportunities. Strain on social services as demand increases, leading to reduced support for those in need. This risk can increase the

vulnerability of the population, exacerbating the risks across all systems where people are exposed.

10.3.2.2 Exposure and Vulnerability

The change in mean temperature is used as an overall proxy for climate change. All NUTS3 regions are projected to experience an increase in air temperature. In an RCP4.5 scenario daily mean temperature is projected to increase by 1.1°C by 2050, and 1.5°C by 2100. In an RCP8.5 scenario daily mean temperature is projected to increase by 1.5°C by 2050, and 2.7°C by 2100. The Mid-East and South-East regions most affected across both RCP4.5 (1.5°C by 2100) and RCP8.5 (2.7°C by 2100) scenarios.

The whole of Irish society is exposed to this risk. As of the Census 2021, the population in Ireland is 5,149,139 people. There is also a projected increase in population (increase of 1.124 million by 2040 (High Migration Scenario, ESRI (2024)),

Vulnerable populations, such as the elderly, children, and those with pre-existing health conditions, are disproportionately affected, potentially leading to higher rates of morbidity and mortality. Based on Census 2021, 776,315 people in Ireland are aged over 65. This means that 15.08% of the population are over 65. The highest proportion of over 65-year-olds are in the West (17.2%) and Border (17.2%) regions. The number of people aged over 65 anticipated to double from 2022 (c.781,000) to 2042 (c.1.4 million), growing from 15% of the population to 23% (CSO 2024, M2 scenario).

10.3.2.3 Consequence

- **Damage:** Limited or rare losses initially with an increase to substantial losses by 2050 in both scenarios. It will increase to critical levels under a RCP4.5 by 2100, however, damage will potentially increase to a very large and frequent levels under a RCP8.5 scenario.

- **System Functionality:** Initially there will be a temporary or moderate disturbance on this system, however, as the impacts of climate change

increase in the future, the Social system will potentially face long-term disturbances.

- **Extent and Pervasiveness:** This risk will have a large extent and very high pervasiveness, with all parts of society impacted, especially within the RCP8.5 scenario.

- **Cascading Effects:** If social inequalities are exacerbated, increase the vulnerability of the population, exacerbating the risks across all systems where people are exposed (temporarily and in the long-term). In turn, there will be temporary to long-term impacts on the Health System, i.e., physical and mental health wellbeing, increase in healthcare service demand, and the Economy and Finance System, e.g., increased expenditure, such as repairs, maintenance, insurance premia, emergency response, and welfare costs. The Social System is highly interconnected with all systems, meaning all risks could worsen if maladaptation occurs. This could lead to long-term and irreversible cascading effects across all systems, significantly impacting the Social System.

- **Changes through time**: As the impacts of climate change increase, there is potential for increased emergency response, government action, and adaptation. If these are not provided, or effective, there will be an increase in the impacts of this risk. Furthermore, there is a projected population increase of 1.124 million by 2040 (High Migration Scenario, ESRI, 2024) and the rise in the over-65 population, increasing exposure and vulnerability.

10.3.2.4 Confidence

Hazard Confidence: There is a High-level confidence in the increasing temperature projections, and therefore climate change, which are provided by the national downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

Consequence Confidence: There is low confidence in the consequence as there is uncertainty on the timing of the increase in consequence, and the impact of the cascading risks from the other system will have on this system.

10.3.2.5 Adaptation

To address the risk of exacerbating societal inequalities due to climate change impacts on community wellbeing, employment, education, and social services, several practices have been implemented. These measures help manage impacts and ensure resilience.

Reliability

- *Policy and Governance:* Strong policy frameworks and governance structures support adaptation, with coordinated severe weather responses, while building regulations and the National Broadband Plan enhance infrastructure resilience and connectivity.
- *Practices in Place:* The National Dialogue on Climate Action and National Youth Assembly engage diverse groups in climate discussions, while securing water supply by boreholes, humanitarian relief schemes, media notices, and remote working strategies ensure resource availability and communication during extreme weather.
- *Monitoring and Early Warning Systems:* The National Incident Management System reports extreme weather events and circulates warnings, while Uisce Éireann's text alerts and emergency water supplies support vulnerable customers during emergencies.

Resistance

- *Community Engagement and Education:* The National Dialogue on Climate Action and National Youth Assembly foster public participation and awareness, while public health risk assessments and advice during air pollution events help communities respond to health risks, and the National Broadband Plan keeps remote and vulnerable communities connected.

- *Research and Development:* "Climate Change in the Irish Mind" provides insights into public perceptions and behaviours, informing climate adaptation strategies and policies.

Recovery and Response

- *Sector-Specific Adaptation Actions:* The Energy Interconnector from Ireland to France enhances energy security, while emergency response planning and HSE emergency management ensure health services and critical infrastructure remain operational during climate events.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

10.3.2.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

11 Water Security

11.1 System Description

The Water Security system focuses on the availability and management of water resources. The main sub-system of Water Security therefore is water supply. The elements of water supply at risk of climate change are agricultural use, civil and domestic use, economy, energy use, environment, industry and service use, and water quality.

Ireland's biodiversity and ecosystems are already experiencing significant pressures and of the 59 habitats listed for Ireland in EU Habitats Directive (92/43/EEC), most have an unfavourable status with almost half showing ongoing declines (NPWS, 2019a). This means that the Water Security System will be further strained by the compounding effects of climate change, making it more difficult for the system to adapt and recover in the face of the additional impacts of climate change.

Water Security as a system is relevant across adaptation sectors but is most relevant for the Water Quality and Water Services Infrastructure sector. Water security also has relevance for the Biodiversity, Electricity and Gas Networks, Flood Risk Management, Built Environment and Planning, Health, Agriculture, Forestry, Seafood, and Tourism sectors. At an EU level, the Water Security System is also relevant to the Business and Industry and Financial sectors, which do not map directly to an adaptation policy sector in the Irish context.

11.2 Summary of Climate Change Risks

Table .1 shows a summary of the consequences for the risks identified to the Water Security System under both RCP4.5 and RCP8.5 scenarios across three-time horizons (2030, 2050, and 2100).

Table 11.1: Summary of Climate Change Risks in the Water Security System. Lim = Limited, Sub = Substantial, Cri = Critical, Cat = Catastrophic.

ID	Risk	Consequence RCP4.5			Consequence RCP8.5		
		2030	2050	2100	2030	2050	2100
WS01	Risk of contamination of water supply due to saline intrusion as a result of sea level rise and coastal flooding	Lim	Lim	Lim	Lim	Lim	Lim
WS02	Risk of increased demand on water supply due to extreme cold	Lim	Lim	Lim	Lim	Lim	Lim
WS03	Risk of water supply contamination as a result of overland flows of pollutants to watercourses due to extreme precipitation	Sub	Sub	Cri	Sub	Sub	Cri
WS04	Risk of contamination of water supplies due to flooding (fluvial, surface water, and groundwater)	Sub	Sub	Sub	Sub	Sub	Sub
WS05	Risk of reduced water supply and increases in water demand due to drought conditions and extreme heat	Lim	Sub	Sub	Lim	Sub	Cri

11.3 Risks

11.3.1 WS01 Risk of contamination of water supply due to saline intrusion as a result of sea level rise and coastal flooding

11.3.1.1 Risk Summary

Table 11.2: WS01 Risk of contamination of water supply due to saline intrusion as a result of sea level rise and coastal flooding.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of contamination of water supply due to saline intrusion as a result of sea level rise and coastal flooding	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	High					
Consequence Confidence	Low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

11.3.2 WS02 Risk of increased demand on water supply due to extreme cold

11.3.2.1 Risk Summary

Table 11.3: WS02 Risk of increased demand on water supply due to extreme cold.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of increased demand on water supply due to extreme cold	Limited	Limited	Limited	Limited	Limited	Limited
Urgency	Watching Brief					
Hazard Confidence	High					
Consequence Confidence	Low					

No description is provided for this risk as its urgency is Limited across all time horizons in both scenarios.

11.3.3 WS03 Risk of water supply contamination as a result of overland flows of pollutants to watercourses due to extreme precipitation

11.3.3.1 Risk Summary

Table 11.4: WS03 Risk of water supply contamination as a result of overland flows of pollutants to watercourses due to extreme precipitation.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of water supply contamination as a result of overland flows of pollutants to watercourses due to extreme precipitation	Substantial	Substantial	Critical	Substantial	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Low					
Consequence Confidence	Low					

Extreme precipitation events in Ireland can lead to overland flows of pollutants into watercourses, posing a significant risk to water supply quality. Communities relying on surface water sources are particularly vulnerable to contamination from agricultural runoff, industrial discharges, and urban pollutants during heavy rainfall. Contaminated water supplies can lead to health issues, increased water treatment costs, and disruptions to daily life, particularly affecting vulnerable populations.

11.3.3.2 Exposure and Vulnerability

All NUTS3 regions are projected to experience an increase in five-day precipitation across both RCP4.5 (10.2% (0.4 - 21.1%) by 2100) and RCP8.5 (16.5% (3.8 - 31.4%) by 2100). Similarly, each region will see an increase in the number of very wet days under both RCP4.5 (an increase of 0.8 days (0.3 - 1.3 days per year) by 2100) and RCP8.5 (an increase of 1.4 days (0.7-2.1 days per year) by 2100).

11.3.3.3 Consequence

- **Damage:** Overland flows of pollutants to watercourses due to extreme precipitation can cause moderate damage to water supply in 2030 and 2050, such as drinking water contamination and temporary water shortages. By 2100, the risk increases to Critical, with large and frequent damage. Ireland has experienced the impact of such risk, for instance:
    - Extreme cold in 2009/2010 saw thousands of houses with frozen stopcocks due to the shallow nature of many of our domestic connections and shallow pipes in Group Water Supply Schemes.
- **System Functionality**: In 2030 and 2050, overland flows of pollutants to watercourses due to extreme precipitation can lead to temporary or moderate disturbances in. By 2100, there are long-term disturbances projected.
- **Extent and Pervasiveness**: The impact is substantial in 2030 and 2050, affecting a wide range of regions. By 2100, the extent and pervasiveness of the impact are large, affecting a greater number of areas.
- **Cascading Effects**: In 2030 and 2050, temporary cascading effects are projected. These cascading effects include the Health System, i.e., waterborne diseases (e.g., VTEC, Cryptosporidium), Energy, i.e., operational issues, and Food Production and Supply Chain, i.e., reduced agricultural productivity, Biodiversity and Ecosystems, i.e., loss of species and degradation of habitats, and Marine and Coastal Ecosystems, i.e., harmful algal bloom. By 2100, these effects are long-term, with significant cascading impacts beyond the immediate damage.
- **Change through time:** In both scenarios, the changing climate conditions will continually increase the frequency and severity of extreme precipitation and flooding events. However, there are only minor differences in exposure between RCP4.5 and RCP8.5.

11.3.3.4 Confidence

Hazard Confidence: For extreme precipitation there is Low confidence in the trend of increasing frequency with the projections derived from the national downscaled projections (TRANSLATE). The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for the extreme heat variables (and heatwaves). The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios.

Consequence Confidence: The confidence in the consequence is Low. There is uncertainty to the timing of future impacts, and if the frequency and severity of extreme precipitation events will sufficiently increase to result is a risk consequence level greater than Limited.

11.3.3.5 Adaptation

To address the risk of water supply contamination due to overland flows of pollutants, several practices have been implemented:

Reliability

- *Policy and Governance:* Strong policy frameworks and governance structures support adaptation, with planning regulations and Section 28 Guidelines managing flood risks, while OPW Capital Flood Relief Scheme, Minor Flood Mitigation Works, and flood protection schemes enhance water infrastructure resilience.
- *Practices in Place:* Uisce Éireann's National Water Resource Plan, informed by catchment scale water quality monitoring, identifies risk management approaches, while the National Nature-based Solutions Implementation Strategy and Nature Restoration Law promote sustainable practices. The Water Quality and Water Services Infrastructure Climate Change Sectoral Adaptation Plan, planning regulations, and the National Catchment Flood Risk Assessment and Management Programme manage flood risks, with

supplementary planning guidance and Scheme Climate Change Adaptation Plans enhancing resilience.

- *Monitoring and Early Warning Systems:* Continuous monitoring of water reservoir and river levels, alarm triggers for power loss at treatment plants, Uisce Éireann's text alerts, and a national flood forecasting and warning service manage extreme precipitation impacts.

Resistance

- *Community Engagement and Education:* Public awareness campaigns and community-led initiatives monitor water quality and inform about contamination risks, while the National Dialogue on Climate Action and National Youth Assembly encourage public participation and awareness.
- *Research and Development:* Ocean Knowledge 2030, coastal change research programmes, and sector-specific initiatives like Farming for Water EIP and Waters for LIFE EIP address extreme precipitation impacts on water supply.

Recovery and Response

- *Sector-Specific Adaptation Actions:* Alarm triggers for power loss at treatment plants, Uisce Éireann's emergency repairs, National Catchment Management Plans, the National Resource Water Plan, and the Water Scarcity Action Plan for low water availability.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

11.3.3.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

11.3.4 WS04 Risk of contamination of water supplies due to flooding (fluvial, surface water, and groundwater)

11.3.4.1 Risk Summary

Table 11.5: WS04 Risk of contamination of water supplies due to flooding (fluvial, surface water, and groundwater).

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of contamination of water supplies due to flooding (fluvial, surface water, and groundwater)	Substantial	Substantial	Substantial	Substantial	Substantial	Substantial
Urgency	More Action Needed					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Flooding in Ireland, including fluvial, surface water, and groundwater flooding, poses a significant risk of contaminating water supplies. Communities dependent on these water sources are vulnerable to contamination from agricultural runoff, sewage overflow, and industrial pollutants during flood events. Contaminated water supplies can lead to health issues, increased water treatment costs, and disruptions to daily life, particularly affecting vulnerable populations.

11.3.4.2 Exposure and Vulnerability

There are water abstraction points present in all NUTS3 regions which could be exposed. Based on CFRAM data for a 1 in 100-year event, 11.6% (RCP4.5 by 2100) to 12.5% (RCP8.5 by 2100) of water abstraction points are projected to be exposed to fluvial flooding. CFRAM data indicates the highest proportion of exposed water abstraction points are in the Midlands Region.

NIFM data for a 1 in 100-year event projects that 5.8% (RCP4.5 by 2100) to 7.1% (RCP8.5 by 2100) of water abstraction points will be exposed to fluvial flooding.

NIFM data indicates the highest proportion of exposed water abstraction points are in the Mid-East Region.

11.3.4.3 Consequence

- **Damage:** There is potential for substantial losses to Water Supply, with this risk present occurring in Ireland. For instance:
    - During the winter of 2015/16, extensive and prolonged river and groundwater flooding affected agriculture, private homes and business, and human health through contamination of water sources ((Murphy et al., 2023).
    - Heavy rainfall occurred in Donegal in August 2017, with over 70mm falling in 9 hours impacting water and wastewater infrastructure with seventeen major water network incidents occurring due to flood damage and six wastewater treatment plants were also affected. A bathing water prohibition notice was issued due to concerns about elevated bacteria levels in the water (Department of Housing, Local Government and Heritage, 2019).
    - In 2015, there was a notable rise in boil water notices due to cryptosporidium contamination. This was a result of inadequate water treatment infrastructure being overwhelmed by flooding (Department of Health, 2019).
- **System Functionality:** Under both scenarios, Water Supply will experience predominantly temporary or moderate disturbances due to flooding.
- **Extent and Pervasiveness:** All NUTS3 Regions are exposed to flooding and there is exposure of water abstraction points in all regions. Therefore, the extent of this risk is large extent with all water abstraction points potentially impacted in 2030, 2050 and 2100 under both scenarios.
- **Cascading Effects:** Temporary to long-term cascading effects are possible, potentially affecting other critical systems and services beyond the Water

Security system. These cascading effects include the Health System, i.e., waterborne diseases, Energy, i.e., operational issues due to reduced access to suitable water, and Food Production and Supply Chain, i.e., reduced agricultural productivity, Biodiversity and Ecosystems, i.e., loss of species and degradation of habitats, and Marine and Coastal Ecosystems, i.e., harmful algal bloom. By 2100, these effects are long-term, with significant cascading impacts beyond the immediate damage.

- **Change through time:** Projections show increased fluvial flood extent and frequency, with no current groundwater flooding projections available. Currently, the risk to protected structures and sites is already Substantial, there is likely to be limited changes in exposure through time. Therefore, minimal changes in consequence are projected between 2030, 2050, and 2100, and the consequence in RCP4.5 and RCP8.5 scenarios is deemed to be Substantial across all time periods.

11.3.4.4 Confidence

Hazard Confidence: There is a medium level of confidence that flooding (fluvial, surface water, and groundwater) will increase in frequency and severity due to climate change. The OPW flood assessments (NIFM and CFRAM) indicate an increase in fluvial flood extent and frequency, with no current projections for available for groundwater flooding. To inform the timing of changes in flood extent and frequency to align OPW scenarios the seasonal Winter projections from TRANSLATE have been used as a proxy. There are no climate projections for surface water flooding extents, therefore proxies including Very Wet Days and Maximum 1-day Precipitation have been used. For groundwater flooding, national extents exist but have limitations as noted by McCormack et al. (2020).

Consequence Confidence: The impacts of flooding are already affecting Ireland; however, limited changes are expected in the future due to limited changes in exposure. Therefore, a High level of confidence is assigned to the consequence of this risk.

11.3.4.5 Adaptation

To address the risk of water supply contamination due to flooding, several practices have been implemented. These measures help manage impacts and protect watercourses.

Reliability

- *Policy and Governance:* Planning regulations and Section 28 Guidelines manage flood risks, while OPW Capital Flood Relief Scheme, Minor Flood Mitigation Works, and flood protection schemes enhance water infrastructure resilience.
- *Practices in Place:* Uisce Éireann's National Water Resource Plan, informed by catchment scale water quality monitoring, identifies risk management approaches, while the National Nature-based Solutions Implementation Strategy and Nature Restoration Law promote sustainable practices. The Water Quality and Water Services Infrastructure Climate Change Sectoral Adaptation Plan and Flood Risk Management Climate Change Sectoral Adaptation Plan, planning regulations, and the National Catchment Flood Risk Assessment and Management Programme manage flood risks, with supplementary planning guidance and Scheme Climate Change Adaptation Plans enhancing resilience.
- *Monitoring and Early Warning Systems:* Continuous monitoring of water reservoir and river levels, alarm triggers for power loss at treatment plants, Uisce Éireann's text alerts, and a national flood forecasting and warning service manage flooding impacts.

Resistance

- *Community Engagement and Education:* Public awareness campaigns and community-led initiatives monitor water quality and inform about contamination risks, while the National Dialogue on Climate Action and National Youth Assembly encourage public participation and awareness.
- *Research and Development:* Research and development focus on mitigating flooding impacts on water supply, supported by Ocean Knowledge 2030. Coastal change research informs adaptation, while the

Farming for Water EIP and Waters for LIFE EIP target sector-specific solutions.

Recovery and Response

- *Sector-Specific Adaptation Actions:* Adaptation actions in the water sector include alarm triggers for power loss at treatment plants, Uisce Éireann's emergency repairs, National Catchment Management Plans, the National Resource Water Plan for sustainable management, and the Water Scarcity Action Plan for low water availability.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

11.3.4.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is that More Action is required.

11.3.5 WS05 Risk of reduced water supply and increases in water demand due to drought conditions and extreme heat

11.3.5.1 Risk Summary

Table 11.6: WS05 Risk of reduced water supply and increases in water demand due to drought conditions and extreme heat.

Risk	RCP4.5			RCP8.5		
	2030	2050	2100	2030	2050	2100
Risk of reduced water supply and increases in water demand due to drought conditions and extreme heat	Limited	Substantial	Substantial	Limited	Substantial	Critical
Urgency	Further Investigation					
Hazard Confidence	Medium					
Consequence Confidence	Medium					

Drought conditions and extreme heat in Ireland pose risks to water supply and increased water demand. Communities relying on surface and groundwater sources are particularly vulnerable to reduced water availability during prolonged dry periods. Reduced water supply can lead to water restrictions, agricultural losses, and increased competition for water resources, affecting both urban and rural populations.

11.3.5.2 Exposure and Vulnerability

All eight NUTS3 regions are projected to experience an increase in the number of heatwave events and number of summer days, with the South-East regions most affected in both RCP4.5 (0.11 events per year by 2100) and RCP8.5 (0.45 events per year by 2100) scenarios.

Water demand can be expected to increase alongside increase in population. Based on projections prepared by ESRI in 2024, under a baseline scenario the national population is anticipated to increase by c.922,000 between 2022 and 2024, resulting in a population of 6.106 million people. Under a scenario accounting for higher rates in inward migration, the population is anticipated to

increase by 1.124 million by 2040, resulting in a population of 6.308 million people. While all regions are expected to experience population growth, relatively higher growth is anticipated in the east and midlands. This will be concentrated in Dublin and the Mid-East NUTS3 regions but is also of particular relevance for the South-East region, given the increase in heatwave events expected.

Moreover, the Irish population is aging. The number of people aged over 65 anticipated to double from 2022 (c.781,000) to 2042 (c.1.4 million), growing from 15% of the population to 23% (CSO 2024, M2 scenario). This increased number of older adults represents a population that are likely to be more vulnerable to the effects of reduced water supply and drought.

Upgrades to water services infrastructure such as those highlighted in Uisce Éireann's Draft Water Services Strategic Plan 2050 have potential to reduce leakage and improve water security.

11.3.5.3 Consequence

- **Damage:** Limited or rare losses initially, with increased damage to large and frequent levels under an RCP8.5 scenario. Ireland already experiences impacts from this risk, for instance:
    - During the heatwave in 2018, high water demands during the hot weather led to depleted reservoir levels in Ireland and water outages in certain areas, which led to a Water Conservation Order (hosepipe ban) being implemented nationwide (Department of Housing, Local Government and Heritage, 2019).
- **System Functionality**: Drought conditions and extreme heat can cause temporary disturbances and short-term disruptions to water supply; however, under an RCP8.5 scenario, these disturbances could become more chronic and therefore long-term if the frequency of extreme heat events increases.
- **Extent and Pervasiveness**: Due to all NUTS3 regions being exposed to changing climate conditions, this risk has potential to occur across a large extent and affect all water supplies.

- **Cascading Effects**: Temporary to long-term cascading effects are possible, potentially affecting other critical systems and services beyond the Water Security system. These cascading effects include the Health System, i.e., waterborne diseases, Built Environment, i.e., Increased requirement for management of water services infrastructure, e.g., maintenance and repairs, Energy, i.e., operational issues due to reduced access to water, and Food Production and Supply Chain, i.e., reduced agricultural productivity, Biodiversity and Ecosystems, i.e., loss of species and degradation of habitats, and Marine and Coastal Ecosystems, i.e., habitat loss and species decline due to water scarcity. By 2100, these effects are long-term, with significant cascading impacts beyond the immediate damage.

- **Change through time:** Projections show increased extreme heat extent and frequency. The consequence increases to Substantial by 2050, as the projected increase in frequency and severity of summer days and heatwave events increases.

11.3.5.4 Confidence

Hazard Confidence: There is a medium level of confidence that drought conditions will increase in the future. Changes in the number of wet days have been used from national downscaled projections (TRANSLATE) which were produced by the national meteorological agency, and peer-reviewed research has been used for SPEI-3, however, further research and variables, i.e., SPEI-6, SPEI-12 are needed to better inform confidence in this hazard.

Consequence Confidence: There is high confidence in the consequence as some of these impacts of this risk have already been observed at a local and short-term/temporary term basis.

11.3.5.5 Adaptation

To address the risk of reduced water supply due to increases in water demand and drought conditions, as well as extreme heat, several practices have been implemented.

Reliability

- *Policy and Governance:* The Water Quality and Water Services Infrastructure Climate Change Sectoral Adaptation Plan and other policies ensure continuous monitoring and adaptation of water services infrastructure to mitigate drought-related risks.
- *Monitoring and Early Warning Systems:* Systems are in place to monitor infrastructure performance during drought conditions.
- *Practices in Place:* Climate Risk Assessments identify vulnerabilities and inform planning.

Resistance

- *Community Engagement and Education*: Public awareness campaigns educate communities on water conservation and infrastructure resilience.
- *Research and Development:* The National Nature-based Solutions Implementation Strategy supports research on enhancing infrastructure resilience against drought.

Recovery and Response

- *Emergency response*: Uisce Éireann conducts emergency repair works to address immediate threats.

Redundancy

- No redundancy measures were identified.

Adaptation Effectiveness

Based on the adaptation information and through stakeholder consultation, current adaptation measures were deemed Moderately Effective for managing this risk.

11.3.5.6 Decision Urgency

Given the level of consequence, levels of existing adaptation, and confidence in the hazard and consequence information, the decision urgency is for Further Investigation.

12 International Dimensions

12.1 Description

International Dimensions refers to the risks that climate change impacts experienced overseas pose for Ireland, highlighting how global factors and cross-border interactions shape national climate change risks. The International Dimensions system covers risks related to the global impacts of climate change on food security, supply chains, economic stability, and human mobility.

Given the cross-cutting nature of these risks, a subsystem has not been assigned to each risk. Additionally, due to the complexity of each risk, a high-level summary of each risk is presented below.

12.1.1 ID1 Risk of global food system instability due to climate change impacts on agricultural production, commodity supply chains, and extreme weather events, resulting in food insecurity and social unrest

Climate change poses significant risks to Ireland's food system, affecting agricultural production, supply chains, and increasing extreme weather events. These factors contribute to food insecurity and potential social unrest.

The TCRII project highlighted that Ireland's agri-food sector is a significant exporter, with 90% of its food production and 9.5% of total exports reaching 180 countries (Murphy et al., 2024). The dairy and beef sectors lead these exports. However, Ireland relies heavily on imports for vegetables, fruits, grains, fertilisers, and animal feed, making it susceptible to supply chain disruptions. While considered food secure, Ireland is not self-sufficient in food production.

The UK and Northern Ireland do not currently recognise food availability as an immediate threat (Challinor and Benton, 2021; Climate Northern Ireland, 2021), but there are concerns about food accessibility, especially for economically marginalised groups. Similarly, Murphy et al., 2024 outlined that households with low and fixed incomes in Ireland are vulnerable to food price fluctuations and related food security challenges. EU membership provides access to integrated food markets, but extreme droughts in southern Europe have led to shortages

and increased costs of fruits and vegetables. Severe weather in Ireland has caused fodder crises, and the 2018 drought in northern Europe complicated fodder imports, highlighting the need for coordinated EU responses. Non-climate factors like the war in Ukraine have increased costs for feed, fertilisers, and fuel, making the agri-food sector more vulnerable.

A prioritisation assessment commissioned by the CCAC identified three transboundary climate risks for Ireland, specifically related to agriculture and food security (Mikaelsson et al., 2024). The most severe risk is the cost-of-living crises and reduced food affordability, driven by climate change impacts on global agriculture supply chains. Additionally, there is a moderate risk to nutrition security due to volatile supply chains for fresh fruit and vegetables, which would disproportionately affect low-income and vulnerable households. These risks arise from the increasing frequency and severity of floods and droughts, exacerbated by existing water stress, affecting crop yields in climate-vulnerable regions around the world, including southern Europe, as well as the impacts of extreme weather on global logistics operations. Furthermore, climate-related disruptions to supply chains for animal feed present a moderate risk to Ireland's dairy and beef sectors, with implications for farming jobs, food sector employment, and export revenues.

The IPCC AR6 notes that evidence on the impact of long-term climate change on crop prices and malnutrition is largely lacking. However, there is medium confidence in the negative impact on crop yields in some regions, such as wheat yields in Europe.

The increasing vulnerability of the global food system may lead to more frequent food price spikes, affecting food accessibility, especially for the most disadvantaged members of society.

12.1.2 ID2 Risk of global supply chain disruptions due to climate-induced impacts on logistics, manufacturing, and interconnected energy networks, leading to economic losses and supply shortages

Climate change is increasingly recognised as a critical threat to global supply chains, impacting logistics, manufacturing, and energy networks. These

disruptions can lead to significant economic losses and supply shortages worldwide, including in Ireland.

Ireland relies heavily on energy imports, meeting almost 80% of its energy needs through imports (SEAI, n.d.), significantly higher than the EU average of 63% (Eurostat, n.d.). Ensuring energy security is crucial, especially with Ireland's electricity managed through a shared network. The North–South interconnector is expected to enhance electricity transmission between Northern Ireland and Ireland (Murphy et al., 2024).

Climate impacts on transport infrastructure outside Ireland can cause supply disruptions within the country (Murphy et al., 2024). Extreme weather events and gradual climate changes, such as sea level rise, are likely to affect key infrastructure globally. Coastal infrastructure is particularly vulnerable, impacting international transport and trade, which is vital for the supply of essential goods.

Storm Darragh caused ferry operations at Holyhead Port to close temporarily in early December 2024 due to extreme winds that significantly damaged the ferry berths (Meskill, 2024). The port resumed operations in mid-January 2025, with some delays and adjustments still in place.

A prioritisation assessment commissioned by the CCAC identified three transboundary climate risks for Ireland, specifically related to supply chains (Mikaelsson et al., 2024). The most severe risk is to business operations, jobs, and export revenues in the pharmaceutical industry due to climate-related disruptions to global supply chains. Additionally, there is a moderate risk to the overall economy, businesses, and the financial sector from global supply chain disruptions. These risks arise from the increasing frequency and severity of extreme weather events, which can disrupt logistics and supply chains worldwide. Furthermore, there is a medium risk to public health from disrupted supplies of essential medicines and other drugs, and a low risk to business operations, jobs, and export revenues on the island of Ireland due to climate-related disruptions to intra-island trade and trade with the UK.

The IPCC AR6 notes that climate events like floods or heatwaves in key production areas disrupt economies both locally and globally (high confidence). For example, the 2011 floods in Thailand caused shortages in the automotive and electronics industries worldwide. Climate change impacts trade significantly, affecting countries like the UK, Japan, the USA, and the EU (medium confidence). While trade can spread risks and amplify damages, it can also help increase resilience.

Climate change increasingly threatens global supply chains, causing economic losses and supply shortages. Ireland, heavily reliant on energy and trade imports, is particularly vulnerable. Extreme weather and gradual climate changes disrupt transport infrastructure and trade, highlighting the urgent need for enhanced energy security and resilience measures.

12.1.3 ID3 Risk of economic crises and exacerbated poverty due to climate change impacts on the global financial system, interdependent financial markets, and inadequate energy transition, resulting in reduced investment and increased inequality

Climate change projections indicate an increased frequency and severity of extreme weather events, which can disrupt economic activities and damage infrastructure. These disruptions can lead to economic crises, as businesses face higher costs and reduced productivity.

The Financial Stability Board (FSB, 2020) highlighted that extreme climate events like floods, droughts, and heatwaves can cause substantial financial exposure for insurance companies, banks, investment firms, and individual investors globally. These risks include physical risks, which involve damage to property and infrastructure from climate events; transition risks, which encompass financial impacts from the shift to a low-carbon economy; and liability risks, which pertain to legal and financial liabilities related to climate change, such as lawsuits and compensation claims.

At the domestic level, climate events can reduce asset values, increase credit risks, and raise capital costs, making insurance less affordable (Murphy et al.,

2024). The CCRA3 report for Northern Ireland highlights these as medium risks, potentially escalating to high risks, with flooding being the most significant threat.

A prioritisation assessment commissioned by the CCAC identified two transboundary climate risks for Ireland, specifically related to energy security (Mikaelsson et al., 2024). The study found there is a moderate risk to energy security from climate impacts on transport and production infrastructure abroad, disrupting the overseas supply of critical minerals. Price shocks or shortages of critical minerals could hinder emission reduction efforts and impact energy security in Ireland. Additionally, the study noted that climate-related damages to existing energy production facilities, storage and transmission networks abroad could potentially compromise energy supplies to the island of Ireland. However, it found there is a low risk to energy security from damage to energy-critical infrastructure abroad due to extreme weather and slow-onset climate change.

Furthermore, there is a low risk to human mobility from reduced air travel due to the effects of extreme weather on UK and global airports, affecting business operations, revenues, and jobs in the tourism sector.

According to the IPCC AR6, extreme weather events cause significant economic damage and reduce economic growth both in the short term and long term, with developing economies being more severely affected than industrialised ones.

Globally, extreme weather events due to climate change can disrupt economic activities, damage infrastructure, and cause substantial financial exposure for various sectors. These global impacts can lead to economic crises in Ireland, as businesses face higher costs, reduced productivity, and increased financial risks.

12.1.4 ID4 Risk of increased cross-border human migration due to environmental and socioeconomic pressures from climate change, leading to resource strain, social conflicts, and loss of livelihoods

Climate change hazards such as extreme heat, floods, droughts, and reduced precipitation can lead to forced migration and displacement (Murphy et al., 2024). However, the relationship between weather events and human movement is complex and depends on socioeconomic factors, with disadvantaged

communities being more vulnerable to forced displacement or being unable to migrate.

Evidence to date indicates that when climate factors drive migration, it results in short distance moves within national borders. The IPCC AR6 notes strong evidence that human-caused climate change has influenced internal displacement due to its impact on extreme weather events. However, the assessment indicates no clear link between long-term climate changes and displacement trends.

It is important to recognise that properly managed migration can bring social, cultural, and economic benefits (Knaepen and Vajpeyi, 2022). Reducing future risks of forced migration due to climate change requires cooperative international efforts to enhance adaptive capacity and promote sustainable development.

13 Opportunities

Climate change, while presenting risks, also offers a range of opportunities that may be leveraged to enhance resilience and sustainability. These opportunities for Ireland are outlined below.

13.1.1 O1 Opportunity of changes in average temperature to tourism leading to increased tourism and expansion of outdoor activity tourism

There is an emerging opportunity for an increase in tourism due to warmer climates that can lead to longer tourist season, thereby attracting more visitors during the off-peak season. This can contribute to more stable employment opportunities within the tourism sector, opening up new markets and untapped destinations. Given our landscape, with some of the best hiking and trekking routes, there is a significant opportunity to attract adventure enthusiasts and nature lovers. Coastal regions can become hubs for a variety of water sports and prolonged periods of camping. The potential for increased tourism can drive investment in local infrastructure, including hotels, restaurants, and transportation networks, boosting the local economy. The tourism industry can leverage this opportunity to promote sustainable practices and market destinations as eco-friendly to attract environmentally conscious travellers. However, this can also potentially lead to increased footprint and risks related to impact on the Biodiversity and Ecosystem System (i.e., B15) and increased tourism in peak seasons can put a strain the Water Security System (i.e., WS05).

13.1.2 O2 Opportunity for increased hydropower generation due to increases in precipitation

While there is a significant risk of increased flooding, there is also an opportunity for energy generation by harnessing the increase in precipitation, potentially flood waters, to produce sustainable energy. Improved energy output and efficiency gains in power generation can be achieved by enhancing the capacity of hydropower plants from utilisation of excess water. Reliance on fossil fuels can be reduced by using hydropower as an energy source contributing to sustainable energy production. The development and expansion of hydropower infrastructure can create jobs, stimulate local economies, and attract investment. However, the

construction of these plants can disrupt the local ecosystems affecting natural habitats, leading to a loss of biodiversity. Another potential hazard can be the displacement of local communities resulting from building these facilities, thus leading to socio-economic challenges.

13.1.3 O3 Opportunity of changes in average ocean temperature and salinity to fisheries/aquaculture increasing shellfish growth and introducing diverse marine species

Changes in average ocean temperature and salinity due to climate change could benefit Ireland's fisheries and aquaculture by enhancing shellfish growth and introducing diverse marine species. Warmer and more saline waters can create favourable conditions for shellfish development and attract new species to Irish waters. However, these changes also pose risks such as the potential for harmful algal blooms (i.e., M05), the displacement of native species (i.e., M06), and ocean acidification (i.e., M07). Examples include increased shellfish yields and the introduction of commercially valuable species, alongside the need for monitoring and management to mitigate ecological disruptions. More research is needed to better understand the opportunities and risks climate change could pose to the seafood sector.

13.1.4 O4 Opportunity of changes in average temperature to food production increasing the growing season, and improving livestock nutrition and grazing

Climate change presents opportunities for Ireland's food production by potentially extending the growing season and enhancing livestock nutrition and grazing. Increased average temperatures can lead to longer growing seasons, allowing for multiple crop cycles and improved pasture quality. However, these benefits come with risks such as heat stress on crops and livestock (i.e., F03 and F06), and the potential for new pests and diseases. Examples include higher yields of certain crops, improved forage quality for livestock, but also the need for adaptive measures to mitigate heat stress and pest management.

13.1.5 O5 Opportunity of changes in average temperature to human health leading to improved physical and mental health by increasing time outdoors and reducing cold-related deaths

Changes in average temperature due to climate change can positively impact human health in Ireland by encouraging more outdoor activities and reducing cold-related deaths. Warmer temperatures increase opportunities for outdoor recreation and physical activity, while also decreasing the incidence of cold-related illnesses. Benefits of this increased outdoor time include improved physical fitness and mental well-being However, these benefits come with risks such as heatwaves, which can lead to heat-related illnesses and exacerbate existing health conditions (i.e., H14). Additionally, increased exposure to tickborne illnesses, which may rise under a warmer climate.

14 Knowledge Gaps

Climate change poses significant risks to various sectors and communities, necessitating comprehensive risk assessments to inform effective adaptation strategies. However, several knowledge gaps and uncertainties hinder our ability to accurately assess and address these risks. Outlined below are the key areas where data and understanding were insufficient, as well as the challenges encountered during the NCCRA.

- **Projections for Key Climatic, Atmospheric, and Oceanic Variables:** National downscaled projections are currently unavailable for several critical climatic, atmospheric, and oceanic variables, including humidity, sea level rise rates, extreme wind, fire weather and wildfire projections, changes in ocean chemistry, drought conditions, and lightning. Projections to address some of these gaps are in the process of being developed, i.e., additional TRANSLATE outputs developed by Met Eireann, ocean climate projections are being developed by the Marine Institute. However, data gaps remain, which limits our ability to accurately assess the risks associated with these variables. Addressing these gaps is essential for developing a comprehensive understanding of climate-related risks.

- **Projections for Key Geophysical Hazards:** National downscaled projections accounting for climate change are currently unavailable for several critical geophysical hazards, including coastal erosion, landslides, groundwater flooding, and surface water/pluvial flooding. This gap in data limits our ability to accurately assess the risks associated with these hazards. Addressing these gaps, especially through the development of hazard maps and projections, is essential for developing a comprehensive understanding of climate-related risks.

- **The OPW Flooding Scenarios:** For the purposes of the CFRAM Programme, the OPW adopted two indicative potential futures for flood risk assessment; the Mid-Range Future Scenario (MRFS) and the High-End Future Scenario (HEFS) (OPW, 2019). A future timeframe is not directly assigned to the MRFS and HEFS, therefore for use within the NCCRA, the timing of the changes

associated with precipitation and mean sea level within the MRFS and HEFS scenarios need to be aligned with the RCP4.5 and RCP8.5 scenarios to be consistent with the NCCRA Methodology and allow the identification of a representative flood extent data layer to be used within the NCCRA. However, global sea level rise information, and proxy variables from TRANSLATE (Winter precipitation change) were used to support this alignment. Consequently, there is uncertainty associated with the timing of changes in coastal and fluvial flooding extent due to this approach.

- **Climate Extremes:** The methodology used to develop the TRANSLATE national downscaled climate projections utilises detrending, which is performed on all RCM 30-year output time series to distil the climate change into a single 30-year climatology rather than a year-by-year changing climate. While this method can enhance the clarity of underlying patterns and provide for the more reliable calculation of internal climate variability, extreme events, and other indices over the 30-year climatology, it can also inadvertently remove extreme events from the dataset associated with interannual variability. By eliminating these extremes, detrending can lead to projections that underestimate the frequency and intensity of such events, potentially resulting in an underassessment of risk. TRANSLATE 2 and 3 are in development which aim to preserve interannual variability and extreme events while still providing accurate projections of climate trends are therefore needed to enhance future climate risk assessments.

- **Climate Tipping Points:** The uncertainty associated with climate tipping points presents significant challenges for their inclusion in national climate risk assessments. Tipping points, such as the collapse of ice sheets or the thawing of permafrost, are characterised by abrupt, irreversible changes that can have far-reaching and severe impacts. Predicting the precise thresholds and timing of these events is inherently difficult. This unpredictability makes it challenging to integrate tipping points into national risk assessments, which typically rely on more stable and predictable climate projections. As a result, there is a risk of underestimating the potential impacts and not adequately preparing for these high-impact, low-probability events. Additionally, gradual changes

linked to phenomena such as the AMOC (Atlantic Meridional Overturning Circulation) that may precede, but not in themselves meet the definition criteria of a tipping point, need to be incorporated into our projections to ensure comprehensive risk assessments.

- **Exposure and Vulnerability Data:** For some risks, it was not possible to undertake spatial analysis due to limited availability of spatial information on asset locations and/or asset function. The absence of thresholds, e.g., operating temperatures, ecosystem tipping points, further exacerbates the challenge of determining the degree of exposure, making it difficult to consistently define and measure risk levels across different elements at risk. Moreover, the lack of detailed vulnerability data, including socio-economic factors, infrastructure and environmental sensitivities, e.g., which marine species are more sensitive to changing ocean conditions, and adaptive capacities, hinders the ability to accurately assess the potential impacts on various populations and systems. Further information on thresholds, vulnerability, and spatial information on exposure would enhance future national risk assessments.

- **Uncertainty in Changes in Exposure and Vulnerability:** Assessing climate risks is complicated by the uncertainty associated with changes in exposure and vulnerability, such as population growth, demographic shifts, and land use changes. Population and demographic changes can significantly alter the vulnerability of communities, as shifts in age, income, and density affect how different groups experience and respond to climate hazards. Additionally, land use changes, driven by urbanisation, agricultural expansion, or deforestation, can modify the landscape in ways that influence the severity and distribution of climate impacts. For example, urban expansion can increase surface runoff and flood risk, while deforestation can exacerbate soil erosion. These dynamic factors introduce variability and uncertainty into risk assessments, making it challenging to assess future exposure accurately.

  At the national level, understanding the specific vulnerabilities of various exposures is challenging, however these vulnerabilities can change over time

due to climate change, economic and demographic changes, and technological advancements. Thus, a more comprehensive understanding of changing vulnerability is essential for improved risk assessment.

- **Consideration of Policy Changes:** When assessing climate risks, it is crucial to consider the impacts of evolving government policies, e.g., urban densification, renewable energy, built environment decarbonisation, sustainable farming, electric vehicle and public transit promotion, nature-based water solutions, and enhancing green spaces. Urban densification policies, e.g., Project Ireland 2040, Ireland's National Planning Framework, aim to reduce urban sprawl and promote more efficient land use, which can influence exposure to climate hazards like heatwaves and flooding. The shift towards renewable energy sources, driven by policies to reduce greenhouse gas emissions, e.g., Climate Action Plan 2025, can alter the energy landscape and affect the resilience of energy infrastructure. Additionally, the increased reliance on electrification for heating, supported by policies to decarbonise buildings, introduces new vulnerabilities and dependencies on the electrical grid. Changes in agricultural policies, e.g., Food Vision 2030, such as promoting sustainable farming practices, can impact land use and water resource management, influencing the risk of droughts and soil erosion. Transportation policies that encourage the use of electric vehicles and/ or public transit e.g., National Sustainable Mobility Policy, can reduce emissions but also require robust infrastructure to support these systems. Water policies that encourage the use of nature-based solutions, e.g., Water Action Plan 2024, require proper maintenance to support these systems. Furthermore, policies aimed at enhancing green spaces and biodiversity, e.g., Ireland's 4th National Biodiversity Action Plan 2023–2030, can mitigate some climate risks but need to be integrated into broader urban planning strategies. These policy changes can significantly shape the risk landscape, and their potential impacts must be integrated into comprehensive climate risk assessments to ensure robust and adaptive strategies.

- **Assessment of Acute Compounding Risks:** The current risk assessment approach evaluates acute hazards as single events, focusing on the potential

risks and cascading impacts on systems. Due to complexity, the NCCRA was not fully able to consider the compounding and aggregating impacts of acute risks occurring sequentially or concurrently. For instance, a prolonged drought can dry out vegetation, increasing the likelihood of wildfires. When a wildfire occurs, it can burn away vegetation and create hydrophobic (water-repellent) soil surfaces. These sealed surfaces reduce the soil's ability to absorb water. If heavy precipitation follows, the lack of vegetation and the hydrophobic soil can lead to rapid runoff and severe flooding. This sequence of events—drought leading to wildfire, which then leads to flooding—demonstrates how interconnected hazards can compound and exacerbate overall risk. The chronic risks within systems, such the risk of reduced crop yields due to changes in climate conditions, e.g., temperature, were considered where feasible. The evidence base for acute compound risk, especially across sectors, is in development through Sectoral Adaptation Plans, however, the lack of a fully integrated risk assessment that considers all types of complex interactions limits our understanding of the full spectrum of risk and can lead to underpreparedness for complex, multi-hazard scenarios.

- **Assessing Adaptation Effectiveness**: Assessing the effectiveness of current adaptation actions to mitigate climate risks is highly uncertain. There is no information as to what degree of climate change that current adaptation plans and actions provide a level of protection for. A critical gap is the absence of a national register or information knowledge base that documents adaptation actions and their proposed benefits or outcomes, making it difficult to track progress and share best practices. Development of such a resource is complicated by the fact that the long-term nature of climate change means that the benefits of adaptation actions may not be immediately apparent, complicating efforts to measure their success. Furthermore, the lack of standardised metrics and methodologies, such as long-term cost-benefit analysis for evaluating adaptation effectiveness further adds to the uncertainty. Moreover, adaptation actions often involve multiple sectors and stakeholders, making it difficult to isolate the effects of specific measures. This complexity is compounded by the need to account for socioeconomic factors,

such as population growth and economic development, which can influence the outcomes of adaptation efforts.

- **Financial Implications of Climate Risks:** Climate change result in direct and indirect financial costs for both the public and private sector, for instance, this could be as a result of response and repair during and after a risk event, short and long-term business interruption as result of a risk being realised, or the implementation of adaptation actions required to enhance resilience. Assessing the financial implications of climate risk is crucial for ensuring economic stability, enabling informed decision-making, managing risks, planning for insurance and financial sustainability, and complying with regulatory requirements. However, a comprehensive assessment of financial implications within the NCCRA has not be included due to the challenges associated with financial assessment. For instance, the UK Climate Change Risk Assessment (CCRA) faced difficulties in assessing financial implications due to several factors (Watkiss et al., 2021). One major challenge was the complexity and uncertainty associated with predicting the economic impacts of climate change across various sectors. Climate risks are inherently uncertain, making it difficult to quantify potential costs and benefits accurately. Additionally, the assessment required a comprehensive analysis of both direct and indirect impacts, which involved extensive data collection and modelling. The valuation of non-market impacts, such as environmental and social effects, also posed significant challenges. Furthermore, the need to consider long-term projections and the dynamic nature of climate change added to the complexity of the financial assessment (Department for Environment, Food & Rural Affairs (2022). These factors collectively made it challenging to provide a precise monetary valuation of climate risks and opportunities.

Addressing the identified knowledge gaps is crucial for developing robust and adaptive climate risk assessments. By improving data availability, integrating diverse knowledge systems, and refining methodologies, understanding of climate-related risks and the effectiveness of adaptation measures can be enhanced.

15 Glossary

Key Term	Definition
Adaptation	In human systems, the process of adjustment to actual or expected climate and its effects, to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2023: Annex 1).
Adaptive Capacity	The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (adapted from MA, 2005) (IPCC, 2022: Annex II).
Assets	'Things of value' that may be exposed or vulnerable to a hazard or risk. Physical, environmental, cultural, financial, or economic element that has tangible, intrinsic or spiritual value.
Baseline	A time period of interest, or a period over which some relevant statistics are calculated (IPCC, 2022, Annex II).
Biodiversity	Biodiversity or biological diversity means the variability among living organisms from all sources including, among other things, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (IPCC, 2023: Annex 1).
Cascading effects (of climate change)	Cascading impacts from extreme weather/climate events occur when an extreme hazard generates a sequence of secondary events in natural and human systems that result in physical, natural, social or economic disruption, whereby the resulting impact is significantly larger than the initial impact. Cascading impacts are complex and multi-dimensional and are associated more with the magnitude of vulnerability than with that of the hazard (IPCC, 2023: Annex 1).
Climate	Climate in a narrow sense is usually defined as the average weather, or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization (WMO). The relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system (IPCC, 2023: Annex 1).
Climate Change	A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/ or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2023: Annex 1).
Climate Projections	A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of the cryosphere, the lithosphere and the biosphere and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations and anthropogenic forcings such as the changing composition of the atmosphere and land-use change (IPCC, 2018: Annex I).

Key Term	Definition
Co-benefits	A positive effect that a policy or measure aimed at one objective has on another objective, thereby increasing the total benefit to society or the environment. Co-benefits are also referred to as ancillary benefits (IPCC, 2022: Annex II).
Community	A community may be a geographical location (community of place), a community of similar interest (community of practice) or a community of affiliation or identity (such as industry).
Confidence	The robustness of a finding based on the type, amount, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgement) and on the degree of agreement across multiple lines of evidence. In this report, confidence is expressed qualitatively (Mastrandrea et al., 2010).
Consequence	The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services) and infrastructure (IPCC, 2022, Annex II).
Disaster	Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery (IPCC, 2018: Annex I).
Driver	Any natural or human-induced factor that directly or indirectly causes a change in a system (adapted from MA, 2005) (IPCC, 2022: Annex II).
Emissions (Anthropogenic)	Emissions of greenhouse gases (GHGs), precursors of GHGs and aerosols caused by human activities. These activities include the burning of fossil fuels, deforestation, land use and land-use changes (LULUC), livestock production, fertilisation, waste management and industrial processes (IPCC, 2023: Annex 1).
Exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC, 2023: Annex 1).
Extreme weather event	The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as ‘climate extremes (IPCC, 2023: Annex 1).
Frequency	The number or rate of occurrences of hazards, usually over a particular period (NZ CCRA Framework, 2019).
Greenhouse gas	Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of radiation emitted by the Earth’s surface, by the atmosphere itself, and by clouds. This property causes the greenhouse effect (IPCC, 2023: Annex 1).
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service

Key Term	Definition
	provision, ecosystems, and environmental resources (IPCC, 2023: Annex 1).
Heatwave	A period of abnormally hot weather, often defined with reference to a relative temperature threshold, lasting from two days to months. Heatwaves and warm spells have various and, in some cases, overlapping definitions (IPCC, 2023: Annex 1).
Impacts (consequences, outcomes)	The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial (IPCC, 2023: Annex 1).
Land use	The total of arrangements, activities and inputs applied to a parcel of land. The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction, conservation, and city dwelling) (IPCC, 2023: Annex 1).
Likelihood	The chance of a specific outcome occurring, where this might be estimated probabilistically. Likelihood is expressed in this report using a standard terminology (Mastrandrea et al., 2010).
Mitigation	A human intervention to reduce emissions or enhance the sinks of greenhouse gases (IPCC, 2023: Annex 1).
Percentile	A partition value in a population distribution that a given percentage of the data values are below or equal to. The 50th percentile corresponds to the median of the population. Percentiles are often used to estimate the extremes of a distribution. For example, the 90th (10th) percentile may be used to refer to the threshold for the upper (lower) extremes (IPCC, 2023: Annex 1).
Representative concentration pathway	Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover (Moss et al., 2008). The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasizes the fact that not only the long-term concentration levels, but also the trajectory taken over time to reach that outcome are of interest (Moss et al., 2010). RCPs were used to develop climate projections in CMIP5 (IPCC, 2023: Annex 1).
Residual risk	The risk related to climate change impacts that remains following adaptation and mitigation efforts. Adaptation actions can redistribute risk and impacts, with increased risk and impacts in some areas or populations, and decreased risk and impacts in others (IPCC, 2022: Annex II).
Resilience	The capacity of interconnected social, economic, and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation (IPCC, 2023: Annex 1).
Risk	The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems (IPCC, 2023: Annex 1).

Key Term	Definition
Risk assessment	The qualitative and/or quantitative scientific estimation of risks (IPCC, 2022: Annex II:).
Stress	Environmental stress denotes both human and naturally induced pressure on the environment. As a subset of this, stress caused by climate change refers to negative environmental impacts caused by gradual changes in atmospheric conditions.
System	A set of things working together as parts of an interconnected network and/or a complex whole (NZ CCRA Framework, 2019).
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a probability density function) or by qualitative statements (e.g., reflecting the judgement 2253 Glossary Annex VII AVII of a team of experts) (IPCC, 2022: Annex II).
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2023: Annex 1).
Wellbeing	A state of existence that fulfils various human needs, including material living conditions and quality of life, as well as the ability to pursue one's goals, to thrive and to feel satisfied with one's life. Ecosystem well-being refers to the ability of ecosystems to maintain their diversity and quality (IPCC, 2023: Annex 1).

16 Acronyms

Acronyms	Definition
AEP	Annual Exceedance Probability
AR5	Fifth Assessment Report
AR6	Sixth Assessment Report
CCRA	Climate Change Risk Assessment
CFRAM	Catchment-based Flood Risk Assessment and Management
CSO	Central Statistics Office
DCCEEW	Department of Climate Change, Energy, the Environment, and Water
DECC	Department of the Environment, Climate and Communications
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
ESRI	Economic and Social Research Institute
EU	European Union
EUCRA	European Climate Risk Assessment
GHG	Greenhouse Gas Emissions
GSI	Geological Survey Ireland
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IW	Internal Waters
LA	Local Authority
LACAP	Local Authority Climate Acton Plan
NAF	National Adaptation Framework
NCCRA	National Climate Change Risk Assessment
NFCS	National Framework for Climate Services
NUTS	Nomenclature of Territorial Units for Statistics
NZ	New Zealand
OPW	Office of Public Works
RCPs	Representative Concentration Pathways
SAP	Sectoral Adaptation Plans
SLR	Sea level rise
SSP	Shared Socioeconomic Pathway
TSL	Territorial Sea Limit
UK	United Kingdom
UKCP18	UK Climate Projections 2018
WP	Work Package

17 References

Armstrong McKay, D., Abrams, J., Winkelmann, R., Sakschewski, B., Loriani, S., Fetzer, I., Cornell, S., Rockström, J., Staal, A., and Lenton, T. (2022) 'Exceeding 1.5°C global warming could trigger multiple climate tipping points', *Science*, 377(6611). doi:10.1126/science.abn7950.

Cámaro García, C.A., and Dwyer, N. (2021) *The Status of Ireland's Climate*, EPA Research Report 386.

CCAC (2025) *Climate Change Advisory Council Annual Review 2025*. Available at: https://www.climatecouncil.ie/councilpublications/annualreviewandreport/CCAC%20AR25%20Our%20Changing%20Climate-final.pdf

Central Bank of Ireland (2024) *The Flood Protection Gap.* Available at: https://www.centralbank.ie/docs/default-source/regulation/industry-market-sectors/insurance-reinsurance/flood-gap-report/flood-protection-gap-report.pdf

Central Statistics Office (2023) *Census of Population 2022*. Available at: https://www.cso.ie/en/statistics/population/censusofpopulation2022.

Clarke, B., Thorne, P., Ryan, C., Zachariah, M., Murphy, C., McCarthy, G., O'Connor, P., Eresanya, E.O., Cahill, N., Coonan, B., and Otto, F. (2023) 'Climate change made the extreme 2-day rainfall event associated with flooding in Midleton, Ireland more likely and more intense', Grantham Institute, Imperial College London; ICARUS Climate Research Centre, Maynooth University; Met Éireann.

Climate Ireland (2025) *Coastal Flooding*. Available at: https://www.climateireland.ie/impact-on-ireland/climate-hazards/coastal-flooding/ [Accessed 16 Jan. 2025].

Committee on Climate Change (2022) *UK Climate Change Risk Assessment 2022: Technical Report*. London: Committee on Climate Change. Available

at: https://www.theccc.org.uk/wp-content/uploads/2021/07/Independent-Assessment-of-UK-Climate-Risk-Advice-to-Govt-for-CCRA3-CCC.pdf.

Cornes, R.C., Tinker, J., Hermanson, L., Oltmanns, M., Hunter, W.R., Lloyd-Hartley, H., Kent, E.C., Rabe, B., and Renshaw, R. (2023) 'The impacts of climate change on sea temperature around the UK and Ireland', Marine Climate Change Impacts Partnership. Available at: https://www.researchgate.net/publication/368713685_The_Impacts_of_Climate_Change_on_Sea_Temperature_around_the_UK_and_Ireland [Accessed 16 Jan. 2025].

Department of Agriculture, Food and the Marine, 2025. *Estimating the Extent of Damage to Forests following Storms Darragh and Eowyn using the National Forest Inventory & Earth observation data*. Available at: https://assets.gov.ie/319780/44224921-919d-4bc0-8415-38ac274ad05e.pdf [Accessed 13 March 2025].

Devoy, R. J. (2008) ‘Coastal vulnerability and the implications of sea-level rise for Ireland.’ J. Coast. Res. 24(2): 325–341.

Duffy, K., De Bruin, K.C., Henry, L., Kweku Kyei, C., Nolan, A., and Walsh, B. (2024) *Health impacts of climate change and mitigation policies in Ireland*. Economic and Social Research Institute. Available at: https://www.esri.ie/publications/health-impacts-of-climate-change-and-mitigation-policies-in-ireland [Accessed 16 Jan. 2025].

Department of Agriculture, Food and the Marine (2023) *Ireland’s Forest Strategy 2023-2030*. Available at: www.gov.ie/pdf/?file=https://assets.gov.ie/269571/90a5e49b-0481-4c58-b296-7c27ac9a7ad6.pdf#page=null.

Department of Agriculture, Food and the Marine (2019) *Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan*. Available at: https://www.gov.ie/pdf/?file=https://assets.gov.ie/75637/95906844-b6de-42b3-ad32-33bcf7ac8158.pdf#page=null [Accessed: 12 December 2024].

Department of Agriculture, Food and the Marine (2023) *Fishery Harbour Centres and Coastal Infrastructure Development Programme 2024*. Available at: https://assets.gov.ie/283386/6ed19143-b885-4a0e-8889-ac84e2686e47.pdf.

Department of Agriculture, Food and the Marine (2023) *Shannon Callows Flood Scheme 2023*. Available at: https://www.gov.ie/en/service/b218a-shannon-callows-flood-scheme-2023.

