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Assessment on Prioritising Transboundary Climate Risks for Ireland

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Assessment on Prioritising Transboundary Climate Risks for Ireland

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Assessment commissioned by the Climate Change Advisory Council (Ireland)

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Hills and farmland near Dingle, County Kerry, Ireland.

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EXECUTIVE SUMMARY

Global warming is causing dramatic changes to climate and weather systems around the world. Human activity has increased greenhouse gas emissions, leading to more frequent and intense extreme weather events and rising sea levels, as well as more gradual, but devastating, long term, irreversible shifts in seasons, more variable weather and warmer seas.

While the island of Ireland has already experienced extreme temperatures and floods in recent years, it is also exposed to cross-border and cascading risks triggered by climate change impacts beyond its borders. Until recently, these so-called *transboundary climate risks* have largely been neglected in the scientific and political discourse on climate change adaptation.

Adaptation to climate impacts has usually been framed as a local concern. In policy circles, it is regarded as matter for vulnerable countries in the global south. Yet in recent years there has been a rude awakening among governments and businesses as global supply chains have been increasingly being disrupted by heatwaves, droughts, storms and floods, as well as geopolitical events. The fact that transboundary climate risks are going to increase over time has serious repercussions for social cohesion, the economy and environment on the island of Ireland. Cross-border thinking is well-established in Ireland; the challenge is to embed climate resilience in existing processes and to act strategically in the face of new risk horizons.

Several countries have begun to consider the systemic and cascading dimensions of climate risks in their adaptation planning. Ireland has now started that process. The Environment Protection Agency's recently published report on transboundary climate risks described how climate risks propagate through different pathways to adversely affect ecosystems, economies and wider society on the island of Ireland. The report's authors called for further research to better understand the most prominent transboundary climate risks. They also highlighted the need to understand how governance structures and public policies could be most effectively leveraged to manage these risks and enhance systemic resilience.

The current study was commissioned by the Irish Climate Change Advisory Council to further explore transboundary climate risks in three specific areas: agriculture and food security, infrastructure and trade, and biophysical systems and ecosystem services. It considers risks that cascade from beyond the island's shores, as well as those that cross internal jurisdictional borders. It draws on a literature review, as well as consultation with government officials and experts from national authorities (see Section 2).

The study identifies and assesses 17 transboundary climate risks with potentially serious ecological, economical and societal repercussions for the island of Ireland (see table of risks below). It is not a comprehensive risk assessment but uses an assessment methodology based on likelihood and magnitude to rank severity (see Section 2). The policy landscape relevant to each risk is described in the full report. Here we summarise the top risks and key policy recommendations.

Transboundary climate risks to agriculture and food security

The study identified three transboundary climate risks relating to agriculture and food security. The risk of **cost-of-living crises and reduced food affordability**, due to the impacts of climate change on agriculture supply chains globally, is rated most severe among the three. However, the study also found there to be a moderate **risk to nutrition security caused by volatile supply chains for fresh fruit and vegetables**, which would disproportionately affect low-income and vulnerable households. These transboundary climate risks stem from the increasing frequency and severity of floods and droughts (amplified by existing water stress) on crop yields in climate-vulnerable agriculture regions around the world, including southern Europe, as well as the impacts of extreme weather on global logistics

operations. Climate-related disruptions to supply chains for animal feed were found to present a moderate **risk to Ireland's dairy and beef sectors**, with implications for farming and food sector jobs and export revenues.

Transboundary climate risks to infrastructure and trade

The study highlighted the cross-border and cascading effects of supply chain disruptions in key manufacturing countries. These risks result from – or are exacerbated by – extreme weather impacts on critical transport and other built infrastructure, with economy-wide consequences. Due to Ireland's high dependence on international trade, and the prominent role of global finance in the Irish economy, the island faces **moderate risk** particularly to **critical raw materials supply chains** and **foreign direct investments**, which could result in **diminished tax revenues** from affected multinational corporates in the long term. The lack of economic diversification renders Ireland particularly vulnerable to these transboundary climate risks; public policies that support greater industrial specialization are likely to make things worse.

Disruptions caused by climate change to supplies of medicines and other pharmaceutical inputs present a particularly **high risk to business operations, jobs and export revenues in the pharmaceutical industry in the Republic of Ireland** - considering the sector's sizable role in the economy. This risk was also found to be **moderate for Northern Ireland**. The island of Ireland also faces **moderate risk from shortages of essential medicines and other drugs**, which could be particularly dangerous if coinciding with pandemic outbreaks or significant rises in infectious diseases and other ailments that are expected to increase as the climate changes. Risk to businesses, jobs and export revenues due to intra-island trade disruptions from climate change were considered relatively low.

Another sector that is highly vulnerable to climate-related supply chain disruption is the energy sector. Critical minerals price shocks, or shortages, could undercut efforts by authorities in both jurisdictions to meet their emission reductions targets, with **long-term consequences for energy security on the island of Ireland**. Climate-related damages to existing energy production facilities, storage and transmission networks abroad could potentially compromise energy supplies to the island of Ireland, although this risk was assessed as relatively low. However, industrial policy ambitions to boost foreign direct investment into data centres could potentially exacerbate transboundary climate risks to energy security, due to the resulting increase in energy demand.