Department of Culture, Heritage and the Gaeltacht (2019) *Biodiversity Climate Change Sectoral Adaptation Plan*. Available at: https://www.npws.ie/sites/default/files/publications/pdf/Biodiversity-Climate-Change-Sectoral-Adaptation-Plan.pdf.

Department of the Environment, Climate and Communications (2019) *Electricity and Gas Networks Sector. Climate Change Adaptation Plan*. Available at: https://www.gov.ie/pdf/?file=https://assets.gov.ie/77095/15ef9327-168a-439e-8ef5-8aaa11934471.pdf#page=null [Accessed: 12 December 2024].

Department of the Environment, Climate and Communications (2024) *National Adaptation Framework*. Available at: https://www.gov.ie/en/press-release/d7b72-minister-ryan-publishes-irelands-second-statutory-national-adaptation-framework/ [Accessed: 16 January 2025].

Department for Environment, Food & Rural Affairs (2022). UK Climate Change Risk Assessment 2022. Available at: https://www.gov.uk/government/publications/uk-climate-change-risk-assessment-2022 (Accessed: 11 March 2025).

Department of Health (2019) *Health Climate Change Sectoral Adaptation Plan*. Available at: https://www.gov.ie/pdf/?file=https://assets.gov.ie/75646/9e0dce8a-cebf-496a-aed4-fbe8c285183c.pdf#page=null [Accessed: 12 December 2024].

Department of Housing, Local Government and Heritage (2019) *Built and Archaeological Heritage Climate Change Sectoral Adaptation Plan*. Available at: https://www.gov.ie/pdf/?file=https://assets.gov.ie/246863/2660361a-6b77-4b58-b040-aea8fd960606.pdf#page=null [Accessed: 12 December 2024].

Department of Housing, Local Government and Heritage (2019) *Water Quality and Water Services Infrastructure Climate Change Sectoral Adaptation Plan*. Available at: https://www.gov.ie/pdf/?file=https://assets.gov.ie/75644/057df848-7665-4df1-9abf-1a493f1de7f9.pdf#page=null [Accessed: 12 December 2024].

Department of Housing, Local Government and Heritage (2024) *Guidance Document 11: A Guide to Flood Emergencies*. Available at: https://assets.gov.ie/230606/0d57af8f-f378-472e-8b1a-3865b3241f16.pdf [Accessed 16 Jan. 2025].

Department of Housing, Local Government and Heritage (2024) *Nature Based Management of Urban Rainwater and Urban Surface Water Discharges: A National Strategy*. Available at: https://www.gov.ie/en/publication/d9a24-nature-based-management-of-urban-rainwater-and-urban-surface-water-discharges-a-national-strategy/ [Accessed 16 Jan. 2025].

Department of Housing, Local Government and Heritage (2024) *River Basin Management Plan 2022-2027*. Available at: https://www.gov.ie/en/policy-information/8da54-river-basin-management-plan-2022-2027/ [Accessed 16 Jan. 2025].

Department of Housing, Local Government and Heritage (2020) *Marine Planning Policy Statement*. Available at: https://assets.gov.ie/68903/2b09bbb21365470484ccf491d918e58e.pdf.

Department of Housing, Local Government and Heritage (2023) *National Marine Planning Framework Baseline Report*. Available at: https://assets.gov.ie/294556/8d6858e0-8ad4-4e87-bc0b-40ee9f219a2c.pdf.

Department of Transport (2019) *Transport Sector Climate Change Sectoral Adaptation Plan*. Available at: https://www.gov.ie/pdf/?file=https://assets.gov.ie/75640/92e6d141-7616-438e-b8cf-ab7cbb55a175.pdf#page=null [Accessed: 12 December 2024].

Eurostat (2024) *Shedding light on energy in Europe – 2024 edition*. Available at: https://ec.europa.eu/eurostat/web/interactive-publications/energy-2024 [Accessed 21 January 2025].

European Commission (2004) *Living with coastal erosion in Europe: Sediment and Space for Sustainability*. Available at: http://www.eurosion.org/project/eurosion_en.pdf [Accessed 16 Jan. 2025].

European Commission (2025) *Nature Restoration Law*. Available at: https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en [Accessed: 16 January 2025].

European Commission (2025) *The Habitats Directive*. Available at: https://environment.ec.europa.eu/topics/nature-and-biodiversity/habitats-directive_en [Accessed 16 Jan. 2025].

European Environment Agency (2024) *European Climate Risk Assessment*. EEA Report No 1/2024. Available at: https://www.eea.europa.eu/publications/european-climate-risk-assessment [Accessed 16 Jan. 2025].

European Environment Agency (n.d.) *Climate-ADAPT*. Available at: https://climate-adapt.eea.europa.eu/en.

Financial Stability Board (2020) *The implications of climate change for financial stability*. Available at: https://www.fsb.org/2020/11/the-implications-of-climate-change-for-financial-stability/ [Accessed 21 January 2025].

Geological Survey Ireland (2025) *National Coastal Change Assessment*. Available at: https://www.gsi.ie/en-ie/programmes-and-projects/marine-and-coastal-unit/projects/Pages/National-Coastal-Change-Assessment.aspx [Accessed: 16 January 2025].

Government of Ireland (2020) *A Framework for Major Emergency Management*. Available at: https://assets.gov.ie/180183/5dca2e44-350b-492a-bdc3-e5b1135a918d.pdf [Accessed 16 Jan. 2025].

Government of Ireland (2022) *Water Environment (Abstractions and Associated Impoundments) Act 2022*. Available at: https://www.irishstatutebook.ie/eli/2022/act/48/enacted/en/html [Accessed 16 Jan. 2025].

IPCC (2014) 'Summary for policymakers'. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., and White, L.L. (eds) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

IPCC (2022) 'Annex II: Glossary'. In: Möller, V., van Diemen, R., Matthews, J.B.R., Méndez, C., Semenov, S., Fuglestvedt, J.S., and Reisinger, A. (eds) *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2897–2930. doi:10.1017/9781009325844.029.

IPCC (2023) *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Core Writing Team, Lee, H. and Romero, J. (eds). IPCC, Geneva, Switzerland, 184 pp. doi: 10.59327/IPCC/AR6-9789291691647.

IPCC (2022) *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., and Rama, B. (eds). Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp. doi: 10.1017/9781009325844.

Irish Water (n.d.) *Incident Management and Emergency Response*. Available at: https://www.water.ie/help/supply/incident-management-and-e.

Irish Water (n.d.) *National Water Resources Plan*. Available at: https://www.water.ie/projects/strategic-plans/national-water-resources.

Kelly, J., O'Flynn, C., and Maguire, C. (2013). Risk analysis and prioritisation for invasive and non-native species in Ireland and Northern Ireland. Available at: https://invasivespeciesireland.com/wp-content/uploads/2013/03/Risk-analysis-and-prioritization-29032012-FINAL.pdf (Accessed: 13 March 2025).

Knaepen, H., and Vajpeyi, I. (2022) *Policy Brief: European responses to transboundary climate impacts and insecurity.* Cascades. Available at: https://www.cidob.org/sites/default/files/2025-04/Policy%20Brief.%20European%20responses%20to%20transboundary%20climate%20impacts%20and%20insecurity.pdf

Local Authority Waters Programme (LAWPRO) (2023) *Farming for Water European Innovation Partnership*. Available at: https://farmingforwater.ie.

Marine Institute (2017) *National Marine Research and Innovation Strategy 2017-2021*. Available at: https://www.marine.ie/site-area/research-funding/national-marine-research-strategy/national-marine-research-innovation-0.

Mateus, C. and Potito, A. (2022) 'Long-term trends in daily extreme air temperature indices in Ireland from 1885 to 2018', *Weather and Climate Extremes*, 36, p.100464. Available at: https://www.researchgate.net/publication/360690839_Long-term_trends_in_daily_extreme_air_temperature_indices_in_Ireland_from_1885_to_2018 [Accessed 16 Jan. 2025].

McCarthy, G.D., Plecha, S., Charria, G., Simon, A., Poppeschi, C., and Russo, A. (2023) 'The marine heatwave west of Ireland in June 2023', *Weather*, 78(6), pp. 162-170. Available at: https://rmets.onlinelibrary.wiley.com/doi/10.1002/wea.4498 [Accessed 16 Jan. 2025].

McCormack, T., Campanyà, J. and Naughton, O. (2022) 'A methodology for mapping annual flood extent using multi-temporal Sentinel-1 imagery', *Remote Sensing of Environment*, 282, p. 113273. doi: 10.1016/j.rse.2022.113273.

Met Éireann (2023) *Translate: One Climate Resource for Ireland*. Available at: https://www.met.ie/science/translate [Accessed 16 Jan. 2025].

Met Éireann (2023) Ireland's Climate Averages: Updated 30 year climate averages for the period 1991-2020. Available at https://www.met.ie/climate/30-year-averages. [Accessed 10th March 2025].

Met Éireann (2025) *Annual Climate Statement for 2024*. Available at: https://www.met.ie/annual-climate-statement-for-2024.

Meskill, T. (2025) 'Holyhead sailings resume following closure in December', *RTÉ*. Available at: https://www.rte.ie/news/ireland/2025/0116/1491115-holyhead-sailings/ [Accessed 21 January 2025].

Mikaelsson, M., Harris, K. and Benzie, M. (2024) *Assessment on Prioritising Transboundary Climate Risks for Ireland*. Stockholm Environment Institute & Adaptation Without Borders.

Ministry for the Environment (2020) *National Climate Change Risk Assessment for New Zealand – Arotakenga Tūraru mō te Huringa Āhuarangi o Aotearoa: Method report – Pūrongo whakararangi*. Wellington: Ministry for the Environment.

Murphy, C., Heaphy, L., Quinn, T., O'Brien, E., and Nolan, P. (2023) *Ireland's Climate Change Assessment Volume 3: Being Prepared for Ireland's Future Climate*. Environmental Protection Agency, Ireland, 276 pp.

Murphy, C., Kettle, A., Meresa, H., Golian, S., Bruen, M., O'Loughlin, F., and Mellander, P. (2023) 'Climate Change Impacts on Irish River Flows: High Resolution Scenarios and Comparison with CORDEX and CMIP6 Ensembles', *Water Resource Management*, 37, pp. 1841–1858. doi: 10.1007/s11269-023-03458-4.

Murphy, C., Leonard, K., Moore, R., and Flood, S. (2024) *Transboundary Climate Risks for the Island of Ireland (TCRII)*. Environmental Protection Agency. Available at: https://www.epa.ie/publications/research/climate-change/Research_Report-449.pdf [Accessed 21 January 2025].

Murphy, C. and Meresa, H., 2024. HydroPredict: Ensemble River Flow Scenarios for Climate Change Adaptation

National Biodiversity Data Centre. (n.d.). About. Available at: https://invasives.ie/about/ (Accessed: 13 March 2025).

National Parks and Wildlife Service (2023) *National Biodiversity Action Plan 2023-2030*. Available at: https://www.npws.ie/legislation/national-biodiversity-action-plan.

National Parks and Wildlife Service (n.d.) *Reefs*. Available at: https://www.npws.ie/marine/marine-habitats/reefs (Accessed: 3 February 2025).

Nolan, G. and Flanagan, J. (2020) *High-resolution Climate Projections for Ireland – A Multi-model Ensemble Approach*. EPA Research Report 339.

Nolan, G., Cusack, C., and Fitzhenry, D. (eds) (2023) *Irish Ocean Climate and Ecosystem Status Report*. Marine Institute. Available at: https://oar.marine.ie/handle/10793/1844.

Noone, C., McClean, D., Gallagher, D., McElwain, J., and Thorne, P. (2023) *Ireland's Climate Change Assessment Volume 1: Climate Science – Ireland in a Changing World*. Environmental Protection Agency, Ireland, 228 pp.

O'Brien, E., Ryan, P., Holloway, P., Wang, J., Nowbakht, P., Phillips, C., Fitton, J., O Dwyer, B., and Nolan, P. (2023) *Met Éireann Translate report*. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre. Available at: TRANSLATE - Met Éireann - Seirbhís Náisiúnta Meitéareolaíochta na hÉireann.

O'Mahony, J., Vanmechelen, A. and Holloway, P. (2023) 'Quantifying the distribution and potential biotic interactions between deer and flora using species

distribution modelling', *Annals of GIS*, 29(4), pp. 553–568. doi: 10.1080/19475683.2023.2226196.

Office of Public Works (2019b) *Flood Risk Management Climate Change Sectoral Adaptation Plan*. Available at: https://www.gov.ie/pdf/?file=https://assets.gov.ie/75643/8aa7d5a4-f443-45cd-8953-a7029c6b19f9.pdf#page=null [Accessed: 12 December 2024].

Office of Public Works (2019a) *Irish Coastal Protection Strategy Study (ICPSS)*. Available at: https://www.gov.ie/en/publication/eed0fb-irish-coastal-protection-strategy-study-icpss/.

Office of Public Works (2020) *National Indicative Fluvial Mapping Project: Final Report*. Available at: https://s3-eu-west-1.amazonaws.com/docs.floodinfo.opw/floodinfo_docs/MCR6058-RT002-R03-00-complete.pdf.

Office of Public Works (2025) *Capital Flood Relief Scheme*. Available at: https://www.floodinfo.ie/scheme-info/ [Accessed 16 Jan. 2025].

Office of Public Works (2025) *Minor Flood Mitigation Works and Coastal Protection Scheme*. Available at: https://www.gov.ie/en/publication/0e3b3d-minor-flood-mitigation-works-and-coastal-protection-scheme/ [Accessed: 16 January 2025].

O'Neill, B., Aalst, M. v. and Z. Zaiton Ibrahim (2022) 'Key Risks Across Sectors and Regions'. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Paranunzio, R., Dwyer, E., Fitton, J.M., Alexander, P.J., and O'Dwyer, B. (2021) 'Assessing current and future heat risk in Dublin city, Ireland', *Urban Climate*, 40, p.100983. Available at: https://www.researchgate.net/publication/355058805_Assessing_current_and_future_heat_risk_in_Dublin_city_Ireland [Accessed 16 Jan. 2025].

Pascal, M., Sweeney, J., Cullen, E., Schwartz, J., and Goodman, P. (2014) 'Heatwaves and mortality in Ireland, planning for the future', *Irish Geography*, 46(2), pp.203-211. Available at: https://www.researchgate.net/publication/271568747_Heatwaves_and_mortality_in_Ireland_planning_for_the_future [Accessed 16 Jan. 2025].

Pugh, D.T., Bridge, E., Edwards, R., Hogarth, P., Westbrook, G., Woodworth, P.L., and McCarthy, G.D. (2021) 'Mean sea level and tidal change in Ireland since 1842: a case study of Cork', *Ocean Science*, 17(6), pp.1623-1637. Available at: https://www.researchgate.net/publication/356157897_Mean_sea_level_and_tidal_change_in_Ireland_since_1842_a_case_study_of_Cork [Accessed 16 Jan. 2025].

Potsdam Institute for Climate Impact Research (2023) *Tipping Elements – big risks in the Earth System*. Available at: https://www.pik-potsdam.de/en/output/infodesk/tipping-elements. Retrieved 01 February 2025.

Ryan, C., Curley, M., Walsh, S., and Murphy, C. (2021) 'Long-term trends in extreme precipitation indices in Ireland', *International Journal of Climatology*, 42. doi: 10.1002/joc.7475.

Sardar, S., and Islam, M.M. (2024) 'The impact of recreational activities on ecology: An evidence-based systematic review and bibliometric analysis', *Sustainability*, 17(1), p.74. Available at: https://www.researchgate.net/publication/387444822_The_Impact_of_Recreational_Activities_on_Ecology_An_Evidence-Based_Systematic_Review_and_Bibliometric_Analysis [Accessed 16 Jan. 2025].

Shoari Nejad, A., Parnell, A.C., Greene, A., Thorne, P., Kelleher, B.P., Devoy, R.J.N., and McCarthy, G. (2022) 'A newly reconciled dataset for identifying sea level rise and variability in Dublin Bay', *Ocean Science*, 18(2), pp.511-522. Available at: https://os.copernicus.org/articles/18/511/2022/ [Accessed 16 Jan. 2025].

Simpson, J., Lawrence, J., Lempert, R.J., Muccione, V., Mackey, B., New, M.G., O'Neill, B., Otto, F., Pörtner, H.-O., Reisinger, A., Roberts, D., Schmidt, D.N., Seneviratne, S., Strongin, S., and van Aalst, M. (2021) 'A framework for complex climate change risk assessment', *One Earth*, 4(4), pp.489–501. doi: https://doi.org/10.1016/j.oneear.2021.03.005.

Sustainable Energy Authority of Ireland (n.d.) *Imports and import dependency*. Available at: https://www.seai.ie/data-and-insights/seai-statistics/annual-energy-data/energy-supply/imports [Accessed 21 January 2025].

Thorne, P., Noone, C., McClean, D., Gallagher, D., McElwain, J., and Murphy, C. (2023) *Ireland's Climate Change Assessment*. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Uisce Éireann (2023) *National Water Resources Plan*. Available at: https://www.water.ie/projects/strategic-plans/national-water-resources [Accessed 16 Jan. 2025].

van den Hurk, B., Pinardi, N., Bisaro, A., Galluccio, G., Jiménez, J.A., Larkin, K., Melet, A., Pomarico, L.G., Richter, K., Singh, K., van de Wal, R., and Winter, G. (2024) 'Sea Level Rise in Europe: Summary for Policymakers'. In: van den Hurk, B., Pinardi, N., Kiefer, T., Larkin, K., Manderscheid, P., and Richter, K. (eds) *Sea Level Rise in Europe: 1st Assessment Report of the Knowledge Hub on Sea Level Rise (SLRE1)*. Copernicus Publications, State Planet, 3-slre1, 1. Available at: https://doi.org/10.5194/sp-3-slre1-1-2024.

Waters of LIFE (n.d.) *Waters of LIFE Project*. Available at: https://www.watersoflife.ie.

Watkiss, P., Cimato, F., Hunt, A. (2021). Monetary Valuation of Risks and Opportunities in CCRA3. Supplementary Report for UK Climate Change Risk Assessment 3, prepared for the Climate Change Committee, London.

Appendix A: Detailed Hazard and Climate Information

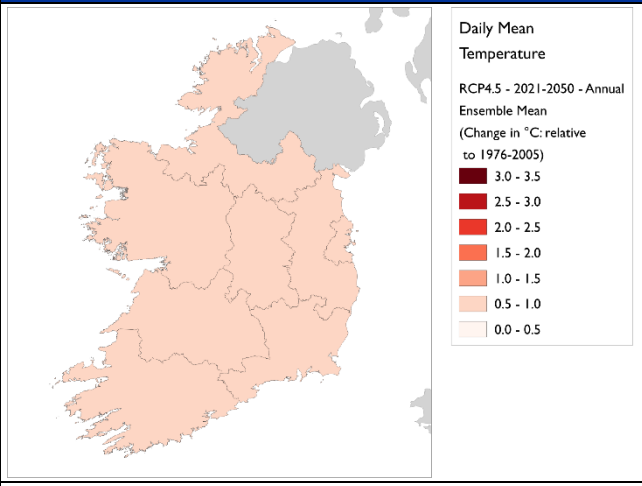
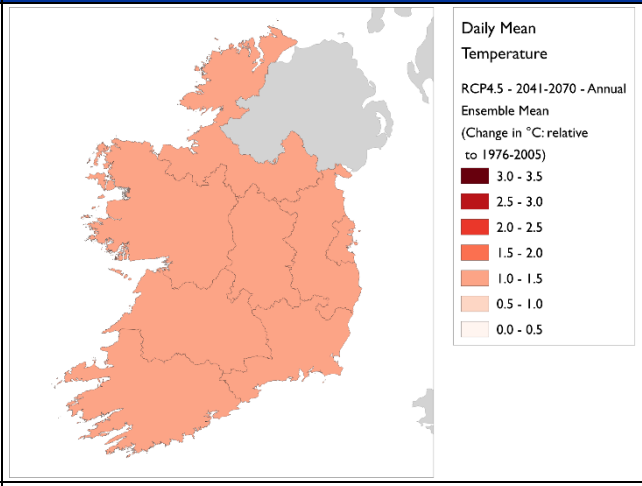
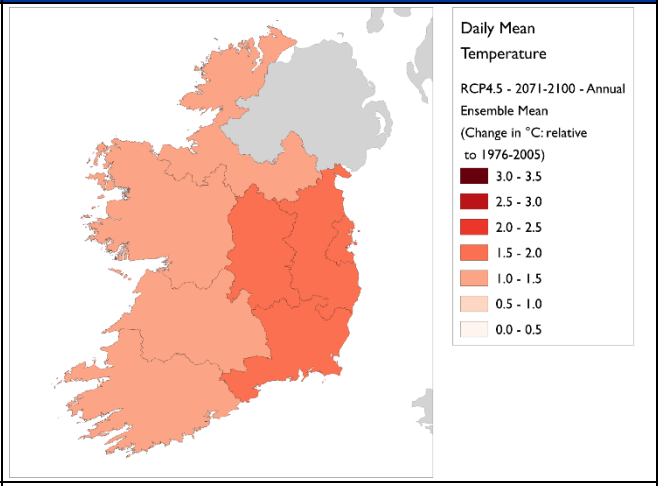
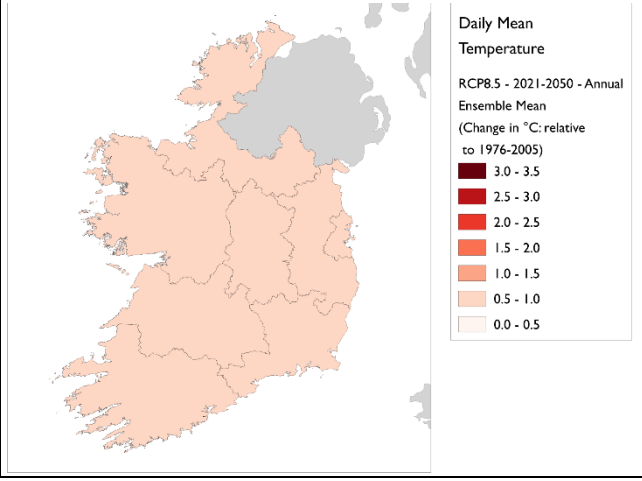
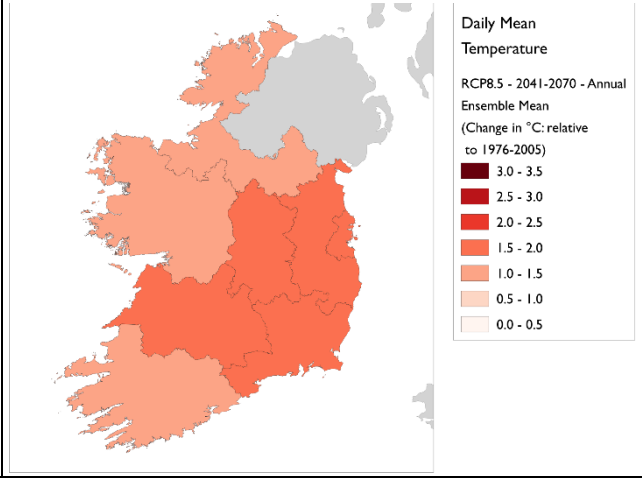
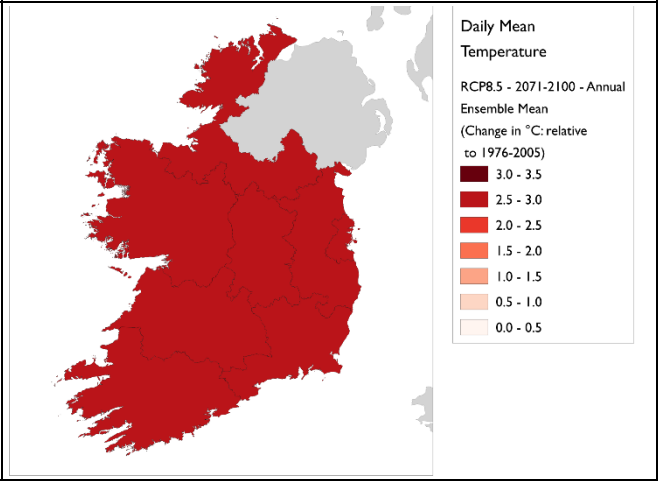
Hazard	Variable	Description	Data Source	Comment
Changes in Average Temperature	Mean Temperature (tmean)	Average mean temperature during period of interest (annual or seasonal)	TRANSLATE	National downscaled projections.
Extreme Heat	Summer Days (su)	No. of days with maximum temperature >25°C	TRANSLATE	National downscaled projections.
	No. of heatwaves (csu)	No. of heatwaves (periods of at least 5 consecutive summer days)	TRANSLATE	National downscaled projections.
Extreme Cold	Frost Days (fd)	No. of days when minimum temperatures are <0°C	TRANSLATE	National downscaled projections.
	Icing Days (id)	No. of days when maximum temperatures are <0°C	TRANSLATE	National downscaled projections.
Changes in Precipitation	Precipitation (tot_prec)	Projection of average levels of precipitation	TRANSLATE	National downscaled projections.
Extreme Precipitation	Wettest 5-Day Period (Rx5day)	Five-day maximum precipitation during the period of interest (annual or seasonal)	TRANSLATE	National downscaled projections.
	Very Wet Days (R30mm)	No. of days with rainfall >30mm	TRANSLATE	National downscaled projections.
	Number of Wet days (RR1)	No. of Wet days (>1mm)	TRANSLATE	National downscaled projections.
Drought	3 month Standardised Precipitation-Evapotranspiration Index (SPEI-3)	SPEI calculated over a 3-month period	HydroPredict (Meresa and Murphy, 2023)	
Wildfire	Fire Weather Index (FWI)	Fire danger based on weather conditions	Climate-ADAPT	
Extreme Wind	Extreme Wind Days	Extreme wind days	Climate-ADAPT	
	Surface Wind Speed	Wind speed at surface	Nolan and Flanagan (2020)	
Fluvial Flooding	1% Annual Exceedance Probability (AEP) Flood Extent	A 1% AEP flood event that has a 1%, or 1 in a 100, chance of occurring or being exceeded in any given year	National Indicative Fluvial Mapping (NIFM) Catchment Flood Risk Assessment and Management (CFRAM)	The OPW scenarios have been aligned to RCP4.5 and RCP8.5 time horizons.
Surface Water Flooding	Very Wet Days (R30mm)	No. of days with rainfall >30mm	TRANSLATE	The data has national coverage at the NUTS 3 level for current and future time horizons that align with RCP4.5 and RCP8.5.

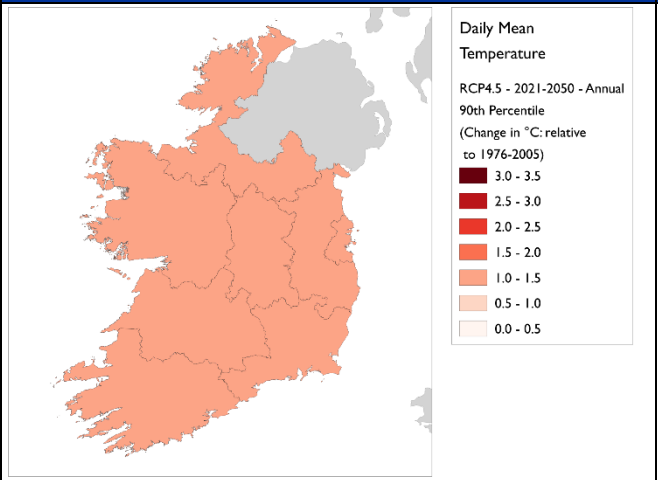
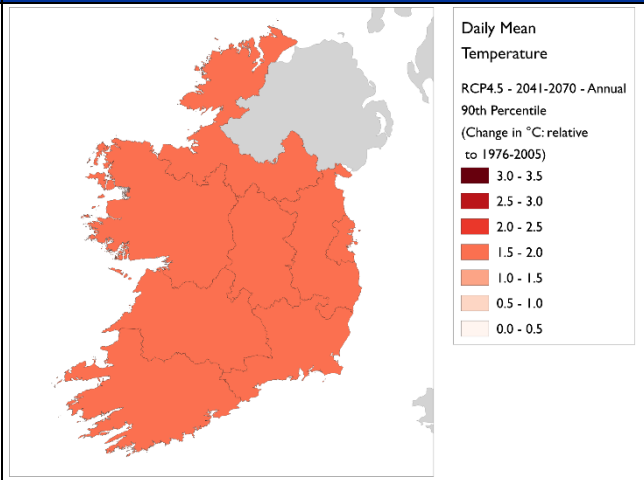
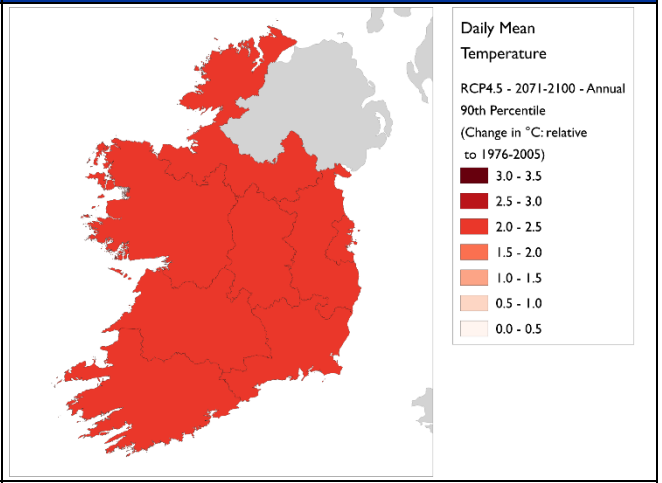
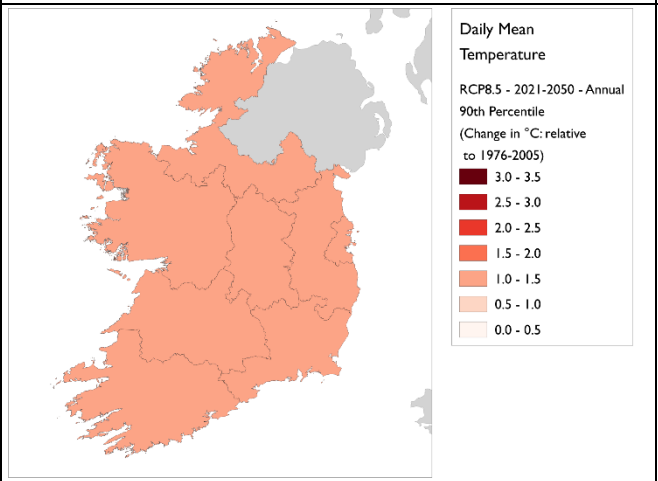
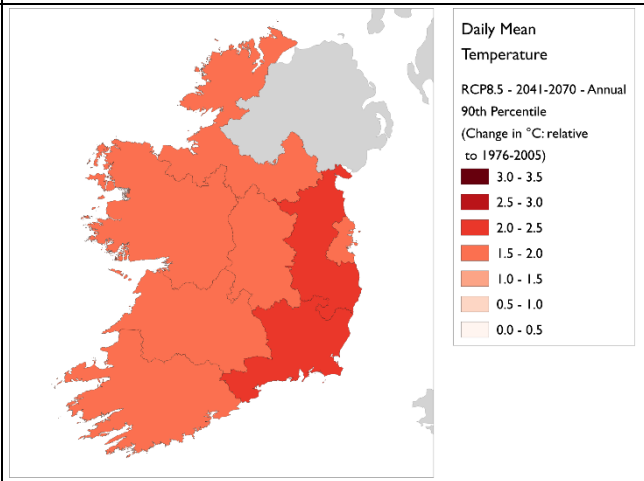
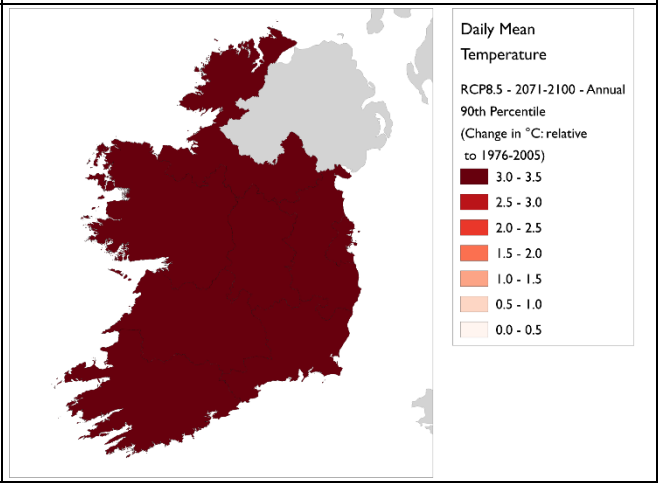
Hazard	Variable	Description	Data Source	Comment
	Wettest Day (Rx1 day)	Max. daily precipitation during the period of interest (annual or seasonal)	TRANSLATE	The data has national coverage at the NUTS 3 level for current and future time horizons that align with RCP4.5 and RCP8.5.
Groundwater Flooding	0.1% Annual Exceedance Probability (AEP) Flood Extent	A 0.1% AEP flood event that has a 0.1%, or 1 in a 1000, chance of occurring or being exceeded in any given year	McCormack et al. (2020) .	Only current flood extents are mapped, there are no future projections.
Sea Level Rise	Total Sea Level Rise	Change in sea level	Fox-Kemper et al. (2021), Kopp et al. (2023), Garner et al.(2021)	
Coastal Flooding	1% Annual Exceedance Probability (AEP) Flood Extent	A 1% AEP flood event that has a 1%, or 1 in a 100, chance of occurring or being exceeded in any given year	National Coastal Flood Hazard Mapping (NCFHM)	The OPW scenarios have been aligned to RCP4.5 and RCP8.5 time horizons.
Coastal Erosion	Eroding coastline	Length of coastline exposed to coastal erosion	Irish Coastal Protection Strategy Study	Future projections do not take into account the impact of climate change.
Ocean Acidification	pH level of seawater	pH at Surface	Coupled Model Intercomparison Project Phase 6 (CMIP6)	The dataset is global, oceanic pH is derived from CMIP6 ensemble projections (anomaly relative to 2005-2014 baseline) for SSP126/SSP585 scenarios.
Sea Surface Temperature	Sea Surface Temperature	SST is derived a from CMIP6 ensemble projections for SSP scenarios from a representative location off the coast off southern Ireland (longitude: 50, latitude: -10).	Coupled Model Intercomparison Project Phase 6 (CMIP6)	The dataset is global, sea surface temperature derived from CMIP6 ensemble projections (anomaly relative to 2005-2014 baseline) for SSP126/SSP585 scenarios.
Lightning	Lightning counts	Change in the number of lightning counts	Kahraman et al (2022)	Only regional projections are available.
Changes in Phenology	Growing Season Start Growing Season Length	- First annual instance of 6 consecutive days where mean temperature > 5˚C - Number of days between growing season start and end	TRANSLATE	The data has national coverage at the NUTS 3 level for current and future time horizons that align with RCP4.5 and RCP8.5.

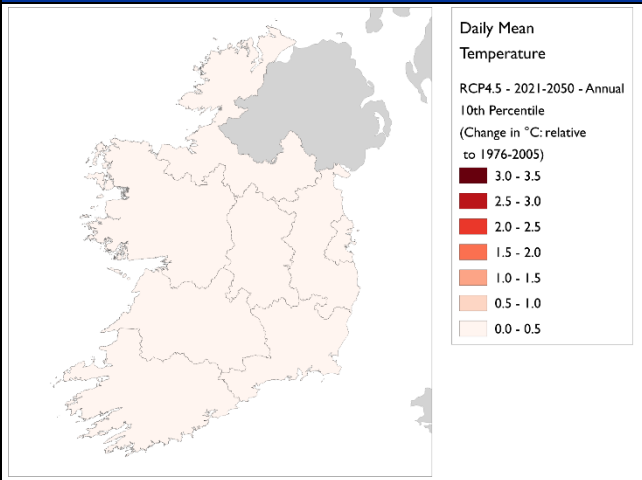
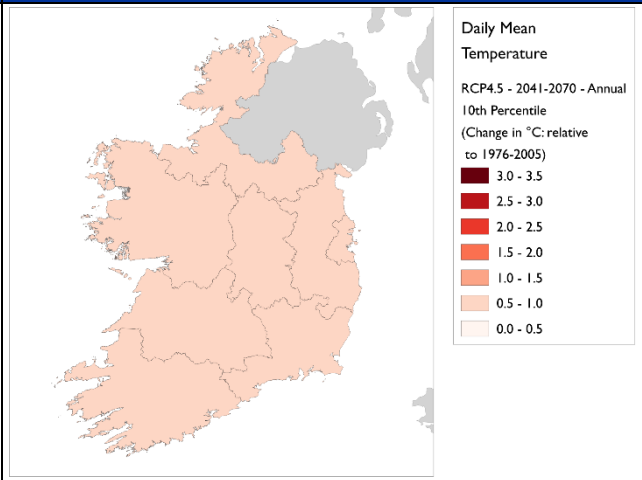
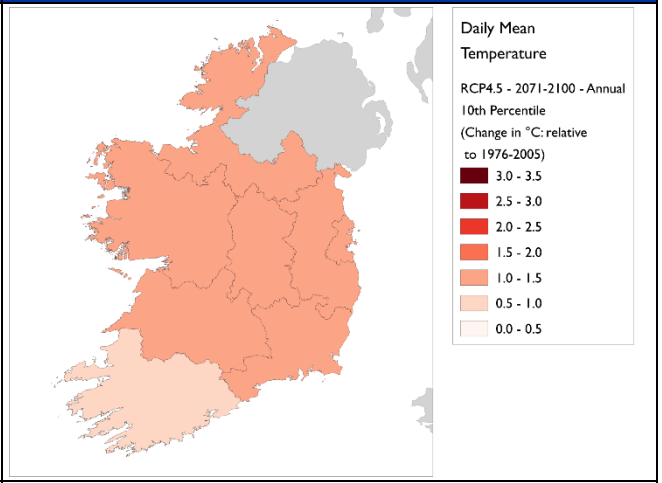
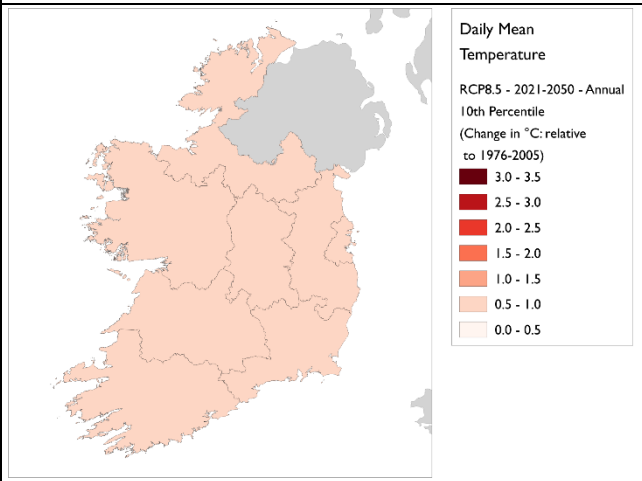
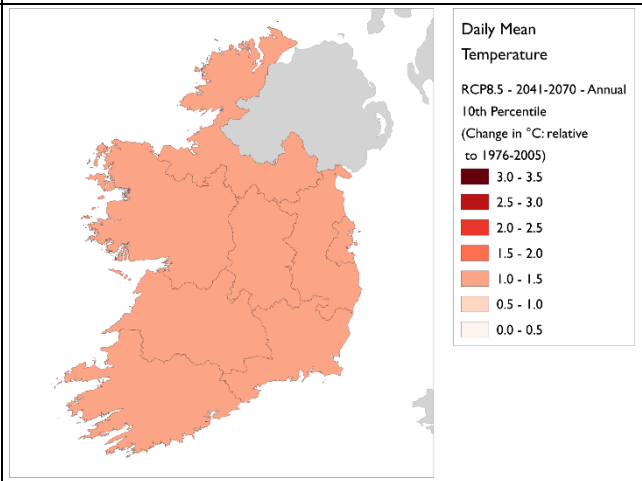
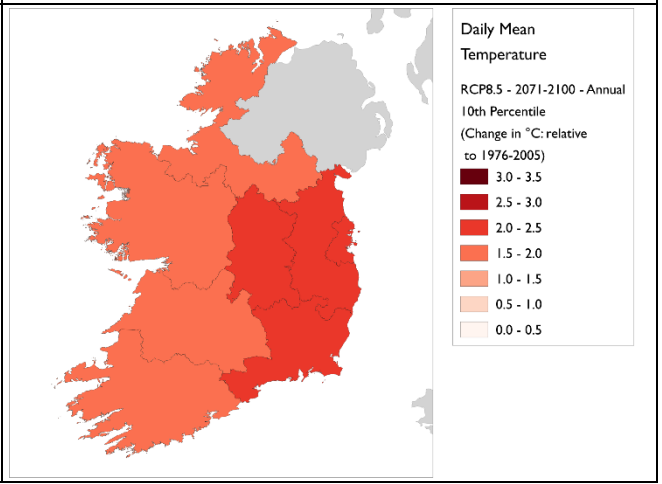
Changes in Average Temperature

Changes in Average Temperature (Daily Mean Temperature)		
National	**Sub-national (NUTS3) zones affected**	
Recent observations or changes	**2050**	**2100**
• Ireland's warming trend is consistent with the global warming trend. Over the last 100 years, Ireland's mean annual temperature has increased by approximately 1ºC and 16 of the top 20 warmest years have occurred since 1990 (Noone et al., 2023; García & Dwyer, 2020). • Observed seasonal temperature anomalies indicate that all seasons exhibit a warming trend. Minimum temperature anomalies show a higher increase in the summer while winter anomalies indicate a more consistent but relatively smaller increase (García & Dwyer, 2020). • During the baseline period (1976 - 2005), Ireland's mean annual temperature was 9.32°C (O'Brien et al., 2023).	• At the NUTS 3 level, all regions are projected to experience an increase in air temperature, with the Mid-East and South-East regions most affected across both RCP4.5 and RCP8.5 scenarios.	• At the NUTS 3 level, all regions are projected to experience an increase in air temperature, with the Mid-East and South-East regions most affected across both RCP4.5 and RCP8.5 scenarios.

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5	• Nationally, daily mean temperature is projected to increase by 0.8°C (0.4-1.2°C) by 2030, with the Mid-East region experiencing the largest increase (0.9°C (0.4-1.2°C)). Considering seasonality, the highest daily mean temperature increase is expected in autumn (1.3°C (0.9-1.8°C)) and the lowest is in the spring (0.5°C (-0.1-0.9°C)).	• Nationally, daily mean temperature is projected to increase by 1.1°C (0.6-1.7°C) by 2050. with the Mid-East region experiencing the largest increase (1.1°C (0.6-1.8°C)). Considering seasonality, highest daily mean temperature increase is expected in autumn (1.5°C (1.1-2.3°C)), and lowest is in spring (0.7°C (0.1-1.1°C)).	• Nationally, daily mean temperature is projected to increase by 1.5°C (1.1-2.2°C) by 2100, with the Mid-East region experiencing the largest increase (1.5°C (1.1-2.2°C)). Considering seasonality, the highest daily mean temperature increase is expected in autumn (2.0°C (1.6-3.1°C)), and the lowest in spring (0.9°C (0.5-1.4°C)).
RCP8.5	• Nationally, daily mean temperature is projected to increase by 0.9°C (0.6-1.3°C) by 2030 with the Mid-East region experiencing the largest increase (1.0°C (0.7-1.4°C)). Considering the seasonality, the highest daily mean temperature increase is expected in the autumn (1.4°C (1.0-1.9°C)), and lowest is in spring (0.5°C (0.2-0.9°C)).	• Nationally, daily mean temperature is projected to increase by 1.5°C (1.1-1.9°C) by 2050s. with the Mid-East region experiencing the largest increase (1.6°C (1.2-2.0°C)). Considering the seasonality, highest daily mean temperature increase is expected in autumn (2.1°C (1.7-2.7°C)), and lowest is in spring (1.0°C (0.5-1.3°C)).	• Nationally, daily mean temperature is projected to increase by 2.7°C (2.0-3.3°C) by 2100. with the Mid-East region experiencing the largest increase (2.8°C (2.0-3.5°C)). Considering seasonality, the highest daily mean temperature increase is expected in autumn (3.4°C (2.7-4.6°C)), and lowest is in spring (2.0°C (1.1-2.4°C)).

	Projected changes by 2030 (Daily Mean Temperature – Mean)	Projected changes by 2050 (Daily Mean Temperature – Mean)	Projected changes by 2100 (Daily Mean Temperature – Mean)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Daily Mean Temperature – 90th Percentile)	Projected changes by 2050 (Daily Mean Temperature – 90th Percentile)	Projected changes by 2100 (Daily Mean Temperature – 90th Percentile
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Daily Mean Temperature - 10th Percentile)	Projected changes by 2050 (Daily Mean Temperature - 10th Percentile)	Projected changes by 2100 (Daily Mean Temperature - 10th Percentile)
RCP4.5			
RCP8.5			

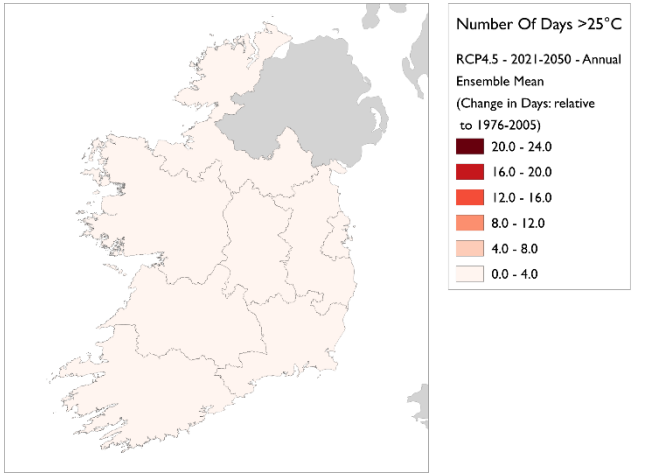
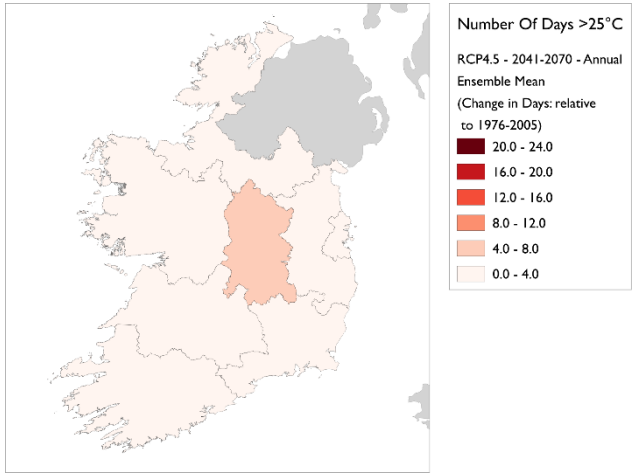
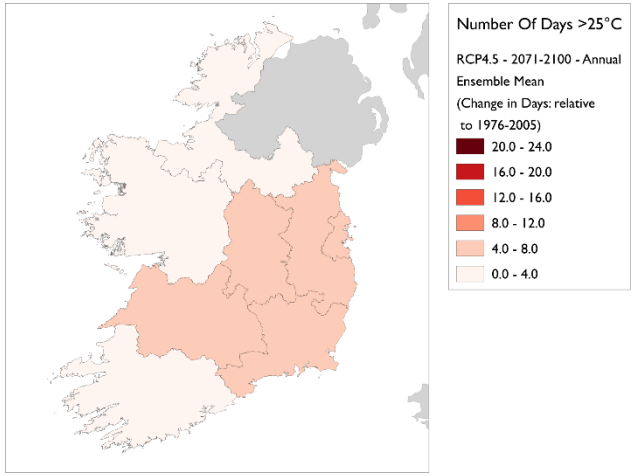
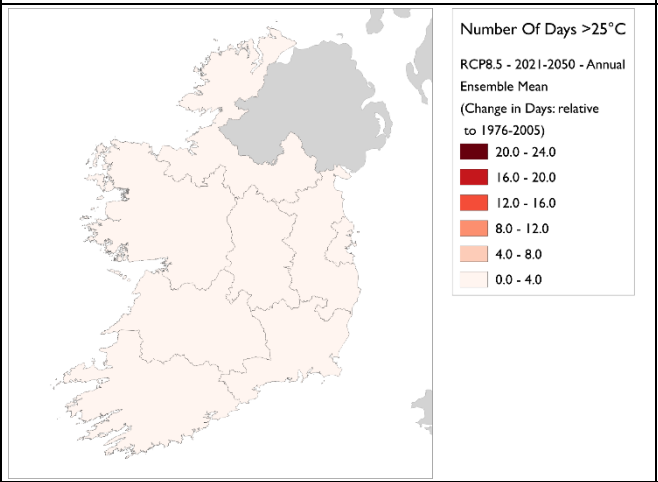
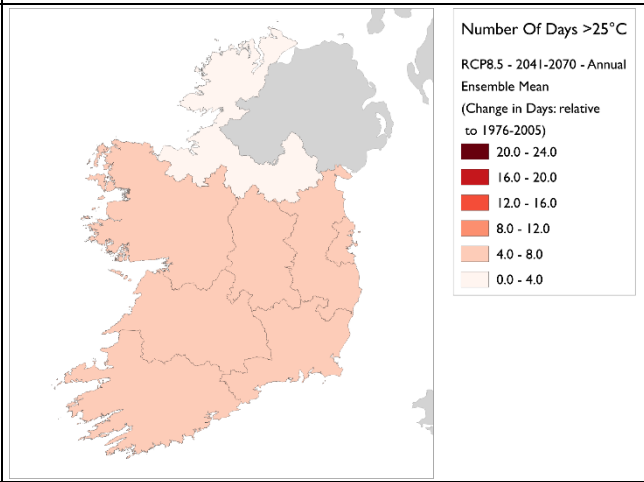
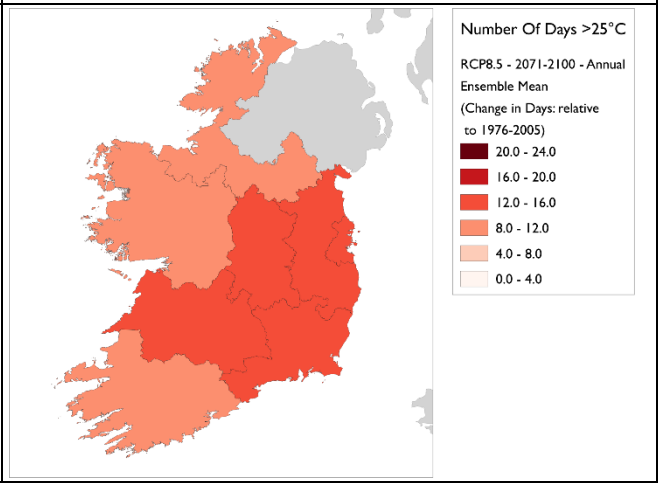
Confidence - High
Agreement: The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for this variable. The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios. **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

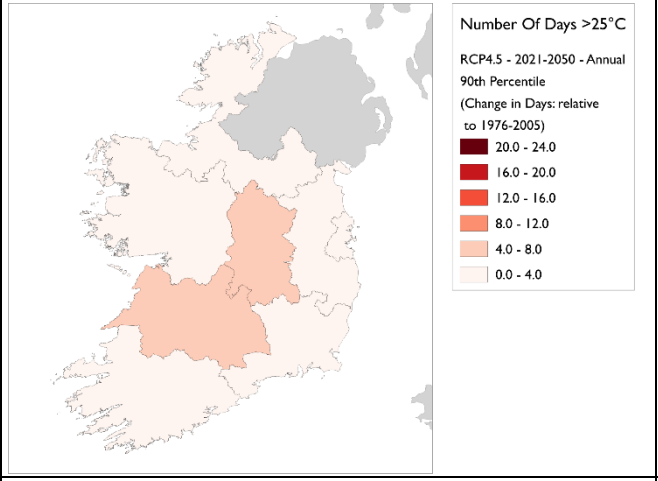
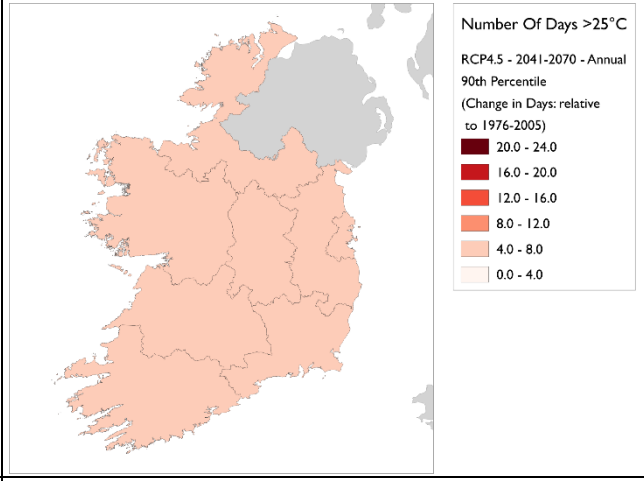
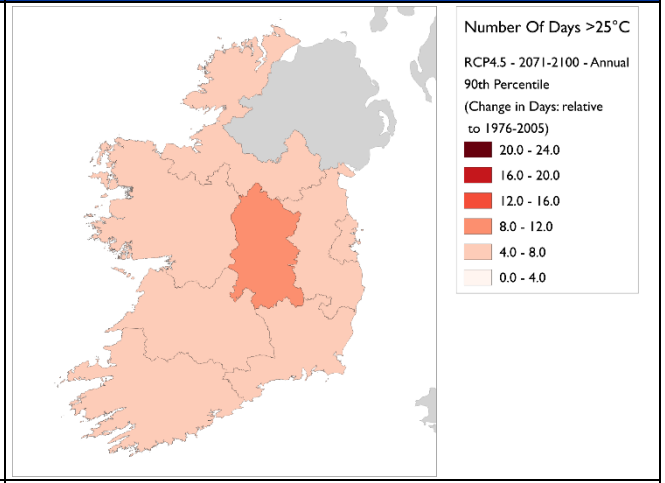
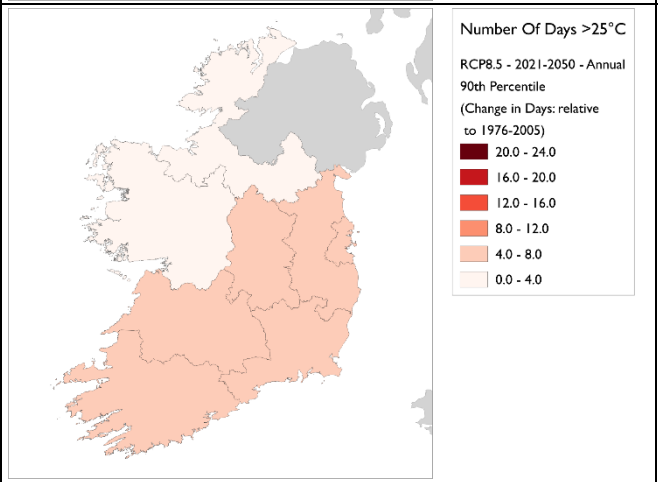
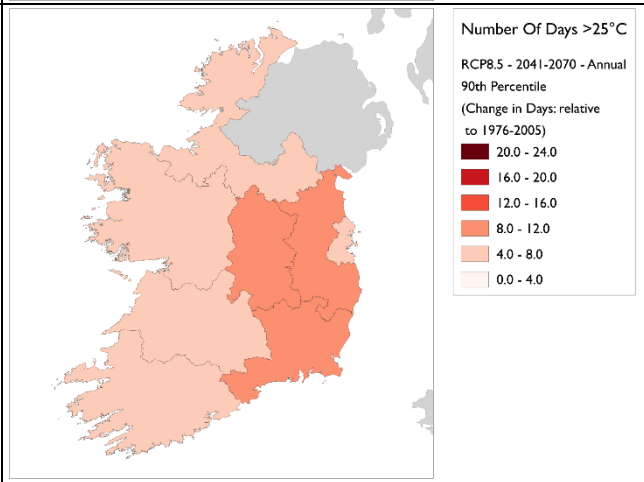
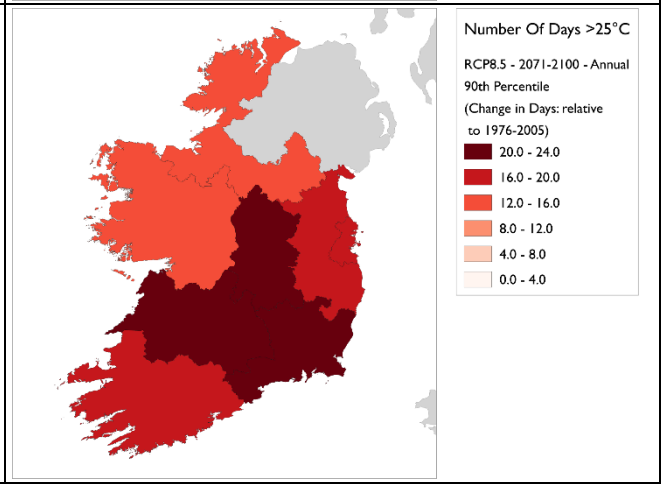
	References
Observations	Noone, C., McClean, D., Gallagher, D. and Thorne, P. (2024). Ireland's Climate Change Assessment 2023. Volume 1: Climate Science-Ireland in a changing World. Summary of Policymakers.
	Cámaro García, C., A., and Dwyer, N. (2021) The Status of Ireland's Climate, EPA Research Report 386.
Projections	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023). Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.

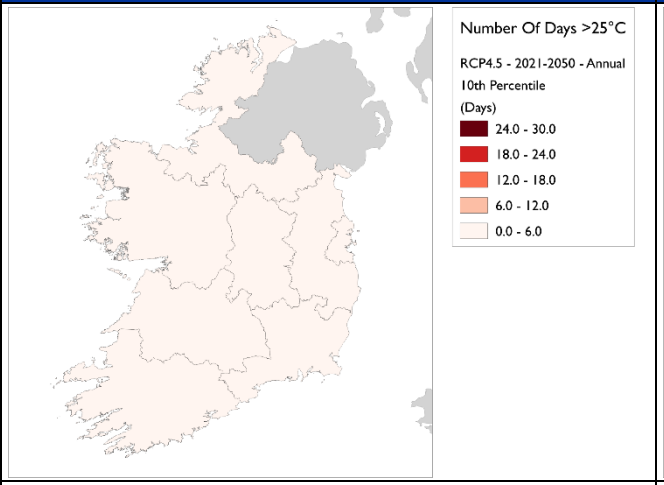
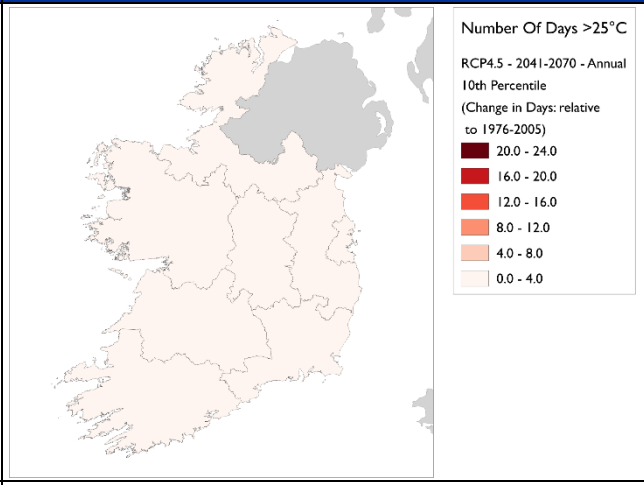
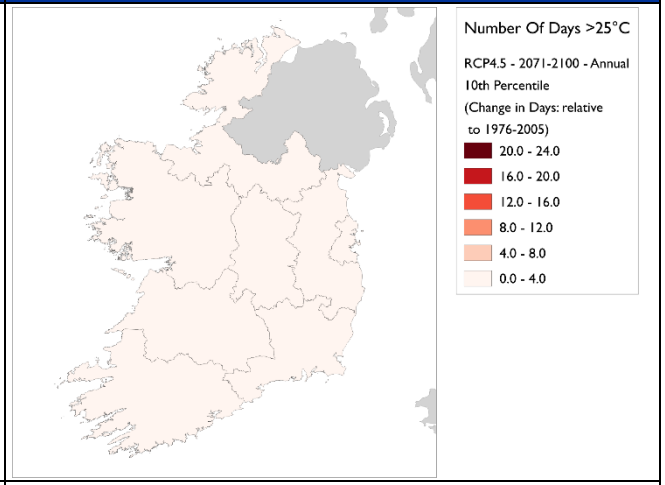
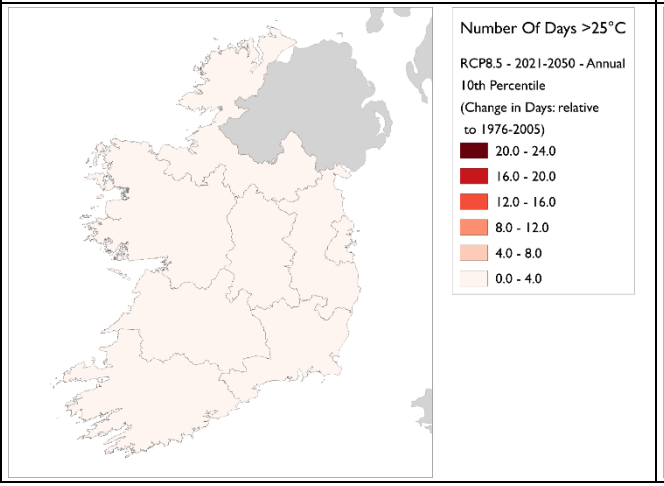
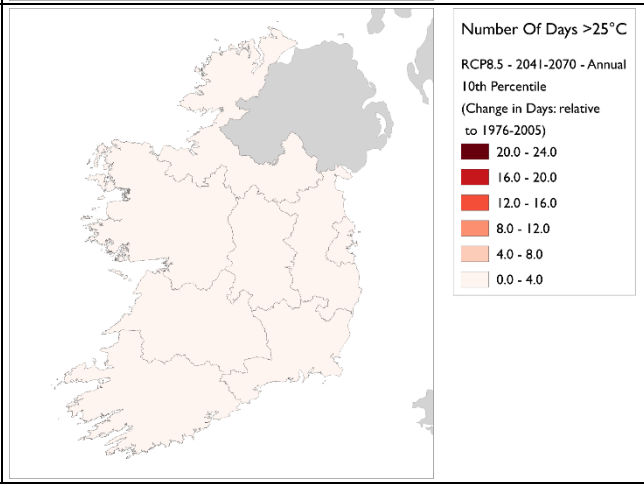
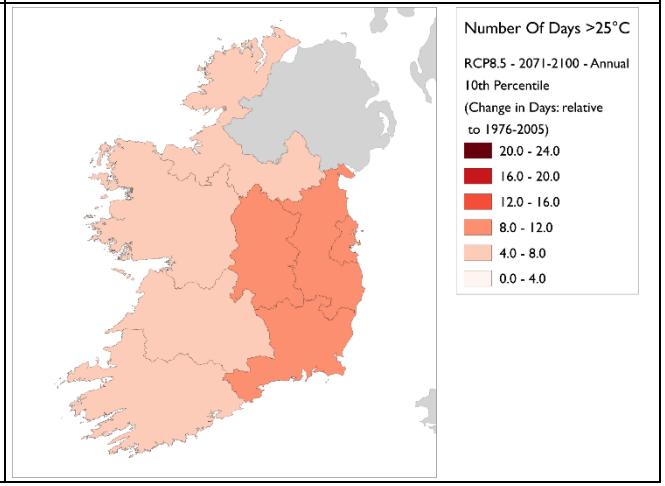
Extreme Heat

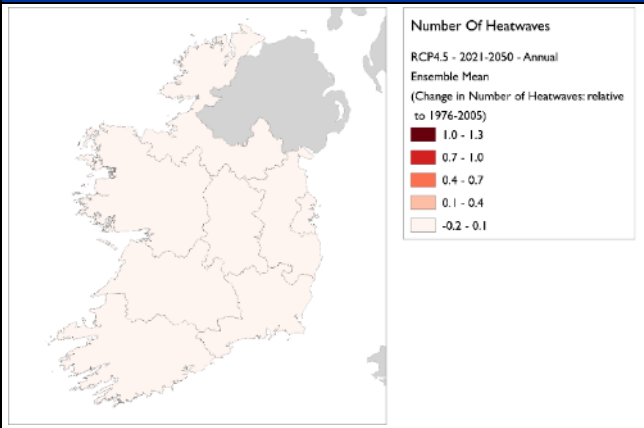
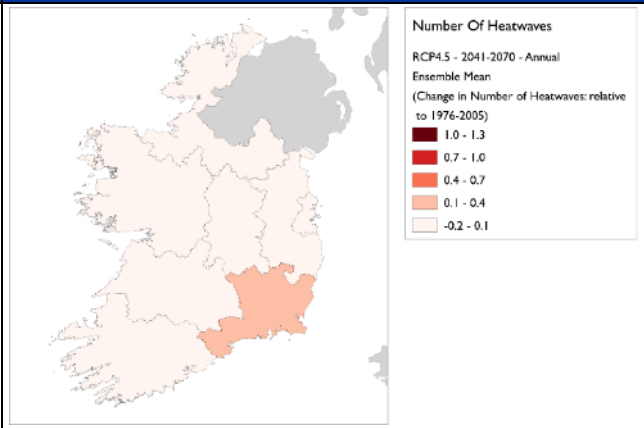
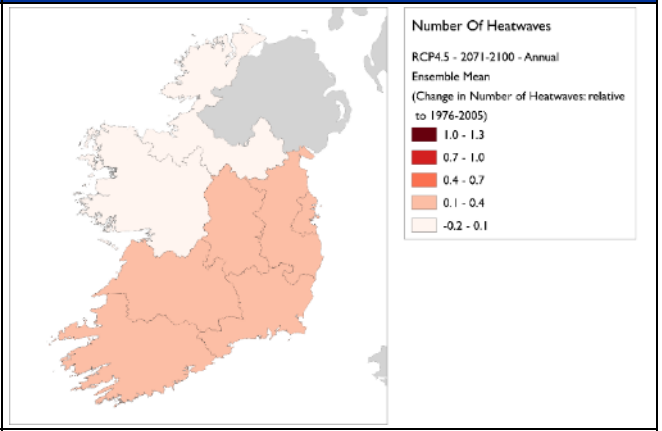
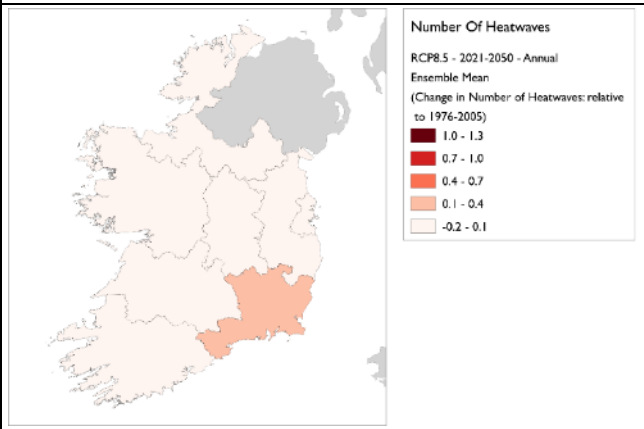
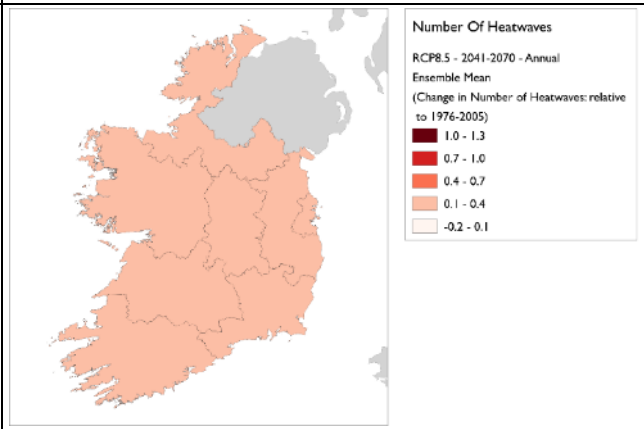
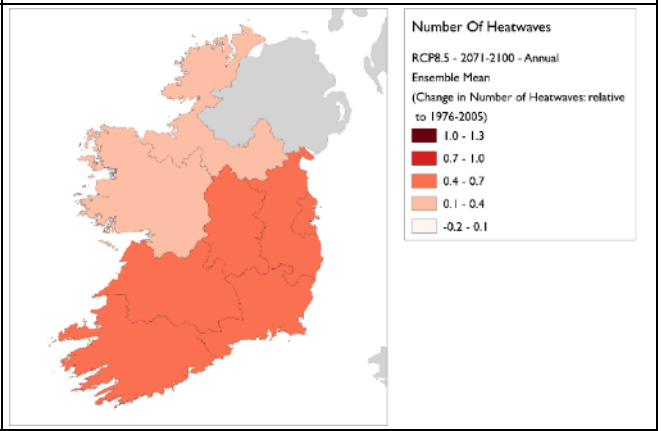
Summer Days (Days above >25°C) and Heatwaves (Periods of at least 5 consecutive summer days)		
National	**Sub-national (NUTS3) zones affected**	
Recent observations or changes	**2050**	**2100**
• In Ireland heatwave events have occurred in 1983, 1984, 1995, 2003, 2006, 2018 and 2021 (Paranunzio et al., 2021; Pascal et al., 2013) • During the baseline period (1976 - 2005) there was an average of 0.09 heatwaves per year across the country, totalling 2.7 heatwaves over the 30-year period. Additionally, there were 2.3 days per year with temperatures exceeding 25°C (O'Brien et al., 2023).	• At the NUTS 3 level, all regions are projected to experience an increase in the number of summer days and number of heatwave events with the South-East region most affected in both RCP4.5 and RCP8.5 scenarios.	• At the NUTS 3 level, all regions are projected to experience an increase in the number of summer days and number of heatwave events with the South-East region most affected in both RCP4.5 and RCP8.5 scenarios.

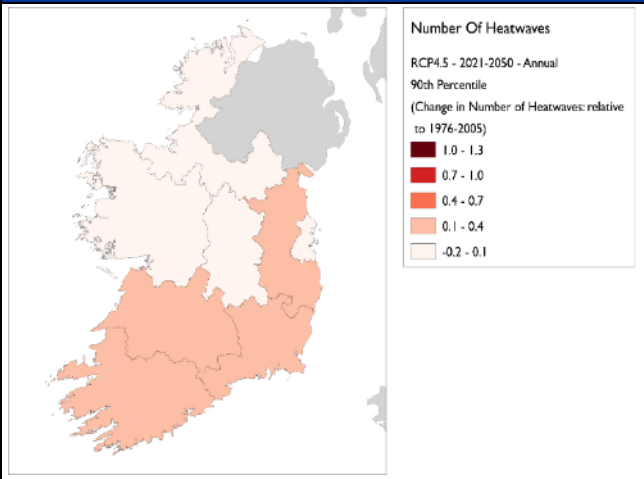
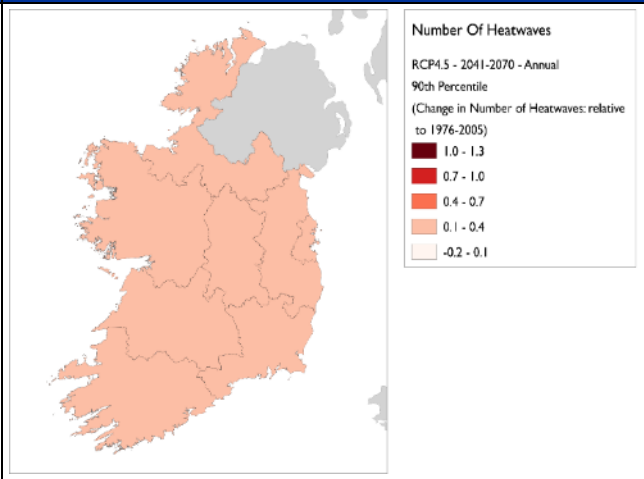
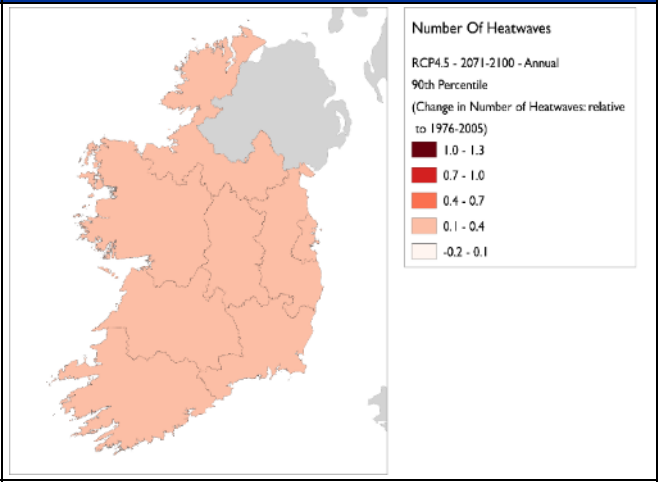
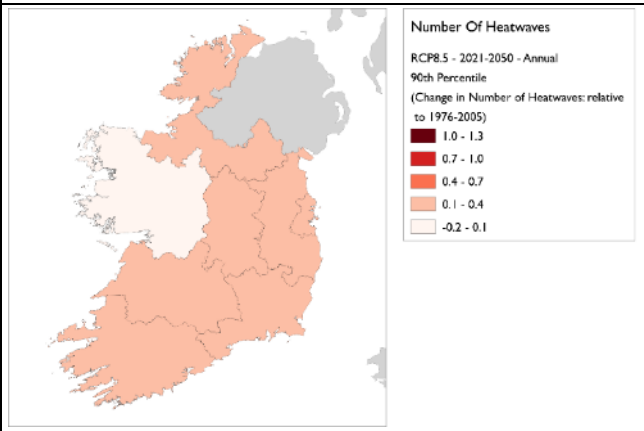
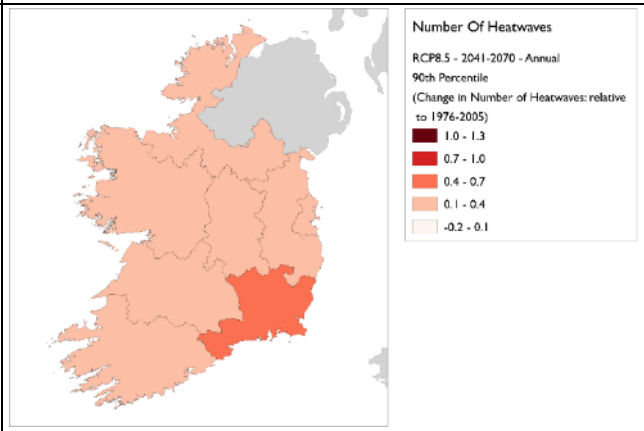
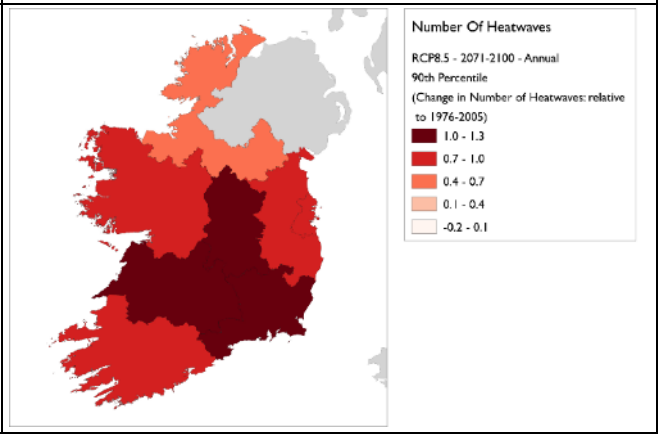
	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5	• Nationally, summer days are projected to increase by 1.7 days (0.5-3.5 days) by 2030 with the Midland region experiencing the largest increase (2.4 days (0.7-4.9 days)). • Nationally, there is no net change in the number of heatwave events (-0.07-0.09 per year) with the South-East region experiencing the largest increase (0.05 per year (-0.03-0.14)).	• Nationally, summer days are expected to increase by 3.0 days (0.9-5.3 days) by 2050 with the Midland region experiencing the largest increase (4.1 days per year (1.3-6.7 days)). • Nationally, there is an increase in the number of heatwave events by 0.06 events (-0.05-0.21 per year) by 2050, with the South-East region experiencing the largest increase (0.12 per year (-0.01-0.32)).	• Nationally, summer days are expected to increase by 4.1 days (1.4-6.5 days) by 2100 with the Midland region experiencing the largest increase (5.6 days per year (2.0-8.8 days)). • Nationally, there is an increase in the number of heatwave events by 0.11 events per year (-0.03-0.27 per year) by 2100, with the South-East region experiencing the largest increase (0.18 per year (0.03-0.38)).
RCP8.5	• Nationally, summer days are projected to increase by 2.3 days (0.5-4.5 days per year) by 2030 with the Midland region experiencing the largest increase (3.1 days (0.8-6.0 days)). • Nationally, there is an increase in number of heatwave events by 0.04 (-0.04-0.14 per year) by 2100, with the South-East region experiencing the largest increase (0.10 per year (0.0-0.2)).	• Nationally, summer days are projected to increase by 4.7 days (2.5-6.7 days) by 2050 with the Midland region experiencing the largest increase (6.4 days (3.4-8.8 days)). • Nationally, there is an increase in the number of heatwave events by 0.15 (0.04-0.28 per year) by 2050, with the South-East region experiencing the largest increase (0.25 per year (0.1-0.4)).	• Nationally, summer days are projected to increase by 11.0 days (6.5-16.8 days) by 2100 with the South-East experiencing the largest increase (14.5 days (8.9-21.3 days)). • Nationally, there is an increase in number of heatwave events by 0.45 (0.16-0.86 per year) by 2100, with the South-East region experiencing the largest increase (0.68 per year (0.3-1.2)).

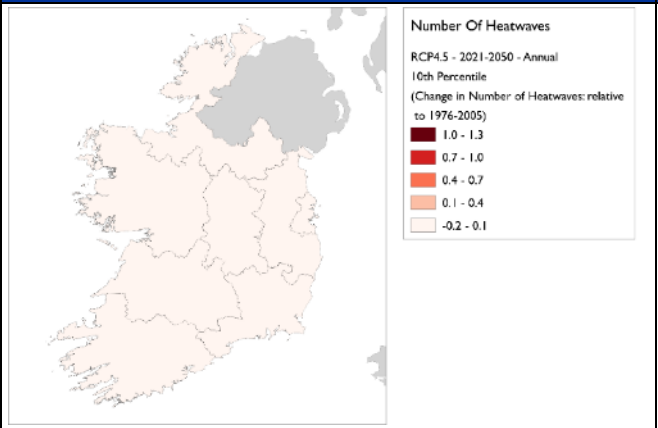
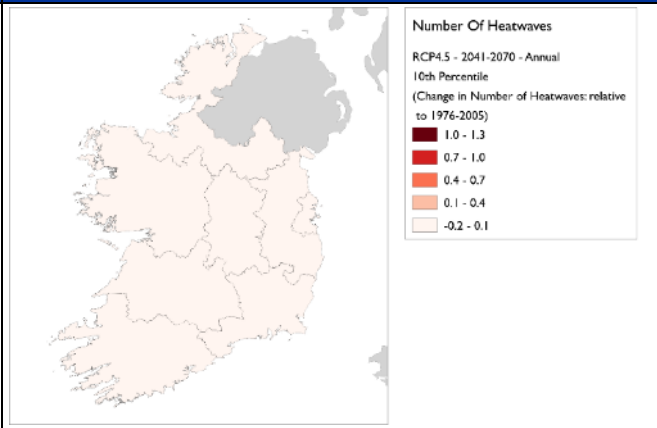
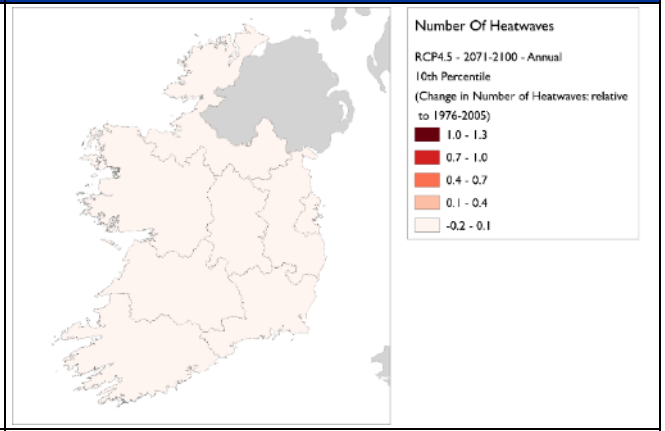
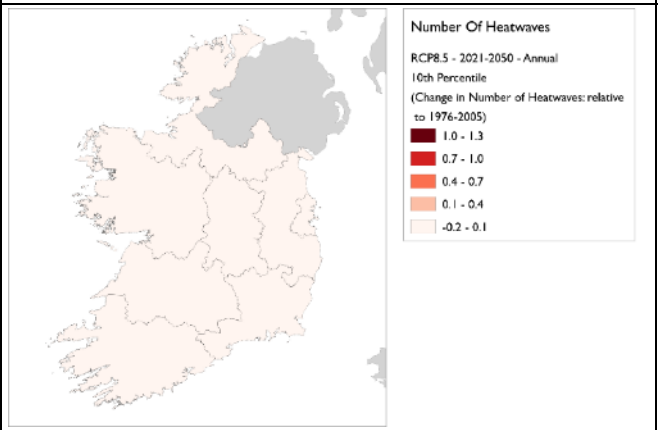
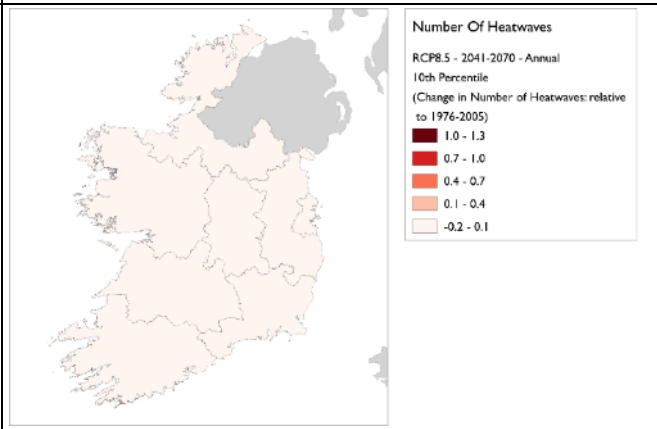
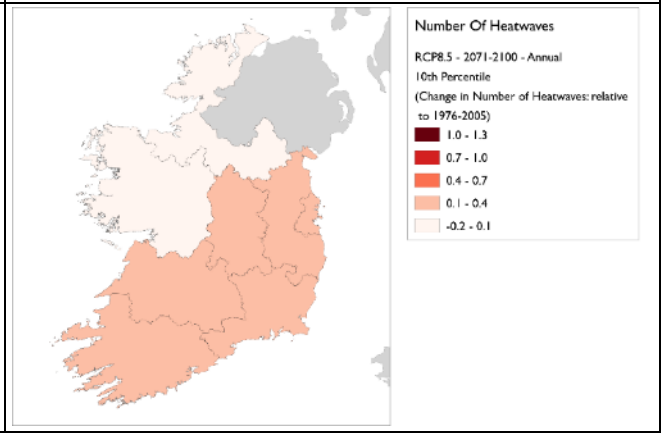
	Projected changes by 2030 (Days above >25°C (Summer Days) – Mean)	Projected changes by 2050 (Days above >25°C (Summer Days) – Mean)	Projected changes by 2100 (Days above >25°C (Summer Days) – Mean)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Days above >25°C (Summer Days) – 90th Percentile)	Projected changes by 2050 (Days above >25°C (Summer Days) – 90th Percentile)	Projected changes by 2100 (Days above >25°C (Summer Days) – 90th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Days above >25°C (Summer Days) – 10th Percentile)	Projected changes by 2050 (Days above >25°C (Summer Days) – 10th Percentile)	Projected changes by 2100 (Days above >25°C (Summer Days) – 10th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Heatwaves (Periods of at least 5 consecutive summer days) – Mean)	Projected changes by 2050 (Heatwaves (Periods of at least 5 consecutive summer days) - Mean)	Projected changes by 2100 (Heatwaves (Periods of at least 5 consecutive summer days) – Mean)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Heatwaves (Periods of at least 5 consecutive summer days) – 90th Percentile)	Projected changes by 2050 (Heatwaves (Periods of at least 5 consecutive summer days) – 90th Percentile)	Projected changes by 2100 (Heatwaves (Periods of at least 5 consecutive summer days) – 90th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Heatwaves (Periods of at least 5 consecutive summer days) – 10th Percentile)	Projected changes by 2050 (Heatwaves (Periods of at least 5 consecutive summer days) – 10th Percentile)	Projected changes by 2100 (Heatwaves (Periods of at least 5 consecutive summer days) – 10th Percentile)
RCP4.5			
RCP8.5			

Confidence - High
Agreement: The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is an increasing trend for this variable. The 10th, ensemble mean, and the 90th percentile of the national projections all show an increasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios. **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

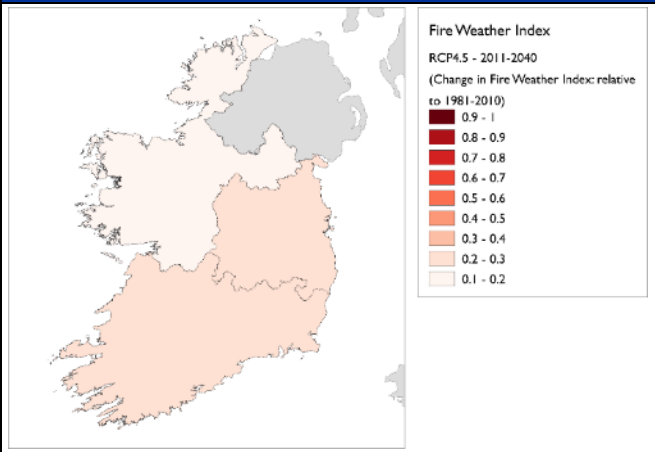
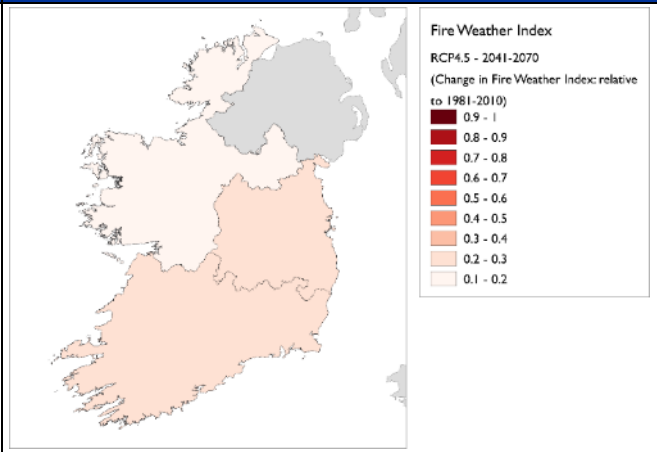
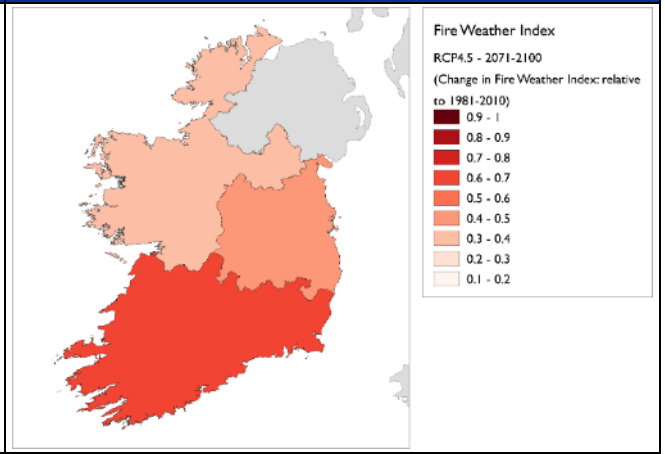
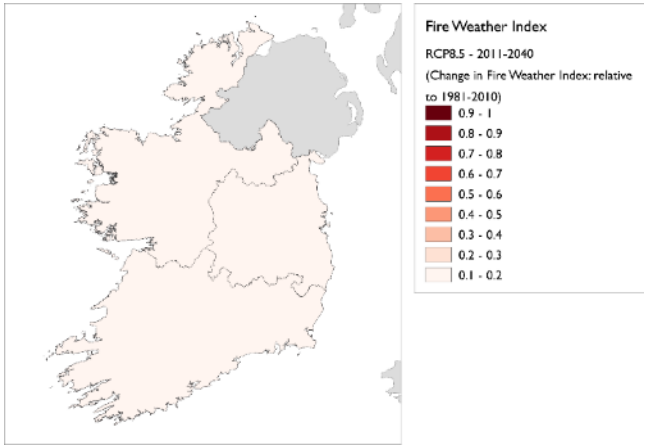
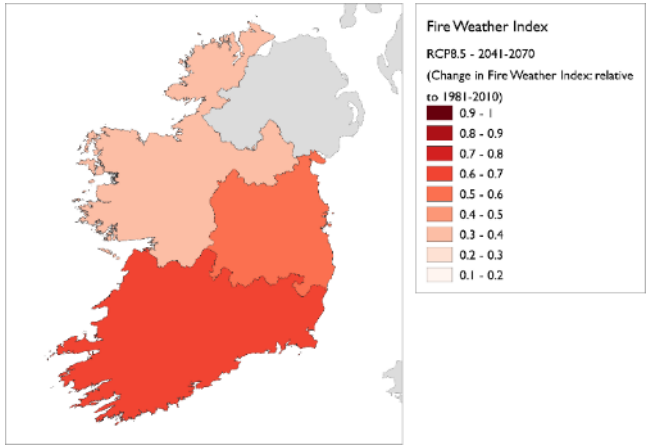
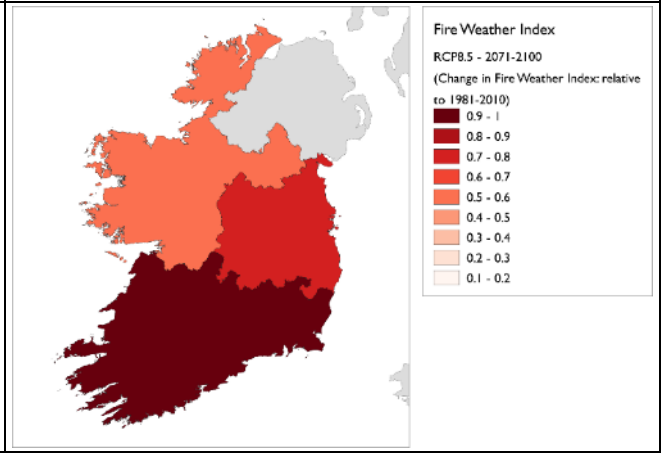
	References
Observations	Paranunzio, R., Dwyer, E., Fitton, J.M., Alexander, P.J. and O'Dwyer, B. (2021). Assessing current and future heat risk in Dublin city, Ireland. Urban Climate, 40, p.100983.
	Pascal, M., Sweeney, J., Cullen, E., Schwartz, J. and Goodman, P. (2013). Heatwaves and mortality in Ireland, planning for the future. Irish Geography, 46(3), pp.203-211.
	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023). Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.
Projections	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023). Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.

Wildfire

Wildfire (Fire Weather Index (FWI))		
National	**Sub-national (NUTS2) zones affected (projected)**	
Recent and past effects or changes	**2050**	**2100**
• Recent observations suggest that peatlands and lowland blanket bogs have the highest frequency of wildfire incidents. In Ireland, fires occur primarily between March and June. A time series of combined forest area burned and annual fire service mobilisation indicates a slight decreasing trend over the last two decades (Cámaro García and Dwyer, 2021). • Additionally, historical analysis (1981-2010) of the Fire Weather Index (FWI) using ERA5 reanalysis data shows no discernible trends (Climate ADAPT).	• At the NUTS 2 level, projected FWI anomaly (from1980-2010) shows the Southern region is projected to experience the largest increase in FWI (0.62).	• At the NUTS 2 level, projected FWI anomaly (from1980-2010) shows the Southern region is projected to experience the largest increase in SWI (0.92).

	Projected changes by 2030[+]	Projected changes by 2050	Projected changes by 2100
RCP4.5	• All regions in Ireland are projected to experience a small increase in annual FWI, with the Eastern and Midland region (0.25) showing the highest increase from the 1981-2010 baseline.	• All regions in Ireland are projected to experience a small increase in FWI, with the Southern region (0.27) showing the highest increase from the 1981-2010 baseline.	• All regions in Ireland are projected to experience a small increase in FWI, with the Southern region (0.62) showing the highest increase from the 1981-2010 baseline.
RCP8.5	• All regions in Ireland are projected to experience a small increase in annual FWI, with the Eastern and Midland region (0.18) showing the highest increase from 1981-2010 baseline.	• All regions in Ireland are projected to experience a small increase in FWI, with the Southern region (0.62) showing the highest increase from the 1981-2010 baseline.	• All regions in Ireland are projected to experience a small increase in FWI, with the Southern region (0.95) showing the highest increase from the 1981-2010 baseline.

Confidence - Low
Agreement: There are limited global, regional, and national scale projections available related to the changes in fire weather for Ireland. **Robustness:** National scale projections do not exist for fire weather; therefore European scale projections (EURO-CORDEX) have been used.

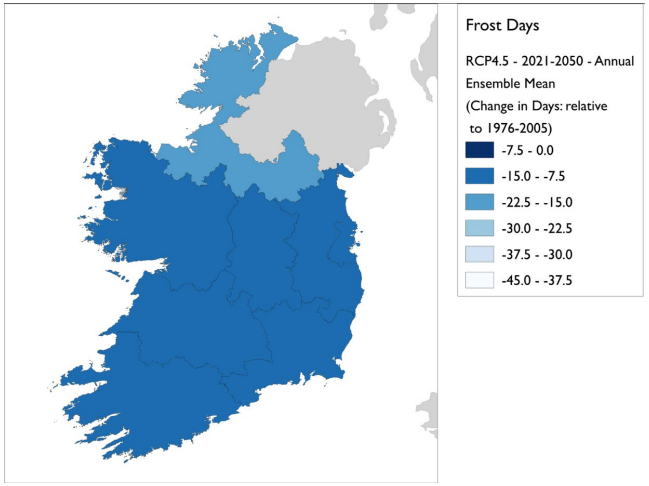
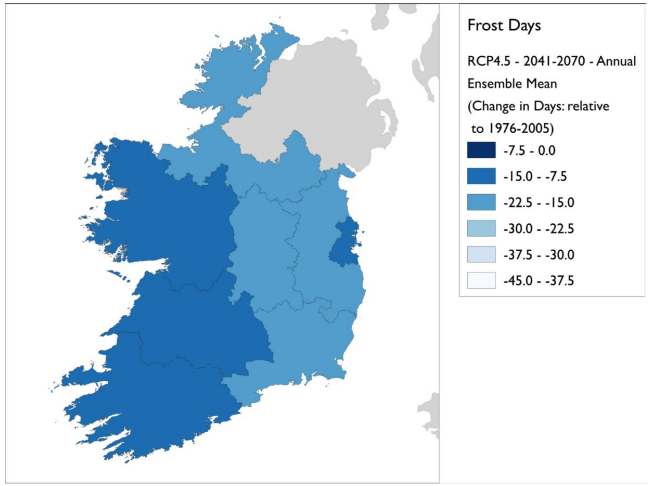
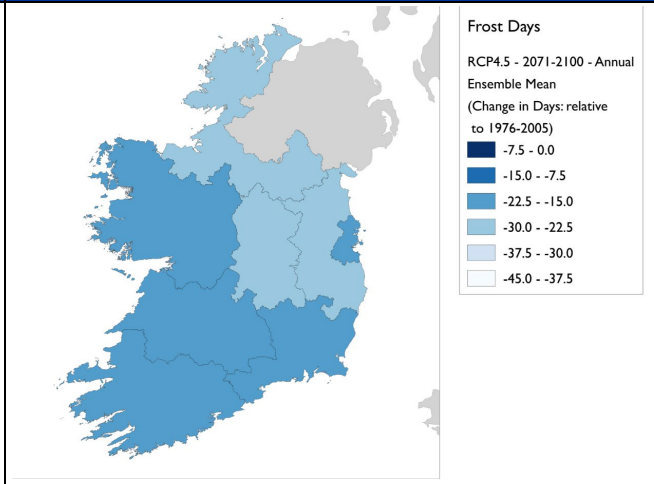
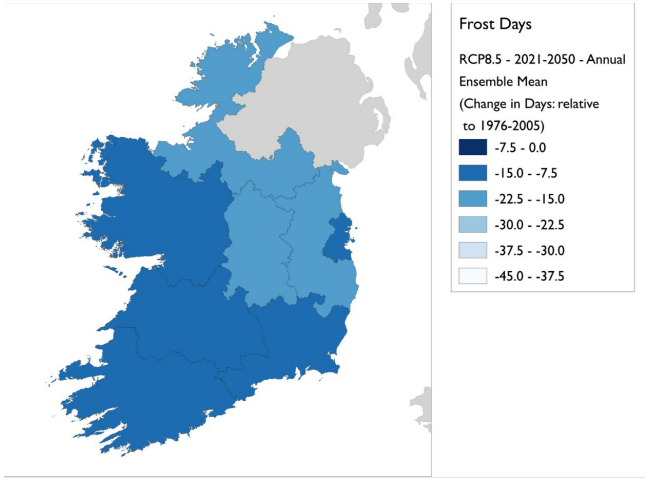
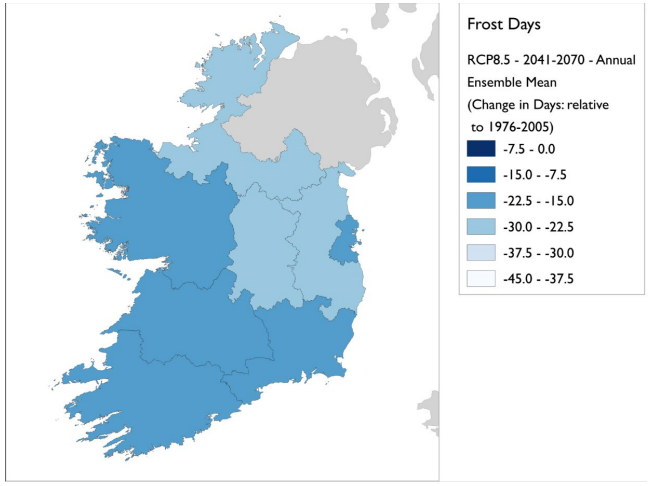
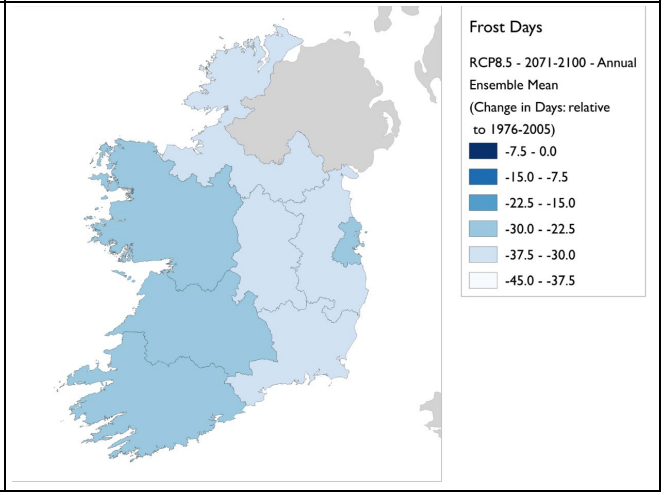
	Projected changes by 2030 (Fire Weather Index)	Projected changes by 2050 (Fire Weather Index)	Projected changes by 2100 (Fire Weather Index)
RCP4.5			
RCP8.5			

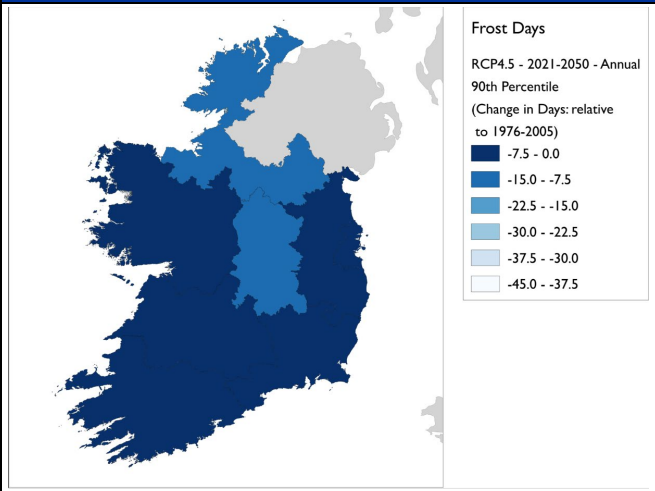
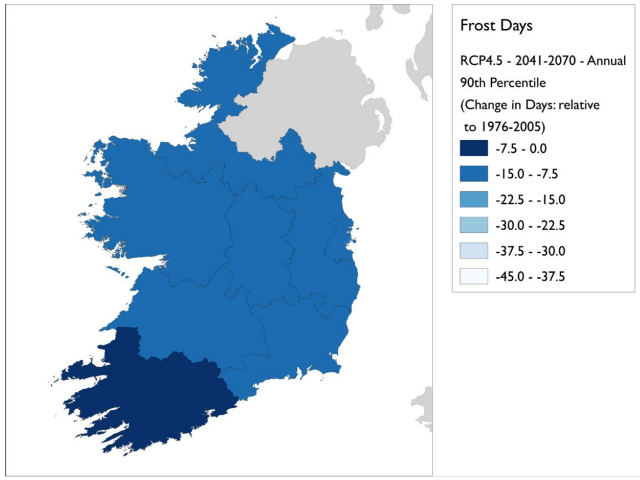
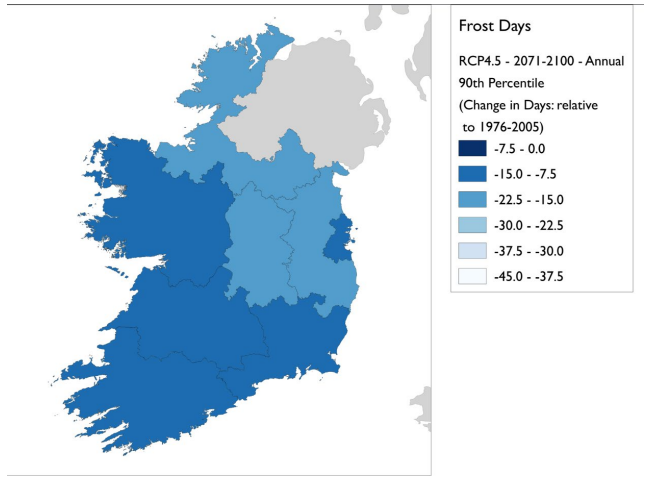
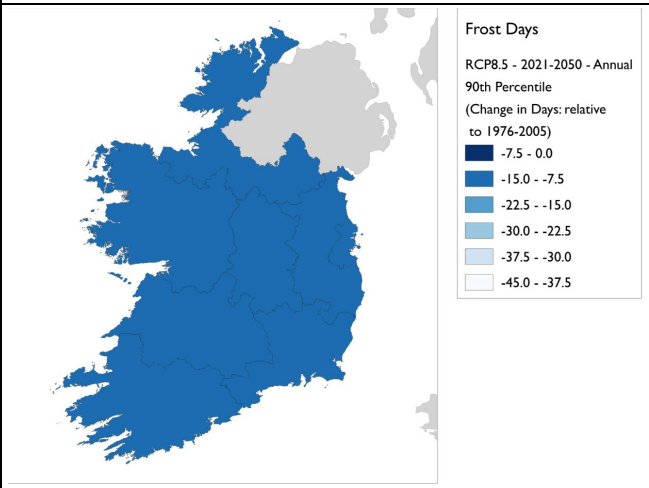
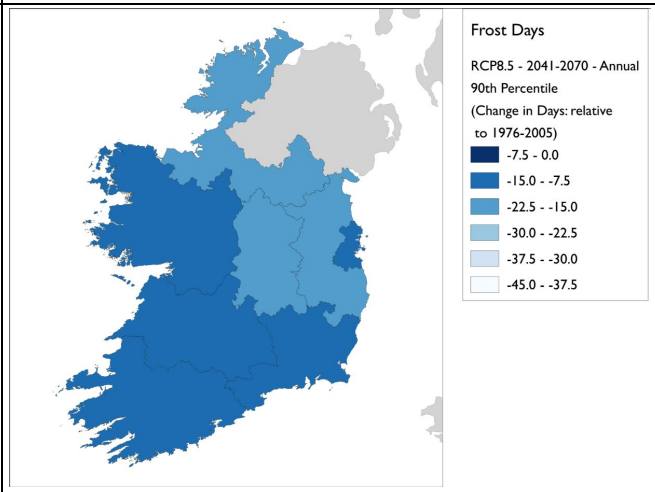
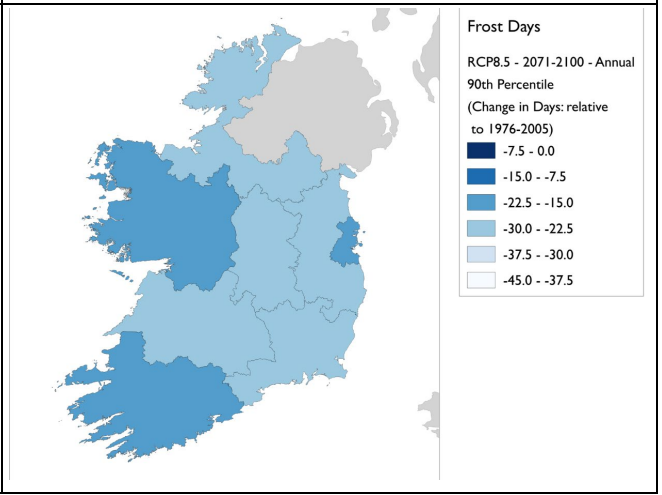
	References
Observations	Cámaro García, C., A., and Dwyer, N. (2021) The Status of Ireland's Climate, EPA Research Report 386.
	Climate Adapt (2024) Fire Weather Index. Available at https://climate-adapt.eea.europa.eu/en/metadata/indicators/fire-weather-index
Projections	Climate Adapt (2024) Fire Weather Index. Available at https://climate-adapt.eea.europa.eu/en/metadata/indicators/fire-weather-index

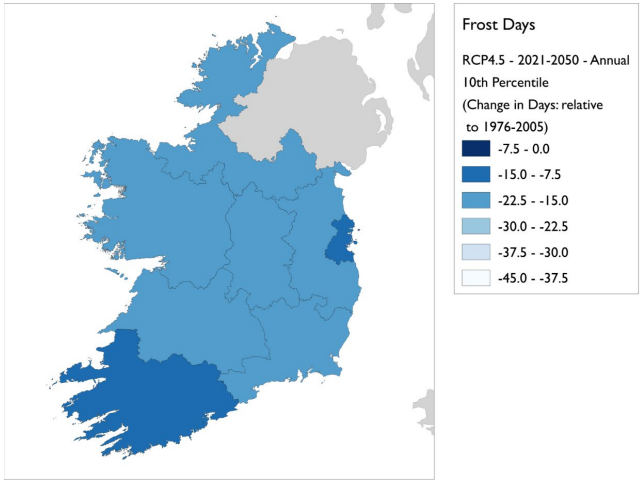
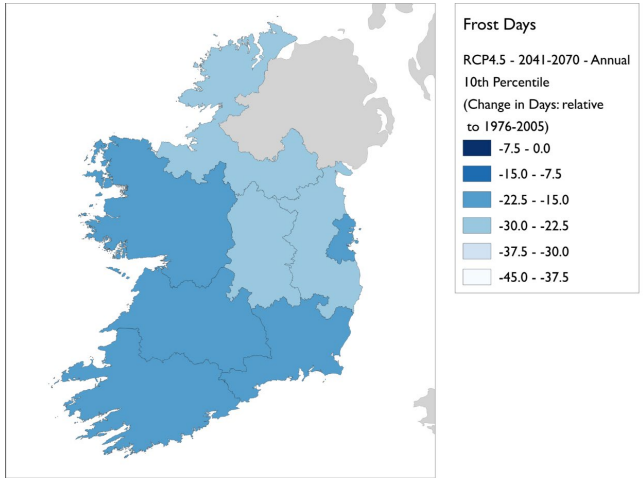
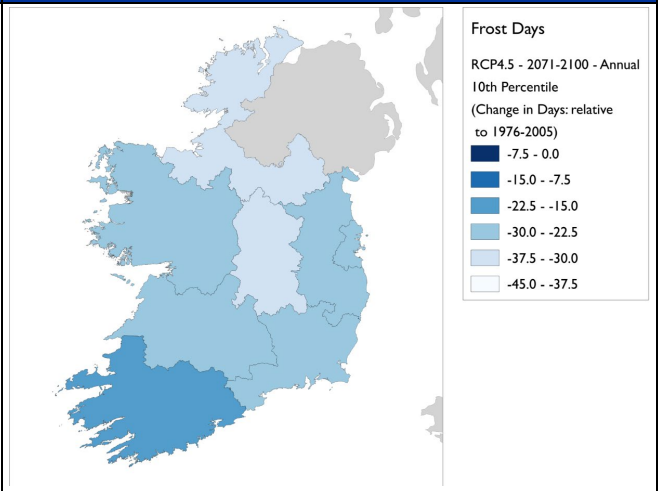
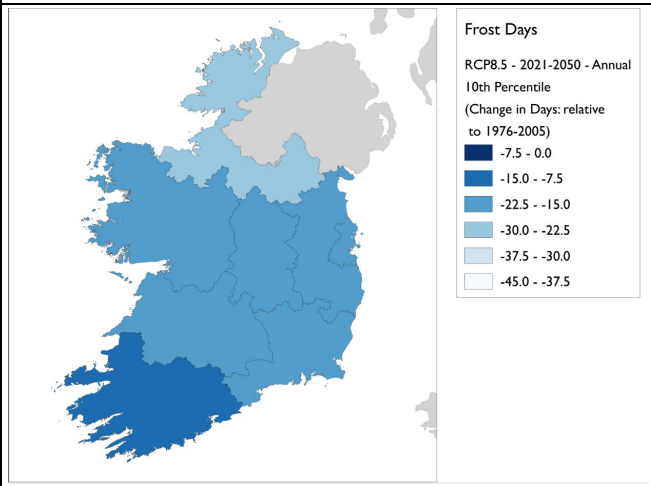
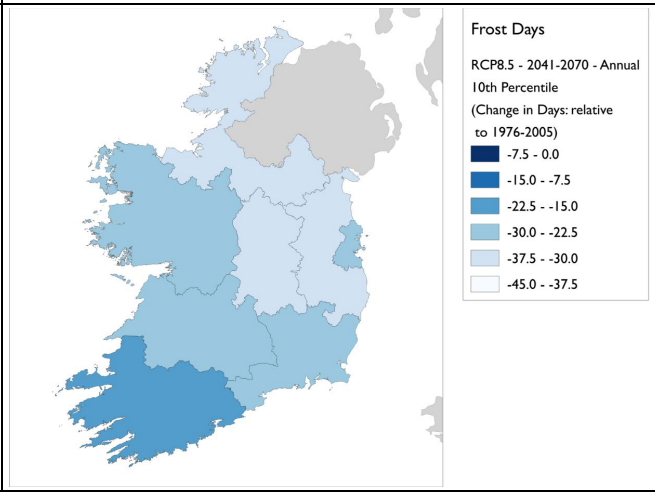
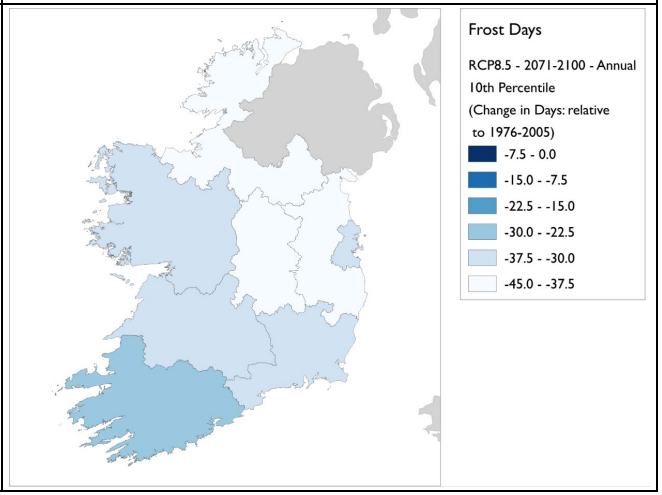
Extreme Cold

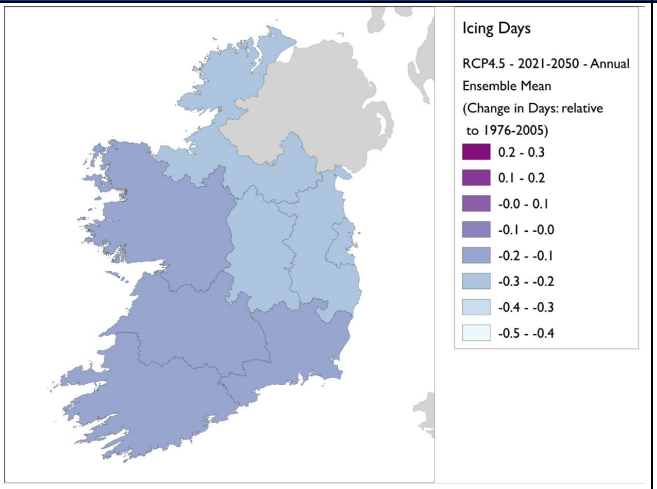
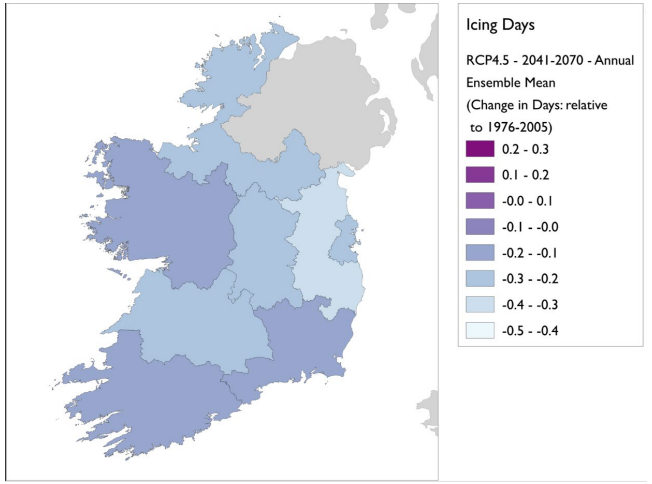
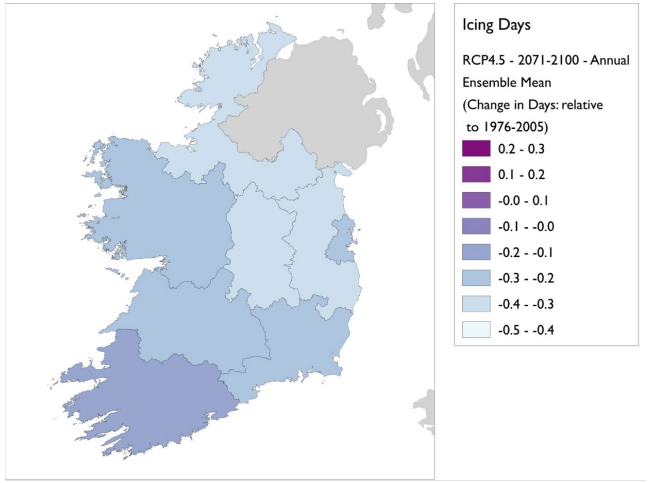
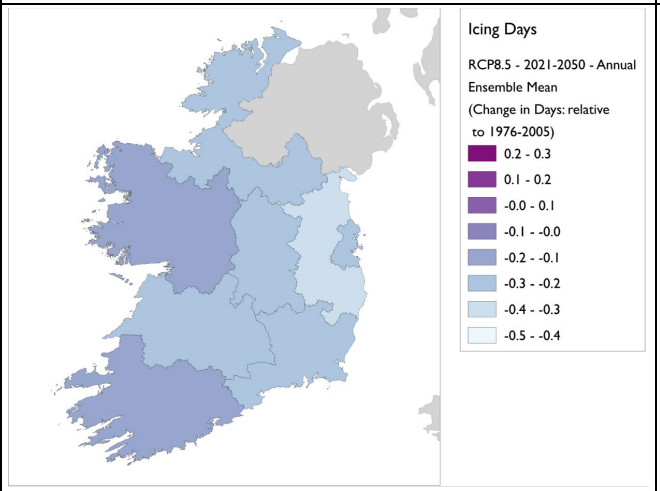
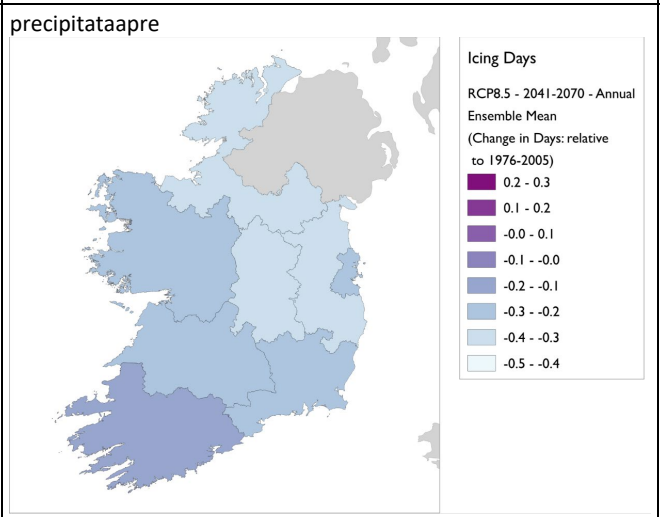
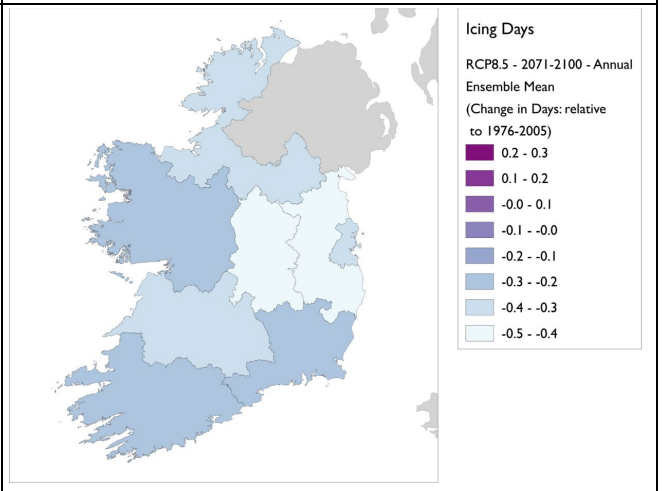
Frost Days (daily minimum temperature < 0˚C) and Icing Days (daily maximum temperature < 0˚C)		
National	**Sub-national (NUTS3) zones affected (projected)**	
Recent and past effects or changes	**2050**	**2100**
• Historical analysis (1885 - 2018) shows a significant decreasing trend in the number of frost days annually (−13.7 days) and in the spring (−5.8 days), autumn (−3.4 days), and winter (−4.9 days). Additionally, there is a significant increasing trend in the annual minimum temperature (1.1°C), with greater increases observed in the autumn (1.6°C) and spring (1.4°C) seasons (Mateus and Potito 2022). • During the baseline period of 1976-2005, Ireland experienced an average of 40.6 frost days and 0.4 icing days per year (O'Brien et al., 2023).	• At the NUTS 3 level, all regions are projected to experience a decrease in the number of frost days and a decrease in the number of icing days across RCP4.5 and RCP8.5 scenarios.	• At the NUTS 3 level, all regions are projected to experience a decrease in the number of frost days and a decrease in the number of icing days across RCP4.5 and RCP8.5 scenarios.

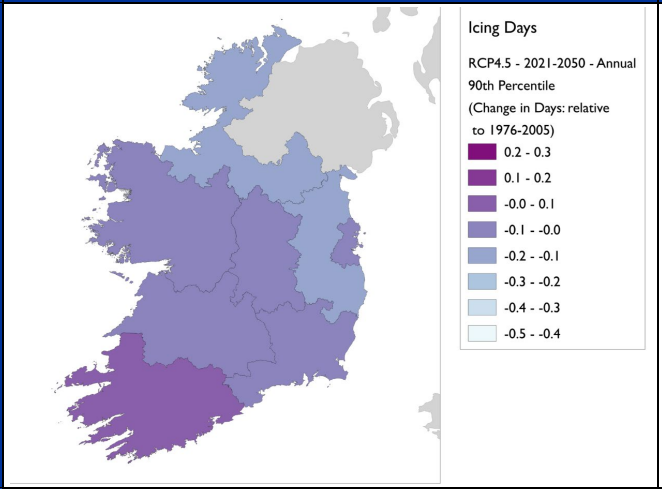
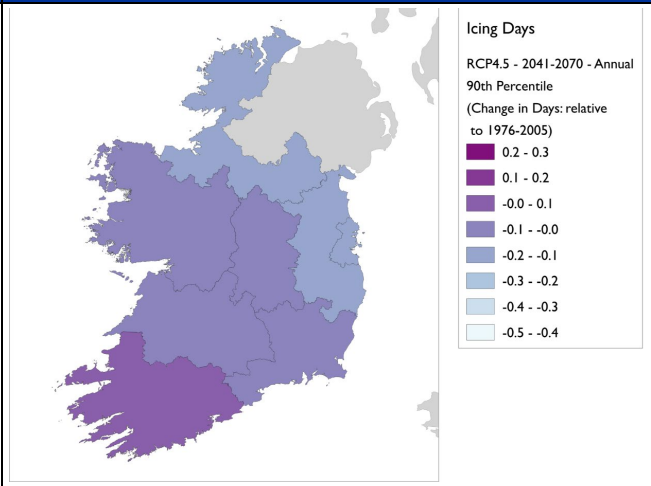
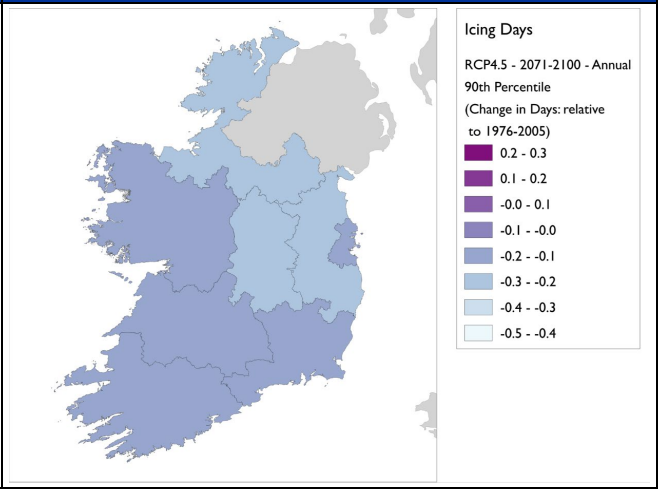
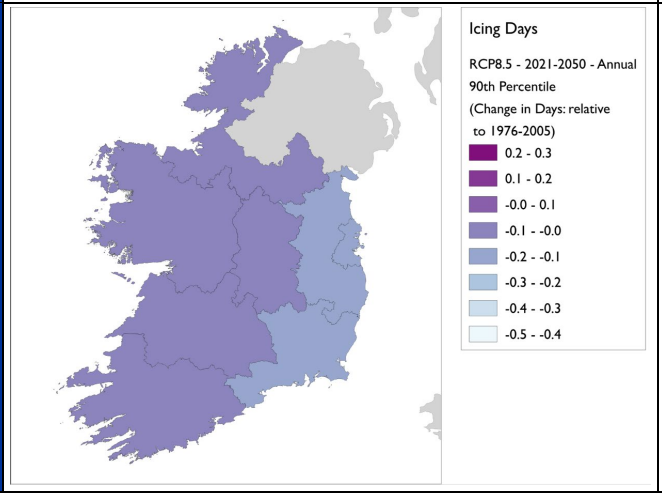
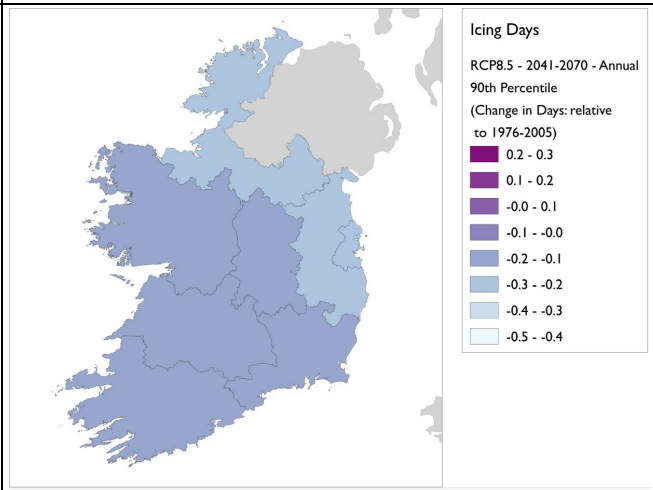
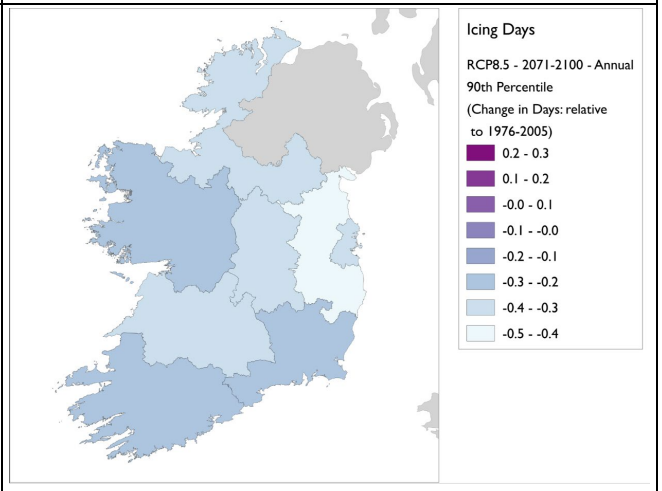
	Projected changes by 2030[+]	**Projected changes by 2050**	**Projected changes by 2100**
RCP4.5	• Nationally, the number of frost days is expected to decrease by 13.1 days (-18.4- -7.4) by 2030, with the Border region experiencing the largest decrease (-15.1 days (-21.7 - -8.6)) in number of frost days. • Nationally, the number of icing days is expected to decrease by 0.2 days (-0.3- -0.1) by 2030, with the Mid-East region experiencing the largest decrease (-0.28 days) in number of icing days.	• Nationally, the number of frost days is expected to decrease by 16.18 days (-22.1 - -8.8) by 2050, with the Border region experiencing the largest decrease (-18.8 days (-26.0 - -10.3)) in number of frost days. • Nationally, the number of icing days is expected to decrease by 0.24 days (-0.4- -0.1) by 2050, with the Mid-East region experiencing the largest decrease (-0.32 days) in number of icing days.	• Nationally, the number of frost days is expected to decrease by 21.1 days (-27.2- -15.0) by 2100, with the Border region experiencing the largest decrease (-24.5 days (-31.4 - -17.6)) in frost days. • Nationally, the number of icing days is expected to decrease by 0.3 days (-0.4- -0.2) by 2100, with the Mid-East region experiencing the largest decrease (-0.4 days) in number of icing days.
RCP8.5	• Nationally, number of frost days are expected to decrease by 15.1 days (-19.6- -10.9) by 2030, with the Border region experiencing the largest decrease (-17.8 days (-22.9 - -12.7)) number of frost days. • Nationally, the number of icing days is expected to decrease by 0.2 days (-0.3- -0.1) by 2030, with the Mid-East region experiencing the largest decrease (-0.3 days) in number of icing days.	• Nationally, number of frost days are expected to decrease by 21.6 days (-27.8- -15.5) by 2050, minimum temperature also expected to increase during this period. with the Border region experiencing the largest decrease (-25.3 days (-32.6 - -18.2)) in number of frost days. • Nationally, the number of icing days is expected to decrease by 0.30 days (-0.4- -0.2) by 2050, with the Mid-East region experiencing the largest decrease (-0.4 days) in number of icing days.	• Nationally, number of frost days are expected to decrease by 31.4 days (-37.0- -24.7) by 2100, with the Border region experiencing the largest decrease (-36.5 days (-43.3 - -28.9)) in frost days. • Nationally, the number of icing days is expected to decrease by 0.36 days (-0.4- -0.3) by 2100, with the Mid-East region experiencing the largest decrease (-0.5 days) in number of icing days.

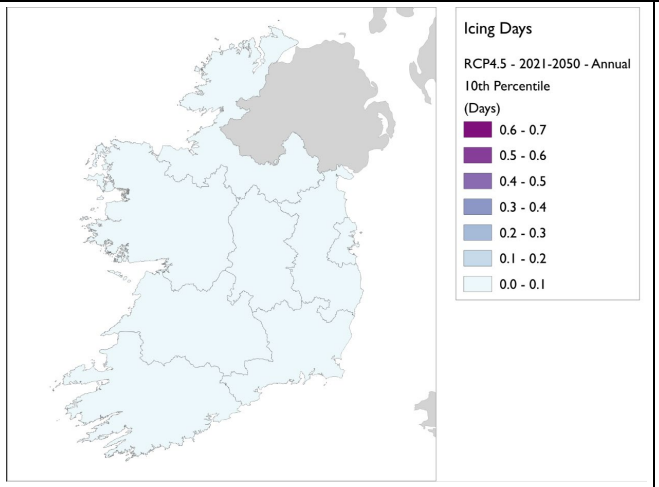
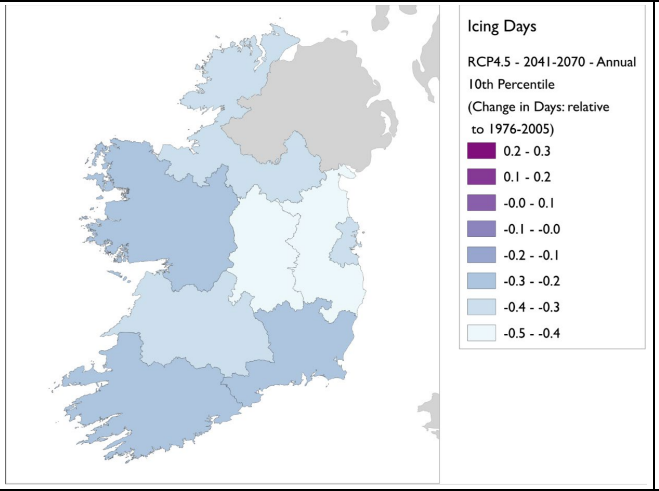
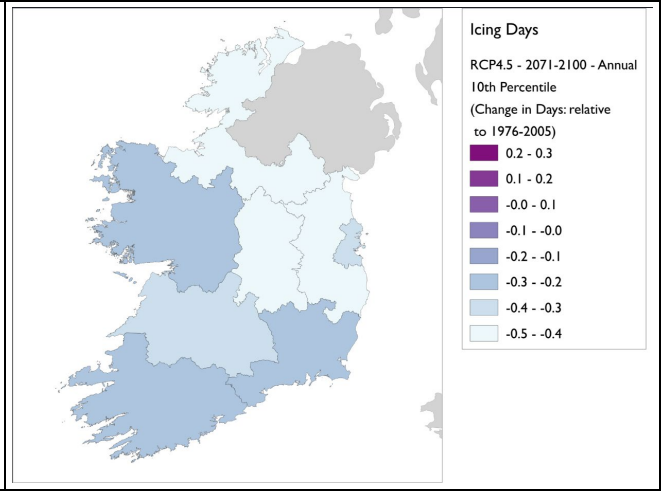
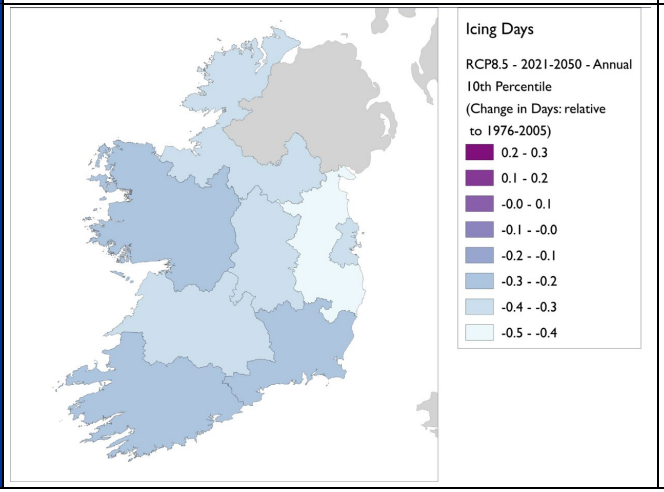
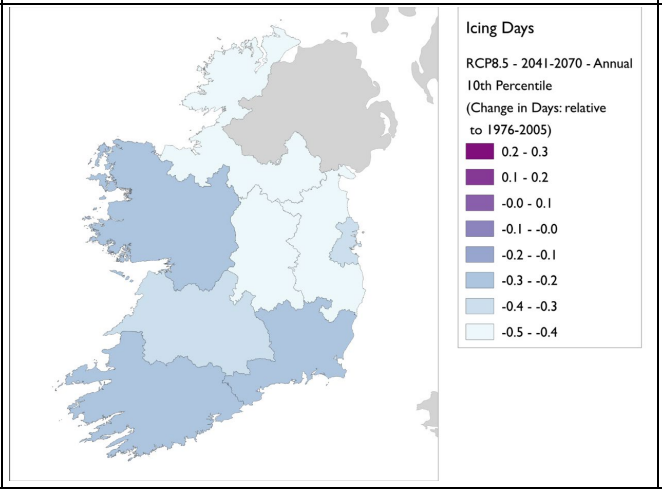
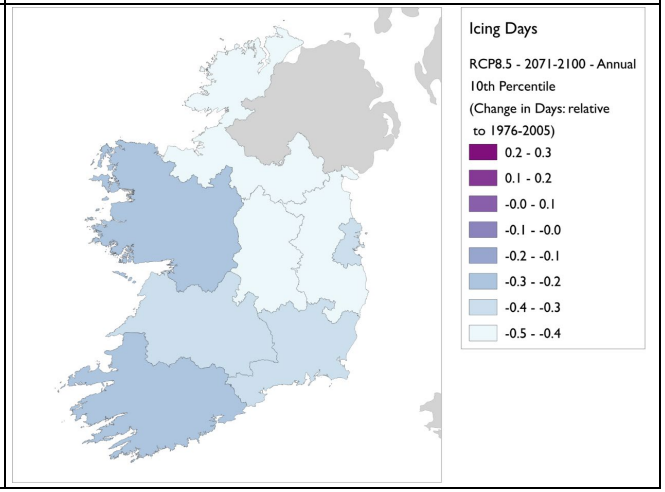
	Projected changes by 2030 (Frost Days (daily minimum temperature < 0˚C) – Mean)	Projected changes by 2050 (Frost Days (daily minimum temperature < 0˚C) – Mean)	Projected changes by 2100 (Frost Days (daily minimum temperature < 0˚C) - Mean)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Frost Days (daily minimum temperature < 0˚C) – 90th Percentile)	Projected changes by 2050 (Frost Days (daily minimum temperature < 0˚C)) – 90th Percentile	Projected changes by 2100 (Frost Days (daily minimum temperature < 0˚C) – 90th Percentile
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Frost Days (daily minimum temperature < 0˚C) – 10th Percentile	Projected changes by 2050 (Frost Days (daily minimum temperature < 0˚C) – 10th Percentile	Projected changes by 2100 (Frost Days (daily minimum temperature < 0˚C) – 10th Percentile
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Icing Days (daily maximum temperature < 0˚C) – Mean)	Projected changes by 2050 (Icing Days (daily maximum temperature < 0˚C) – Mean)	Projected changes by 2100 (Icing Days (daily maximum temperature < 0˚C) – Mean)
RCP4.5			
RCP8.5		precipitataapre 	

	Projected changes by 2030 (Icing Days (daily maximum temperature < 0˚C) – 90th Percentile)	Projected changes by 2050 (Icing Days (daily maximum temperature < 0˚C) – 90th Percentile)	Projected changes by 2100 (Icing Days (daily maximum temperature < 0˚C) – 90th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Icing Days (daily maximum temperature < 0˚C) – 10th Percentile)	Projected changes by 2050 (Icing Days (daily maximum temperature < 0˚C) – 10th Percentile)	Projected changes by 2100 ` (Icing Days (daily maximum temperature < 0˚C) – 10th Percentile)
RCP4.5			
RCP8.5			

Confidence – High
Agreement: The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections all agree that there is a decreasing trend for these variables. The 10th, ensemble mean, and the 90th percentile of the national projections all show a decreasing trend across all NUTS3 regions in both RCP4.5 and RCP8.5 scenarios. **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform these variables using a robust and peer-reviewed modelling approach.

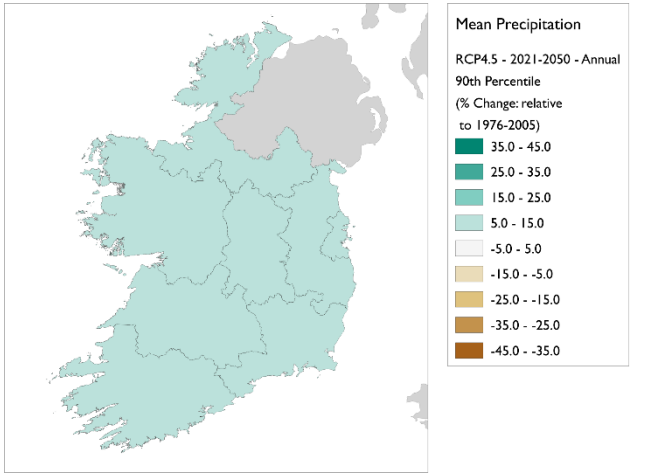
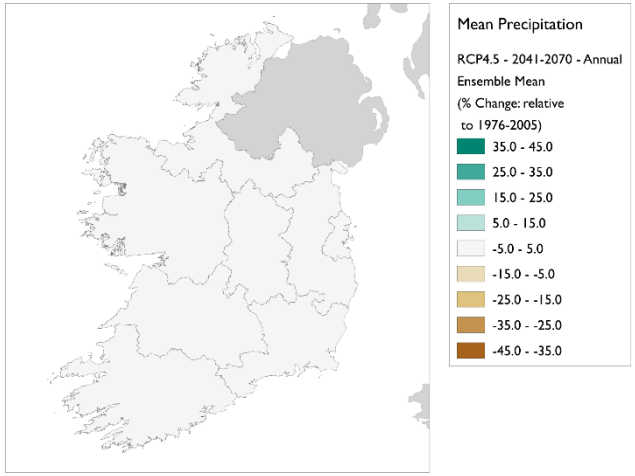
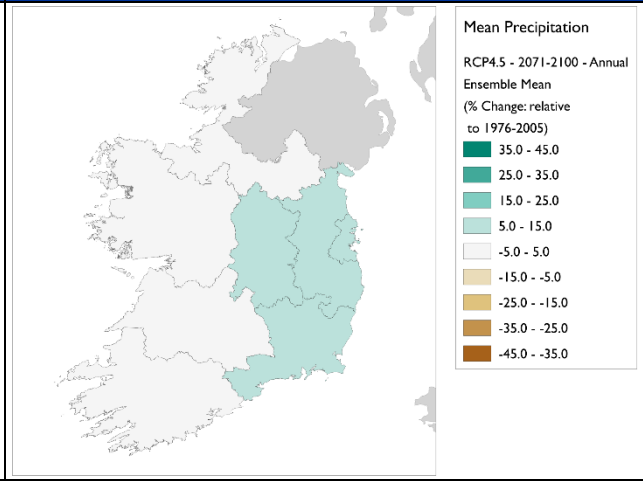
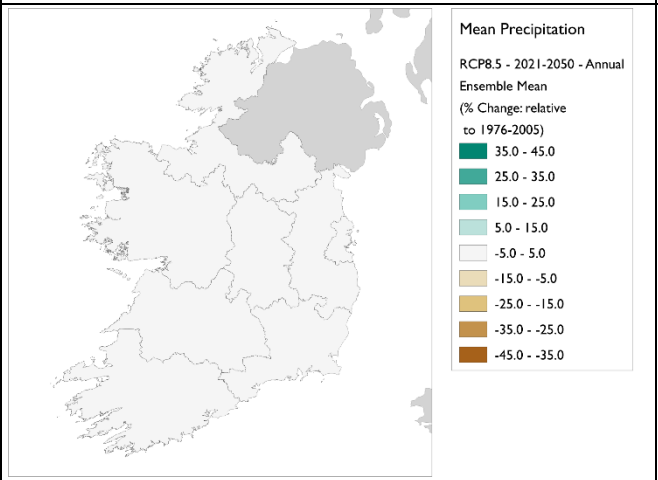
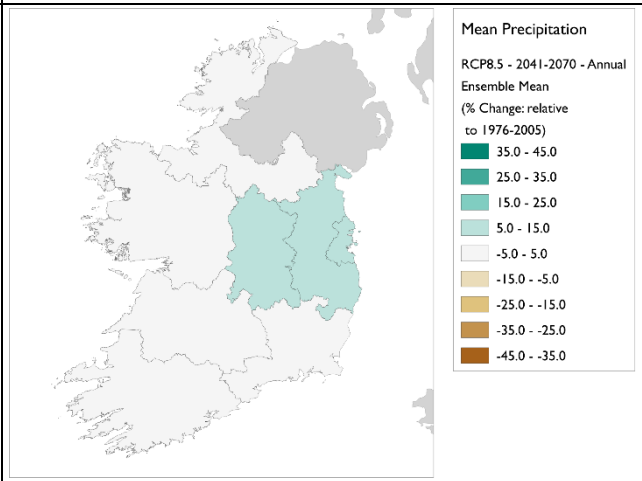
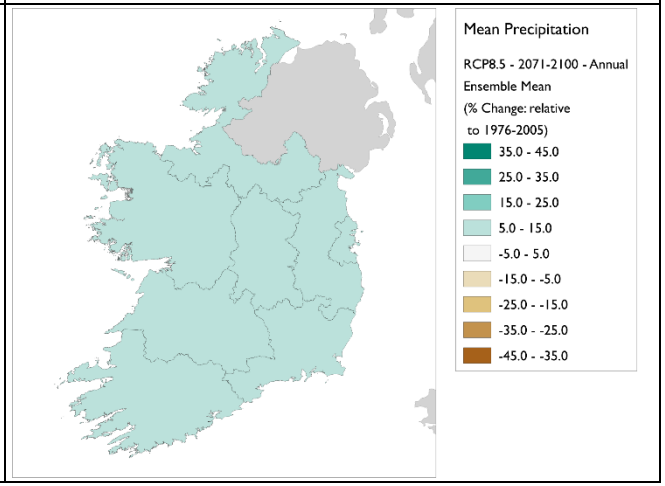
	References
Observations	Mateus, C. and Potito, A. (2022) Long-term trends in daily extreme air temperature indices in Ireland from 1885 to 2018. Weather and Climate Extremes, 36, p.100464. Available at https://www.sciencedirect.com/science/article/pii/S2212094722000469
	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023) Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.
Projections	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023) Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.

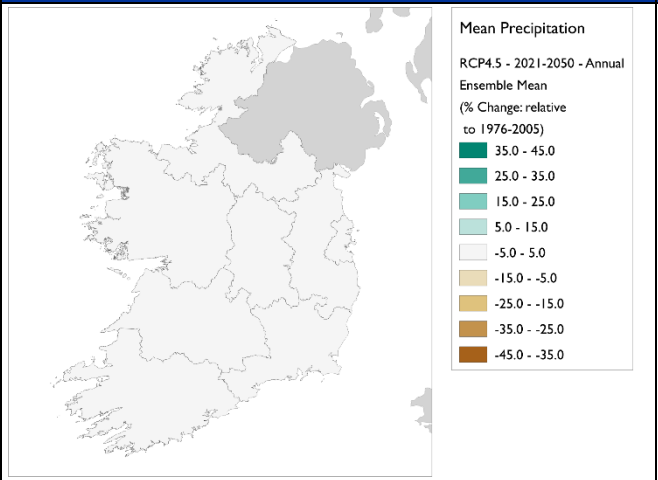
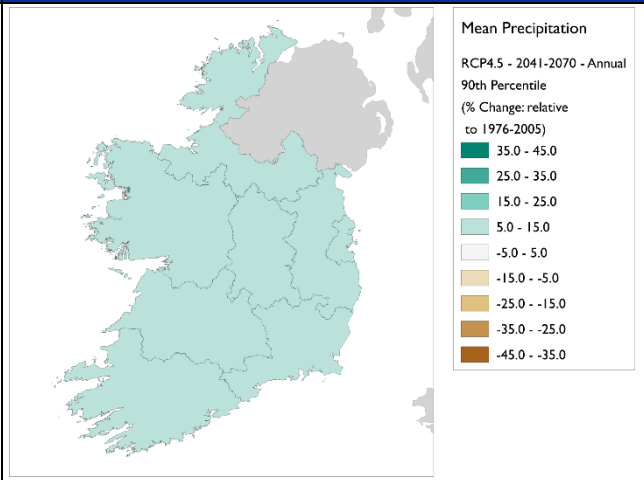
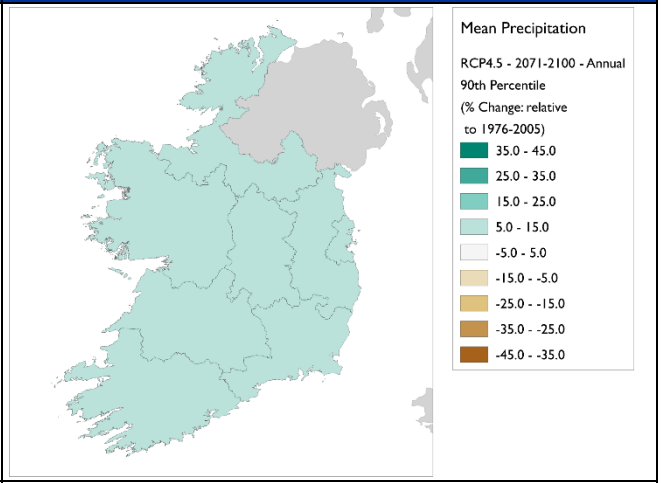
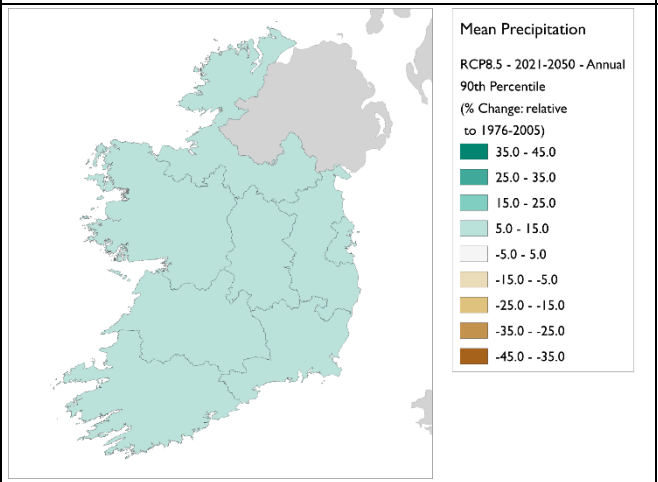
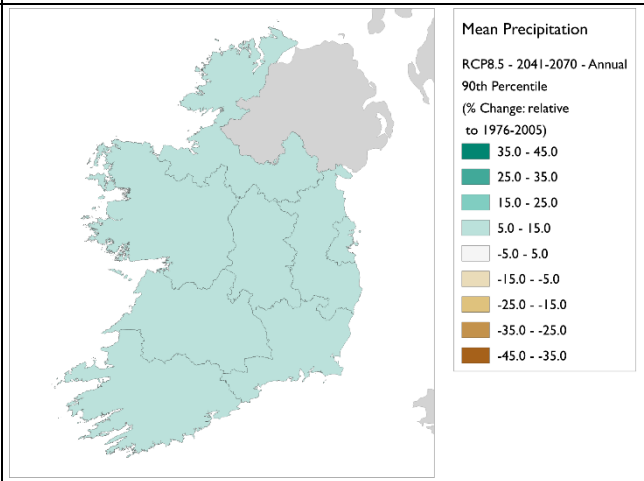
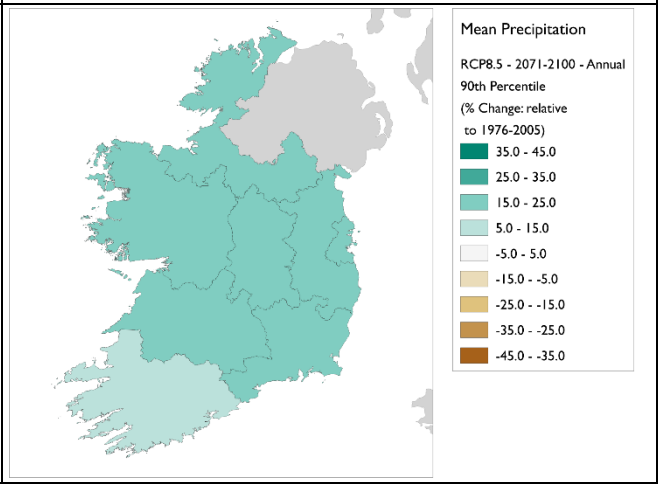
Changes in Precipitation

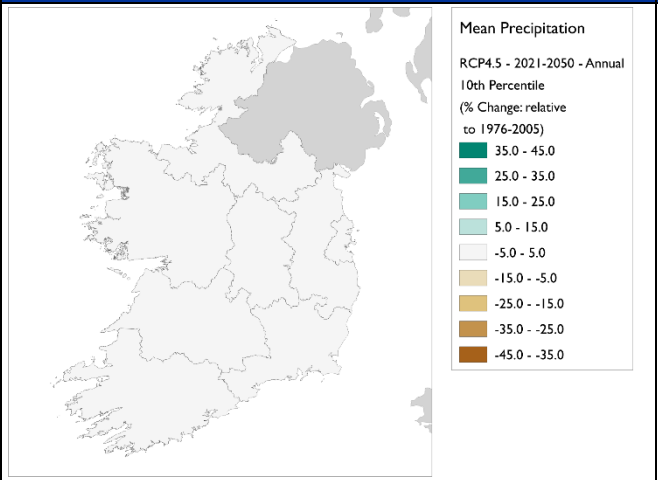
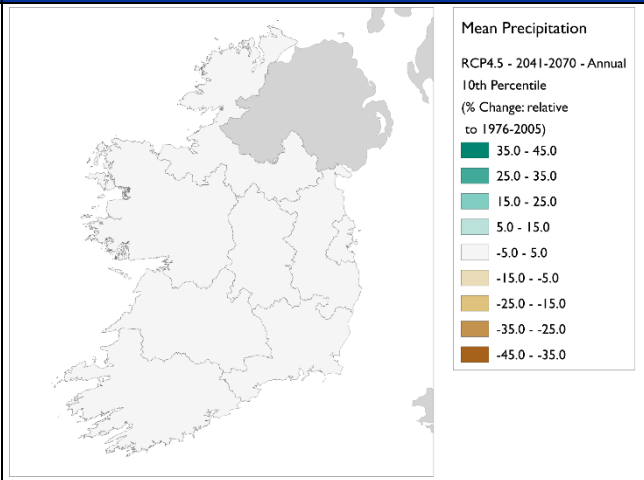
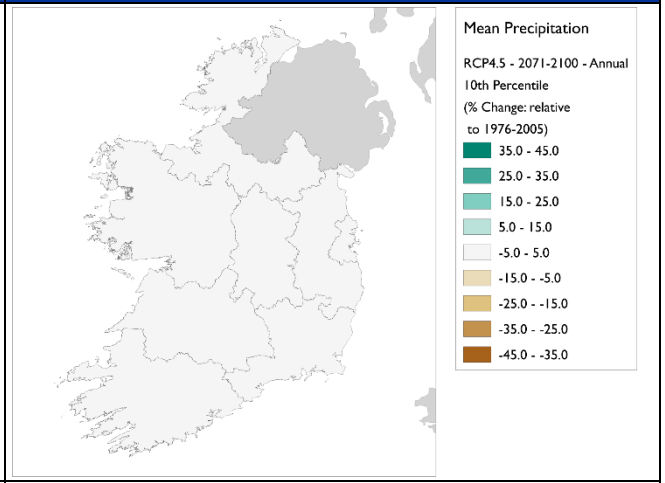
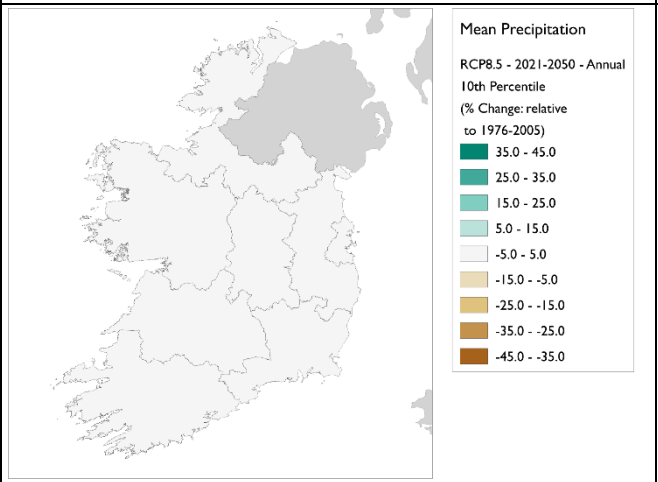
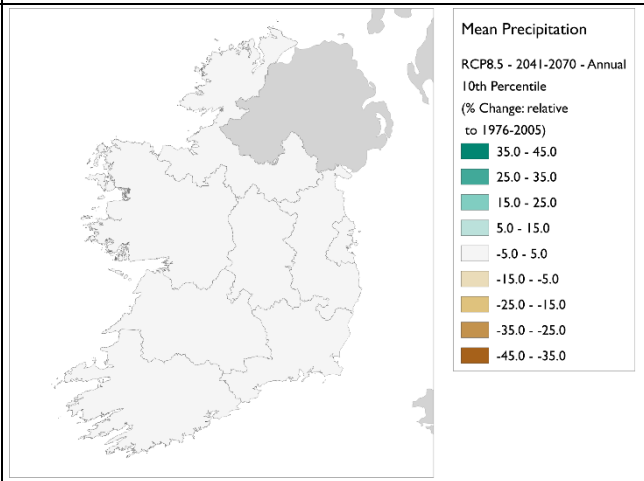
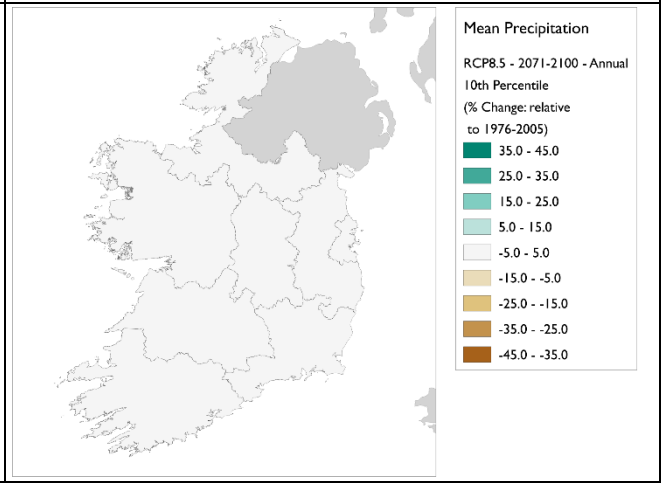
Average Precipitation (Mean Precipitation)		
National	**Sub-national (NUTS3) zones affected (projected)**	
Recent and past effects or changes	**2050**	**2100**
• Annual average amounts of precipitation are increasing in Ireland. Average annual rainfall has increased from 1961-1990 to 1991-2020 by 7%. This observed trend also shows an increase in winter precipitation and a decrease in summer precipitation. Overall, the precipitation pattern also exhibits a strong decadal variability (García & Dwyer, 2020). • The period 2006-2015 was the wettest decade in the 305-year record for the island of Ireland (García & Dwyer, 2020). • During the baseline period (1976 – 2005), Ireland experienced a mean annual total precipitation of 1,209 mm per year (O'Brien et al., 2023).	• At the NUTS 3 level, all regions are projected to experience an increase in mean annual precipitation with the Mid-East and Dublin regions registering the highest increase across both RCP4.5 and RCP8.5.	• At the NUTS 3 level, all regions are projected to experience an increase in mean annual precipitation with the Mid-East and Dublin regions registering the highest increase across both RCP4.5 and RCP8.5.

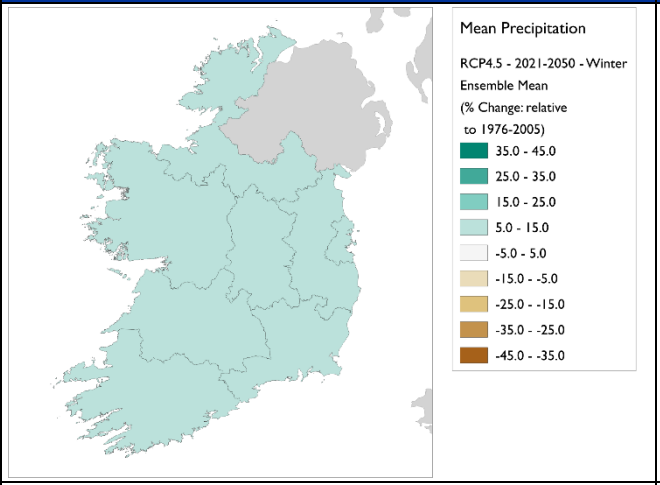
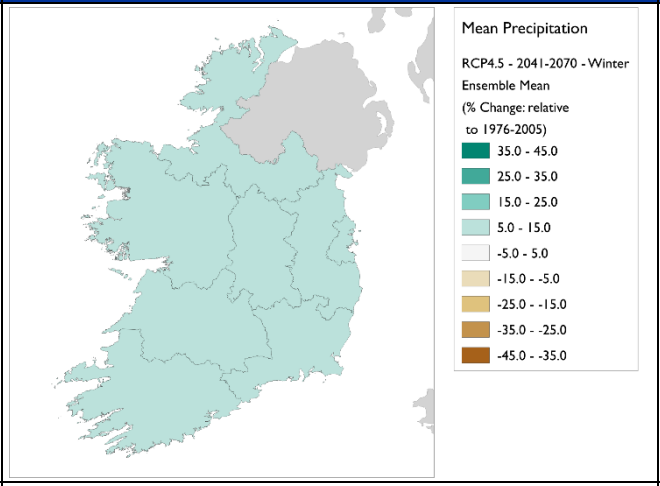
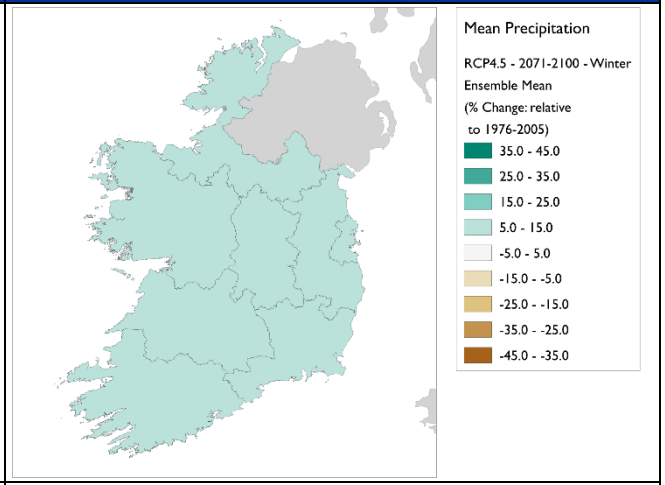
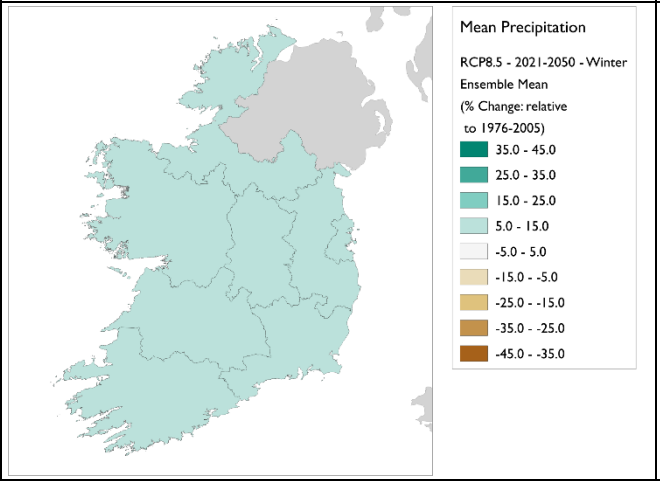
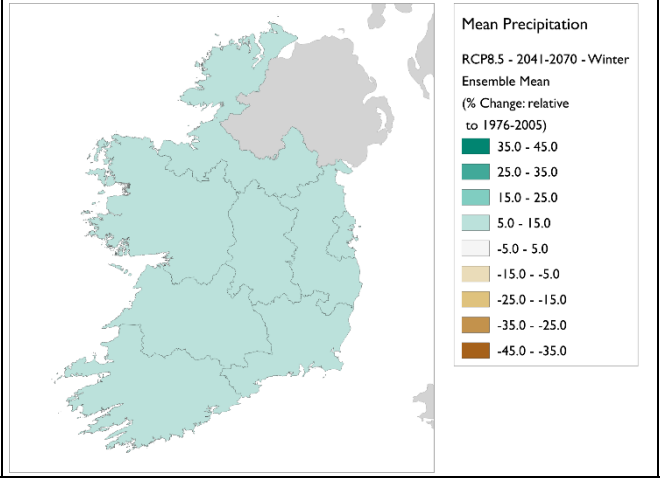
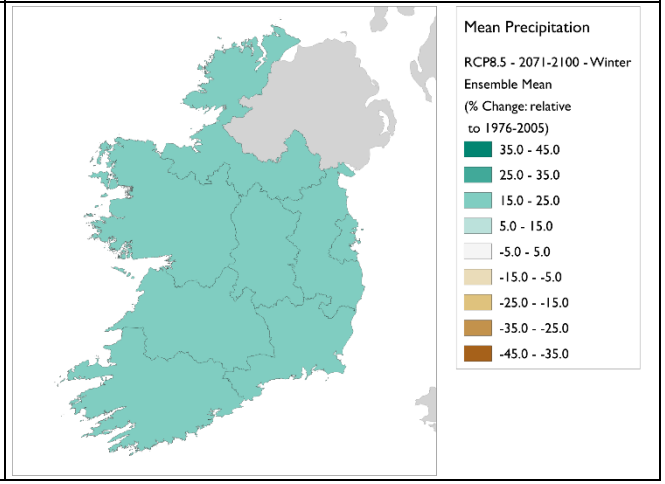
	Projected changes by 2030⁺	**Projected changes by 2050**	**Projected changes by 2100**
RCP4.5	• Nationally, mean annual precipitation is expected to increase by 3.3 % (-0.5 - 7.8%) by 2030, with the Dublin region experiencing the largest increase (4.3 % (-0.1-8.2%)). • Considering seasonality, the winter season is projected to have the highest increase in precipitation at 6.9% (-1.1-16.4%), while the summer season is expected to see the lowest increase in precipitation at 0.9% (-8.3-11.0%).	• Nationally, mean annual precipitation is expected to increase by 2.9 % (-1.6 - 7.8%) by 2050, with the Dublin region have the largest increase (4.2% (-1.0-8.8%)). • Considering the seasonality, the winter season is projected to experience the highest increase precipitation of 7.7% (-1.1-19.7%), and the summer season is projected to see a decrease in precipitation of -1.8% (-12.5-8.7%).	• Nationally, mean annual precipitation is expected to increase by 5.0 % (0.0 - 9.9%) by 2100, with the Mid-East region experiencing the largest increase (6.6% (2.2-11.1%)). • Considering the seasonality, the winter season is projected to have the highest increase in precipitation of 11.5% (3.8-19.2%), and the summer season is expected to see a decrease in precipitation of -2.0% (-12.9-6.8%).
RCP8.5	• Nationally, mean annual precipitation is expected to increase by 3.1 % (-0.7 - 7.1) by 2030, with the Dublin region experiencing the largest increase (4.7% (-0.3-10.5%)). • Considering the seasonality, winter season projected	• Nationally, mean annual precipitation is expected to increase by 4.8 % (-0.2 – 10.3%) by 2050, with the Dublin region experiencing the largest increase (6.7% (1.6-12.8%)). • Considering the seasonality, the winter season is projected to have the highest increase in precipitation of 12.5% (3.7-22.2%)	• Nationally, mean annual precipitation is expected to increase by 8.9 % (1.2-16.0%) by 2100, with the Dublin region experiencing the largest increase (10.7% (3.2-17.2%)). • Considering the seasonality, the winter season is

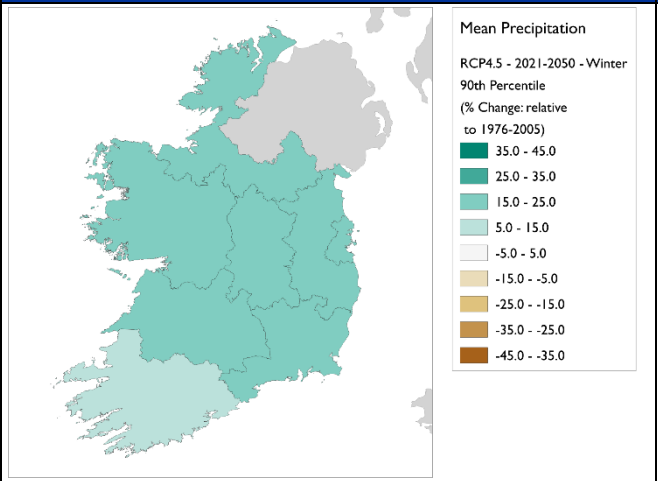
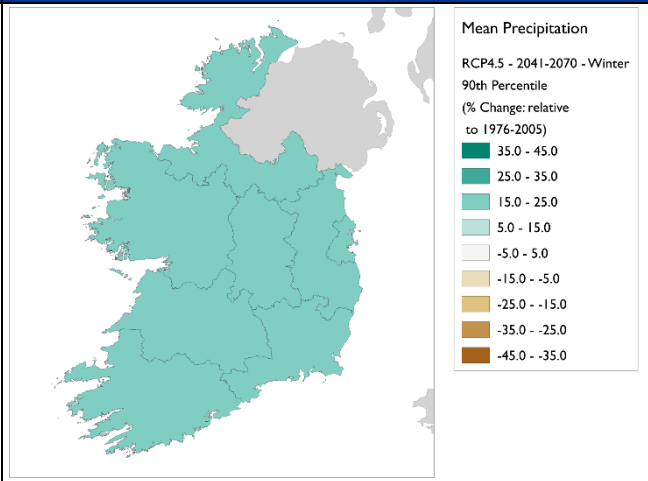
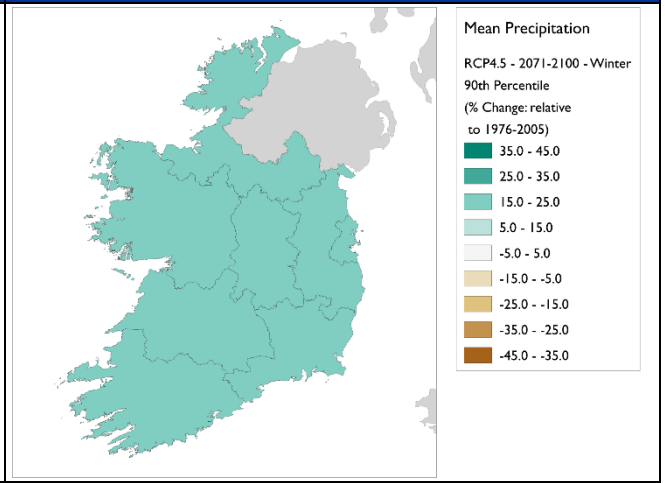
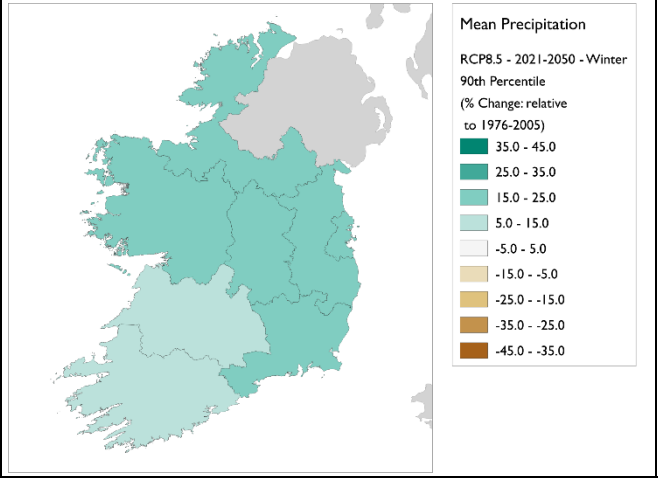
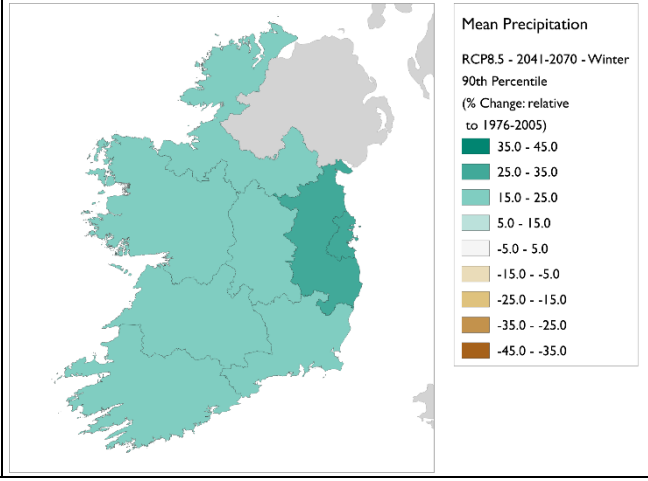
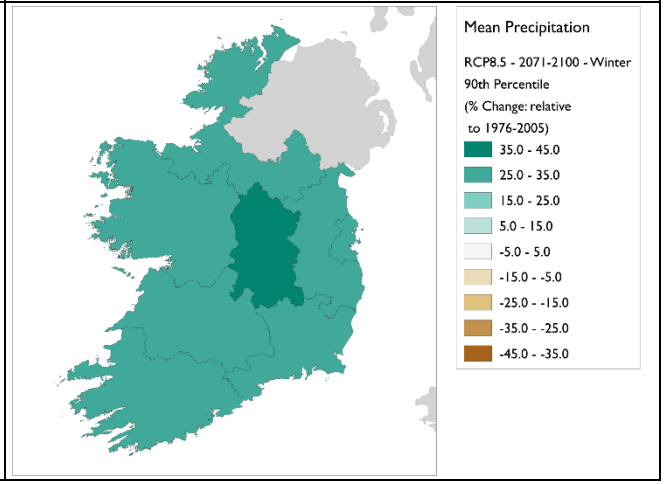
	to have a highest increase precipitation by 7.1% (0.21 – 15.7%), and in summer season to expect a decrease in precipitation of -2.1% (-11.1-7.2%).	, and the summer season is expected to see a decrease in precipitation of -5.5% (-15.6-4.9%).	projected to have the highest increase in precipitation of 20.9% (10.0-33.0%), and the summer season is expected to see a decrease in precipitation of -7.3% (-21.8-6.6%).

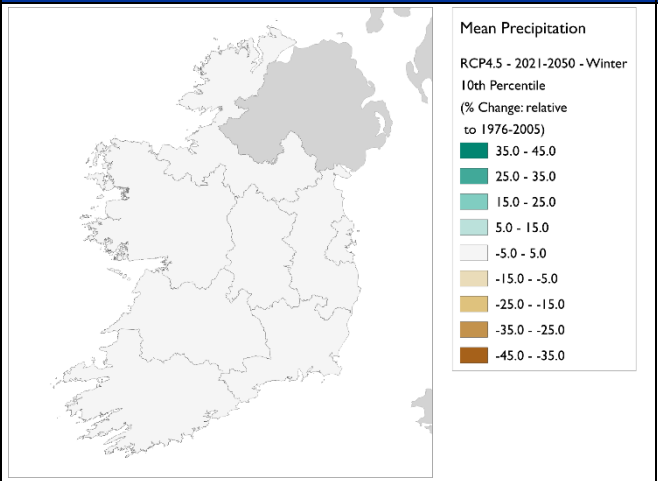
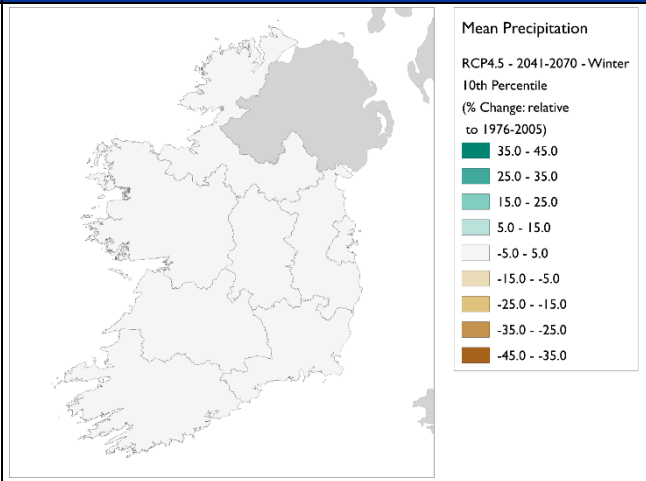
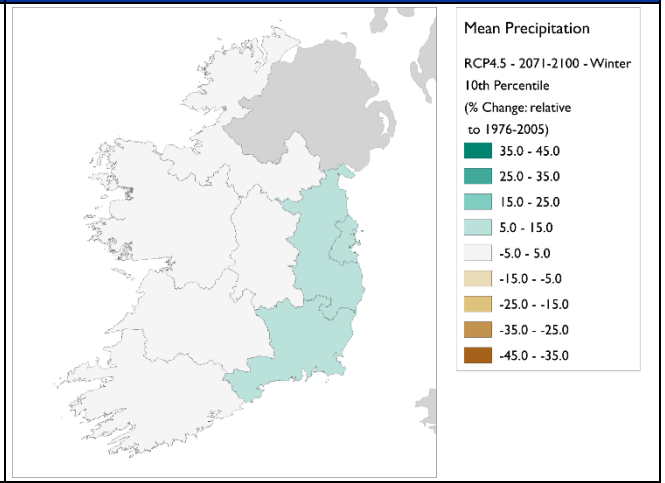
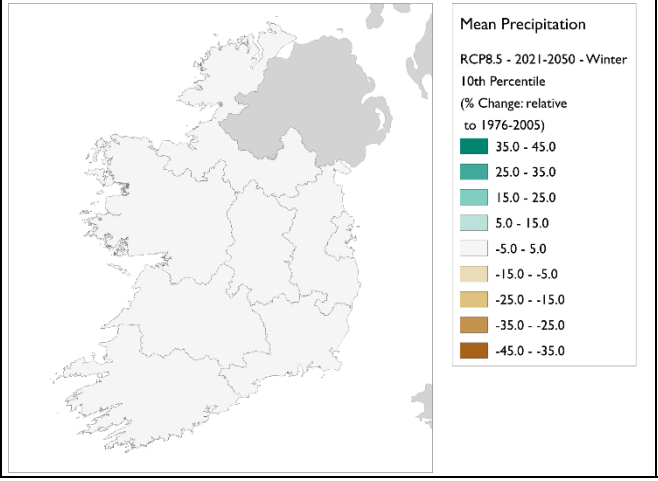
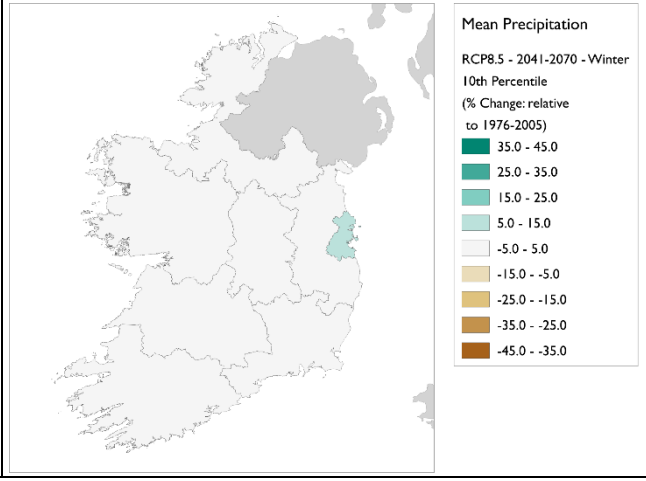
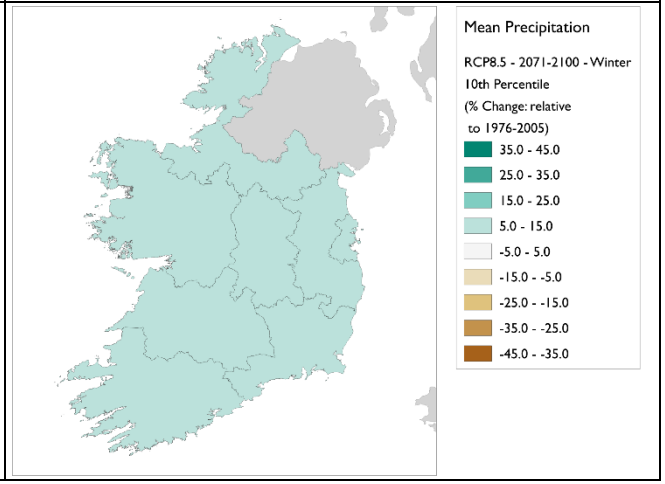
	Projected changes by 2030 (Mean Precipitation (Annual) – Mean)	Projected changes by 2050 (Mean Precipitation (Annual) – Mean)	Projected changes by 2100 (Mean Precipitation (Annual) – Mean)
RCP4.5			
RCP8.5			

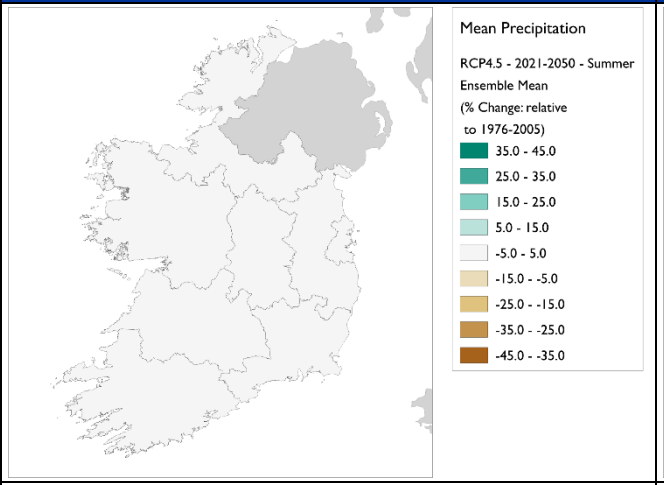
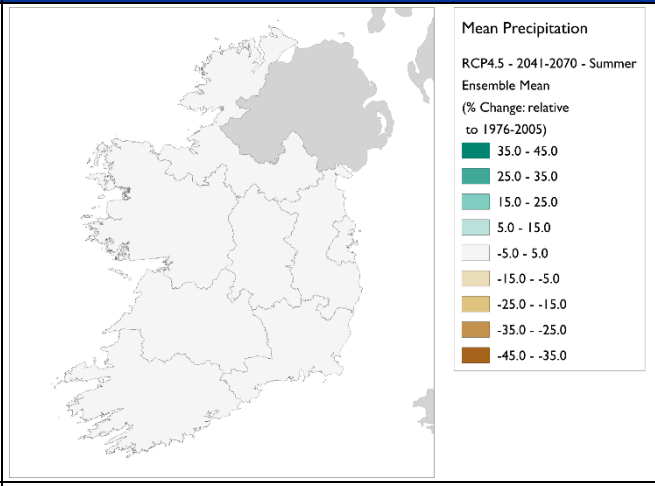
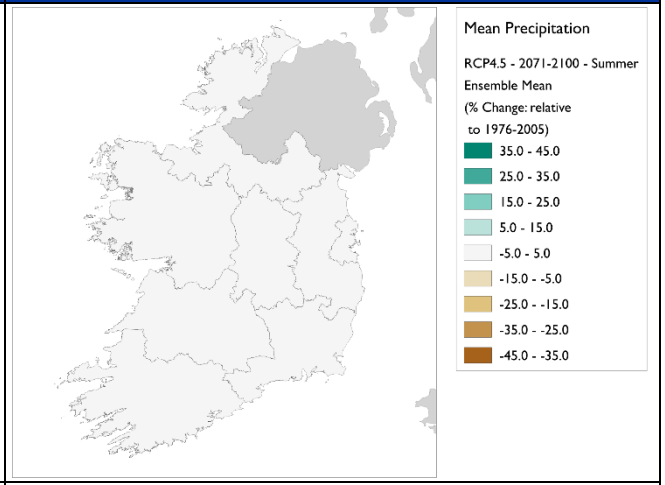
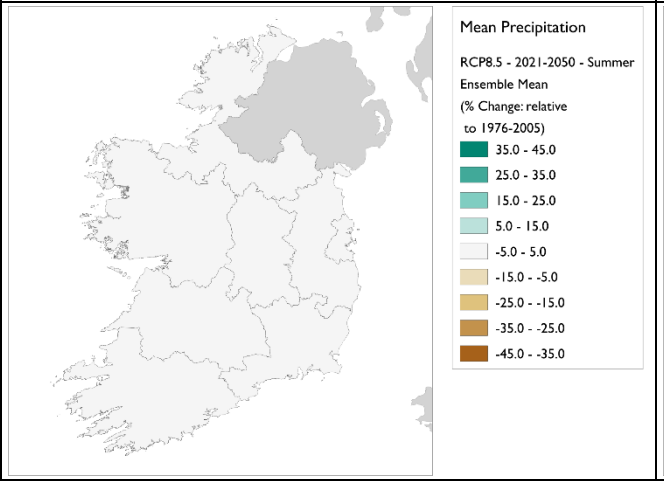
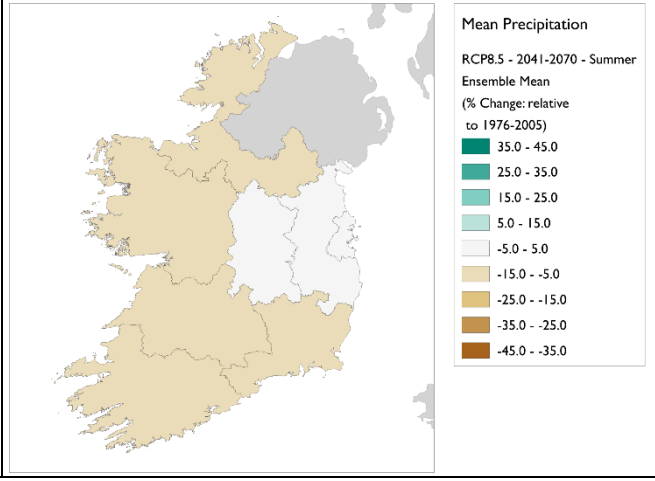
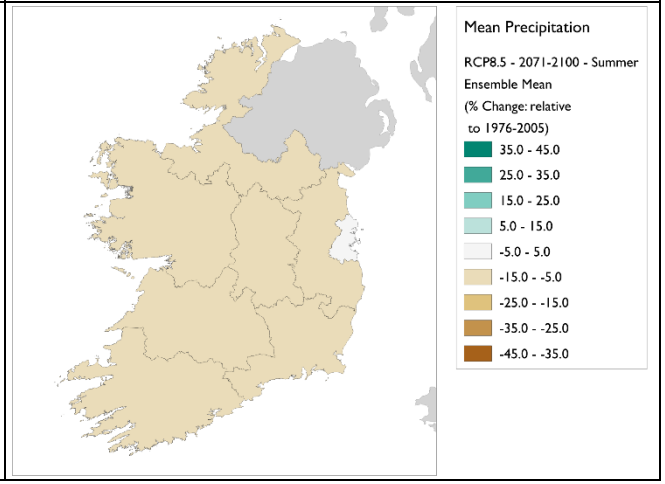
	Projected changes by 2030 (Mean Precipitation (Annual) – 90th Percentile)	Projected changes by 2050 (Mean Precipitation (Annual) – 90th Percentile)	Projected changes by 2100 (Mean Precipitation (Annual) – 90th Percentile)
RCP4.5			
RCP8.5			

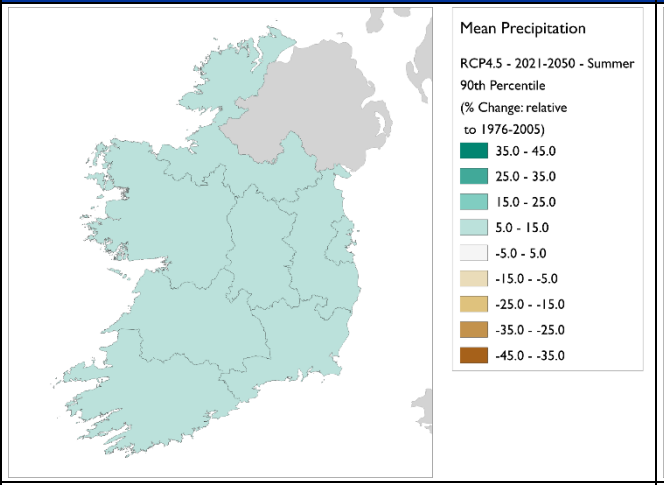
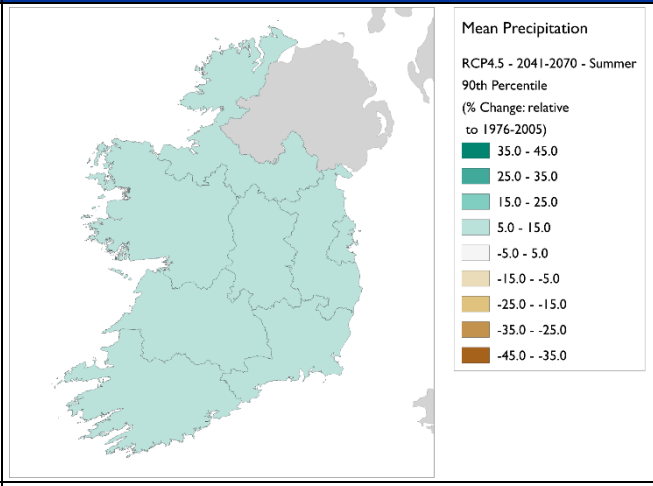
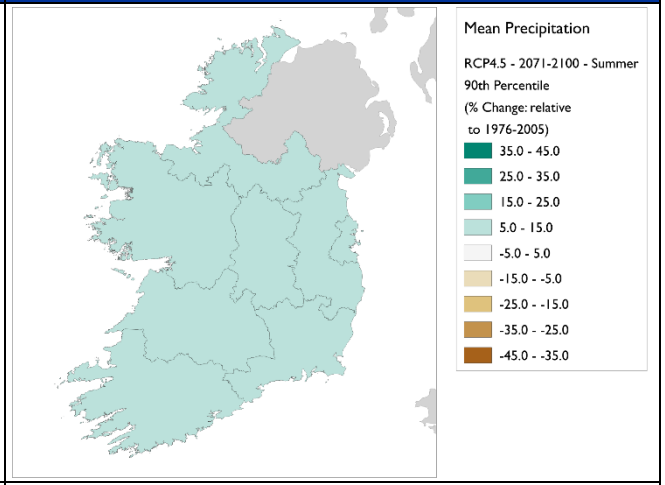
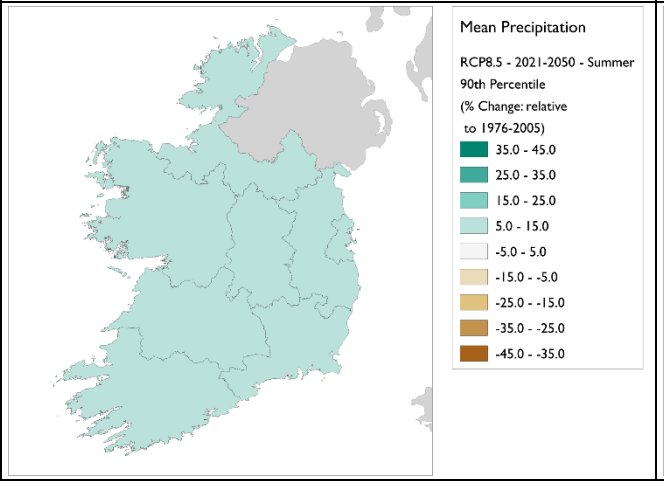
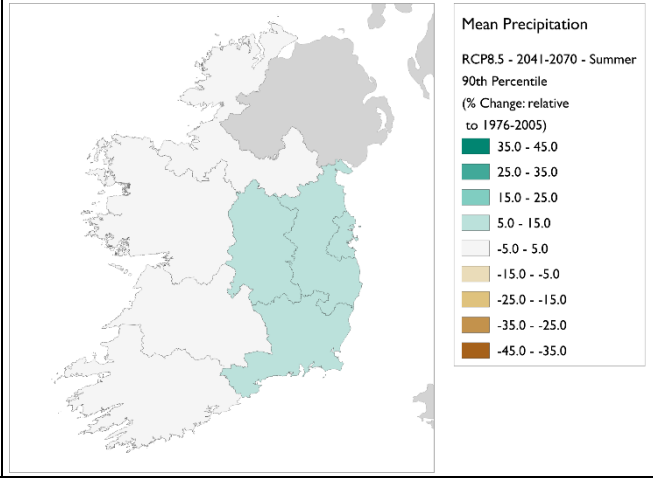
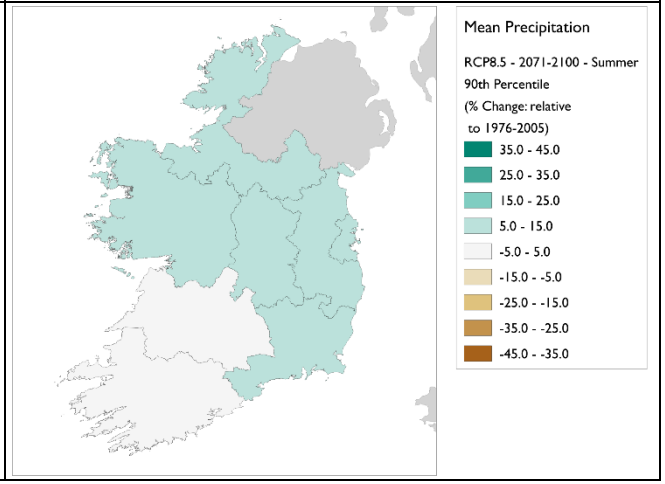
	Projected changes by 2030 (Mean Precipitation (Annual) – 10th Percentile)	Projected changes by 2050 (Mean Precipitation (Annual) – 10th Percentile)	Projected changes by 2100 (Mean Precipitation (Annual) – 10th Percentile)
RCP4.5			
RCP8.5			

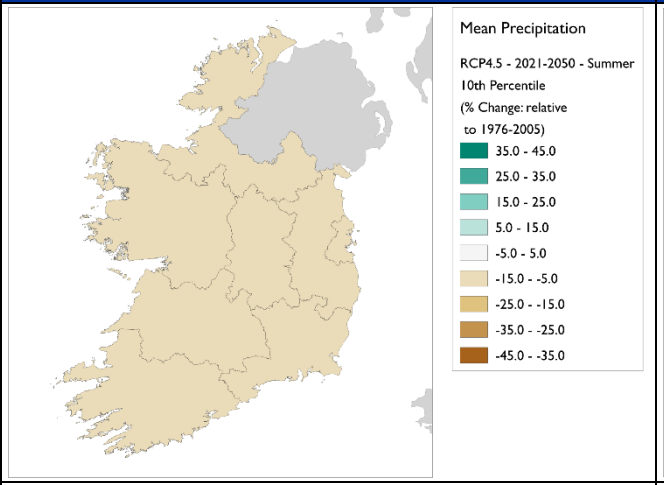
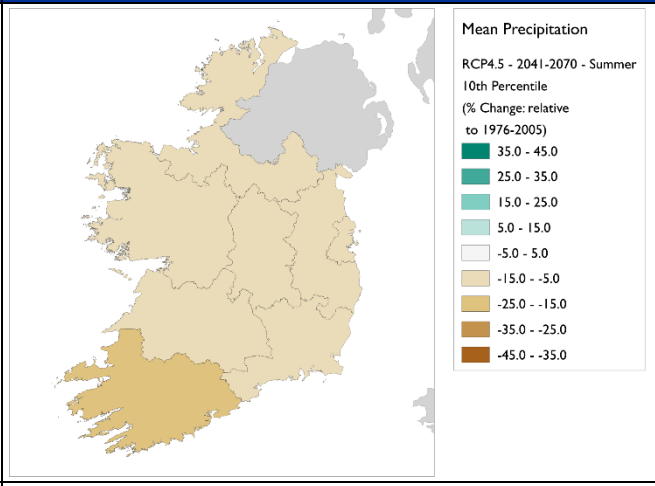
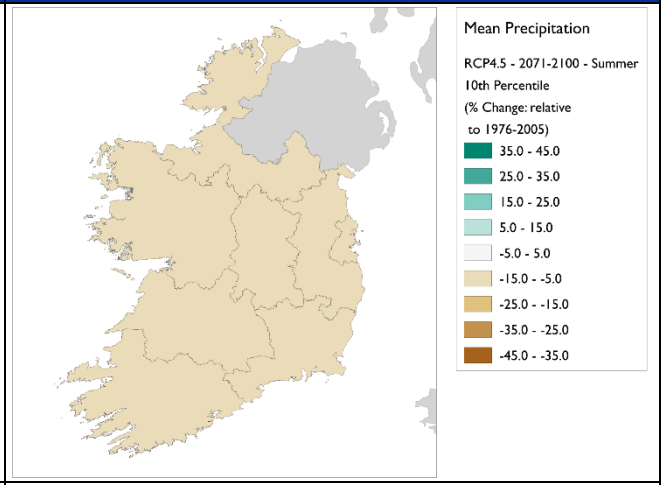
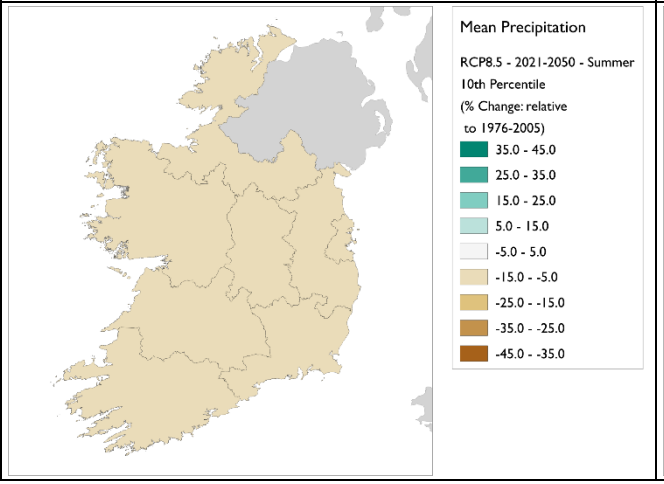
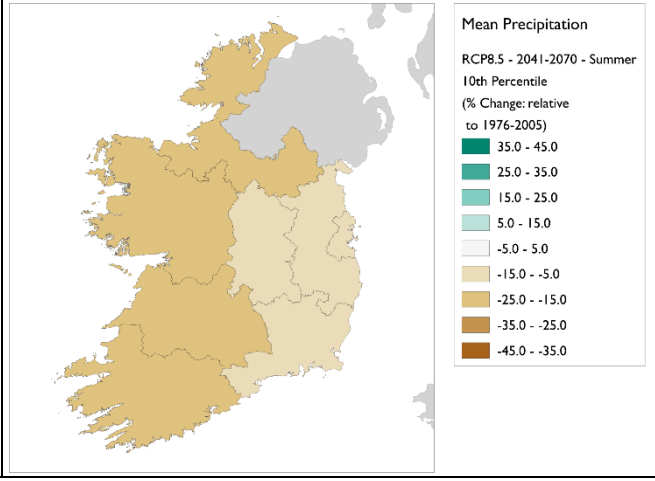
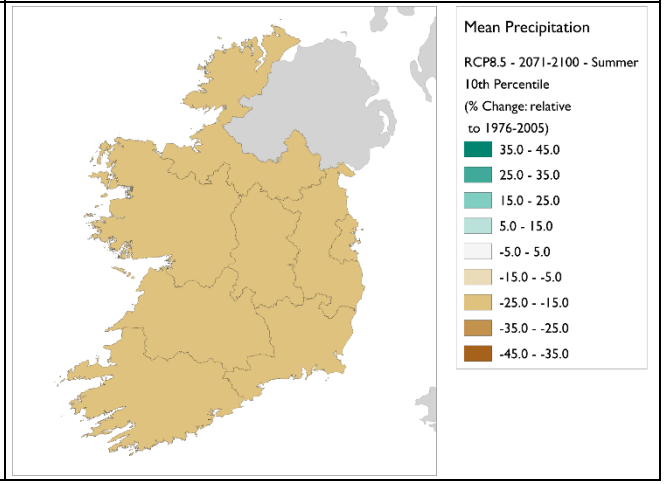
	Projected changes by 2030 (Mean Precipitation (Winter) – Mean)	Projected changes by 2050 (Mean Precipitation (Winter) – Mean)	Projected changes by 2100 (Mean Precipitation (Winter) – Mean)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Mean Precipitation (Winter) – 90th Percentile)	Projected changes by 2050 (Mean Precipitation (Winter) – 90th Percentile)	Projected changes by 2100 (Mean Precipitation (Winter) – 90th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Mean Precipitation (Winter) – 10th Percentile)	Projected changes by 2050 (Mean Precipitation (Winter) – 10th Percentile)	Projected changes by 2100 (Mean Precipitation (Winter) – 10th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Mean Precipitation (Summer) – Mean)	Projected changes by 2050 (Mean Precipitation (Summer) – Mean)	Projected changes by 2100 (Mean Precipitation (Summer) – Mean)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Mean Precipitation (Summer) – 90th Percentile)	Projected changes by 2050 (Mean Precipitation (Summer) – 90th Percentile)	Projected changes by 2100 (Mean Precipitation (Summer) – 90th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Mean Precipitation (Summer) – 10th Percentile)	Projected changes by 2050 (Mean Precipitation (Summer) – 10th Percentile)	Projected changes by 2100 (Mean Precipitation (Summer) – 10th Percentile)
RCP4.5			
RCP8.5			

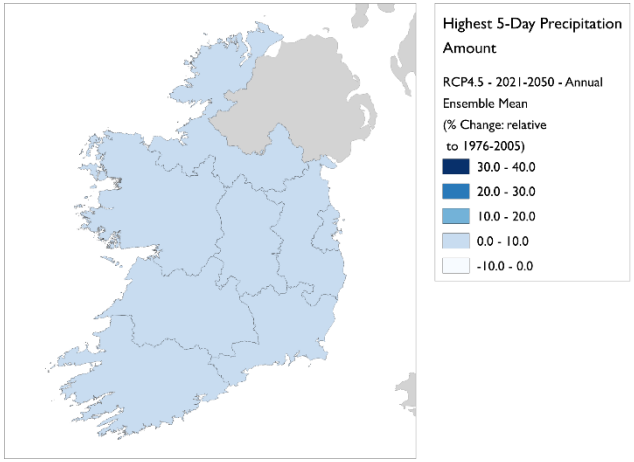
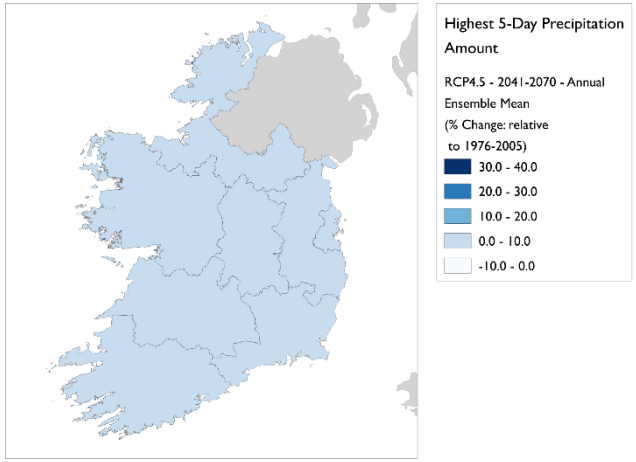
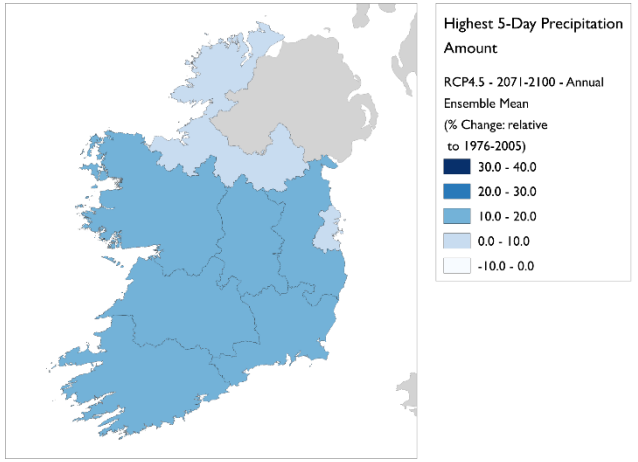
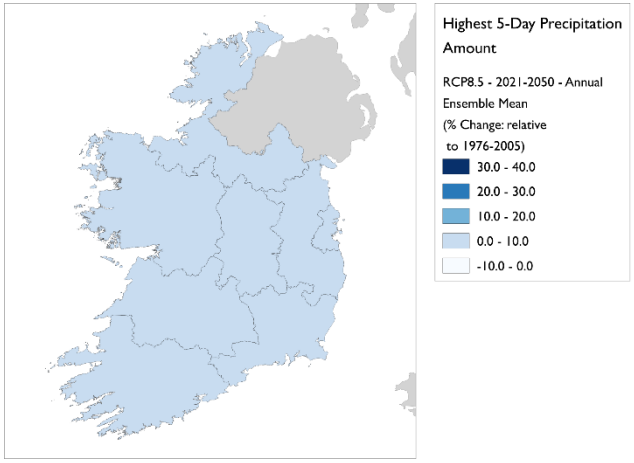
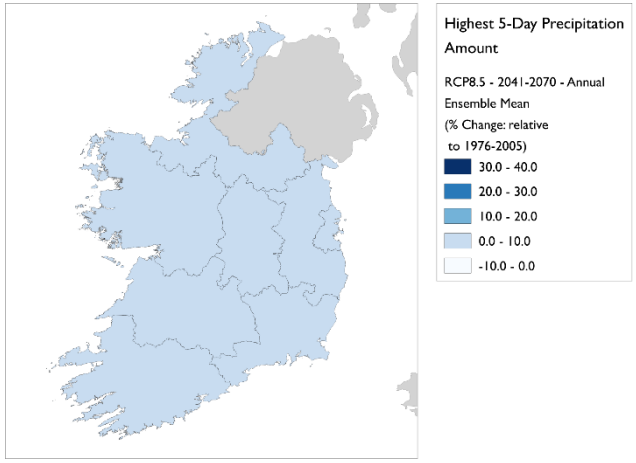
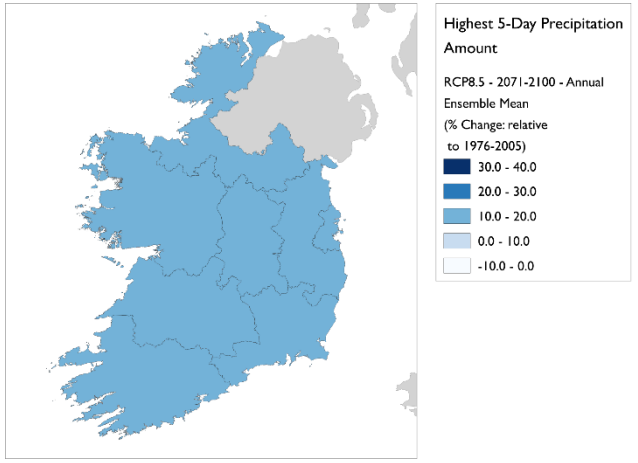
Confidence – Low
Agreement: The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections generally agree that there is an increasing trend for annual precipitation. However, within the national projections, the 10th percentile shows a different trend to the ensemble mean, and the 90th percentile, with the 10th percentile showing decreases in this variable in both scenarios, whereas the ensemble mean and 90th percentile show an increasing trend. For Winter precipitation, within the national projections, the 10th percentile shows a spatial different trend to the ensemble mean, and the 90th percentile, with the 10th percentile showing a decrease in the west of Ireland in Winter precipitation in both scenarios in 2030, and in the RCP4.5 scenario in 2050, whereas the ensemble mean and 90th percentile show an increasing trend. For Summer precipitation, within the national projections, the 90th percentile shows a different trend to the ensemble mean, and the 10th percentile, with the 90th percentile showing increases in Summer precipitation in both scenarios, whereas the ensemble mean and 10th percentile show a decreasing trend. **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

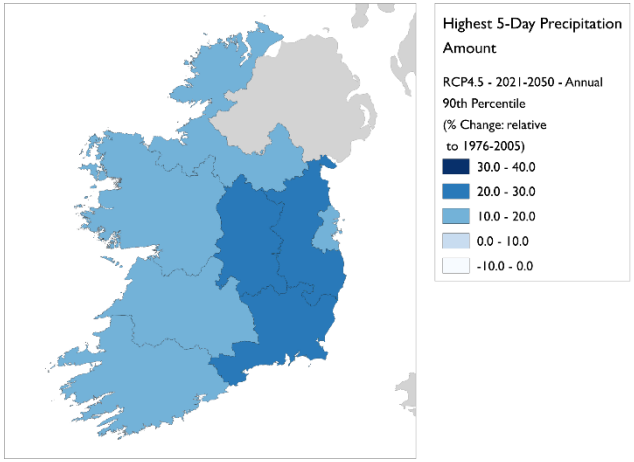
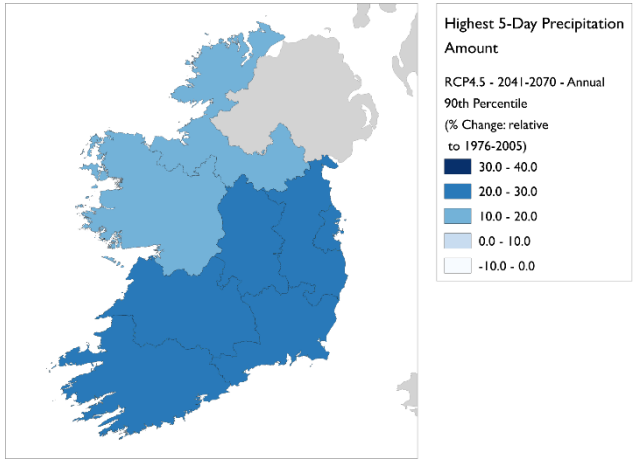
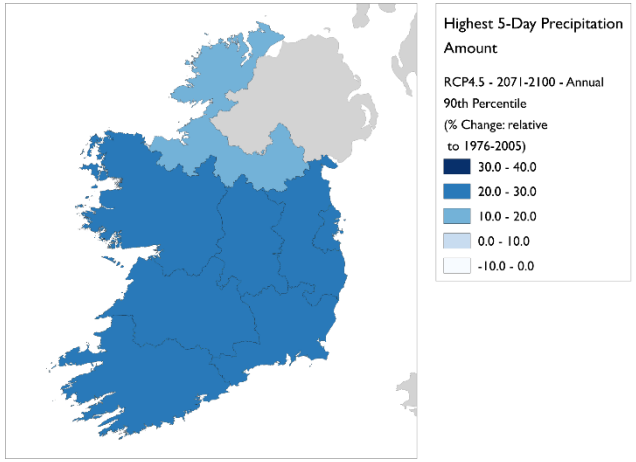
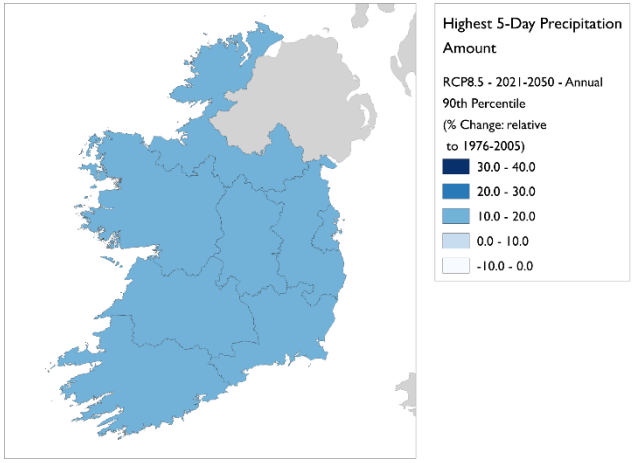
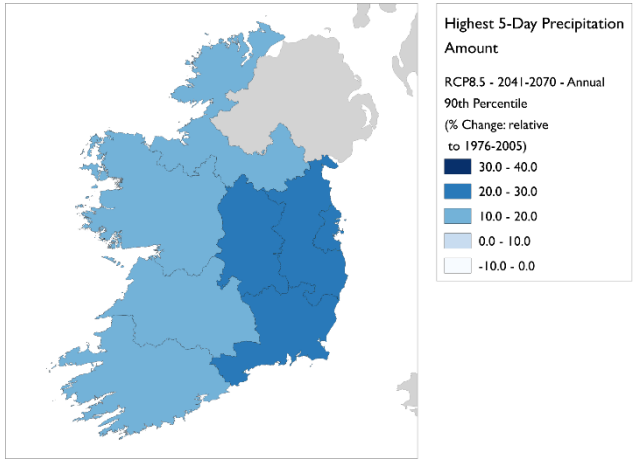
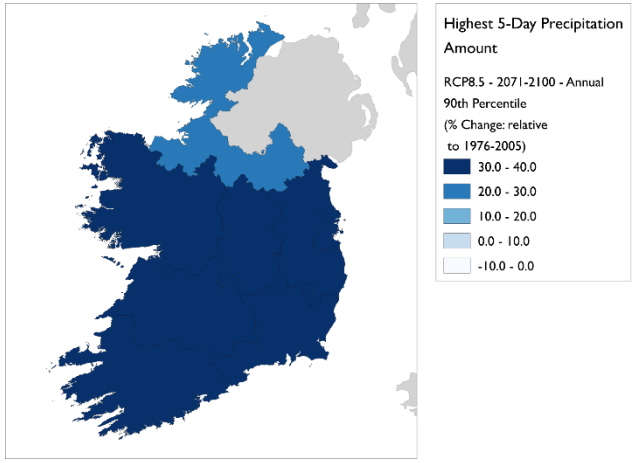
	References
Observations	Cámaro García, C., A., and Dwyer, N. (2021) The Status of Ireland's Climate, EPA Research Report 386.
	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023) Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.
Projections	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023) Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.

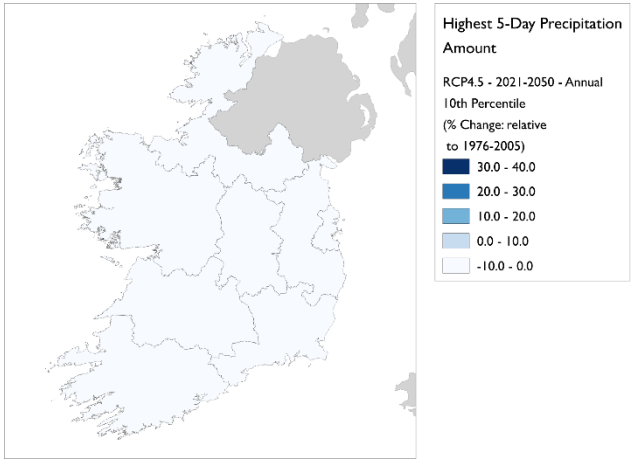
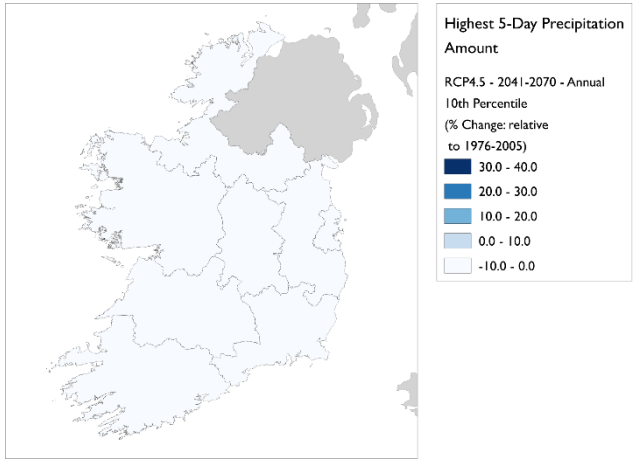
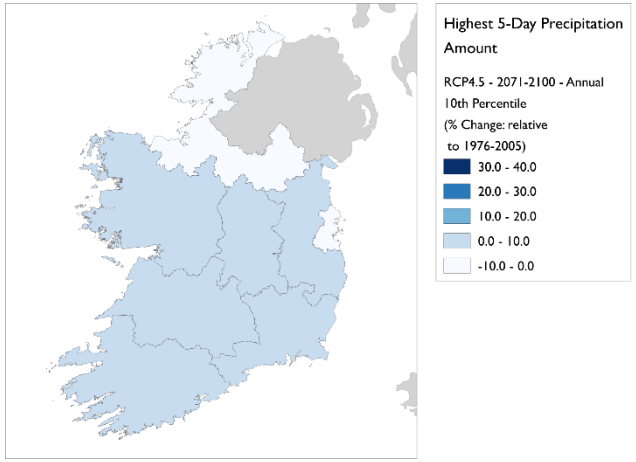
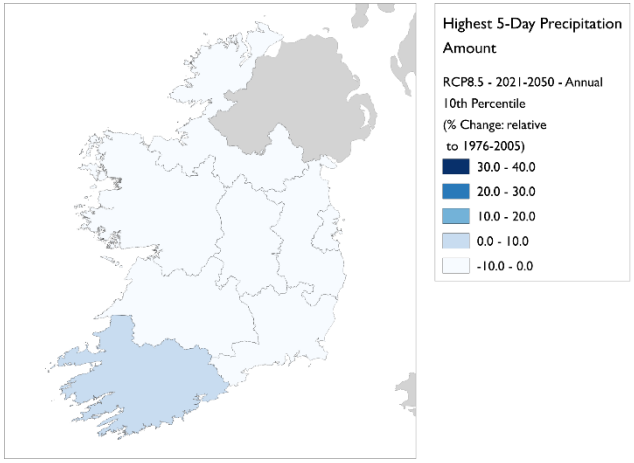
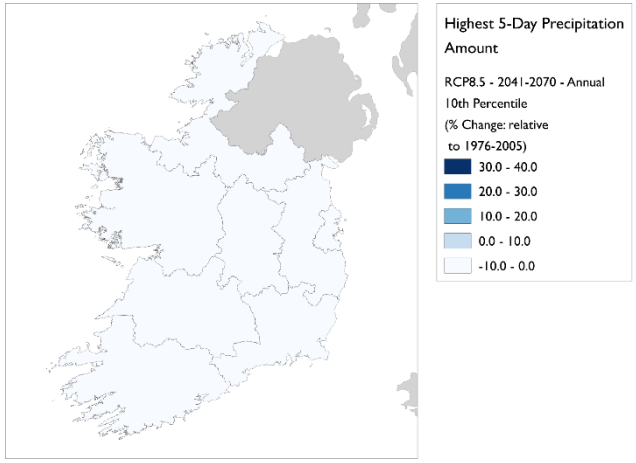
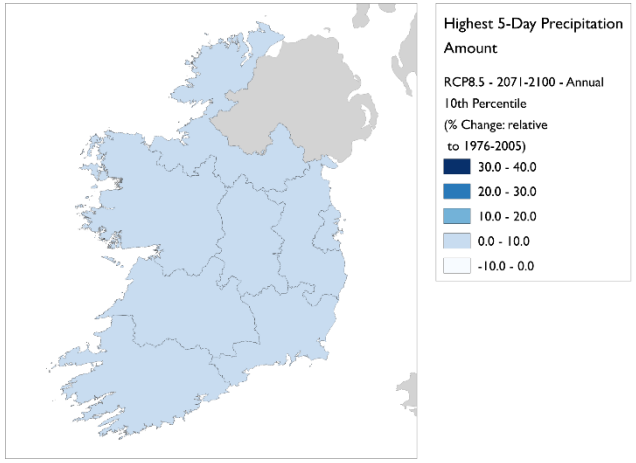
Extreme Precipitation

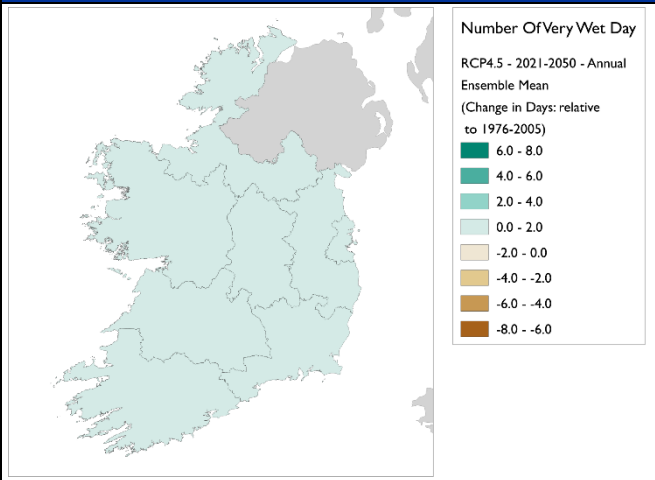
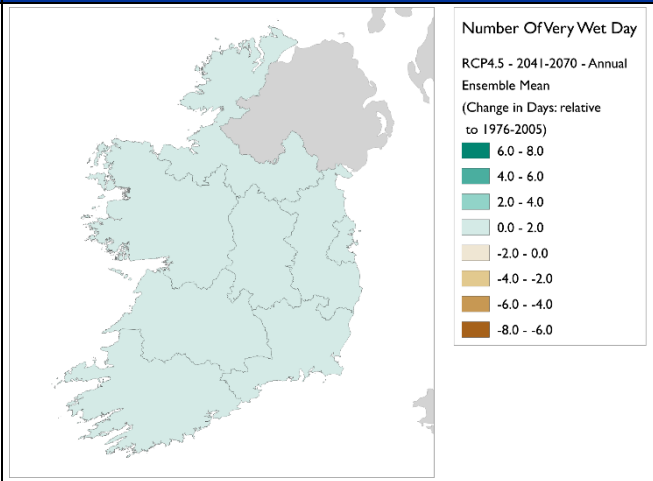
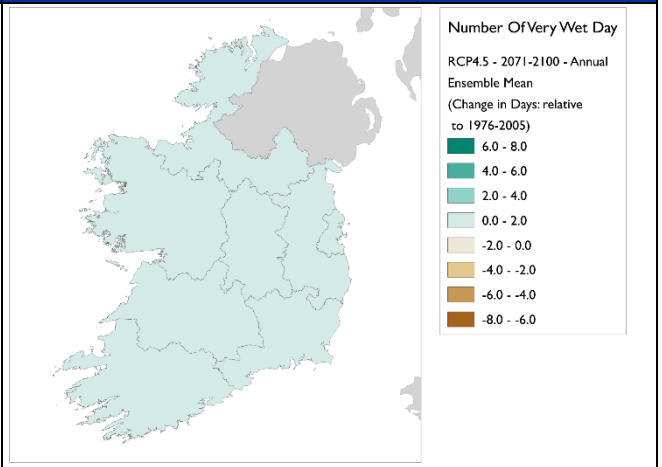
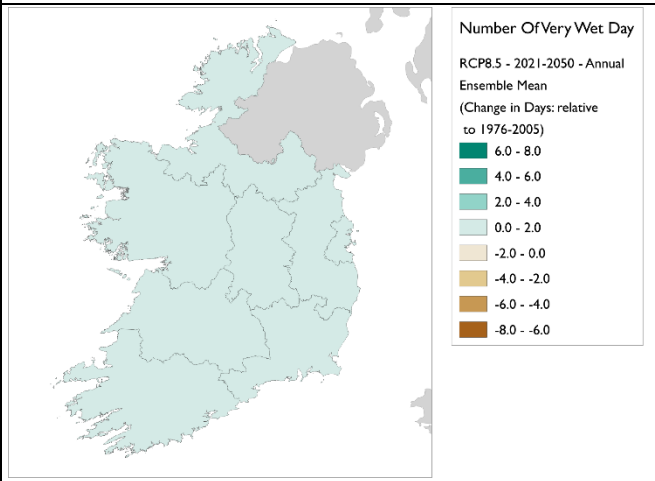
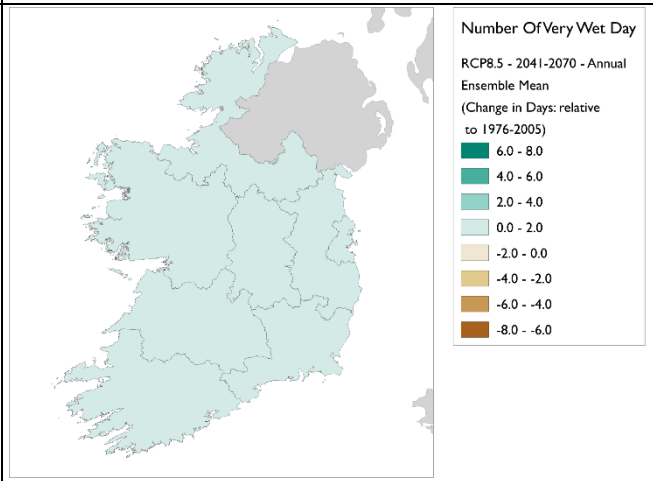
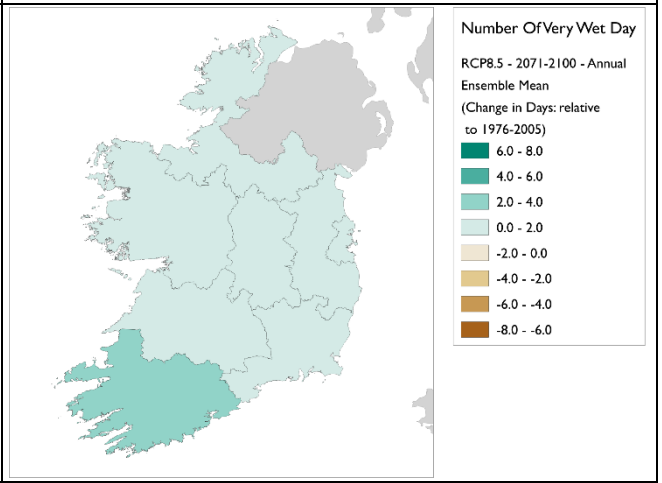
Maximum Consecutive 5-day Precipitation and Very Wet Days (Number of days with rainfall >30mm)		
National	**Sub-national (NUTS3) zones affected (projected)**	
Recent and past effects or changes	**2050**	**2100**
• Historical analysis of recent extreme precipitation trends indicates that in Ireland, the intensity of precipitation is increasing, notably in the East and South-East of Ireland. Additionally, the contribution from heavy and extreme precipitation to annual totals is increasing. However, no persistent trends in annual totals or consecutive wet days have been observed (Ryan et al., 2022). • During the baseline period (1976 - 2005) there was the average maximum 5-day precipitation was 74.3 mm and there was an average of 1.8 very wet days per year (O'Brien et al., 2023).	• At the NUTS 3 level, all regions are projected to experience an increase in intense 5-day precipitation across both scenarios. • Ireland will also experience an increase in the number of very wet days.	• At the NUTS 3 level, all regions are projected to experience an increase in intense 5-day precipitation across both scenarios. • Ireland will also experience an increase in the number of very wet days.

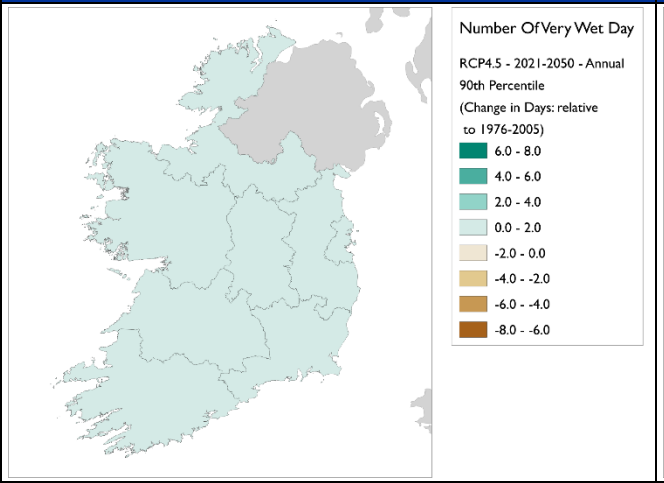
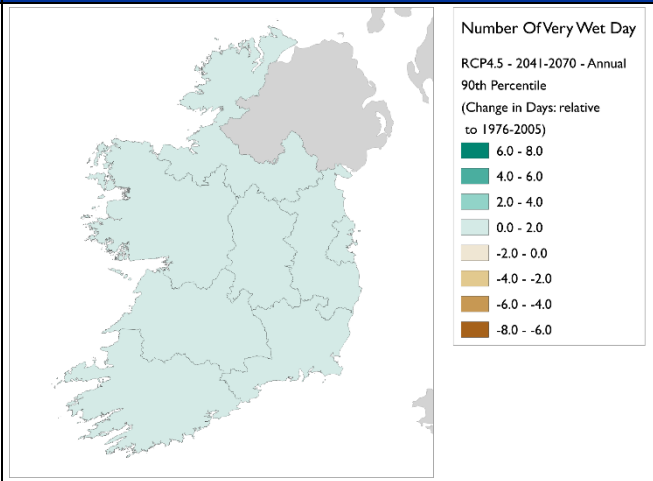
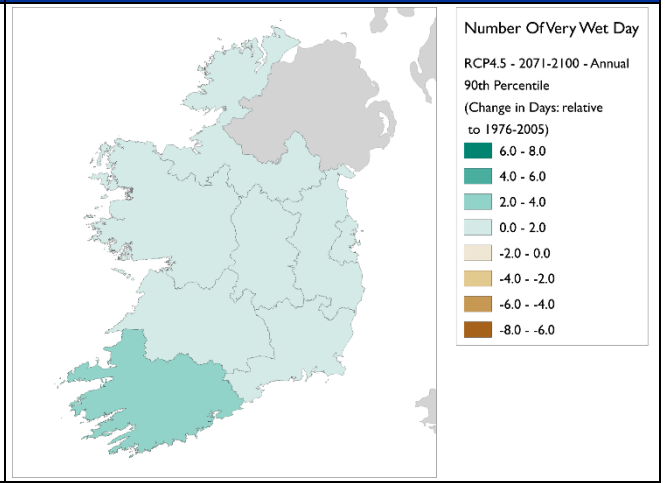
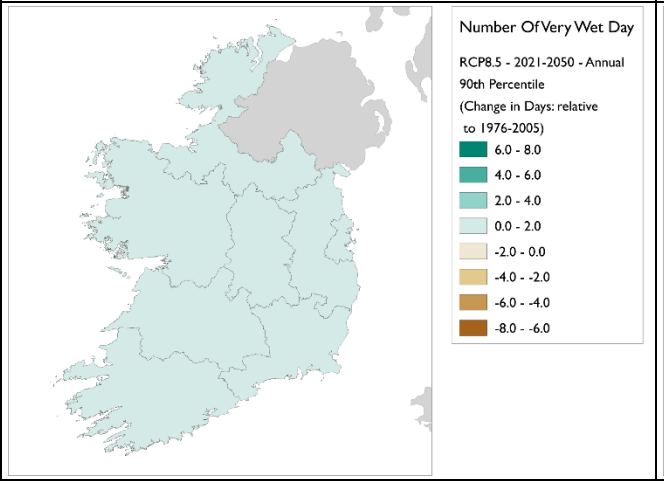
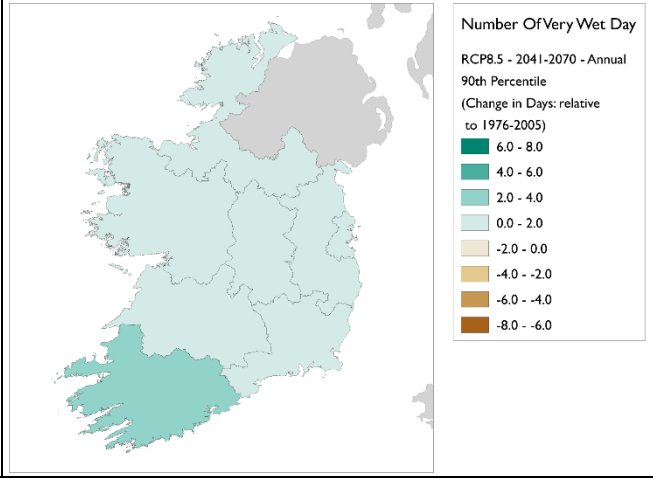
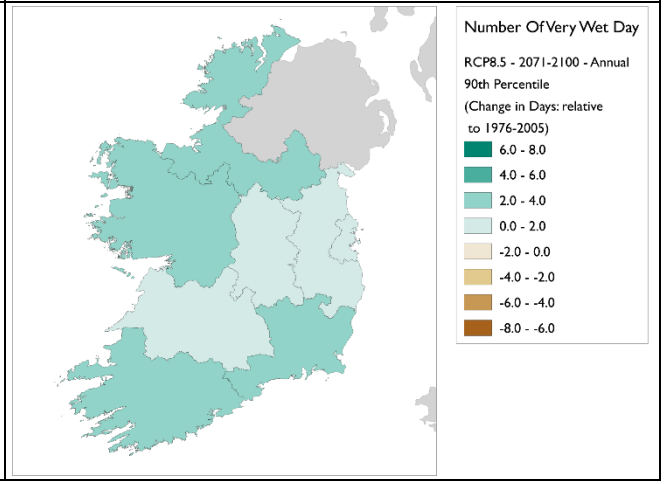
	Projected changes by 2030[+]	Projected changes by 2050	Projected changes by 2100
RCP4.5	• Nationally, there is a projected increase in the maximum 5-day precipitation by 5.5 % (-3.8 - 16.2%) by 2030, with the South-West (8.7% (-0.6-18.4%)) region experiencing the largest increase. • Very wet days also indicate a small increasing trend of 0.5 days per year (0.0 - 1.0 days per year).	• Nationally, there is a projected increase in the maximum 5-day precipitation of 6.7% (-4.1 - 18.9%) by 2050, with the South-East (9.0% (-2.5-21.0%)) and South-West (9.0% (-1.3-21.2%)) regions experiencing the largest increases. • Very wet days also indicate a small increasing trend of 0.5 days per year (0.1 - 1.1 days per year).	• Nationally, there is a projected increase in maximum 5-day precipitation of 10.2% (0.4 - 21.1%) by 2100, with the Mid-East (13.4% (1.4-25.1%)) region experiencing the largest increase. • Very wet days also indicate a small increasing trend of 0.8 days per year (0.3 - 1.3 days per year).
RCP8.5	• Nationally, there is a projected increase in the maximum 5-day precipitation by 5.6 % (-3.4-15.4%) by 2030, with the Mid-East (8.0% (-2.7-19.2%)) region experiencing the largest increase. • Projections for very wet days indicate a small increasing trend of 0.4 days per year (0.0-0.9 days per year).	• Nationally, there is a projected increase in maximum 5-day precipitation by 6.9% (-3.1-18.0%) by 2050, with the Mid-East (9.5% (-3.1-22.8%)) region experiencing the largest increase. • Projections for very wet days also indicate a small increasing trend of 0.7 days per year (0.3-1.3 days per year).	• Nationally, there is a projected increase in maximum 5-day precipitation of 16.5 % (3.8 - 31.4%) by 2100, with the South-West (18.1% (4.1-34.5%)) and West (18.1% (5.8-33.8%)) regions experiencing the largest increases. • Projections for very wet days also indicate a small increasing trend of 1.4 days per year (0.7-2.1 days per year).

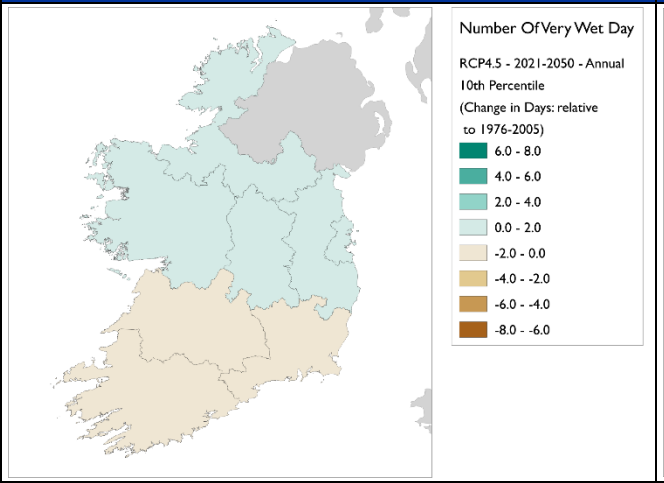
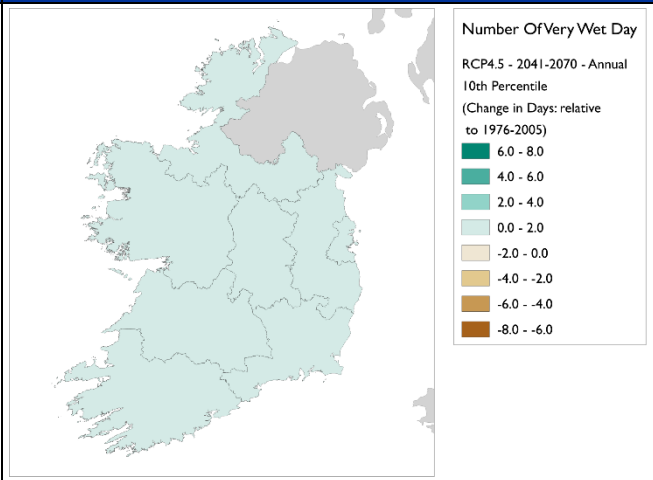
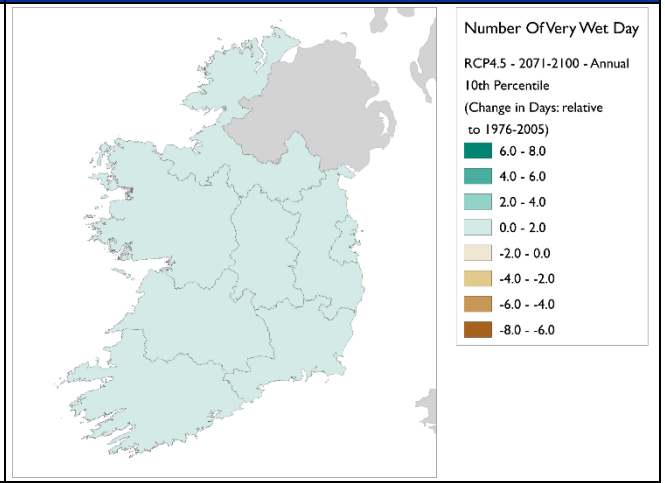
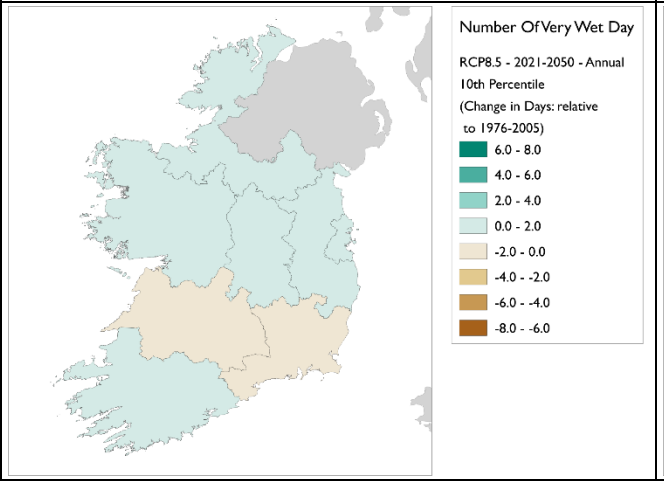
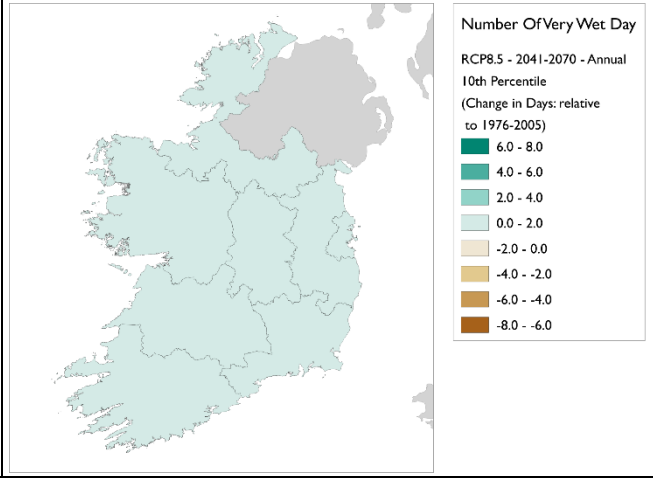
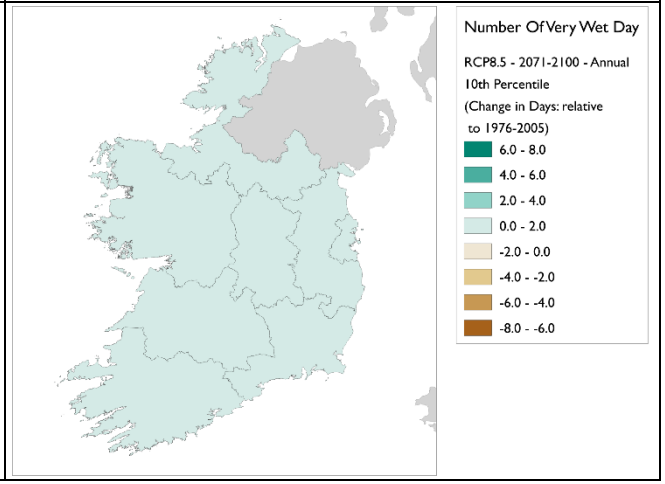
	Projected changes by 2030 (Maximum consecutive 5-day precipitation – Mean)	Projected changes by 2050 (Maximum consecutive 5-day precipitation – Mean)	Projected changes by 2100 (Maximum consecutive 5-day precipitation – Mean)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Maximum consecutive 5-day precipitation – 90th Percentile)	Projected changes by 2050 (Maximum consecutive 5-day precipitation – 90th Percentile)	Projected changes by 2100 (Maximum consecutive 5-day precipitation – 90th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Maximum consecutive 5-day precipitation – 10th Percentile)	Projected changes by 2050 (Maximum consecutive 5-day precipitation – 10th Percentile)	Projected changes by 2100 (Maximum consecutive 5-day precipitation – 10th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Very Wet Days (Number of days with rainfall >30mm) – Mean)	Projected changes by 2050 (Very Wet Days (Number of days with rainfall >30mm) – Mean)	Projected changes by 2100 (Very Wet Days (Number of days with rainfall >30mm) – Mean)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Very Wet Days (Number of days with rainfall >30mm) – 90th Percentile)	Projected changes by 2050 (Very Wet Days (Number of days with rainfall >30mm) – 90th Percentile)	Projected changes by 2100 (Very Wet Days (Number of days with rainfall >30mm) – 90th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Very Wet Days (Number of days with rainfall >30mm) – 10th Percentile)	Projected changes by 2050 (Very Wet Days (Number of days with rainfall >30mm) – 10th Percentile)	Projected changes by 2100 (Very Wet Days (Number of days with rainfall >30mm) – 10th Percentile)
RCP4.5			
RCP8.5			

Confidence: Low
Agreement: The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections generally agree that there is an increasing trend for these variables. However, within the national projections, the 10th percentile shows a different trend to the ensemble mean, and the 90th percentile, with the 10th percentile showing decreases in these variables for both scenarios, whereas the ensemble mean and 90th percentile show an increasing trend. **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

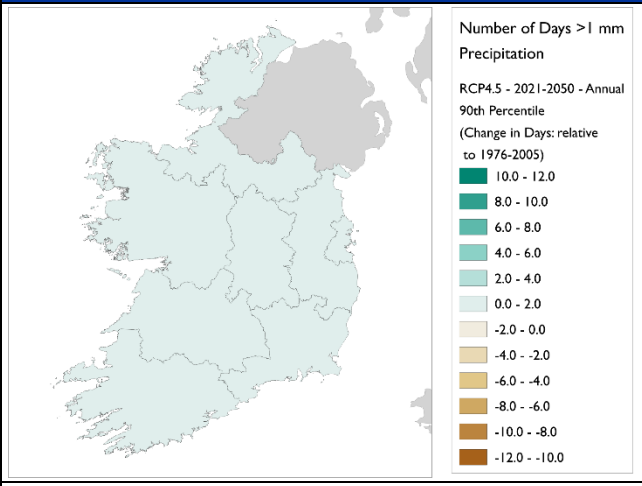
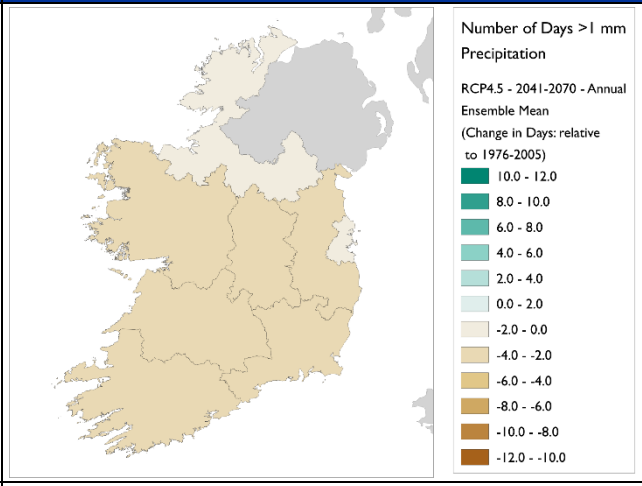
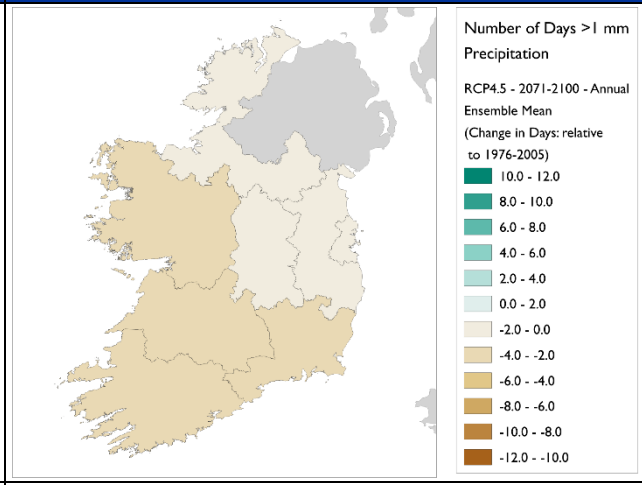
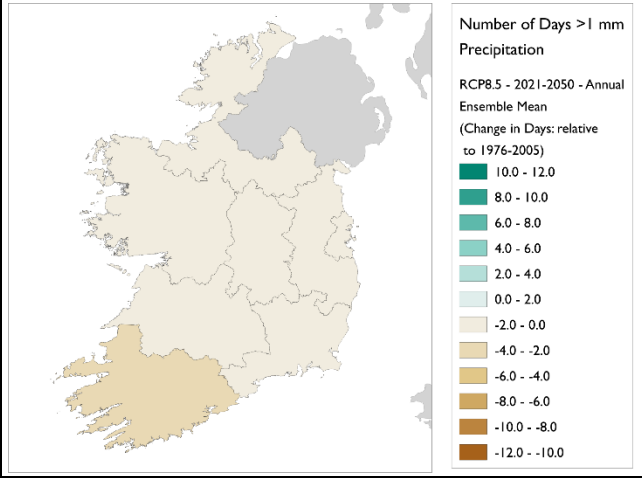
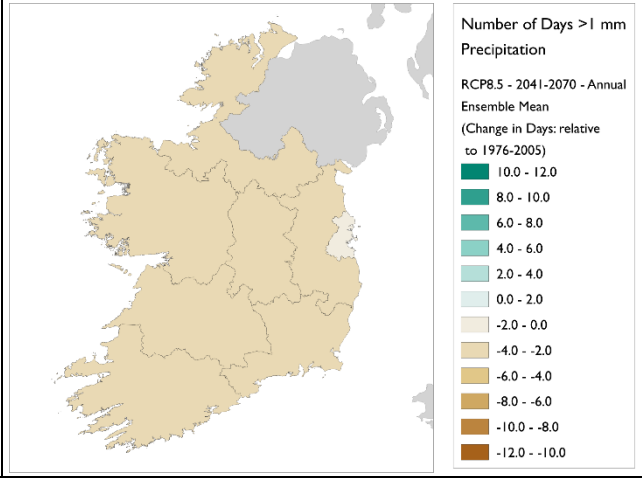
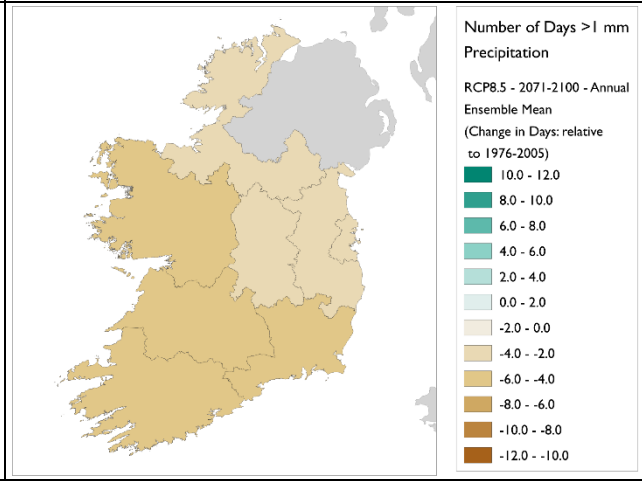
	References
Observations	Ryan, C., Curley, M., Walsh, S. and Murphy, C. (2022) Long-term trends in extreme precipitation indices in Ireland. International Journal of Climatology, 42(7), pp.4040-4061
	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023) Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.
Projections	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023) Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.

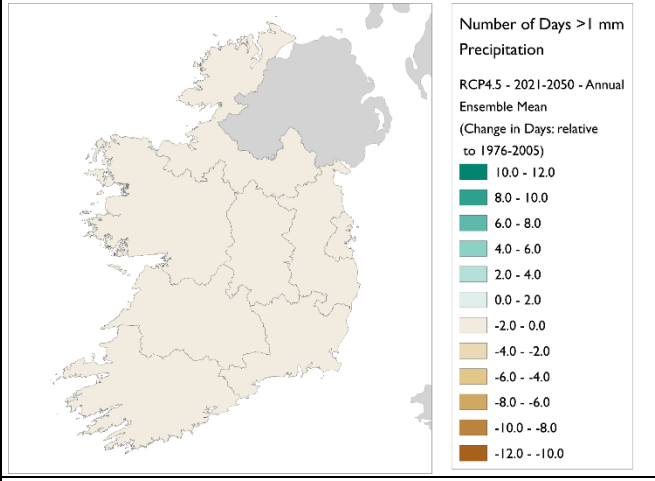
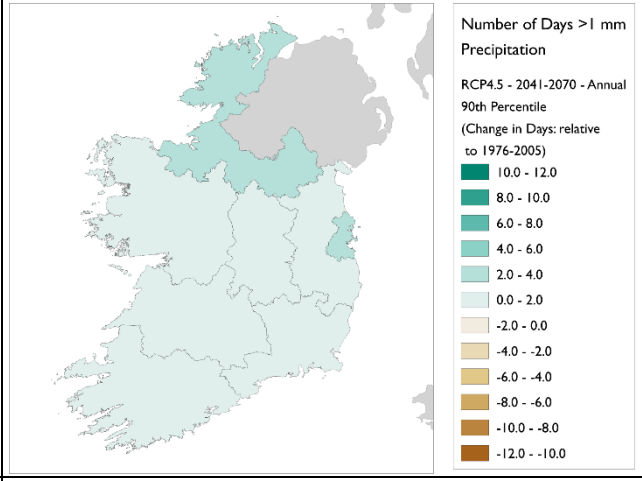
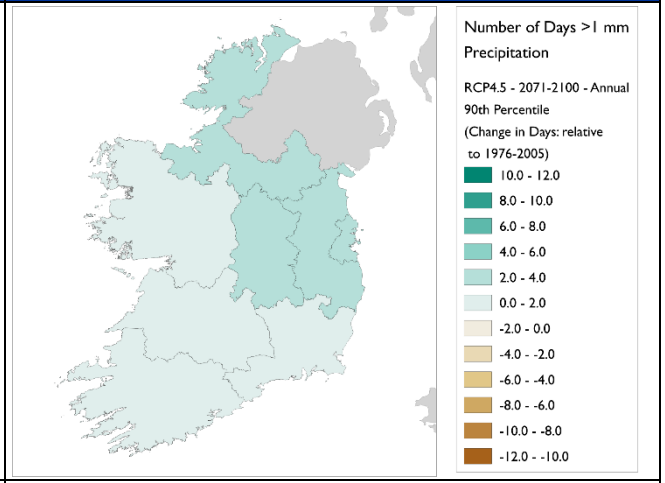
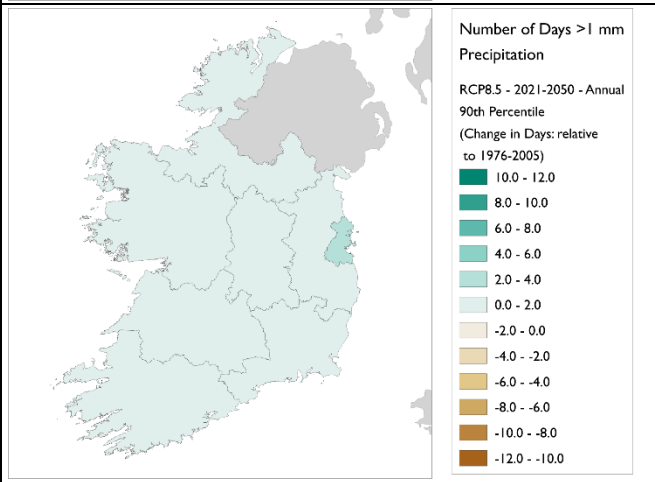
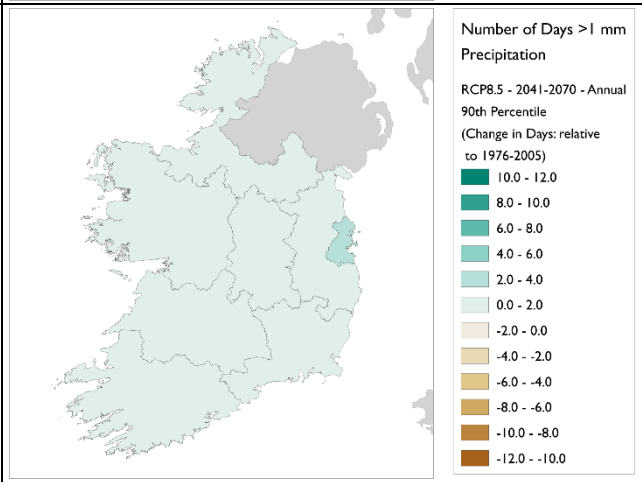
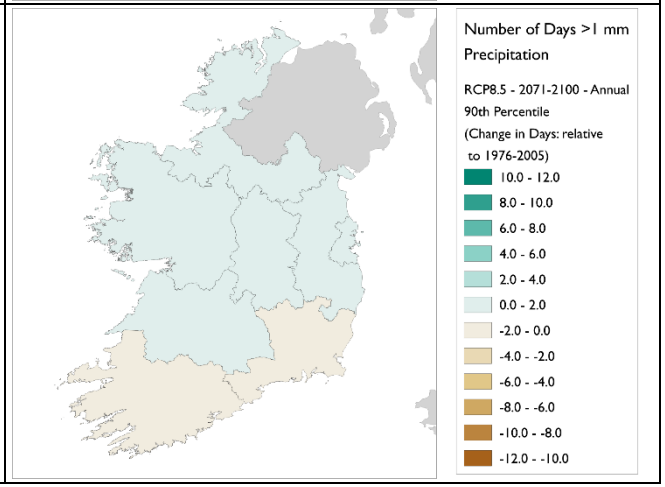
Drought

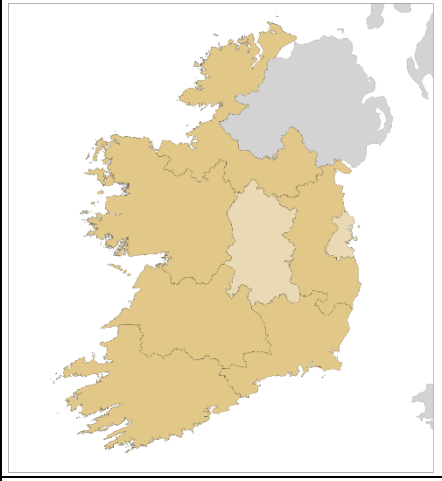
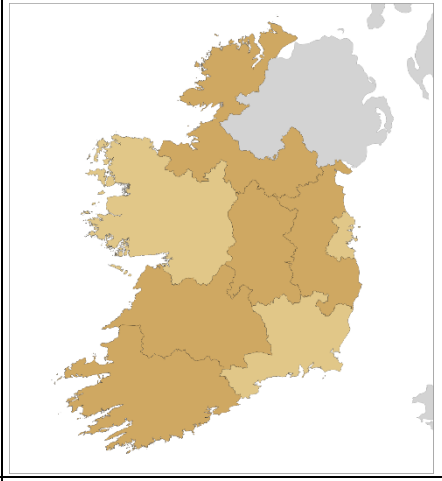
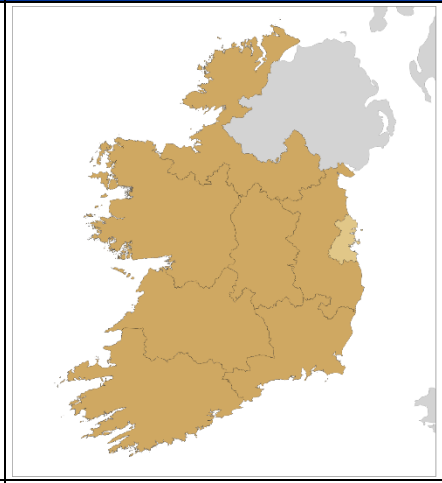
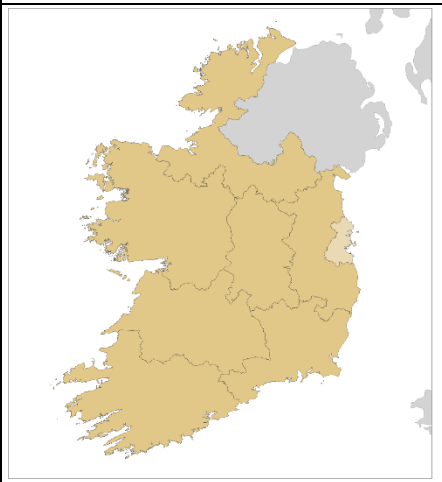
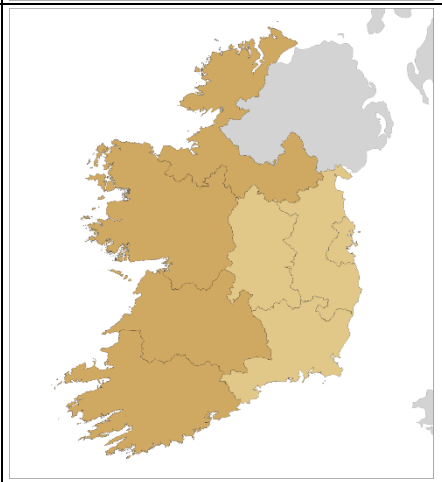
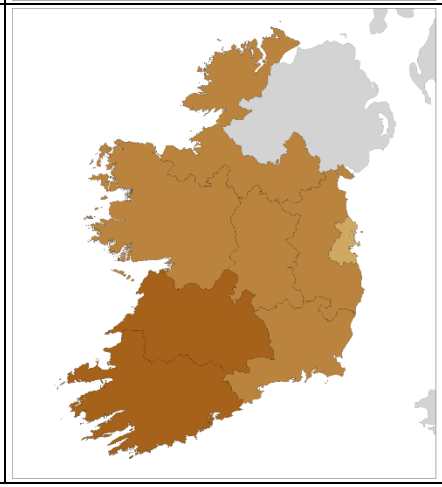
Number of Wet Days (Daily Precipitation >1mm) and SPEI-3 (Standardised Precipitation Evapotranspiration Index – 3 month)		
National	**Sub-national (NUTS3) zones affected (projected)**	
Recent and past effects or changes	**2050**	**2100**
• Ireland in past, subjected to several drought episodes. During 1850-2015, seven major droughts events have been identified and analysis of data for a shorter period suggesting an increase in drought conditions notably over the eastern part of Ireland variability (García & Dwyer, 2020). • During the baseline period (1976 – 2005) there was an annual average of 188.66 wet days per year (O'Brien et al., 2023). • Analysing the Hydropredict SPEI indices for the reference period (1976-2005) indicates that the summer on average is more prone to droughts (SPEI3 < -1), East and Southern regions are prone to droughts.	• All zones will be expected to experience a decrease in number of wet days with the East and South-East regions most affected. SPEI-3 index shows that, in summer and spring season, most of the zones indicated an increase in drought conditions and a general decrease in drought condition in other months. East and Southern regions have higher prevalence of drought conditions in summer and spring with Dublin zones showing the lowest SPEI-3 values (-1.74).	• All zones will be expected to experience a decrease in number of wet days with the East and South-East regions most affected. SPEI-3 index shows that, in summer and spring seasons, most of the zones indicate an increase in drought conditions and a general decrease in drought condition in other months. East and Southern regions have higher prevalence of drought conditions in summer and spring with Dublin zones showing the lowest SPEI-3 values (-1.96).

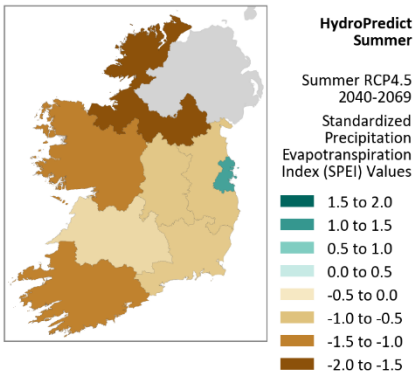
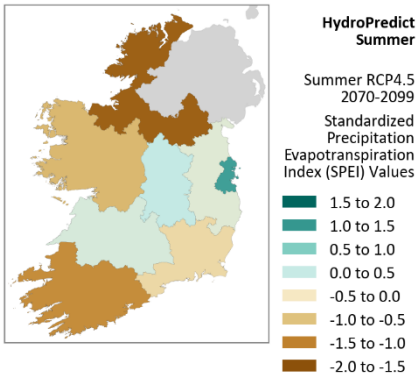
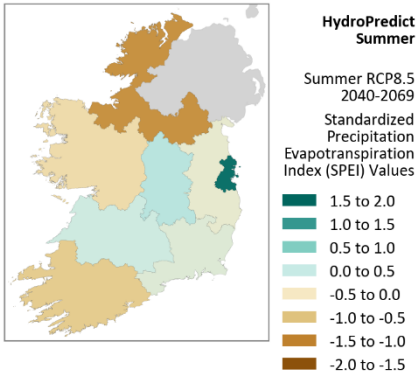
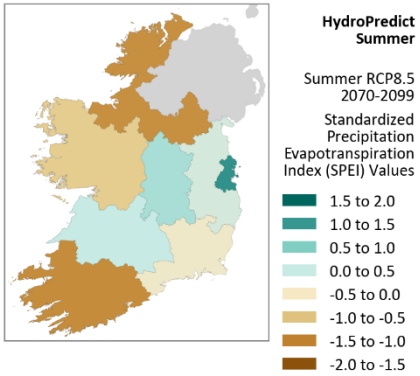
	Projected changes by 2030[+]	**Projected changes by 2050**	**Projected changes by 2100**
RCP4.5	• Nationally, mean annual number of wet days is expected to decrease by 1.1% (-4.47-1.53%) by 2030, with the East region experiencing the largest decrease (-1.66%).	• Nationally, mean annual number of wet days is expected to decrease by 2.4% (-6.2 – 1.5%) by 2050, with the East region experiencing the largest decrease (3.2%). • SPEI-3 indices show lower values (<-1) and prevalence of drought conditions in summer season, followed by the spring season with milder drought condition. In winter and autumn seasons, and in all zones, with all positive SPEI-3 values, indicating absence of drought episodes. Compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, mostly decreasing trend in autumn season.	• Nationally, mean annual number of wet days are expected to decrease by 2.2% (-6.6-1.6%) by 2100 with the East region experiencing the largest decrease (-2.8%). • SPEI-3 indices show lower values (<-1) and higher prevalence of drought conditions in summer season, followed by spring season with milder drought condition (. In winter and autumn seasons, and in all zones, with all positive SPEI-3 values, indicating absence of drought episodes. Compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, mostly decreasing trend in autumn season.
RCP8.5	• Nationally, mean annual number of wet days is expected to decrease by 1.5% (-4.5 – 1.3%) by 2030, with the East region experiencing the largest decrease (-2.07%).	• Nationally, mean annual number of wet days are expected to decrease by 2.6% (-6.2 – 1.1%) by 2050, with the East region experiencing the largest decrease (-3.3%). • SPEI-3 indices show lower values (<-1) and higher prevalence	• Nationally, mean annual number of wet days are expected to decrease by 4.06% (-9.7 – 0.5%) by 2100, with the East region experiencing the largest decrease (-5.07%).

		of drought conditions in summer season, followed by the spring season with milder drought condition In winter and autumn seasons, and in all zones, with all positive SPEI-3 values, indicating absence of drought episodes. Compared to reference values of SPEI-3, there is an increase in drought condition pronounced in spring and summer, with a mostly decreasing trend in autumn season.	• SPEI-3 indices show lower values (<-1) and higher prevalence of drought conditions in summer season, followed by spring season with milder drought condition (with exception of Dublin zone with -1.24). In winter and autumn seasons, and in all zones, with all positive SPEI-3 values, indicating absence of drought episodes. Compared to reference values of SPEI-3, there is an increase in drought conditions pronounced in spring and summer, mostly decreasing trend in autumn season.

	Projected changes by 2030 (Number of Wet days (Rainfall >1 mm)) – Mean	Projected changes by 2050 (Number of Wet days (Rainfall >1 mm)) – Mean	Projected changes by 2100 (Number of Wet days (Rainfall >1 mm)) – Mean
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Number of Wet days (Rainfall >1 mm))– 90th Percentile	Projected changes by 2050 (Number of Wet days (Rainfall >1 mm)) – 90th Percentile	Projected changes by 2100 (Number of Wet days (Rainfall >1 mm))– 90th Percentile
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Number of Wet days (Rainfall >1mm))– 10th Percentile	Projected changes by 2050 (Number of Wet days (Rainfall >1mm)) – 10th Percentile	Projected changes by 2100 (Number of Wet days (Rainfall >1mm))– 10h Percentile
RCP4.5			
RCP8.5			

	Projected changes by 2050 (SPEI-3) - Mean	Projected changes by 2100 (SPEI-3) - Mean
RCP4.5		
RCP8.5		

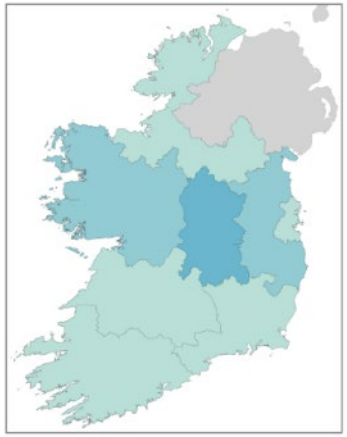
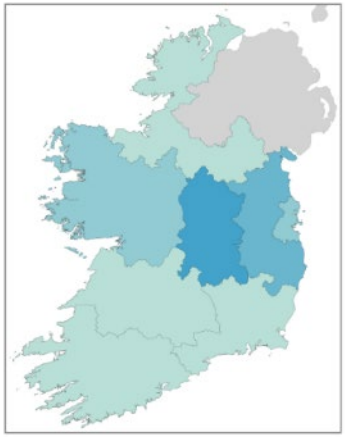
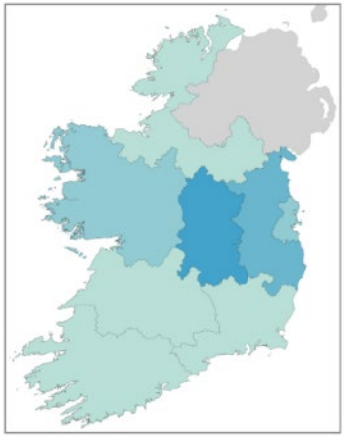
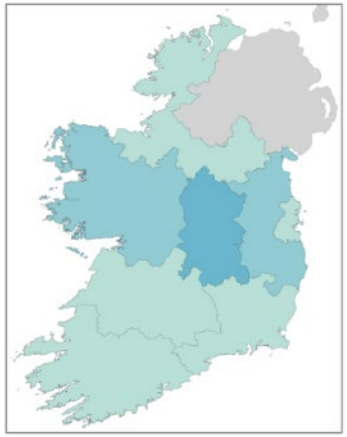
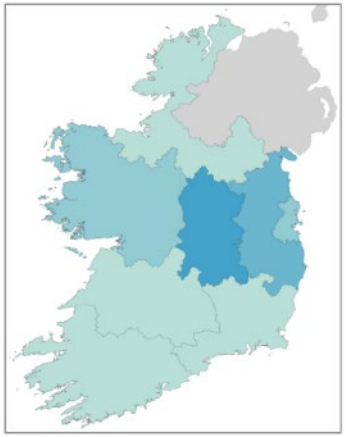
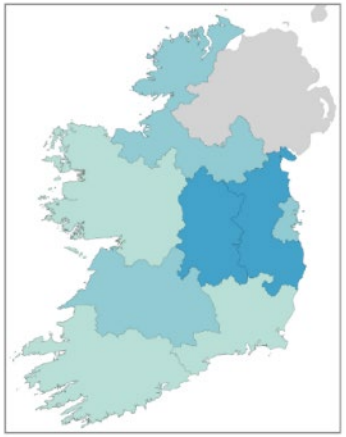
Confidence - Low
Agreement: The national projections, the 90th percentile shows a different trend to the ensemble mean, and the 10th percentile, with the 90th percentile showing increases in this variable in both scenarios, whereas the ensemble mean and 10th percentile show an increasing trend. **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform the number of wet days using a robust and peer-reviewed modelling approach. Published peer-reviewed research has been used to inform SPEI-3.

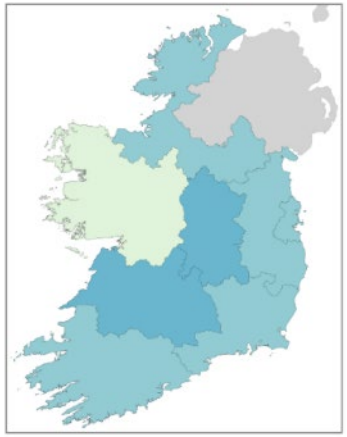
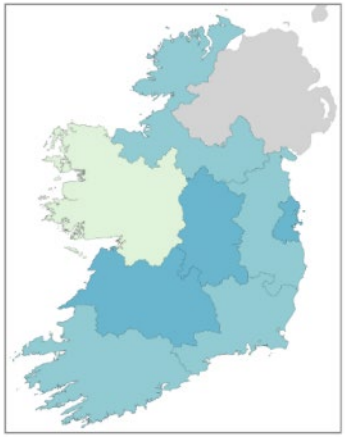
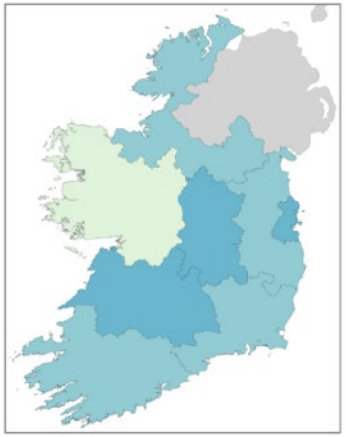
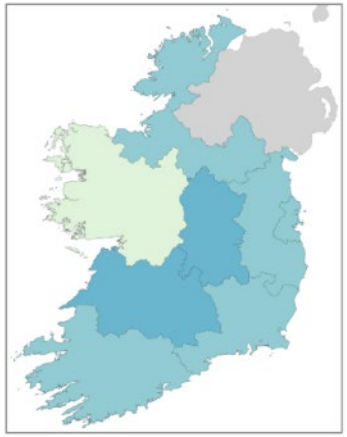
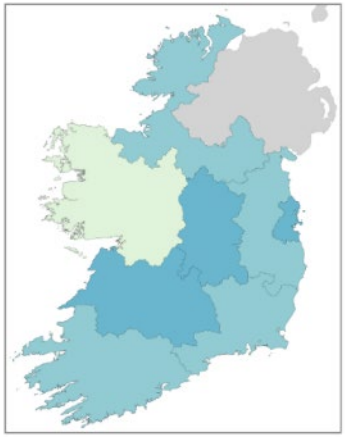
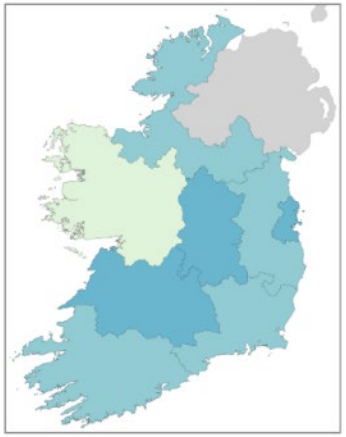
	References
Observations	Cámaro García, C., A., and Dwyer, N. (2021) The Status of Ireland's Climate, EPA Research Report 386.
	Murphy, C. and Meresa, H., 2024. HydroPredict: Ensemble River Flow Scenarios for Climate Change Adaptation
Projections	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023). Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.
	Meresa, H. and Murphy, C. (2023) Climate change impacts on spatial and seasonal meteorological drought characteristics for the island of Ireland. International Journal of Climatology, 43, 14, 6523-6539. Available at https://doi.org/10.1002/joc.8217

Fluvial Flooding

Fluvial Flooding (1% AEP)		
National	**Sub-national (NUTS2) zones affected (projected)**	
Recent and past effects or changes	**2050**	**2100**
• Ireland has been subject to a number of major flood fluvial events over recent decades. Notable or significant past fluvial flood events since 1980 include November 1980, August 1986, January 1995, January 1996, November 2000, November 2002, November 2009, October 2011, June 2012, Winter 2015/16, August 2017, and November 2017 (Flood Risk Management SAP, 2019). • More recently, in October 2023, an extreme 2-day rainfall event caused by Storm Babet brought record rainfall amounts to the south of Ireland, leading to significant flooding, with the town of Midleton, County Cork, severely impacted (Clarke et al., 2024).	• At the NUTS 3 level, all regions are projected to experience an increase in total land area impacted by flooding with the Midland region most affected.	• At the NUTS 3 level, all regions are projected to experience an increase in total land area impacted by flooding with the Midland region most affected.

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5	• Nationally, under the 1% AEP scenario, NIFM projects that 2.05% of the total land area could be at risk of flooding by 2030. The Midlands region is most at risk, with 2.65% of the total land area impacted. • Nationally, under the 1% AEP scenario, CFRAM projects that 1.45% of the total land area could be at risk of flooding by 2030. The Midlands region is most at risk, with 2.79% of the total land area impacted.	• Nationally, under the 1% AEP scenario, NIFM projects that 2.29% of the total land area could be at risk of flooding by 2050. The Midlands region is most at risk, with 3.06% of the total land area impacted. • Nationally, under the 1% AEP scenario, CFRAM projects that 1.73% of the total land area could be at risk of flooding by 2050. The Midlands region is most at risk, with 3.36% of the total land area impacted.	• Nationally, under the 1% AEP scenario, NIFM projects that 2.29% of the total land area could be at risk of flooding by 2100. The Midlands region is most at risk, with 3.06% of the total land area impacted. • Nationally, under the 1% AEP scenario, CFRAM projects that 1.73% of the total land area could be at risk of flooding by 2050. The Midlands region is most at risk, with 3.36% of the total land area impacted.
RCP8.5	• Nationally, under the 1% AEP scenario, NIFM projects that 2.05% of the total land area could be at risk of flooding by 2030. The Midlands region is most at risk, with 2.65% of the total land area impacted. • Nationally, under the 1% AEP scenario, CFRAM projects that 1.45% of the total land area could be at risk of flooding by 2030. The Midlands region is most at risk, with 2.79% of the total land area impacted.	• Nationally, under the 1% AEP scenario, NIFM projects that 2.29% of the total land area could be at risk of flooding by 2050. The Midlands region is most at risk, with 3.06% of the total land area impacted. • Nationally, under the 1% AEP scenario, CFRAM projects that 1.73% of the total land area could be at risk of flooding by 2050. The Midlands region is most at risk, with 3.36% of the total land area impacted.	• Nationally, under the 1% AEP scenario, NIFM projects that 2.38% of the total land area could be at risk of flooding by 2100. The Midlands region is most at risk, with 3.13% of the total land area impacted. • Nationally, under the 1% AEP scenario, CFRAM projects that 1.95% of the total land area could be at risk of flooding by 2100. The Midlands region is most at risk, with 3.94% of the total land area impacted.

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5			
RCP8.5			

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5			
RCP8.5			

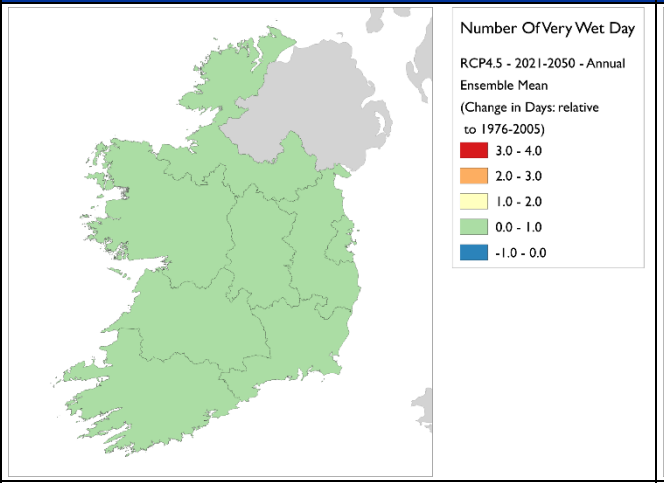
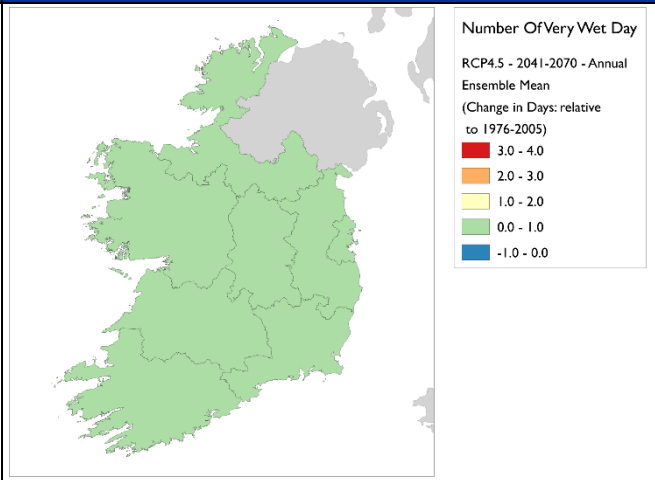
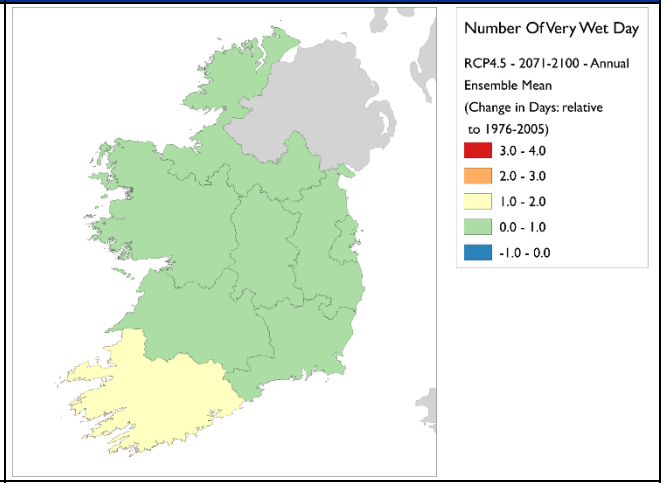
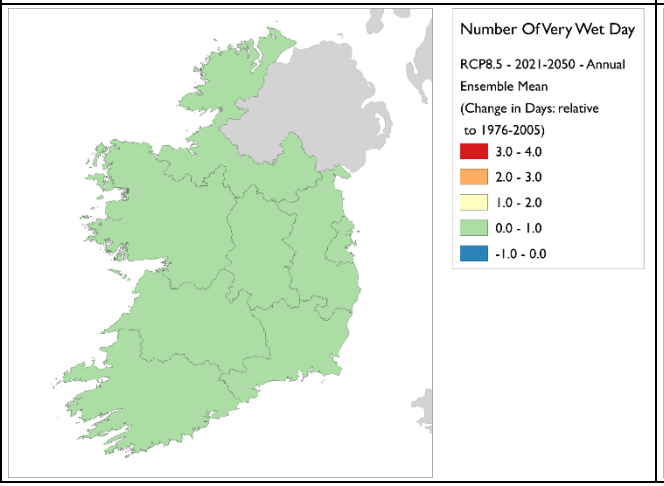
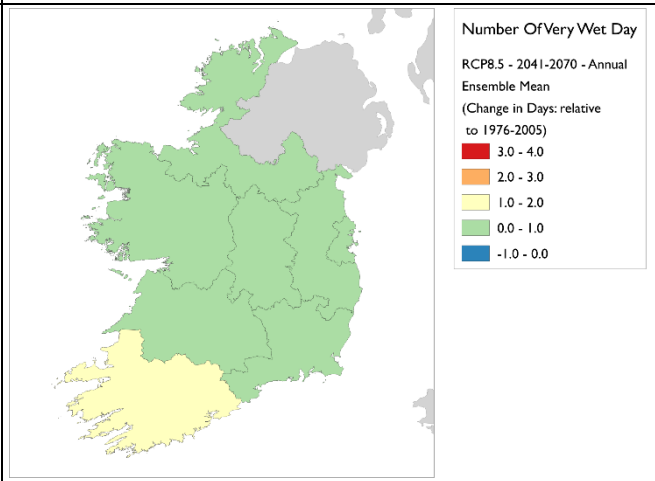
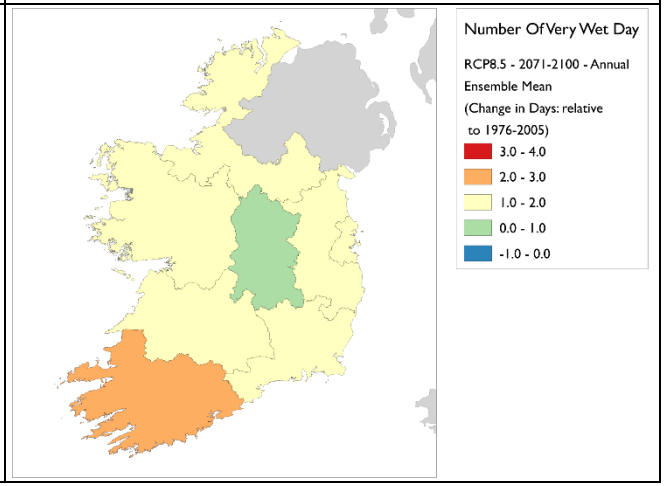
Confidence - Medium
Agreement: Two assessments of flood extent have been produced by OPW (NIFM and CFRAM) that show an increase in flood extent and frequency in the future. It should be noted that the 1% AEP projections for 2050 for RCP4.5 and RCP8.5 both assume the 1%AEP MRFS value therefore there is no variation numbers for area exposed between scenarios (see the NCCRA Methodology for further information). **Robustness:** The change in flood extent and frequency has been assessed by the national authority (OPW) following a rigorous modelling approach, however, projections for changes in daily extreme precipitation are not available therefore to inform the timing of changes in flood extent and frequency, hence a proxy of seasonal changes have been used (TRANSLATE Winter precipitation projections).

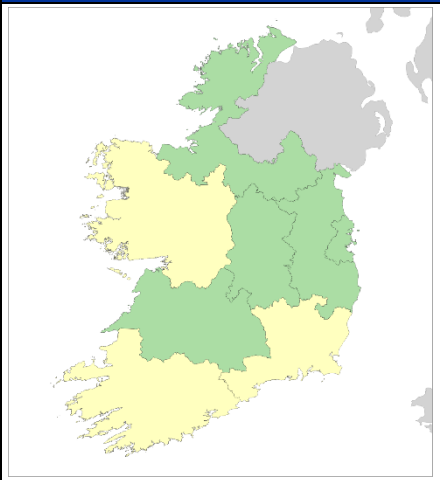
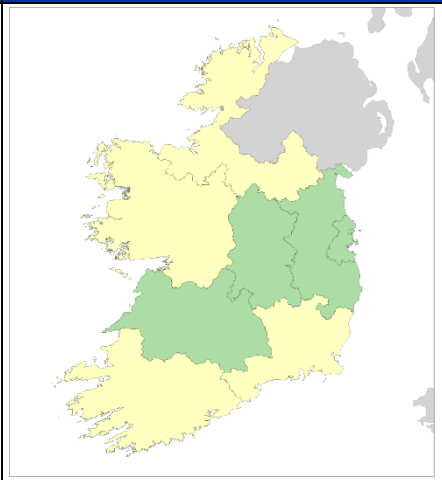
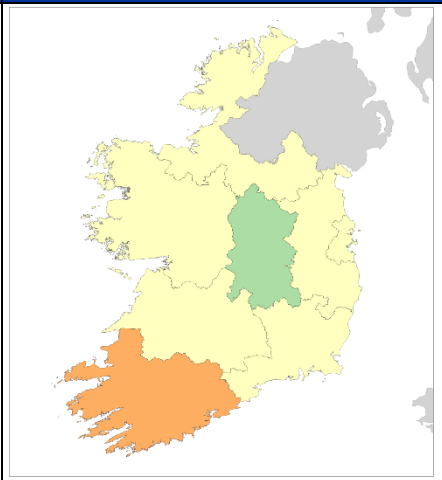
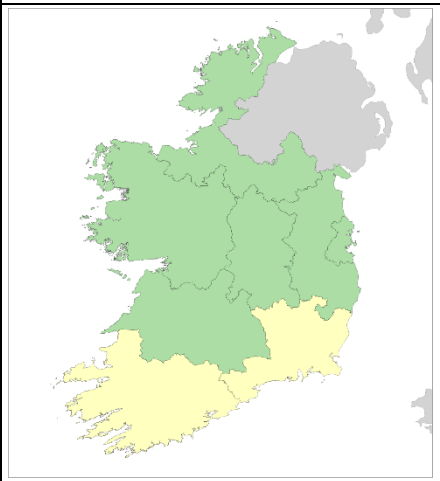
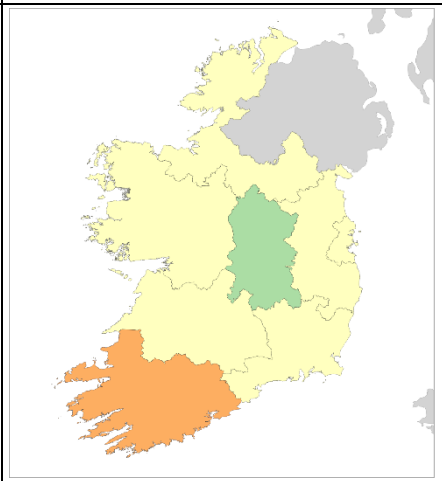
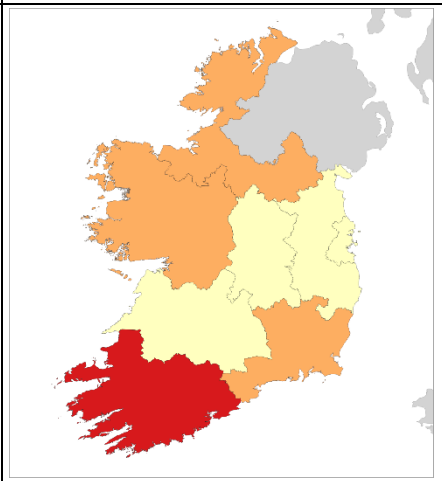
	References
Observations	Office of Public Works (OPW). (2019). Climate Change Sectoral Adaptation Plan for Flood Risk Management (2019-2024). Available at: www.opw.ie
	Clarke, B., Thorne, P., Ryan, C., Zachariah, M., Murphy, C., McCarthy, G., O'Connor, P., Eresanya, E.O., Cahill, N., Coonan, B., and Otto, F. (2023). Climate change made the extreme 2-day rainfall event associated with flooding in Midleton, Ireland more likely and more intense. Grantham Institute, Imperial College London; ICARUS Climate Research Centre, Maynooth University; Met Éireann.
Projections	OPW (2020) National Indicative Fluvial Mapping (NIFM) Project Final Report. Available at: https://s3-eu-west-1.amazonaws.com/docs.floodinfo.opw/floodinfo_docs/MCR6058-RT002-R03-00-complete.pdf
	OPW (n.d.) Catchment Flood Risk Assessment Management (CFRAM). Available at: https://www.floodinfo.ie/map/general_map_user_guidance_notes/

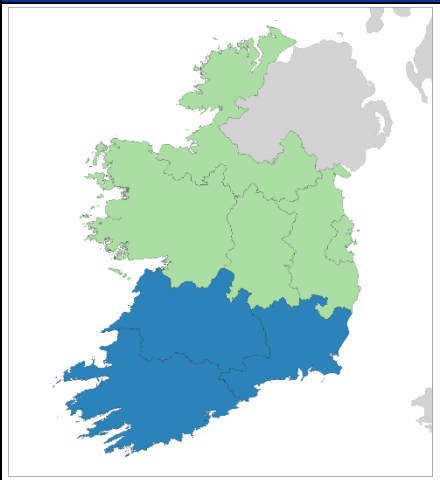
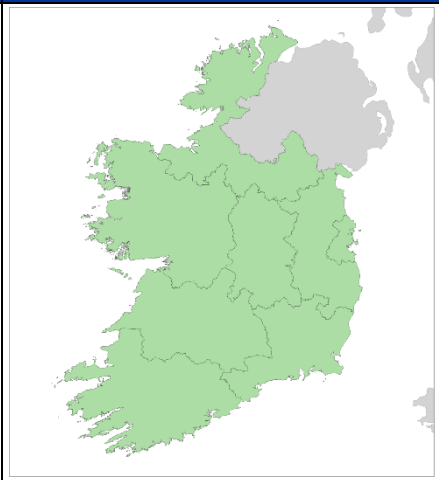
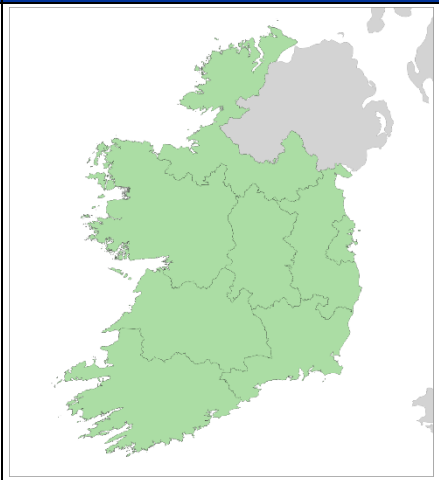
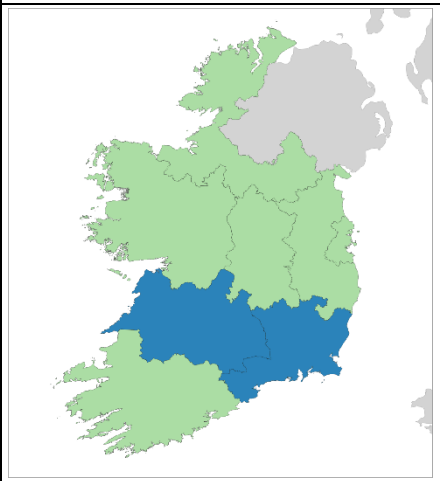
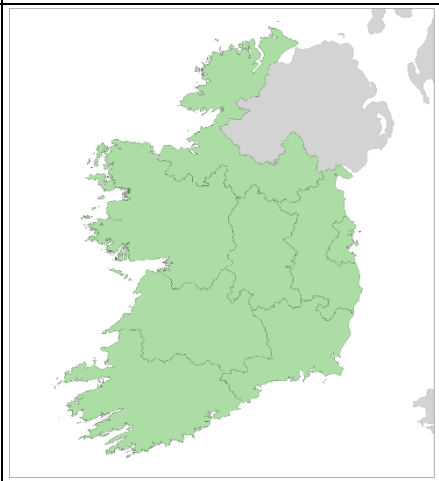
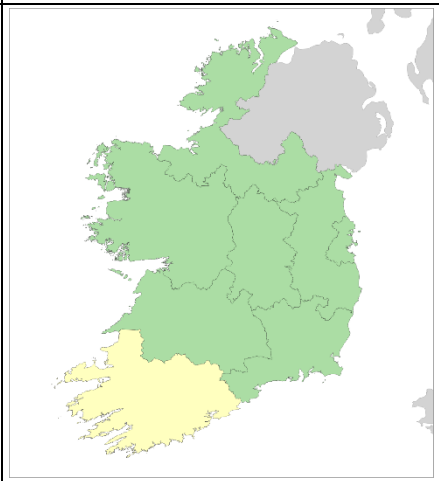
Surface Water Flooding

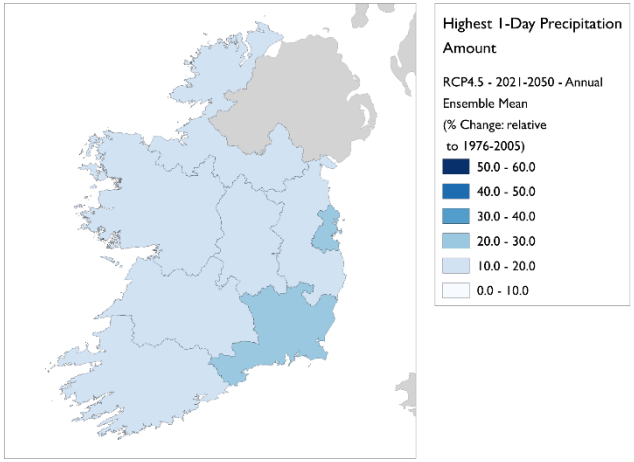
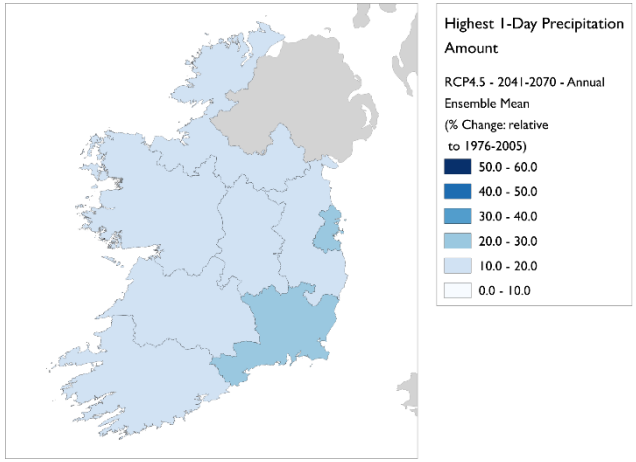
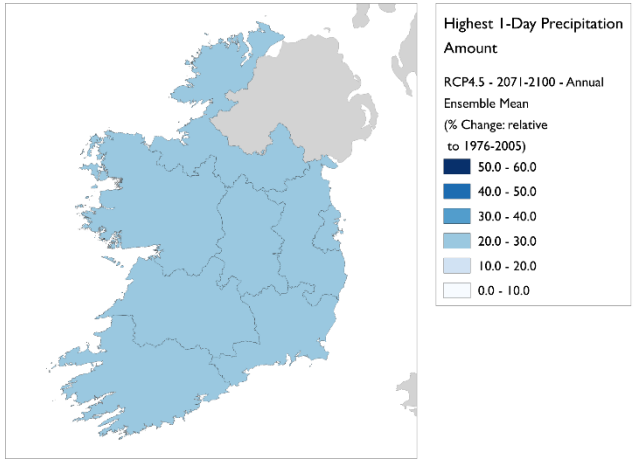
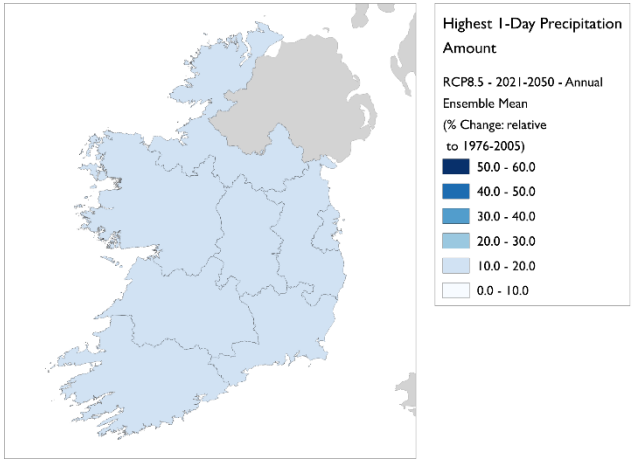
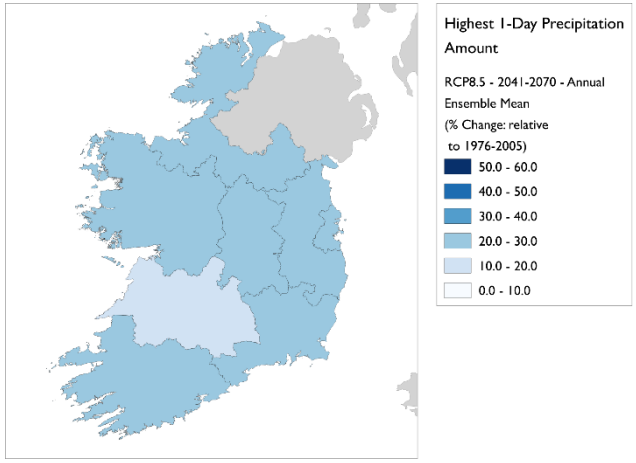
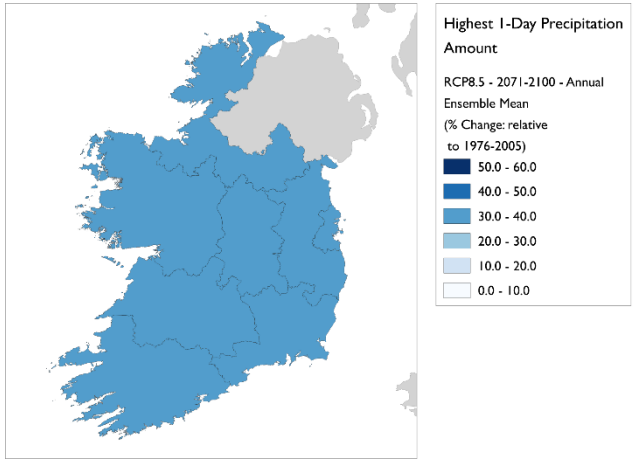
Very Wet Days (Number of days with rainfall >30mm) and Maximum 1-day Precipitation		
National	**Sub-national (NUTS3) zones affected (projected)**	
Recent and past effects or changes	**2050**	**2100**
• Pluvial flooding happens when rainfall surpasses the capacity of urban stormwater drainage systems or the ground's ability to absorb it. • During the baseline period (1976 - 2005) there was an average of 1.76 very wet days per year (O'Brien et al., 2023). • Ireland has been subject to a number of major flood pluvial events over recent decades. Notable or significant past floods in Ireland have occurred in October 2011 and June 2012 (Flood Risk Management SAP, 2019).	• At the NUTS 3 level, all regions are projected to experience an increase in very wet days by 2050. Additionally, maximum 1-day precipitation is projected to increase across all regions with the Dublin and West regions experiencing the highest increases.	• At the NUTS 3 level, all regions are to projected to experience an increase in very wet days by 2100. Additionally, maximum 1-day precipitation is projected to increase across all regions with the Dublin and West regions experiencing the highest increases.

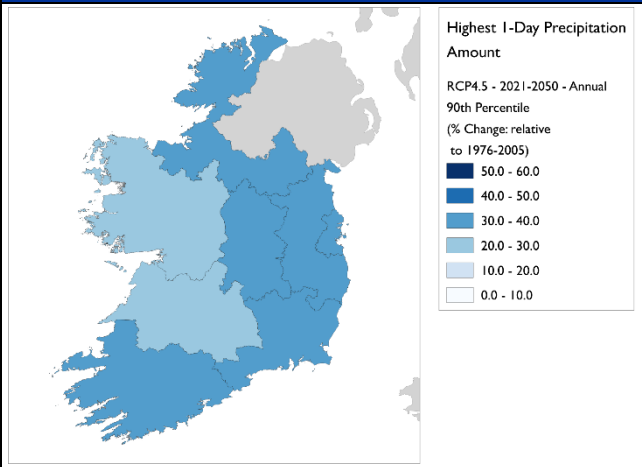
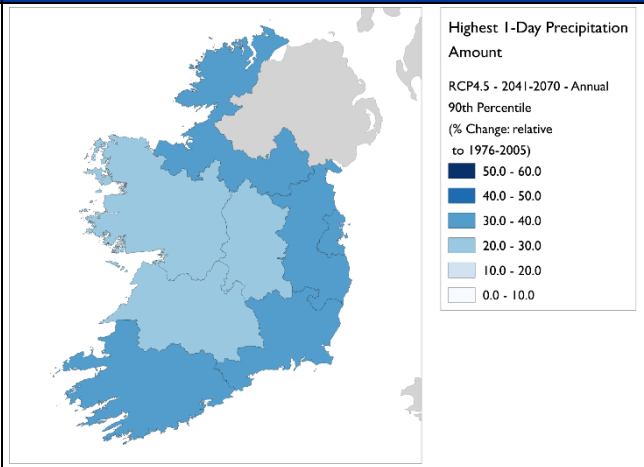
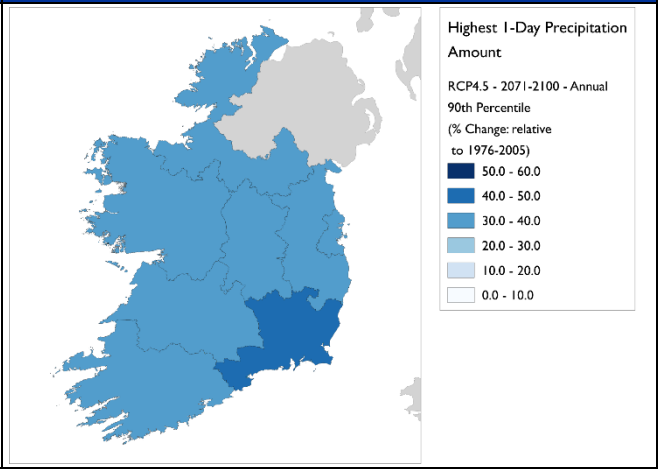
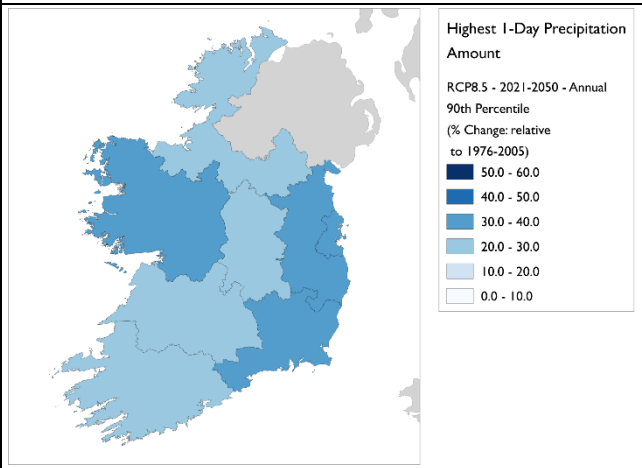
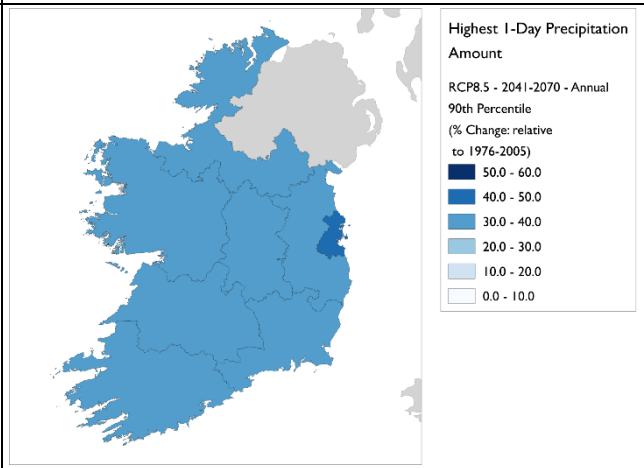
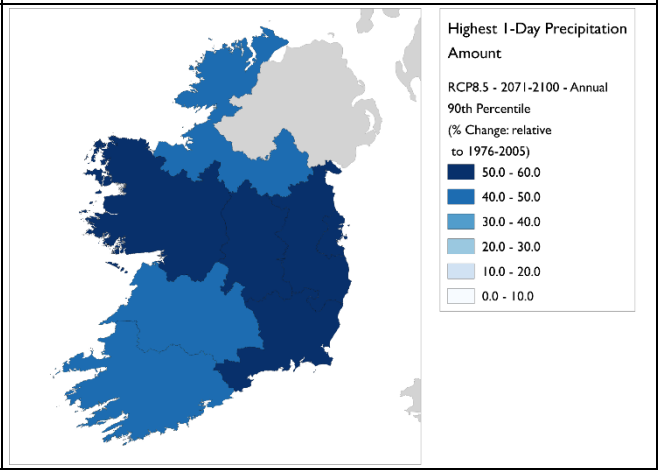
	Projected changes by 2030	**Projected changes by 2050**	**Projected changes by 2100**
RCP4.5	• Very wet days (above 30 mm of precipitation) indicate a small increasing trend of 0.5 days per year (0.0 – 1.0 days per year). • Nationally, maximum 1-day precipitation is projected to increase by 18.6% (6.9 – 31.8%), with the Dublin (21.4% (8.2-39.2%)) region experiencing the highest increase.	• Very wet days (above 30 mm of precipitation) indicate a small increasing trend of 0.5 days per year (0.1 – 1.1 days per year). • Nationally, maximum 1-day precipitation is projected to increase by 18.7% (7.1 – 31.8%), with the Dublin (21.4% (6.7-36.0%)) region experiencing the highest increase.	• Very wet days (above 30 mm of precipitation) indicate a small increasing trend of 0.8 days per year (0.3 – 1.3 days per year). • Nationally, maximum 1-day precipitation is projected to increase by 23.9% (11.1 – 38.0%), with the South-East (26.9% (12.2-42.9%)) experiencing the highest increase.
RCP8.5	• Very wet days (above 30 mm of precipitation) indicate a small increasing trend of 0.4 days per year (0.0 - 0.9 days per year). • Nationally, maximum 1-day precipitation is projected to increase by 17.47% (6.1 – 30.1%), with the Dublin (19.2% (6.5-33.5%)) region experiencing the highest increase.	• Very wet days (above 30 mm of precipitation) indicate a small increasing trend of 0.7 days per year (0.3 – 1.3 days per year). • Nationally, maximum 1-day precipitation is projected to increase by 22.7% (10.8 – 36.1%), with the Dublin (26.3% (12.0-42.6%) and region experiencing the highest increase.	• Very wet days (above 30 mm of precipitation) indicate a small increasing trend of 1.4 days per year (0.7 -2.2 days per year). • Nationally, maximum 1-day precipitation is projected to increase by 34.3% (19.9- 50.2%), with the South-East (36.4% (20.0-54.6%)) and West (36.4% (22.6-52.5%)) regions experiencing the highest increases.

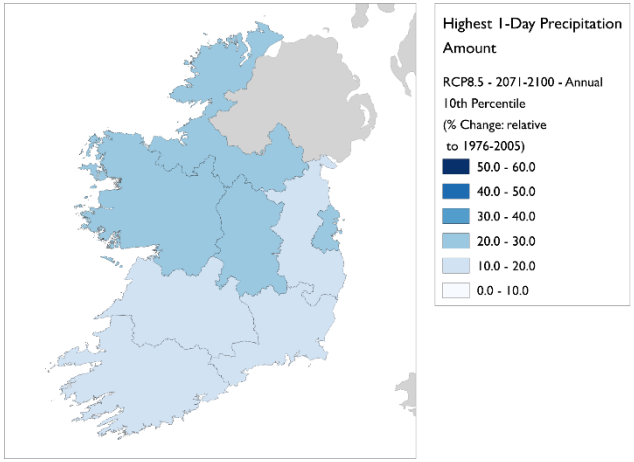
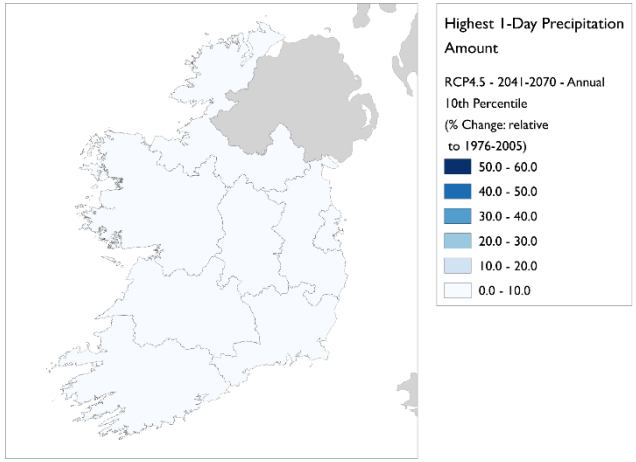
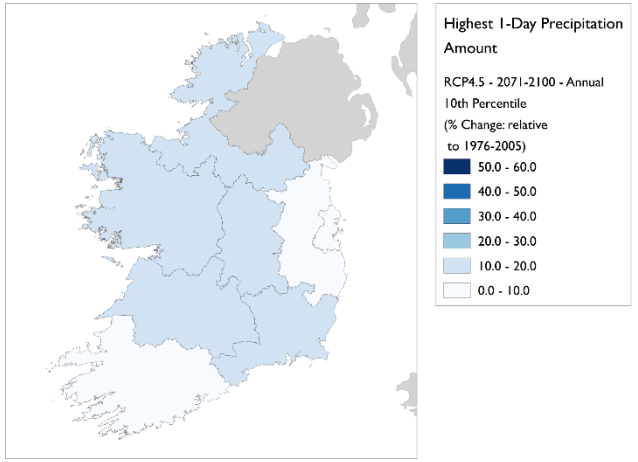
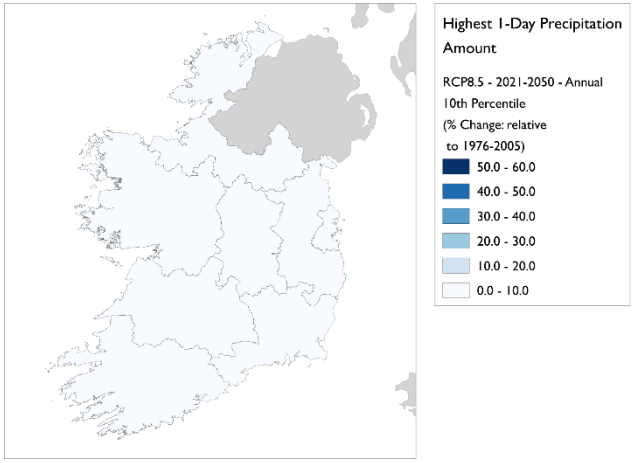
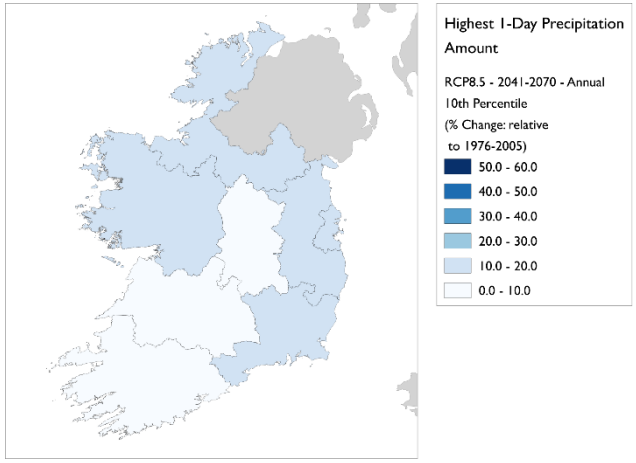
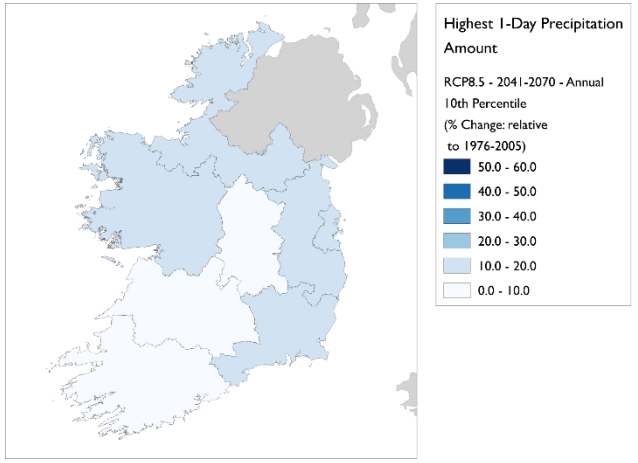
	Projected changes by 2030 (Very Wet Days (Number of days with rainfall >30mm) – Mean)	Projected changes by 2050 (Very Wet Days (Number of days with rainfall >30mm) – Mean)	Projected changes by 2100 (Very Wet Days (Number of days with rainfall >30mm) – Mean)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Very Wet Days (Number of days with rainfall >30mm) – 90th Percentile)	Projected changes by 2050 (Very Wet Days (Number of days with rainfall >30mm) – 90th Percentile)	Projected changes by 2100 (Very Wet Days (Number of days with rainfall >30mm) – 90th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Very Wet Days (Number of days with rainfall >30mm) – 10th Percentile)	Projected changes by 2030 (Very Wet Days (Number of days with rainfall >30mm) – 10th Percentile)	Projected changes by 2030 (Very Wet Days (Number of days with rainfall >30mm) – 10th Percentile)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Maximum 1-day precipitation – Mean)	Projected changes by 2050 (Maximum 1-day precipitation – Mean)	Projected changes by 2100 (Maximum 1-day precipitation – Mean)
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Maximum 1-day precipitation – 90th Percentile)	Projected changes by 2050 (Maximum 1-day precipitation – 90th Percentile)	Projected changes by 2100 (Maximum 1-day precipitation – 90th Percentile)
RCP4.5			
RCP8.5			

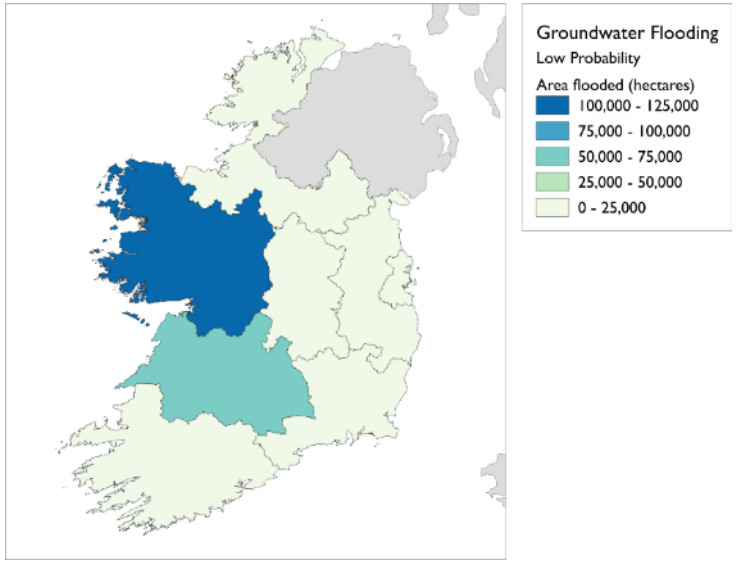
	Projected changes by 2030 (Maximum 1-day precipitation – 10th Percentile)	Projected changes by 2050 (Maximum 1-day precipitation – 10th Percentile)	Projected changes by 2100 (Maximum 1-day precipitation – 10th Percentile)
RCP4.5			
RCP8.5			

Confidence - Low
Agreement: The global (CMIP6), regional (EURO-CORDEX), and national (TRANSLATE) projections generally agree that there is an increasing trend for these variables. However, within the national projections, the 10th percentile shows a different trend to the ensemble mean, and the 90th percentile, with the 10th percentile showing decreases in these variables for both scenarios, whereas the ensemble mean and 90th percentile show an increasing trend. **Robustness:** No modelling currently exist that show the current or future extents of surface water flooding events, therefore proxies of Very Wet Days (Number of days with rainfall >30mm) and Maximum 1-day Precipitation have been used. National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform these variables using a robust and peer-reviewed modelling approach.

	References
Observations	Office of Public Works (OPW) (2019) Climate Change Sectoral Adaptation Plan for Flood Risk Management (2019-2024). Available at: www.opw.ie
	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023). Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.
Projections	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023). Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.

Groundwater Flooding

Groundwater Flooding		
National	**Sub-national (NUTS3) zones affected**	
Recent and past effects or changes	**2050**	**2100**
• Groundwater Flooding in Ireland is primarily associated with the limestone areas of the western lowlands, which extend from the River Fergus in Co. Clare in the south upwards to the areas east of Lough Mask and Corrib in Co. Galway and southern Co. Mayo (McCormack et al., 2020). • Floods during the winters of 2009/2010 and 2015/2016 caused widespread damage and disruption to communities across the country, particularly in the extensive karstic limestone lowlands on the western seaboard (McCormack et al., 2020).	• There are currently no national-scale projections for groundwater flooding in Ireland under the RCP4.5 and RCP8.5 scenarios for 2050.	• There are currently no national-scale projections for groundwater flooding in Ireland under the RCP4.5 and RCP8.5 scenarios for 2100.

	Current
Low Probability Extent (0.1% AEP)	

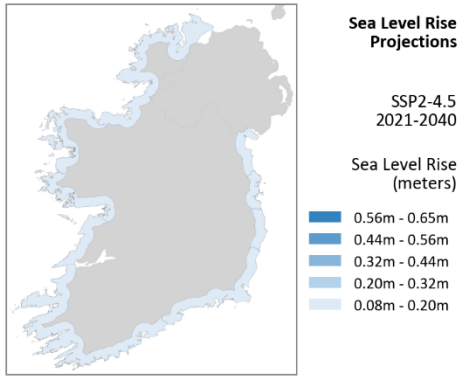
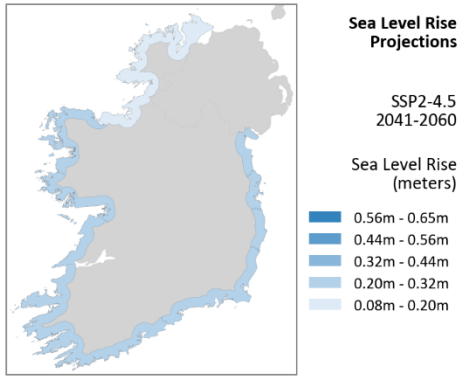
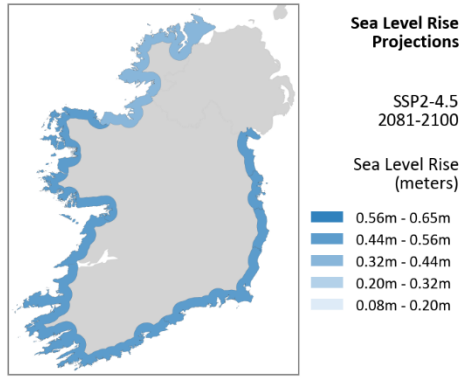
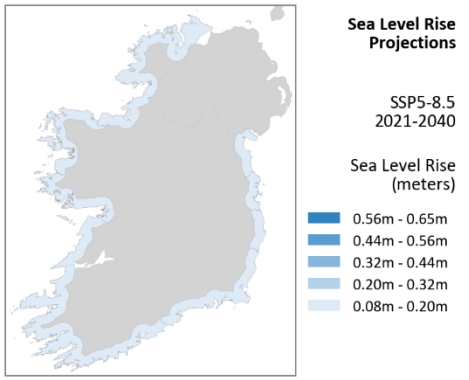
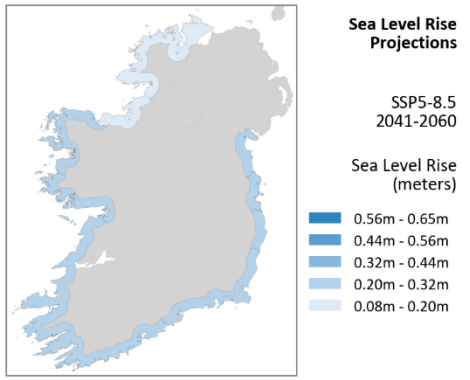
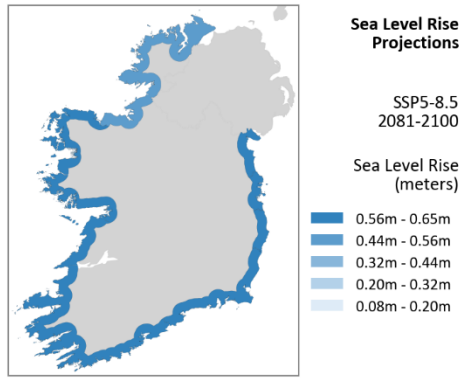
Confidence - Low
Agreement: There are no projections available on the changes in groundwater flood extent and frequency currently available. **Robustness:** National groundwater flood extents have been developed for Ireland, however, a number of limitations apply as outlined in McCormack et al. (2020), i.e., not all sources of groundwater flooding were mapped.

References	
Observations	McCormack, T., Naughton, O., Bradford, R., Campanyà, J., Morrissey, P., Gill, L., Lee, M. (2020) GWFlood Project: Monitoring, Modelling and Mapping Karst Groundwater Flooding in Ireland, Geological Survey Ireland Report .
Flood Extents	McCormack, T., Naughton, O., Bradford, R., Campanyà, J., Morrissey, P., Gill, L., Lee, M. (2020) GWFlood Project: Monitoring, Modelling and Mapping Karst Groundwater Flooding in Ireland, Geological Survey Ireland Report .

Sea Level Rise

Sea Level Rise		
National	**Sub-national (NUTS3) zones affected**	
Recent and past effects or changes	**2050**	**2100**
• Past relative sea level rise (SLR) in the northeastern Atlantic region shows an increasing trend at 1.2 mm/yr (1950-2014) with strong decadal variability from the Atlantic Multidecadal Oscillation (van den Hurk et al. 2024). • Recent studies have shown that in Ireland (Cork and Dublin), sea level rise rates are higher than the global SLR since the late 20th century (Noone et al. 2024). • Using the long-term sea-level record from Dublin port, estimated that long term SLR is 1.1 mm yr^{-1}(1953-2016) and a recent increase of SLR of 7 mm yr^{-1} (1997-2006) (Nejad et al. 2022). This recent increase is mainly attributed to large multi decadal variability. • Mean Sea Level measurements from Cork Harbour, indicates a 2.2 mm yr^{-1} SLR rate using data from 1842 to 2019-2020 (Pugh et al., 2021).	• The sea level around Ireland is projected to rise under both RCP4.5 and RCP8.5 scenarios by 2050 affecting all coastal NUTS3 regions.	• The sea level around Ireland is projected to rise under both RCP4.5 and RCP8.5 scenarios by 2100 affecting all coastal NUTS3 regions.

	Projected changes by 2030	**Projected changes by 2050**	**Projected changes by 2100**
RCP4.5	• Sea levels around Ireland are projected to increase with the sea level rise of 0.12 m (South West) for 2021-2040 with a maximum sea level rise of 0.12 m (5th percentile: 0.07 m, 95th percentile: 0.31 m) by 2040 (longitude: 50, latitude: -10).	• Sea levels around Ireland are projected to increase with the sea level rise of 0.24 m (South West) for 2041-2060 with a maximum sea level rise of 0.32 m (0.15 - 0.55 m) by 2060 (longitude: 50, latitude: -10).	• Sea levels around Ireland are projected to increase with the sea level rise of 0.51 m (South West) for 2081-2100 with a maximum sea level rise of 0.62 m (0.31 – 1.09 m) by 2100 (longitude: 50, latitude: -10).
RCP8.5	• Sea levels around Ireland are projected to increase with the sea level rise of 0.13 m (South West) for 2021-2040 with a maximum sea level rise of 0.19 m (5th percentile: 0.08, 95th percentile: 0.33 m) by 2100 (longitude: 50, latitude: -10).	• Sea levels around Ireland are projected to increase with the sea level rise of 0.26 m (South West) for 2041-2060 with a maximum sea level rise of 0.35 m (0.17 - 0.60 m) by 2060 (longitude: 50, latitude: -10).	Sea levels around Ireland are projected to increase with the sea level rise of 0.65 m (South West) for 2081-2100 with a maximum sea level rise of 0.81 m (0.45 – 1.4 m) by 2100 (longitude: 50, latitude: -10).

	Projected changes by 2030 (Sea Level Rise)	Projected changes by 2050 (Sea Level Rise)	Projected changes by 2100 (Sea Level Rise)
RCP4.5			
RCP8.5			

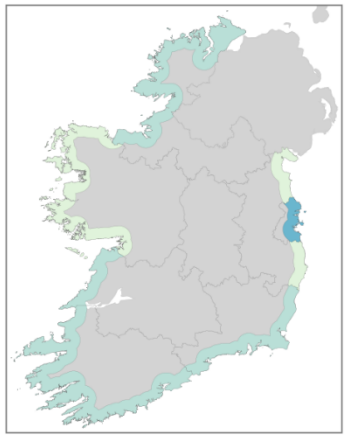
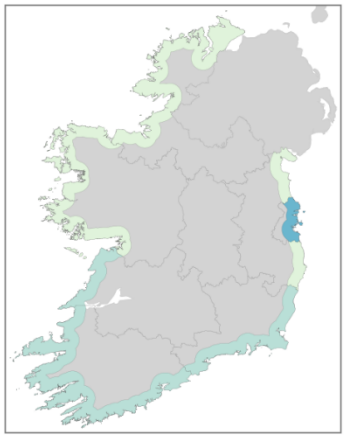
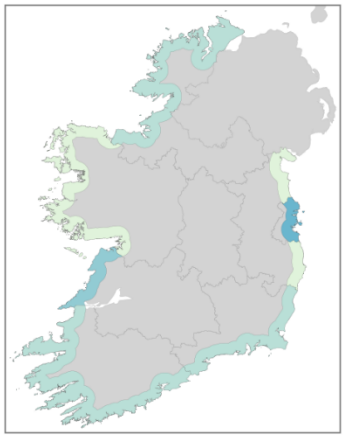
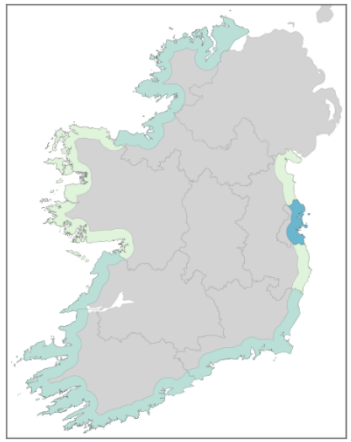
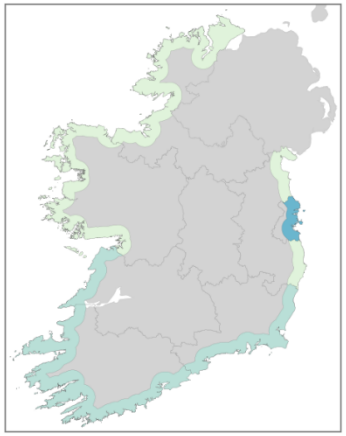
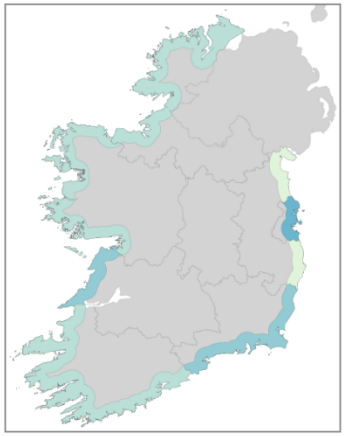
Confidence – High
Agreement: National and global observations of sea level and climate projections for both scenarios show an increase in sea level around Ireland. There is uncertainty surrounding future sea level rise due to low probability events, such as rapid ice sheet collapse, which, despite their low likelihood, could lead to large increases in sea levels. **Robustness:** Global projections been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6.

References	
Observations	van den Hurk, B., Pinardi, N., Kiefer, T., Larkin, K., Manderscheid, P., and Richter, K. (Eds.): Sea Level Rise in Europe: 1st Assessment Report of the Knowledge Hub on Sea Level Rise (SLRE1), Copernicus Publications, State Planet, 3-slre1, https://doi.org/10.5194/sp-3-slre1, 2024
	Noone, C., McClean, D., Gallagher, D. and Thorne, P. (2024) Ireland's Climate Change Assessment 2023. Volume 1: Climate Science-Ireland in a changing World. Summary of Policymakers
	Shoari Nejad, A., Parnell, A.C., Greene, A., Thorne, P., Kelleher, B.P., Devoy, R.J. and McCarthy, G., 2022. A newly reconciled dataset for identifying sea level rise and variability in Dublin Bay. Ocean Science, 18(2), pp.511-522.
	Pugh, D. T., Bridge, E., Edwards, R., Hogarth, P., Westbrook, G., Woodworth, P. L., and McCarthy, G. D. (2021) Mean sea level and tidal change in Ireland since 1842: a case study of Cork, Ocean Sci., 17, 1623–1637, https://doi.org/10.5194/os-17-1623-2021
Projections	Fox-Kemper, B., H. T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S. S. Drijfhout, T. L. Edwards, N. R. Golledge, M. Hemer, R. E. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. S. Nurhati, L. Ruiz, J-B. Sallée, A. B. A. Slangen, Y. Yu (2021) Ocean, Cryosphere and Sea Level Change. In: 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., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1211–1362, doi:10.1017/9781009157896.011.
	Kopp, R. E., Garner, G. G., Hermans, T. H. J., Jha, S., Kumar, P., Reedy, A., Slangen, A. B. A., Turilli, M., Edwards, T. L., Gregory, J. M., Koubbe, G., Levermann, A., Merzky, A., Nowicki, S., Palmer, M. D., and Smith, C. (2023) The Framework for Assessing Changes To Sea-level (FACTS) v1.0: a platform for characterizing parametric and structural uncertainty in future global, relative, and extreme sea-level change, Geosci. Model Dev., 16, 7461–7489, https://doi.org/10.5194/gmd-16-7461-2023.
	Garner, G. G., T. Hermans, R. E. Kopp, A. B. A. Slangen, T. L. Edwards, A. Levermann, S. Nowikci, M. D. Palmer, C. Smith, B. Fox-Kemper, H. T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S. S. Drijfhout, T. L. Edwards, N. R. Golledge, M. Hemer, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. S. Nurhati, L. Ruiz, J-B. Sallée, Y. Yu, L. Hua, T. Palmer, B. Pearson, 2021. IPCC AR6 Sea Level Projections. Version 20210809. Available at https://doi.org/10.5281/zenodo.5914709.

Coastal Flooding

Coastal Flooding		
National	**Sub-national (NUTS3) zones affected (projected)**	
Recent and past effects or changes	**2050**	**2100**
• Coastal flooding poses a significant threat, especially in low-lying areas along the east coast from Dundalk to Dublin and the Wicklow to Wexford coast. The south coast, including Waterford, Dungarvan, Youghal, and Cork City, as well as the west coast areas like Galway City and the Shannon Estuary, are also at high risk (Climate Ireland, 2023).	• At the NUTS 3 level, all coastal regions are projected to experience an increase in total land area impacted by coastal flooding.	• At the NUTS 3 level, all coastal regions are projected to experience an increase in total land area impacted by coastal flooding.

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5	• Nationally, under the 1% AEP scenario, NCFHM projects that 1.01% of the total land area could be at risk of coastal flooding by 2030. The Dublin region is most at risk, with 2.86% of the total land area impacted.	• Nationally, under the 1% AEP scenario, NCFHM projects that 0.95% of the total land area could be at risk of coastal flooding by 2050. The Dublin region is most at risk, with 2.41% of the total land area impacted.	• Nationally, under the 1% AEP scenario, NCFHM projects that 1.04% of the total land area could be at risk of coastal flooding by 2100. The Dublin region is most at risk, with 2.76% of the total land area impacted.
RCP8.5	• Nationally, under the 1% AEP scenario, NCFHM projects that 1.01% of the total land area could be at risk of coastal flooding by 2030. The Dublin region is most at risk, with 2.86% of the total land area impacted.	• Nationally, under the 1% AEP scenario, NCFHM projects that 0.95% of the total land area could be at risk of coastal flooding by 2050. The Dublin region is most at risk, with 2.41% of the total land area impacted.	• Nationally, under the 1% AEP scenario, NCFHM projects that 1.20% of the total land area could be at risk of coastal flooding by 2100. The Dublin region is most at risk, with 3.45% of the total land area impacted.

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5			
RCP8.5			

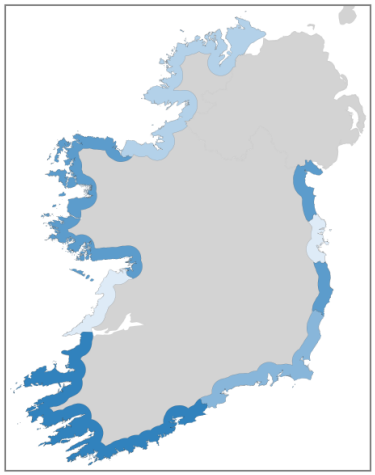
Confidence - High
Agreement: National and global projections for sea level rise show an increase, which will result in an increase in coastal flood extent and frequency. **Robustness:** The change in flood extent and frequency has been assessed by the national authority (OPW) following a rigorous modelling approach, however, to inform the timing of changes in flood extent and frequency, global sea level rise projections (IPCC CMIP6) have been used.

References	
Observations	Climate Ireland (2023) Coastal Flooding. Available at https://www.climateireland.ie/impact-on-ireland/climate-hazards/coastal-flooding/
Projections	Fox-Kemper, B., H. T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S. S. Drijfhout, T. L. Edwards, N. R. Golledge, M. Hemer, R. E. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. S. Nurhati, L. Ruiz, J-B. Sallée, A. B. A. Slangen, Y. Yu (2021) Ocean, Cryosphere and Sea Level Change. In: 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., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1211–1362, doi:10.1017/9781009157896.011.
	Kopp, R. E., Garner, G. G., Hermans, T. H. J., Jha, S., Kumar, P., Reedy, A., Slangen, A. B. A., Turilli, M., Edwards, T. L., Gregory, J. M., Koubbe, G., Levermann, A., Merzky, A., Nowicki, S., Palmer, M. D., and Smith, C. (2023) The Framework for Assessing Changes To Sea-level (FACTS) v1.0: a platform for characterizing parametric and structural uncertainty in future global, relative, and extreme sea-level change, Geosci. Model Dev., 16, 7461–7489, https://doi.org/10.5194/gmd-16-7461-2023.
	Garner, G. G., T. Hermans, R. E. Kopp, A. B. A. Slangen, T. L. Edwards, A. Levermann, S. Nowikci, M. D. Palmer, C. Smith, B. Fox-Kemper, H. T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S. S. Drijfhout, T. L. Edwards, N. R. Golledge, M. Hemer, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. S. Nurhati, L. Ruiz, J-B. Sallée, Y. Yu, L. Hua, T. Palmer, B. Pearson, 2021. IPCC AR6 Sea Level Projections. Version 20210809. Available at https://doi.org/10.5281/zenodo.5914709.
	OPW (2021) National Coastal Flood Hazard Mapping 2021 Flood Mapping Methodology Report. Available at: https://s3-eu-west-1.amazonaws.com/docs.floodinfo.opw/floodinfo_docs/NCFHM_Mapping_Methodology_20210611_v1.0.pdf.

Coastal Erosion

Coastal Erosion		
National	**Sub-national (NUTS3) zones affected**	
Recent and past effects or changes	**2050**	**2100**
• Ireland is exposed to coastal erosion risk primarily because majority of the populated areas are located close to the sea, and in particular coastal zones with softer sediments (Devoy, 2008; Thorne et al., 2023) • 19.9% Ireland's coast already experiencing coastal erosion (EUROSION, 2004). • Sea level rise, along with tides, storm surges, waves, are some of the environmental factors that can drive coastal erosion (van de Wal et al., 2024)	• At the NUTS 3 level, all coastal regions are projected to experience an increase in coastal erosion rates.	• At the NUTS 3 level, all coastal regions are projected to experience an increase in coastal erosion rates.

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5	• There are no national-scale projections for coastal erosion that consider the effects of climate change in Ireland for RCP4.5 2030.	• The length of coastline projected to be at risk of coastal erosion in Ireland by 2050 is 328 km. The South-West (85 km) and South-East (46 km) regions are most at risk (Irish Coastal Protection Strategy Study). However, the effects of climate change have not been included within the ICPSS assessment (ICPSS, RPS Consulting Engineers (2010)).	• There are no national-scale projections for coastal erosion that consider the effects of climate change in Ireland for RCP4.5 2100.
RCP8.5	• There are no national-scale projections for coastal erosion that consider the effects of climate change in Ireland for RCP8.5 2030.		• There are no national-scale projections for coastal erosion that consider the effects of climate change in Ireland for RCP8.5 2100.

	Projected changes by 2050
ICPSS 2010 - 2014	

Confidence - Low
Agreement: Research highlights that increases in sea level are expected to result in coastal change (erosion or accretion), however, the impact (spatial extent and rates of change) this will have on Ireland's coastline is currently unknown. **Robustness:** There are no national scale projections for coastal change (erosion or accretion) available, however, a standard approach of extrapolation of existing rates of erosion have been used for the 2050 time horizon and does not include the effects of climate change.

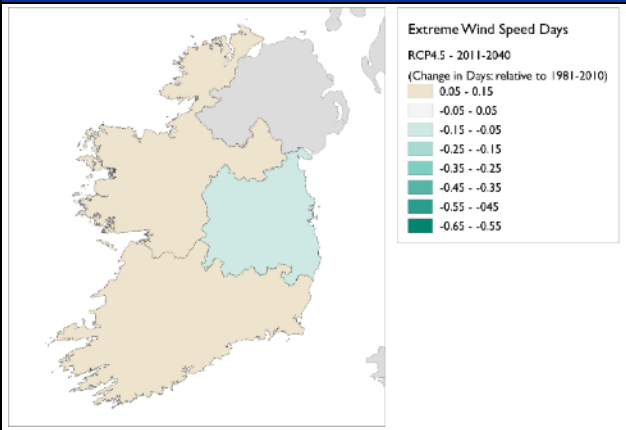
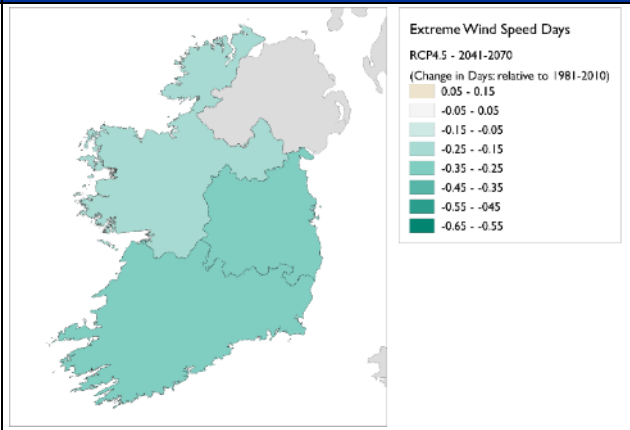
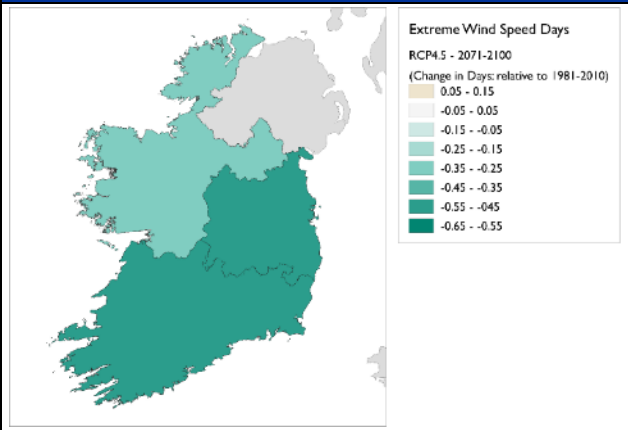
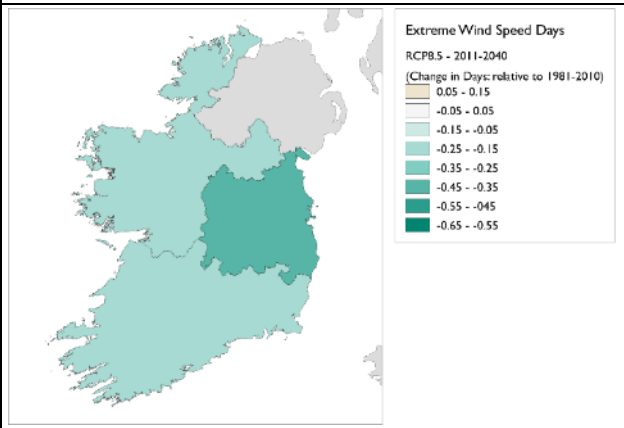
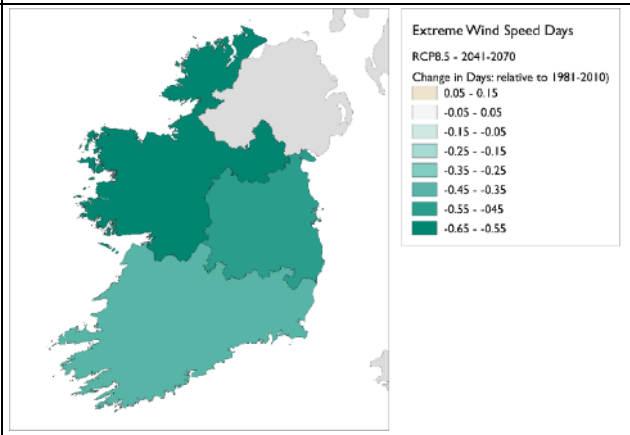
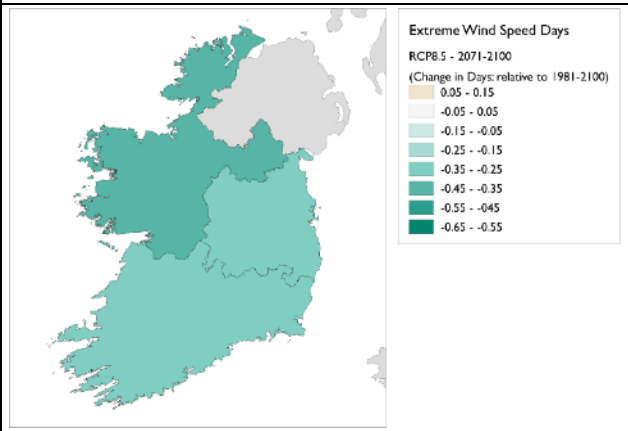
References	
Observations	Devoy, R. J., 2008. 'Coastal vulnerability and the implications of sea-level rise for Ireland.' J. Coast. Res. 24(2): 325–341. Thorne, P., Boucher, J., Caulfield, B., Daly, H., Deane, P., Gallagher, D., Heaphy, L., McClean, D., McDonagh, S., McElwain, J. and McGookin, C., 2023. Ireland's Climate Change Assessment Synthesis Report.
	EUROSION (2004) Project commissioned by General Directorate Environment of the European Commission, http://www.eurosion.org
Projections	van de Wal, R., Melet, A., Bellafiore, D., Camus, P., Ferrarin, C., Oude Essink, G., Haigh, I. D., Lionello, P., Luijendijk, A., Toimil, A., Staneva, J., and Vousdoukas, M. (2024) Sea Level Rise in Europe: Impacts and consequences, in: Sea Level Rise in Europe: 1st Assessment Report of the Knowledge Hub on Sea Level Rise (SLRE1), edited by: van den Hurk, B., Pinardi, N., Kiefer, T., Larkin, K., Manderscheid, P., and Richter, K., Copernicus Publications, State Planet, 3-slre1, 5, https://doi.org/10.5194/sp-3-slre1-5-2024.

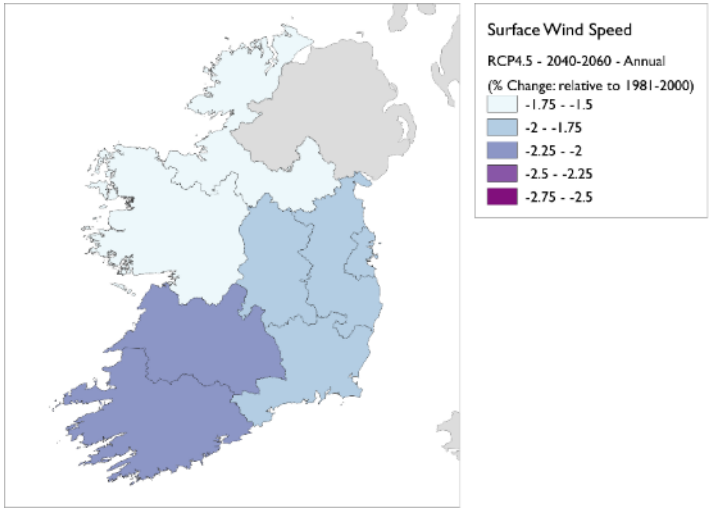
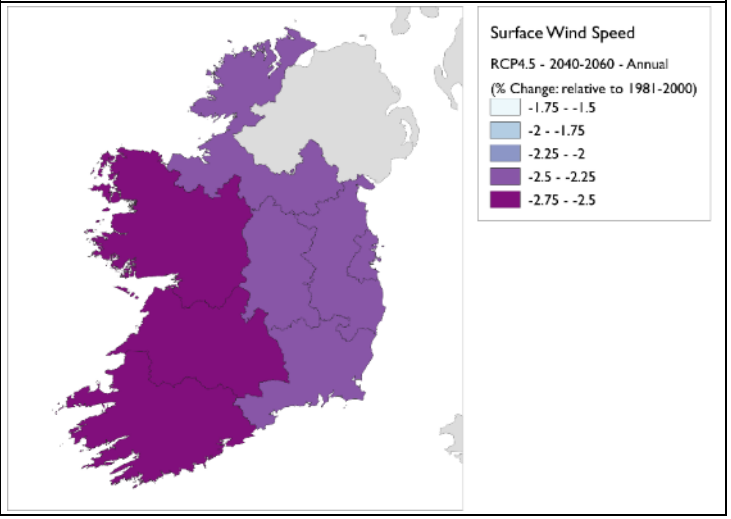
RPS Consulting Engineers, 2010. Final Technical Report 'ICPSS, Phase 2, Work Packages 2, 3 & 4A, Strategic Assessment of Coastal Flooding and Erosion Extents – South East Coast – Dalkey Island to Carnsore Point Pilot Area'

Extreme Wind

Extreme Wind Days (Daily 10 m Wind Speed Exceeding the 98th Percentile Threshold) and Surface Wind Speed (10 m)		
National	**Sub-national (NUTS2) zones affected**	
Recent and past effects or changes	**2050**	**2100**
• Historical wind trends in Ireland do not show a robust signal, as they are mostly dominated by decadal variability (García & Dwyer, 2020). • A recent study identified the 2013/14 winter as the stormiest in records dating back to 1871. The study utilised a metric based on storm frequency and intensity derived from reanalysis data (Matthews et al, 2014, 2016).	• At the NUTS 2 level, projected Extreme wind days index anomaly (from 1981-2010) shows the Northern and Western region with the largest decrease in extreme wind days (-0.62 days).	• At the NUTS 2 level, projected Extreme wind days index anomaly (from1980-2010) shows Northern and Western shows largest decrease in extreme wind days (-0.44 days).

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5	• Overall, Ireland is projected to experience a small increase in extreme wind days, with the Southern region showing the highest increase (0.12 days) from the 1981-2010 baseline. • Surface wind speed projections are not available for this time horizon.	• Overall, Ireland is projected to experience a small decrease in extreme wind days, with the Northern and Western region showing the largest decrease (-0.32 days) from the 1981-2010 baseline. • There is a projected small reduction in the 10-m wind speed of 1.0–2.7% (mean value 1.8%) compared to the 1981-2000 baseline.	• Overall, Ireland is projected to experience a small decrease in extreme wind days, with the Northern and Western region showing the largest decrease (-0.47 days) from the 1981-2010 baseline. • Surface wind speed projections are not available for this time horizon.
RCP8.5	• Overall, Ireland is projected to experience a small decrease in extreme wind days, with the Eastern and Midland region showing the largest decrease (-0.36 days) from the 1981-2010 baseline. • Surface wind speed projections are not available for this time horizon.	• Overall, Ireland is projected to experience a small decrease in extreme wind days, with the Northern and Western region showing the largest decrease (-0.61 days) from the 1981-2010 baseline. • There is a projected small decrease in the 10-m wind speed of 1.6–3.3% (mean value 2.6%) compared to the 1981-2000 baseline.	• Overall, Ireland is projected to experience a small decrease in extreme wind days, with the Northern and Western region showing the largest decrease (-0.44 days) from the 1981-2010 baseline. • Surface wind speed projections are not available for this time horizon.

	Projected changes by 2030 (Extreme Wind Days)	Projected changes by 2050 (Extreme Wind Days)	Projected changes by 2100 (Extreme Wind Days)
RCP4.5			
RCP8.5			

	Projected changes by 2050 (Surface Wind Speed)
RCP4.5	
RCP8.5	

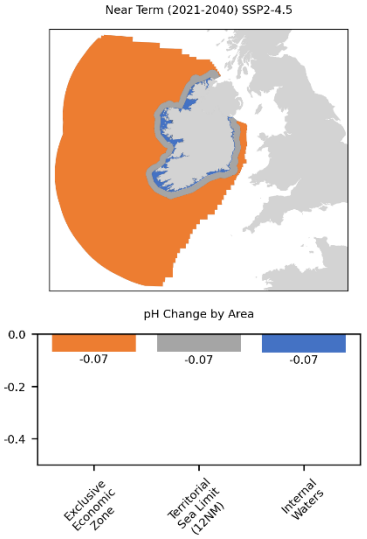
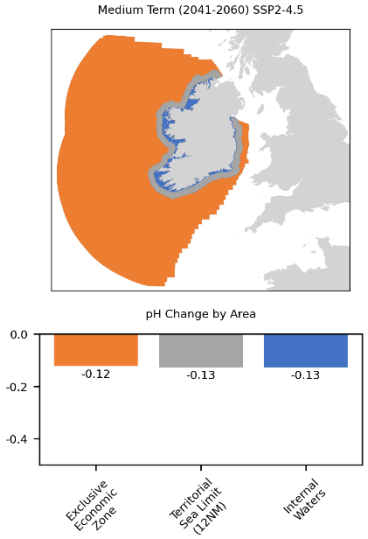
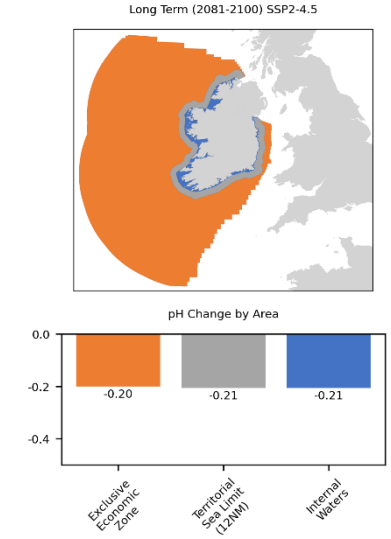
Confidence: Very Low
Agreement: There are limited global, regional, and national scale projections available related to the changes in extreme wind for Ireland. **Robustness:** National scale projections do not exist for extreme wind, therefore European scale projections (EURO-CORDEX) have been used, plus national scale data for average wind speed have been used as a proxy.

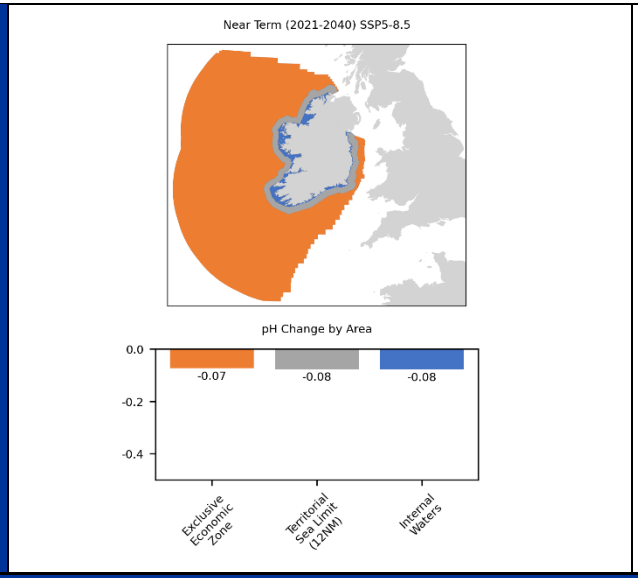
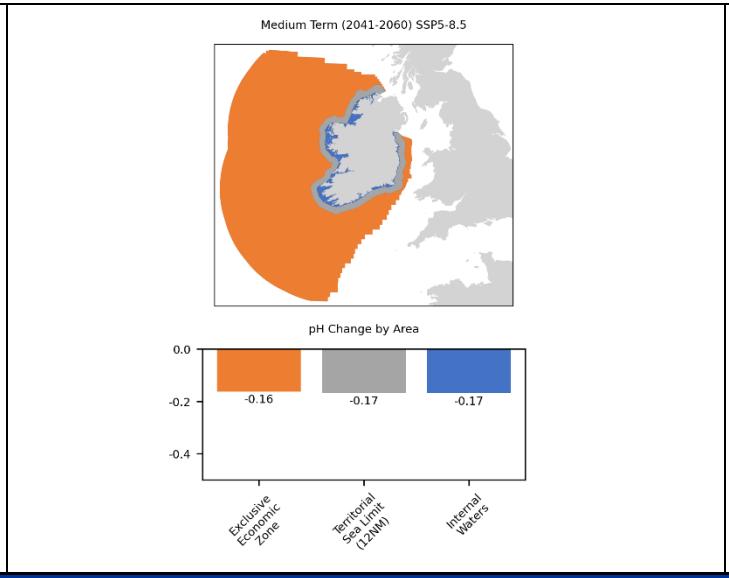
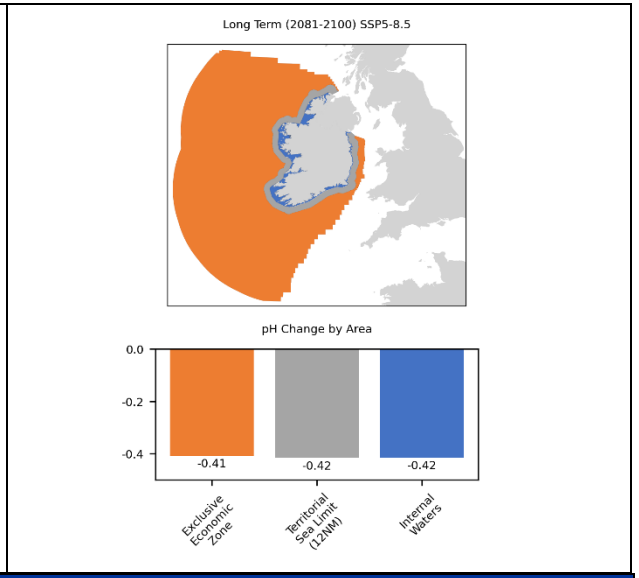
	References
Observations	Cámaro García, C., A., and Dwyer, N. (2021) The Status of Ireland's Climate, EPA Research Report 386.
	Matthews, T., Murphy, C., Wilby, R.L. and Harrigan, S. (2014), 'Stormiest winter on record for Ireland and UK', Nature Climate Change 4, 738–40, DOI:10.1038/nclimate2336
	Matthews, T., Mullan,D., Wilby,R.L., Broderick, C. and Murphy C.(2016),'Past and future climate change in the context of memorable seasonal extremes', Climate Risk Management 11(1), 37–52
Projections	Climate Adapt (2024) Extreme Wind Days. Available at https://climate-adapt.eea.europa.eu/en/metadata/indicators/extreme-wind-days
	Nolan, P., and Flanagan, J. (2020) High-resolution Climate Projections for Ireland – A Multi-model Ensemble Approach. EPA Research Report 339.

Ocean Acidification

Ocean Acidification (pH at surface)		
National	**Sub-national zones affected**	
Recent and past effects or changes	**2050**	**2100**
• Increased carbon concentrations from human activities have been detected not only at the ocean surface but also at depths of 2500 m and potentially reaching 5000 m in the North Atlantic (Nolan et al., 2023). • Observations in the Rockall Trough show a decrease in pH by 0.04 units in subsurface waters (200-500 m) and by 0.03 units in deeper waters (1500-2000 m) where Labrador Sea Water is found, indicating significant acidification over time (Nolan et al., 2023).	• Inland Waters, Transitional Waters, and the Exclusive Economic Zone waters around Ireland are all projected to experience ocean acidification (a decrease in pH) by 2050.	• Inland Waters, Transitional Waters, and the Exclusive Economic Zone waters around Ireland are all projected to experience ocean acidification (a decrease in pH) by 2100.

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5	• The projected mean change in pH at the surface for 2021-2040 relative to 1995-2014: ○ Inland Waters: -0.07 ○ Transitional Waters: -0.07 ○ Exclusive Economic Zone: -0.07	• The projected mean change in pH at the surface for 2041-2060 relative to 1995-2014: ○ Inland Waters: -0.13 ○ Transitional Waters: -0.13 ○ Exclusive Economic Zone: -0.12	• The projected mean change in pH at the surface for 2081-2100 relative to 1995-2014: ○ Inland Waters: -0.21 ○ Transitional Waters: -0.21 ○ Exclusive Economic Zone: -0.20
RCP8.5	• The projected mean change in pH at the surface for 2021-2040 relative to 1995-2014: ○ Inland Waters: -0.08 ○ Transitional Waters: -0.08 ○ Exclusive Economic Zone: -0.07	• The projected mean change in pH at the surface for 2041-2060 relative to 1995-2014: ○ Inland Waters: -0.17 ○ Transitional Waters: -0.17 ○ Exclusive Economic Zone: -0.16	• The projected mean change in pH at the surface for 2081-2100 relative to 1995-2014: ○ Inland Waters: -0.42 ○ Transitional Waters: -0.42 ○ Exclusive Economic Zone: -0.41

	Projected Change (2021 – 2040)	Projected Change (2041 – 2060)	Projected Change (2081 – 2100)
RCP4.5			

RCP8.5			

Confidence – Medium

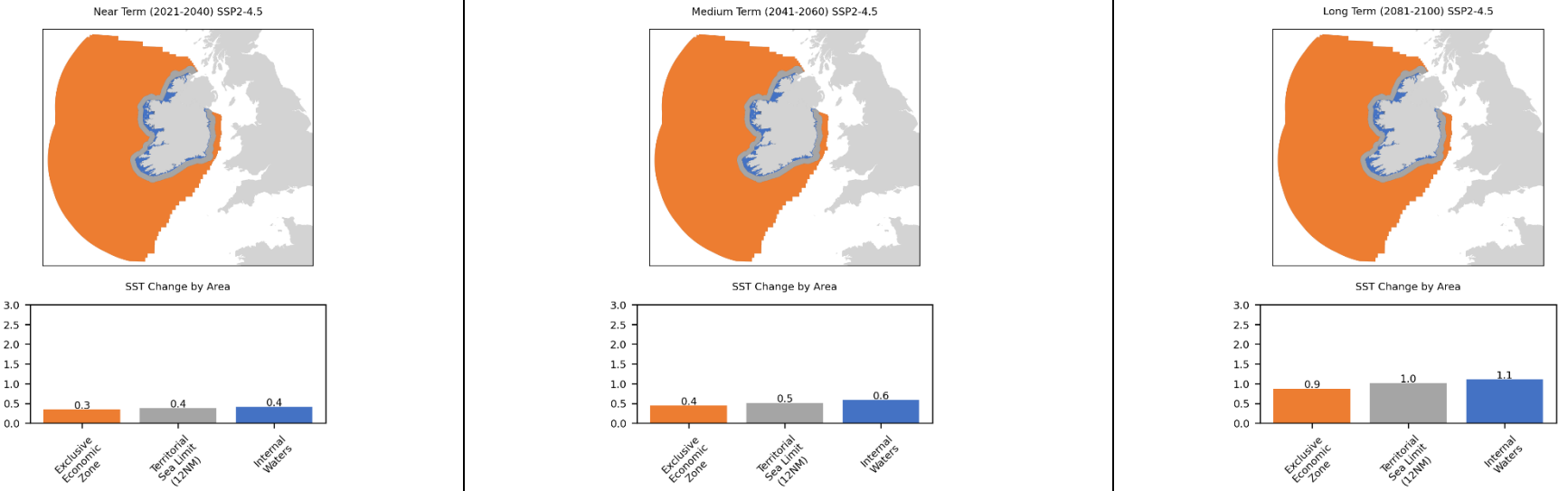
Agreement: Across both scenarios there is a decrease in pH at the surface identified in all waters surrounding Ireland. This aligns the global trend of increasing ocean acidity due to climate change.
Robustness: Global projections been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6, however, no national downscaled projections exist.

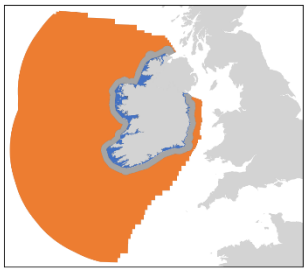
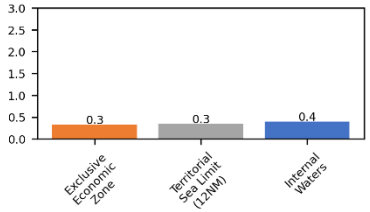
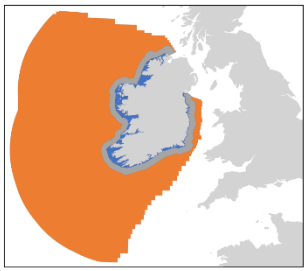
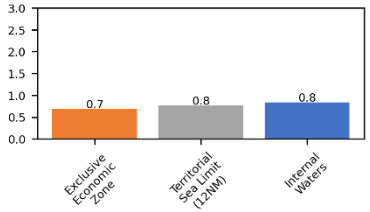
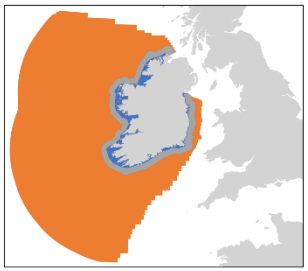
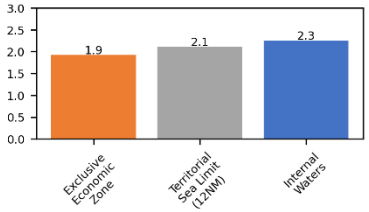
References	
Observations	Nolan, G., Cusack, C., Fitzhenry, D. (Eds.) (2023). Irish Ocean Climate & Ecosystem Status Report. Marine Institute, Galway, Ireland, pp 192.
Projections	Iturbide, M., Fernández, J., Gutiérrez, J.M. et al. (2022) Implementation of FAIR principles in the IPCC: the WGI AR6 Atlas repository. Scientific Data 9, 629. DOI: 10.1038/s41597-022-01739-y (Accessed on 01-09-2024)
	Intergovernmental Panel on Climate Change (2023) Atlas. In Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1927-2058). Cambridge: Cambridge University Press. DOI: 10.1017/9781009157896.021 (Accessed on 01-09-2024) Interactive Atlas available from http://interactive-atlas.ipcc.ch

Sea Surface Temperature

Sea Surface Temperature		
National	**Sub-national zones affected**	
Recent and past effects or changes	**2050**	**2100**
• Temperature records from Malin Head Coastal station show significant warming trend from 1960 to 2020 period, with 0.3°C per decade (Cornes et al., 2023). • Irish waters have warmed since the 1980s, with the highest annual sea surface temperature recorded in 2007 at over 0.8°C above the 1960–1990 average. Recent years have seen a cooling trend of -0.3°C per decade., although they remain 0.4°C warmer in the 21st century relative to 1960–1990 (Nolan et al., 2023). • In the summer of 2023, the North Atlantic experienced its highest sea-surface temperatures since 1982, leading to a severe marine heatwave west of Ireland, with SSTs reaching up to 4°C above average (McCarthy, et al., 2023).	• Inland Waters, Transitional Waters, and the Exclusive Economic Zone waters around Ireland are all projected to experience an increase in sea surface temperature by 2050.	• Inland Waters, Transitional Waters, and the Exclusive Economic Zone waters around Ireland are all projected to experience an increase in sea surface temperature by 2100.

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5	• The projected mean change in sea surface temperature for 2021-2040 relative to 1995-2014: ○ Inland Waters: 0.4°C (0.3-0.6°C) ○ Transitional Waters: 0.4°C (0.3-0.5°C) ○ Exclusive Economic Zone: 0.3°C (0.3-0.6°C)	• The projected mean change in sea surface temperature for 2041-2060 relative to 1995-2014: ○ Inland Waters: 0.6°C (0.4-0.9°C) ○ Transitional Waters: 0.5°C (0.3-0.8°C) ○ Exclusive Economic Zone: 0.4°C (0.3-0.8°C)	• The projected mean change in sea surface temperature for 2081-2100 relative to 1995-2014: ○ Inland Waters: 1.1°C (0.8-1.5°C) ○ Transitional Waters: 1.0°C (0.6-1.3°C) ○ Exclusive Economic Zone: 0.9°C (0.8-1.5°C)
RCP8.5	• The projected mean change in sea surface temperature for 2021-2040 relative to 1995-2014: ○ Inland Waters: 0.4°C (0.3-0.6°C) ○ Transitional Waters: 0.4°C (0.3-0.6°C) ○ Exclusive Economic Zone: 0.3°C (0.2-0.5°C)	• The projected mean change in sea surface temperature for 2041-2060 relative to 1995-2014: ○ Inland Waters: 0.8°C (0.6-1.2°C) ○ Transitional Waters: 0.8°C (0.6-1.2°C) ○ Exclusive Economic Zone: 0.7°C (0.5-1.1°C)	• The projected mean change in sea surface temperature for 2081-2100 relative to 1995-2014: ○ Inland Waters: 2.3°C (1.8-2.9°C) ○ Transitional Waters: 2.1°C (1.8 – 2.9°C) ○ Exclusive Economic Zone: 1.9°C (1.5-2.5°C)

	Projected Change (2021 – 2040)	Projected Change (2041 – 2060)	Projected Change (2081 – 2100)
RCP4.5			

RCP8.5	Near Term (2021-2040) SSP5-8.5  SST Change by Area 	Medium Term (2041-2060) SSP5-8.5  SST Change by Area 	Long Term (2081-2100) SSP5-8.5  SST Change by Area 

Confidence - Low

Agreement: Across both scenarios there is an increase in sea surface temperature identified in all waters surrounding Ireland. This aligns the global trend of increasing sea surface temperature due to climate change.

Robustness: Global projections been used to inform this variable using a number of robust and peer-reviewed modelling approach that have been used within the Intergovernmental Panel on Climate Change Assessment Report 6, however, no national downscaled projections exist.

References	
Observations	Cornes, R.C., Tinker, J., Hermanson, L., Oltmanns, M., Hunter, W.R., Lloyd-Hartley, H., Kent, E.C., Rabe, B. and Renshaw, R. (2023) The impacts of climate change on sea temperature around the UK and Ireland
	Nolan, G., Cusack, C. and Fitzhenry, D. (2023) Irish Ocean Climate and Ecosystem Status Report
	McCarthy G et al. (2023) The Marine Heatwave west of Ireland in June 2023. Weather, p. 321-323.
Projections	Iturbide, M., Fernández, J., Gutiérrez, J.M. et al. (2022) Implementation of FAIR principles in the IPCC: the WGI AR6 Atlas repository. Scientific Data 9, 629. DOI: 10.1038/s41597-022-01739-y (Accessed on 01-09-2024)
	Intergovernmental Panel on Climate Change (2023) Atlas. In Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1927-2058). Cambridge: Cambridge University Press. DOI: 10.1017/9781009157896.021 (Accessed on 01-09-2024) Interactive Atlas available from http://interactive-atlas.ipcc.ch

Lightning

Lightning		
National	**Sub-national (NUTS2)**	
Recent and past effects or changes	**2050**	**2100**
• In Ireland, 2011 to 2019, time series data shows that lightning usually occurs during the summer months also exhibit strong annual variability. The majority of lightning strikes occurs over of sea area than land (Cámaro García and Dwyer, 2020). • Time series of lightning over the land and sea indicates no discernible trend (Cámaro García and Dwyer, 2020)	• No projections are available.	• All NUTS3 Regions and sea areas are potentially exposed to lightning.

	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5	• No projections are available.	• No projections are available.	• No projections are available.
RCP8.5	• No projections are available.	• No projections are available.	• For 2100, projections indicate a northward shift of favourable weather regimes for lighting. This means for the British Isles (and Ireland), lightning counts are projected to double in July and August.

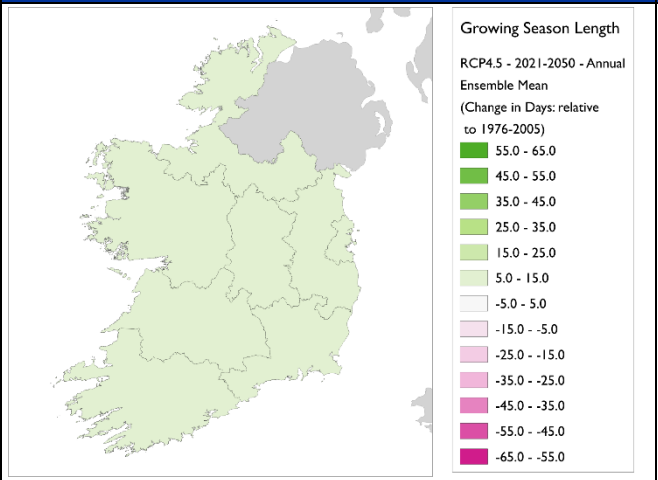
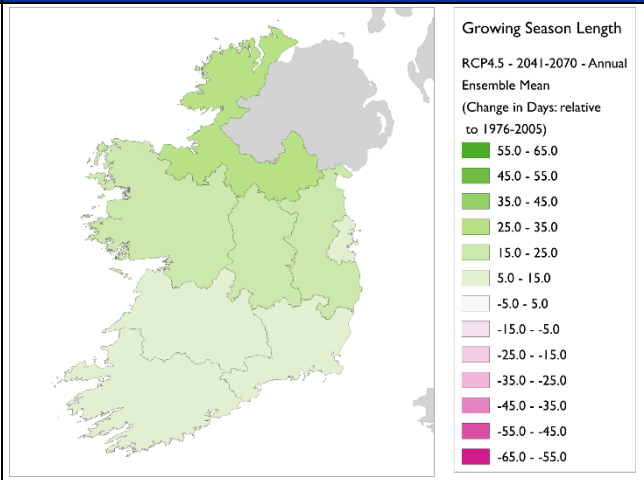
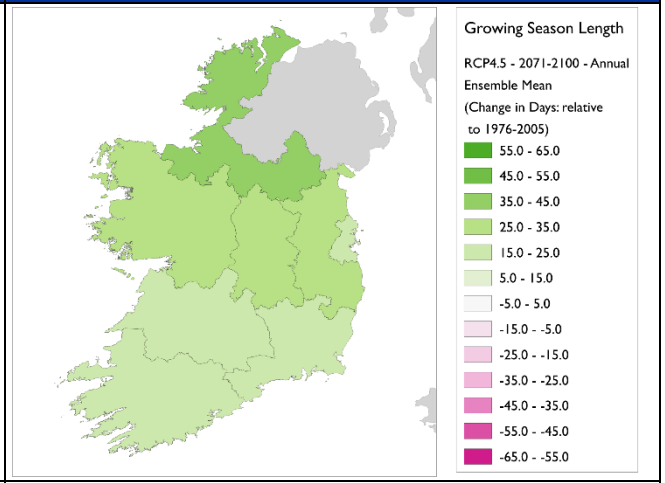
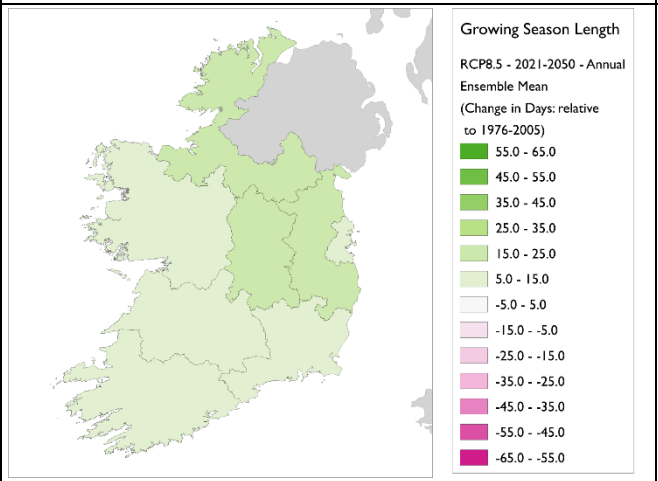
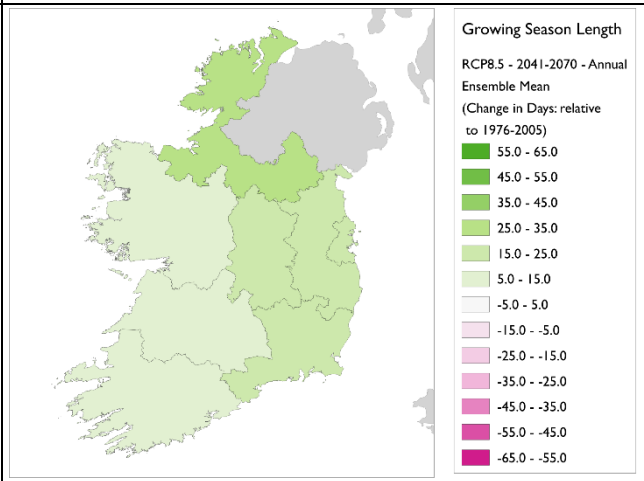
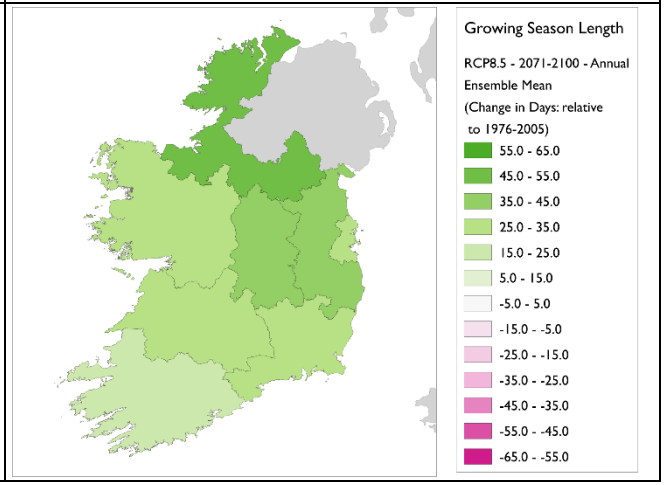
Confidence: Very Low
Agreement: There are very limited number of projections for changes in lightning in Ireland. **Robustness:** The projections for Ireland are obtained from a peer-reviewed publication, however, the research takes a European focus, rather than Irish focus.

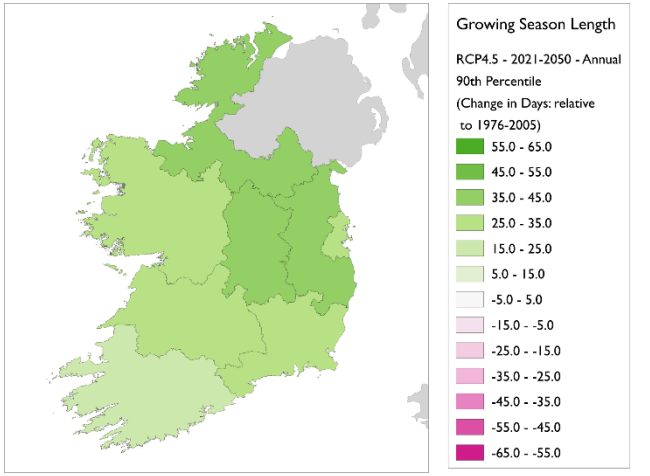
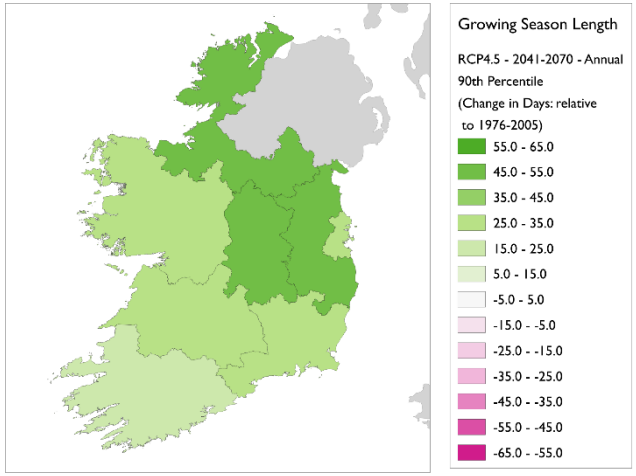
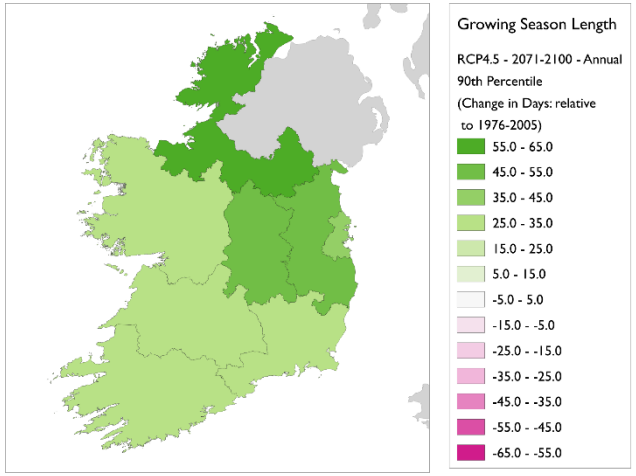
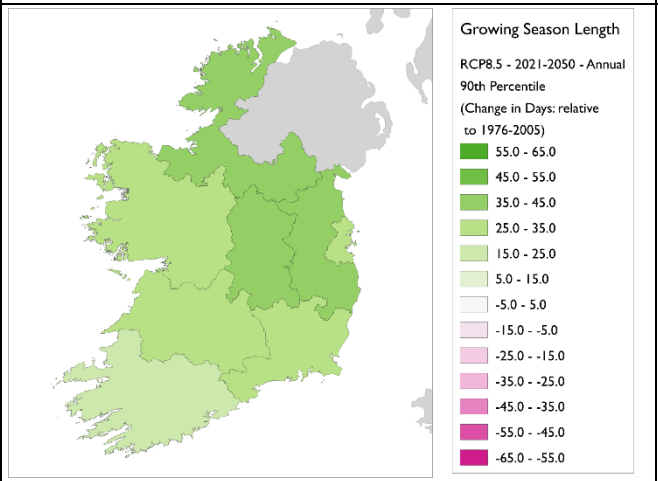
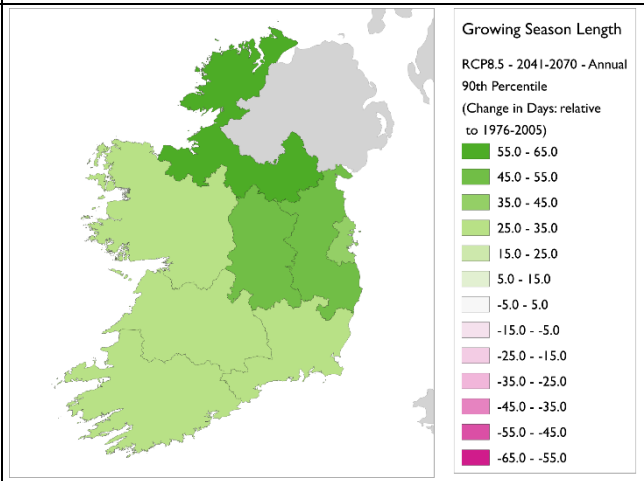
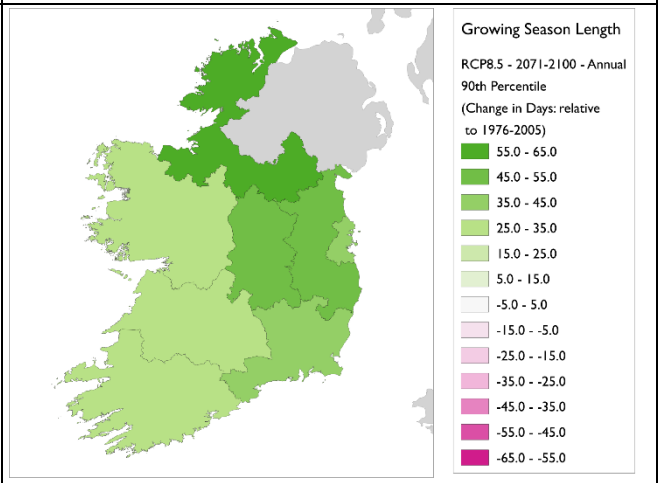
References	
Observations	Cámaro García, C., A., and Dwyer, N. (2021) The Status of Ireland's Climate, EPA Research Report 386.
Projections	Kahraman, A., Kendon, E.J., Fowler, H.J. and Wilkinson, J.M. (2022) Contrasting future lightning stories across Europe. Environmental Research Letters, 17(11), 114023. DOI: 10.1088/1748-9326/ac9b78.

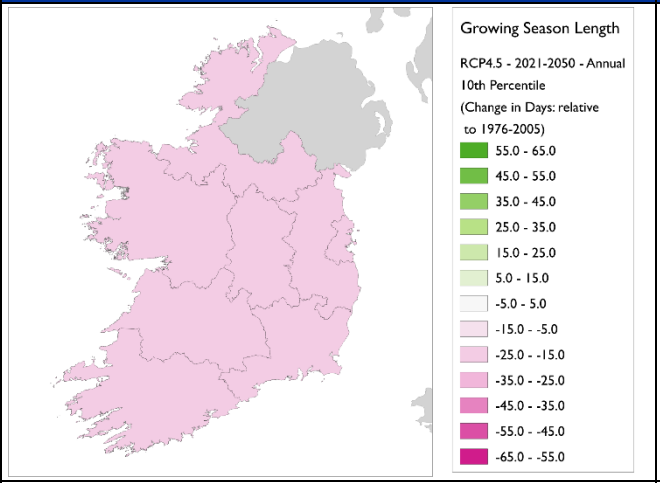
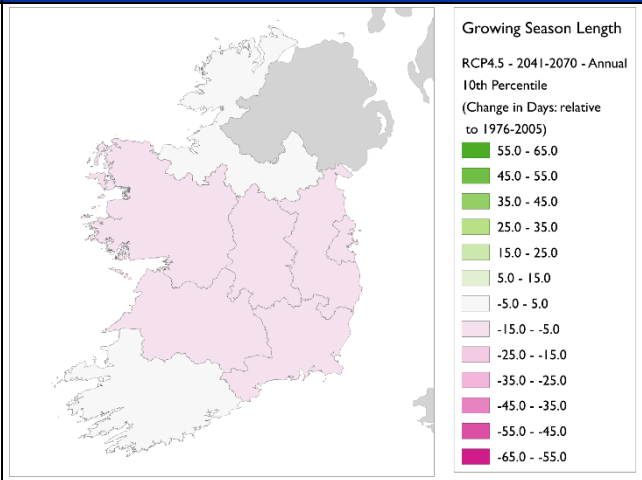
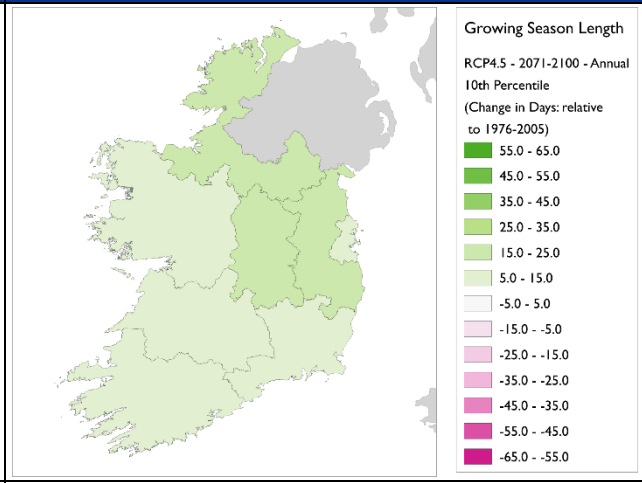
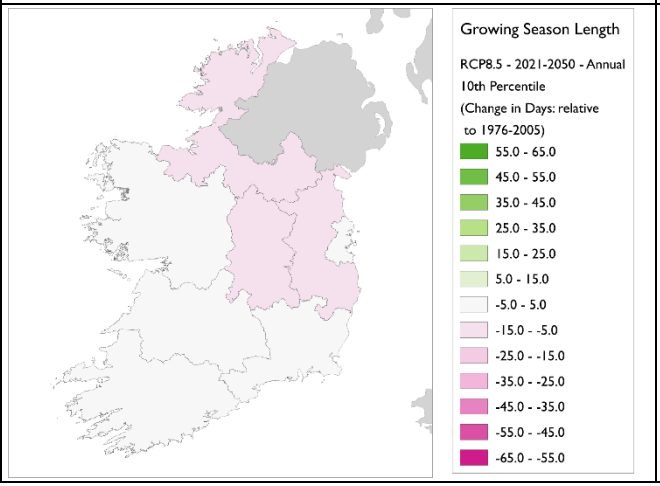
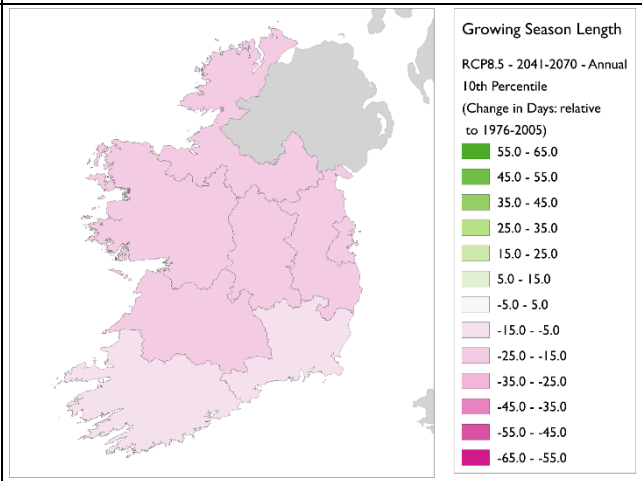
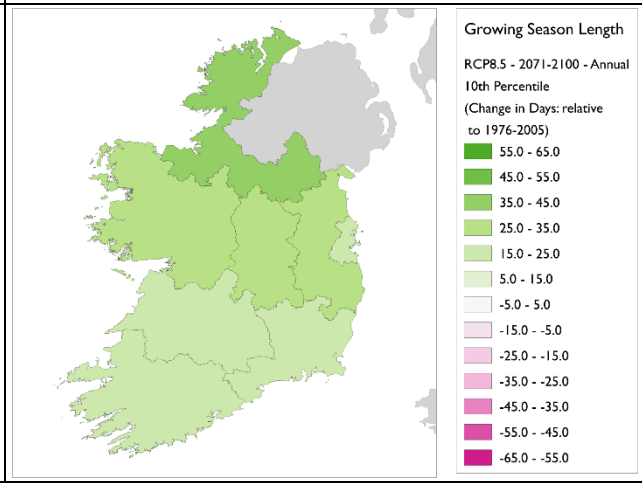
Changes in Phenology

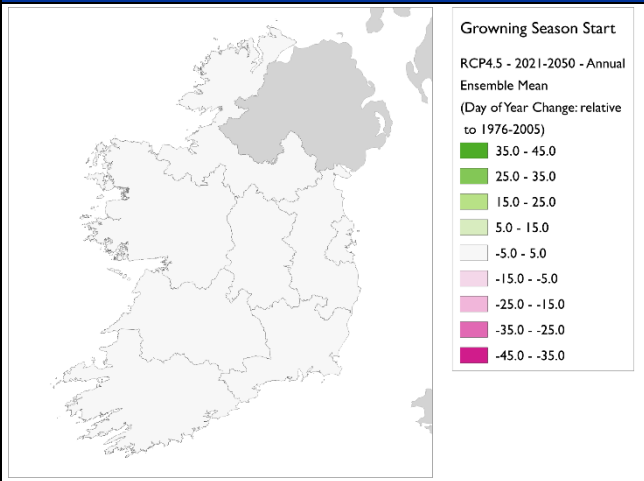
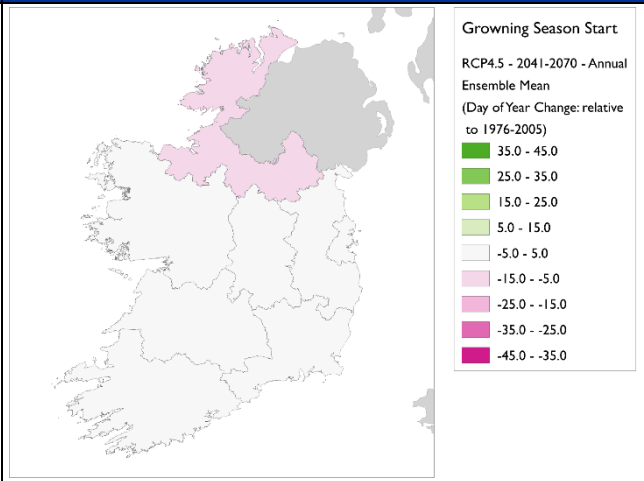
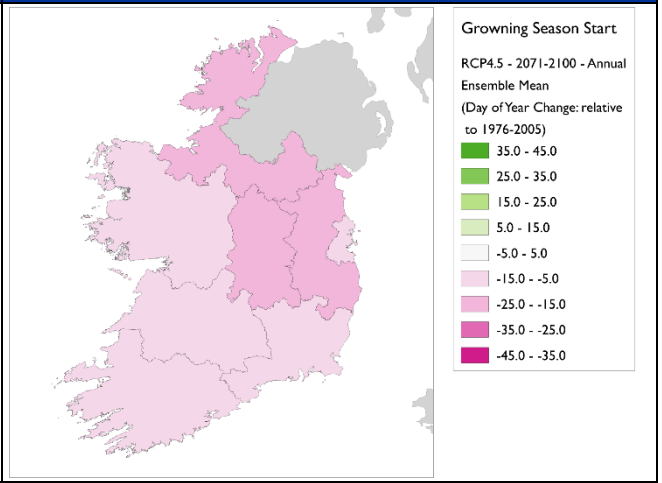
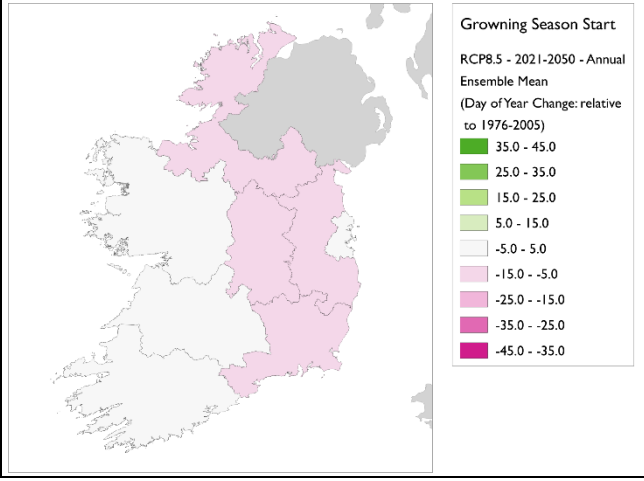
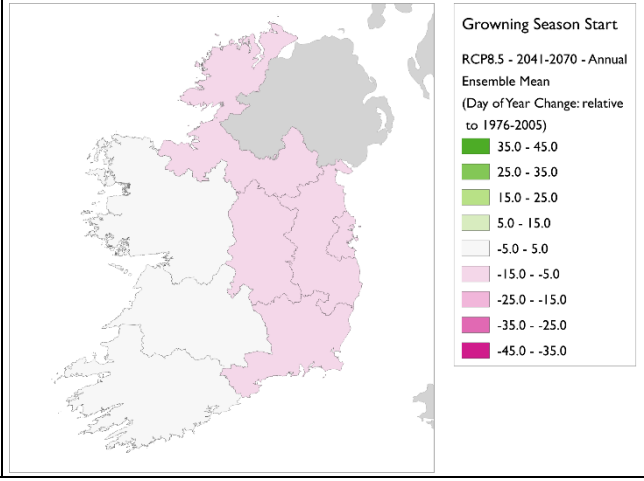
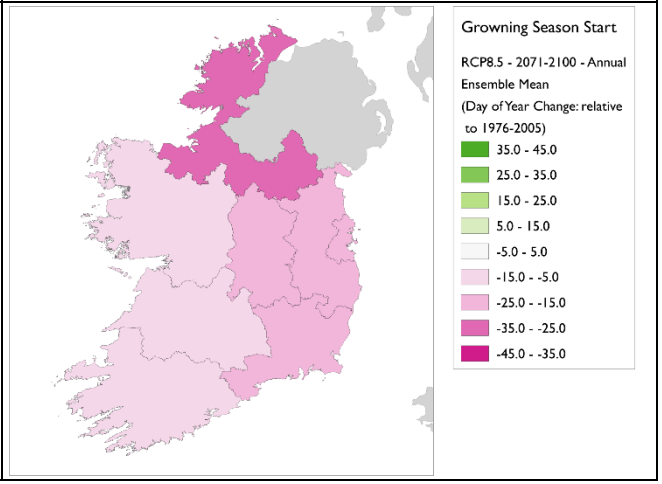
Changes in Phenology (Growing Season Start (First annual instance of 6 consecutive days where mean temperature > 5˚C) and Growing Season Length (Number of days between growing season start and end))		
National	**Sub-national (NUTS2)**	
Recent and past effects or changes	**2050**	**2100**
• During the baseline period (1976 - 2005) the average growing season length was 314.27 days. The growing season started on the 30.5th day of the year during this period (O'Brien et al., 2023).	• At the NUTS 3 level, all regions are projected to experience an increase in growing season length with the Border, Mid-East, and Midland regions experiencing the highest increases across the RCP4.5 and RCP8.5 scenarios.	• At the NUTS 3 level, all regions are projected to experience an increase in growing season length with the Border, Mid-East, and Midland regions experiencing the highest increases across the RCP4.5 and RCP8.5 scenarios.

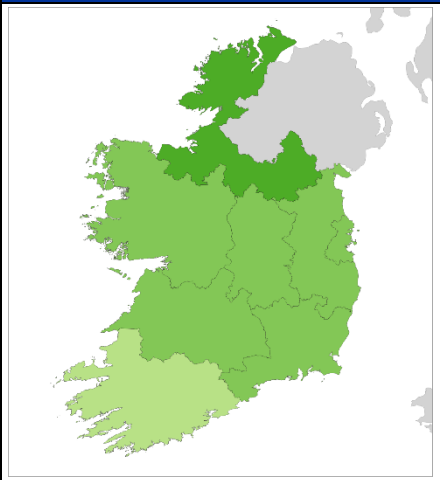
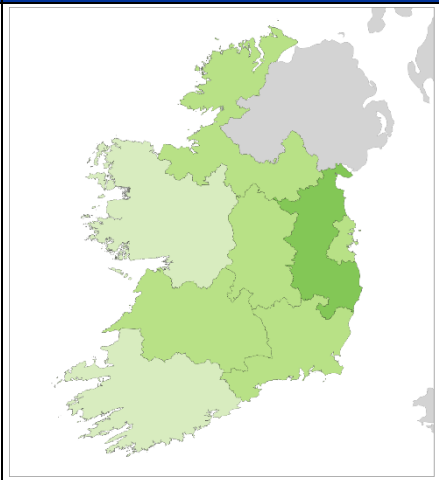
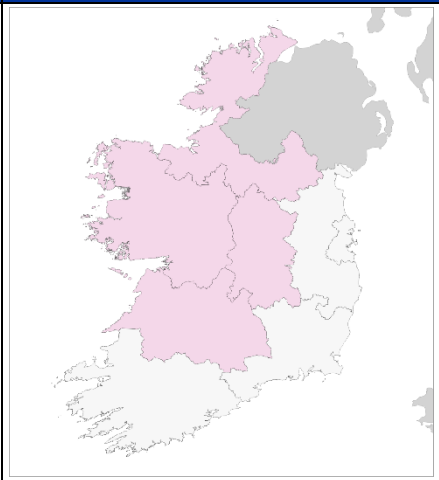
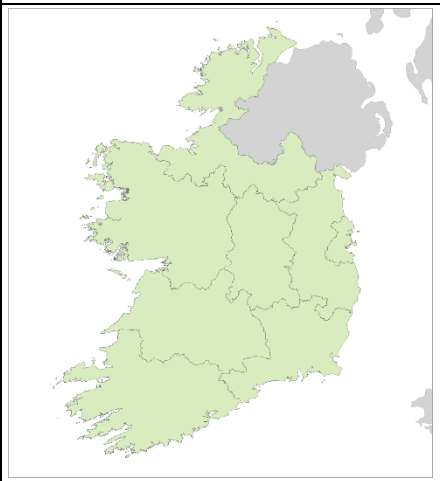
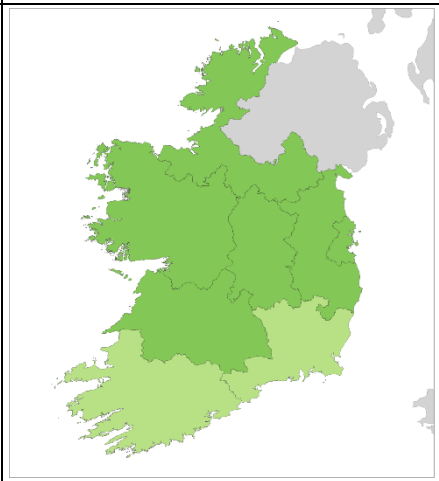
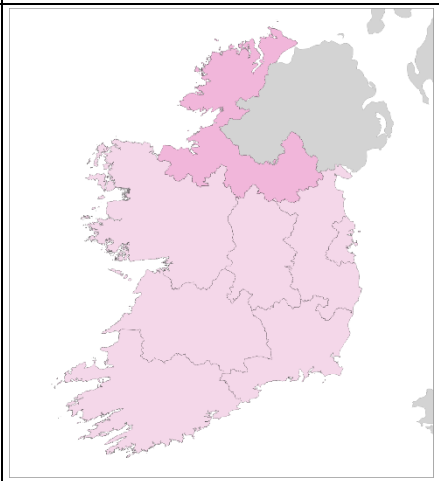
	Projected changes by 2030	Projected changes by 2050	Projected changes by 2100
RCP4.5	• Nationally, the growing season length is projected to increase by 11.0 days (-19.7 – 34.2) by 2030, with the Border (14.2 days (-21.5-40.1 days)) region experiencing the highest increase. • Considering the growing season start, it is projected to occur earlier by -2.50 days (-22.2 – 30.4) by 2030.	• Nationally, growing season length is projected to increase by 19.7 days (-5.9 – 40.9) by 2050, with the Border (28.0 days (-0.5-52.5 days)), region experiencing the highest increases. • Considering the growing season start, it is projected to be occur earlier by -5.1 days (-23.0 – 18.7) by 2050.	• Nationally, growing season length is projected to increase by 31.5 days (16.6 – 43.6) by 2100, with the Border (41.9 days (23.5-57.0 days)), region experiencing the highest increase. • Considering the growing season start, it is projected to occur earlier by -16.1 days (-23.9 - -7.4) by 2100.
RCP8.5	• Nationally, growing season length is projected to increase by 17.2 days (-3.7 – 34.8) by 2030, with the Border (21.7 days (-5.3-42.5 days)) region experiencing the highest increase. • Considering the growing season start, it is projected to occur earlier by -6.7 days (-21.4 – 11.2) by 2030.	• Nationally, growing season length is projected to increase by 19.8 days (-15.6 – 43.8) by 2050, with the Border (26.5 days (15.6-57.2 days)) region experiencing the highest increase. • Considering the growing season start, it is projected to occur earlier by -7.9 days (-21.4 – 25.5) by 2050.	• Nationally, growing season length is projected to increase by 39.9 days (32.0 – 44.6) by 2100, with the Mid-East (43.0 days (33.0-50.2 days)) region experiencing the highest increase. • Considering the growing season start, it is projected to occur earlier by -20.5 days (-24.4 - -14.5) by 2100.

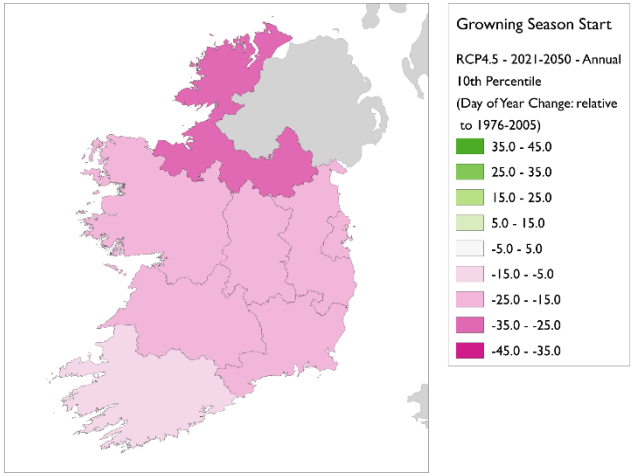
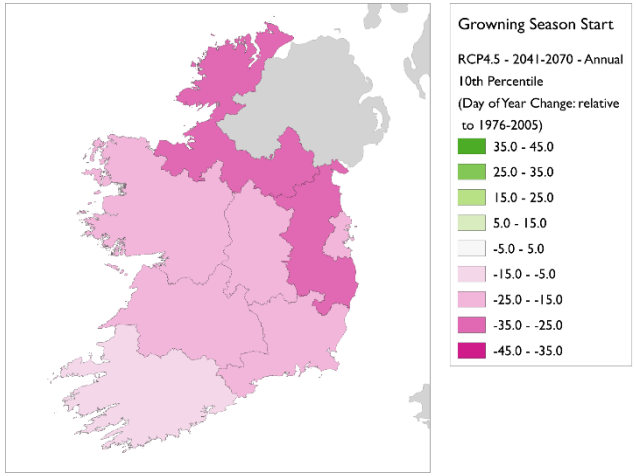
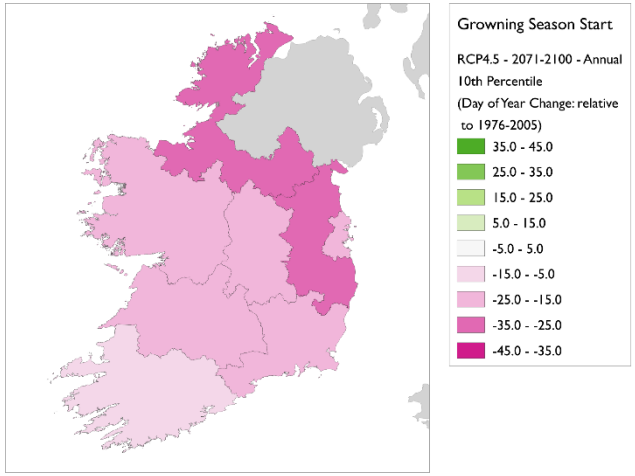
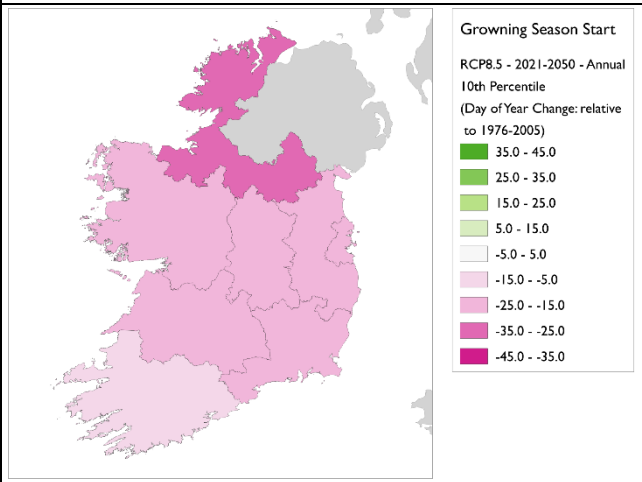
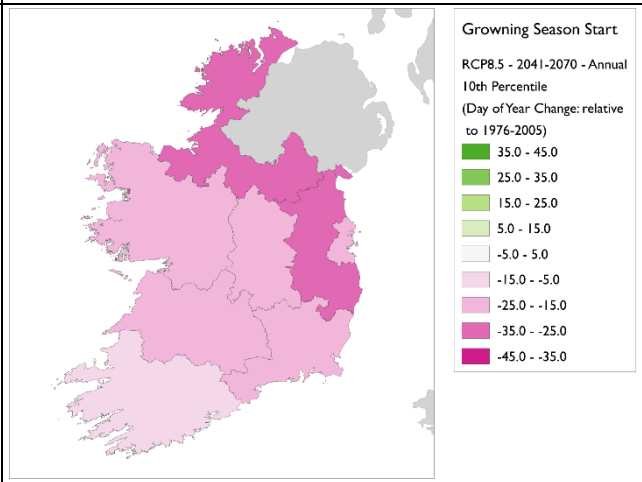
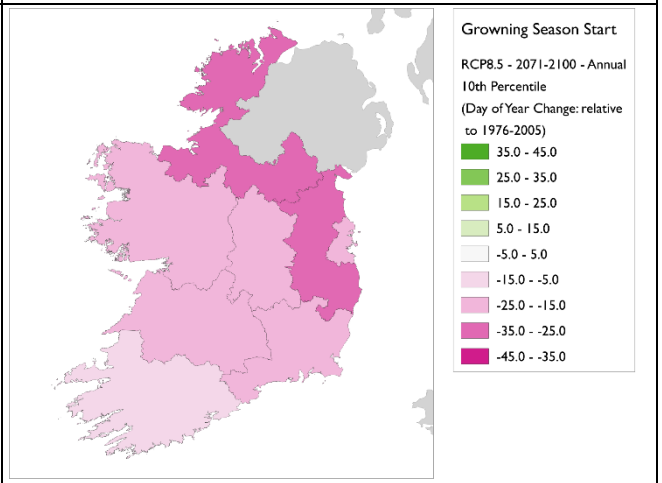
	Projected changes by 2030 (Growing Season Length (First annual instance of 6 consecutive days where temperature mean > 5˚C)) - Mean	Projected changes by 2050 (Growing Season Length (First annual instance of 6 consecutive days where temperature mean > 5˚C)) - Mean	Projected changes by 2100 (Growing Season Length (First annual instance of 6 consecutive days where temperature mean > 5˚C)) - Mean
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Growing Season Length (First annual instance of 6 consecutive days where temperature mean > 5˚C)) – 90th Percentile	Projected changes by 2050 (Growing Season Length (First annual instance of 6 consecutive days where temperature mean > 5˚C)) – 90th Percentile	Projected changes by 2100 (Growing Season Length (First annual instance of 6 consecutive days where temperature mean > 5˚C)) – 90th Percentile
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Growing Season Length(First annual instance of 6 consecutive days where temperature mean > 5˚C))- 10th Percentile	Projected changes by 2050 (Growing Season Length (First annual instance of 6 consecutive days where temperature mean > 5˚C))- 10th Percentile	Projected changes by 2100 (Growing Season Length (First annual instance of 6 consecutive days where temperature mean > 5˚C))- 10th Percentile
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Growing Season Start (Number of days between growing season start and end)) - Mean	Projected changes by 2050 (Growing Season Start (Number of days between growing season start and end) - Mean	Projected changes by 2100 (Growing Season Start (Number of days between growing season start and end) - Mean
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Growing Season Start (Number of days between growing season start and end)- 90th Percentile	Projected changes by 2050 (Growing Season Start (Number of days between growing season start and end)- 90th Percentile	Projected changes by 2100 (Growing Season Length Start (Number of days between growing season start and end)- 90th Percentile
RCP4.5			
RCP8.5			

	Projected changes by 2030 (Growing Season Start (Number of days between growing season start and end) - 10th Percentile	Projected changes by 2050 (Growing Season Start (Number of days between growing season start and end)- 10th Percentile	Projected changes by 2100 (Growing Season Start (Number of days between growing season start and end) - 10th Percentile
RCP4.5			
RCP8.5			

Confidence – Medium
Agreement: For Growing Season Length, within the national projections, the 10th percentile shows a different trend to the ensemble mean, and the 90th percentile, with the 10th percentile showing decreases in the Growing Season Length for 2030 and 2050 and increases in 2100 in both scenarios, whereas the ensemble mean and 90th percentile show a decreasing trend across all time periods. For Growing Season Start, within the national projections, the 90th percentile shows a different trend to the ensemble mean, and the 10th percentile, with the 90th percentile showing increases in the Growing Season Start for 2030 and 2050 and decreases in 2100 in both scenarios, whereas the ensemble mean and 10th percentile show a decreasing trend across all time periods. **Robustness:** National downscaled projections (TRANSLATE) produced by the national meteorological agency have been used to inform this variable using a robust and peer-reviewed modelling approach.

	References
Observations	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023). Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.
Projections	O'Brien,E., Ryan,P., Holloway,P., Wang,J., Nowbakht,P., Phillips,C., Fitton,J., O Dwyer,B. and Nolan,P. (2023). Met Éireann TRANSLATE report. Prepared for Met Éireann by Irish Centre of High-End Computing, University College Cork and the MAREI Centre.

ISBN: 978-1-80009-282-2

© Environmental Protection Agency 2025

Although every effort has been made to ensure **the accuracy of the material contained in this publication, complete accuracy** cannot be guaranteed. Neither the Environmental Protection Agency nor the author(s) accepts any responsibility whatsoever for loss or damage occasioned, or claimed to have been occasioned, in part or in full as a consequence of any person acting or refraining from acting, as a result of a matter contained in this publication. All or part of this publication may be reproduced without further permission, provided the source is acknowledged.