Transboundary climate risks to human mobility could also affect the tourism sectors on the island, but the consequences are likely to be short-lived, with negligible effects on the overall economy.

Transboundary climate risks to biophysical systems and ecosystem services

Climate change is causing dramatic geographical shifts in the distribution of plant and animal species. It is also driving the proliferation of invasive species and infectious diseases all over the world. The study identified five risks relating to these developments. Among them, the **risk to the island's ecosystem and biodiversity** was found to be of greatest severity.

The impacts of invasive species and infectious diseases on **productivity in the agriculture, aquaculture and fishery sectors** were assessed as posing moderate risks due to high potential costs, given the importance of these sectors to the islands' economies. Such dynamics are also likely to pose a threat to the forestry sector. The transboundary consequences of increased infectious disease proliferation were also found to present a moderate risk to public healthcare systems on the island of Ireland, particularly as a result of increased cardiovascular and respiratory disorders; a risk that the authors deemed insufficiently understood and appreciated.

Two risks were also identified relating to the environmental and socioeconomic consequences of climate change impacts on transboundary river basins and the ecosystems services they provide. These were considered relatively minor at present, based on the evidence reviewed.

Existing policy landscape and actions needed

Transboundary climate risks have only recently emerged on policymakers' radars. Among risk professionals, they present a serious and growing concern.

The material impact of transboundary climate risks will be determined by the governance structures, policies and interventions that are in place to enhance resilience in Ireland. Both jurisdictions acknowledge transboundary climate risks in their national risk assessments and adaptation frameworks. However, current policies and practices are inadequate.

There is a major gap in understanding what is at stake. The role of existing policies in exacerbating the island's exposure to these risks is not fully appreciated. Even more worryingly, the ownership of risks resulting from transboundary climate impacts is unclear: it tends to fall beyond the remit of most traditional "adaptation" actors, and yet it is not sufficiently claimed by anyone else. This has so far resulted in a lack of action.

A number of challenges need to be overcome. The imbalance between the policy attention allocated to mitigate climate change, versus adaptation, results in serious capacity and resource constraints among relevant authorities who should be leading the charge on building resilience. Additionally, the current bottom-up sectoral approach to climate adaptation means that there is a lack of understanding of the interdependencies between climatic and non-climatic factors in driving risk. Climate risks are insufficiently integrated into broader policy agendas.

Many decision makers in the public sector seem over-confident about the extent to which private corporations are aware or capable of strategically embedding transboundary climate risks into their plans, investments and assessments.

There is too much complacency around adaptation. Some transboundary climate risks are assumed to be a matter for the private sector exclusively, for example many risks related to supply chains. In other cases, higher tiers of governance are assumed to be responsible, for example in Brussels or London. Policymakers on the island of Ireland should take responsibility for designing and implementing decisive actions that protect against transboundary climate risks. To address some specific risks, an "All-of-Ireland" approach will be necessary. International collaboration could enhance shared resilience. Our key recommendations are presented below.

Strategic risk governance

- Systemic and cascading climate and non-climate risks should be more clearly accounted for in cross-cutting government risk registers, while future climate risk assessments should explicitly assess transboundary climate risks and identify response options. These assessments should clearly assign owners for each transboundary climate risk identified, with actions incorporated into national adaptation plans and other relevant strategies.
- A comprehensive economy-wide assessment should be commissioned to quantify the economic costs of transboundary climate risk to the Irish economy, including supply chain risks. It should highlight vulnerable sectors and risk management needs in the public and private sector.

Mainstreaming

- Relevant government departments should adopt responsibility to lead a broad resilience agenda that includes strategic preparedness, resilience-building and adaptation functions across government for all types of climate and non-climate risks.
- To complement sectoral adaptation plans, these departments should also adopt an integrated top-down approach to assess the interdependence of risks, ensure policy coherence (e.g. with industrial strategies) and enhance institutional capacity to engage with foresight and horizon scanning exercises.

Resourcing

- Government departments should allocate greater resources for adaptation functions across government to help monitor and manage domestic and transboundary climate risks and their interplay with other risks.
- Government departments, on both sides of the border, should explore the feasibility of establishing an Investment Fund for Resilience and Industrial Transition and explore options to create market incentives for private sector investments in strategic redundancies that benefit society, for example in food and critical supply chains.

Collaborating

- Relevant government departments should initiate a dialogue with industry actors to exchange views and clarify responsibilities on the risk management of overseas supply chains. They should also establish public-private partnerships to exchange non-commercially sensitive data on risk exposure in key sectors and explore opportunities for strategic investment coalitions between private actors with shared interests in critical supply chains.
- Relevant government departments should actively engage in adaptation processes under the UNFCCC and other international forums and political dialogues on trade, infrastructure, biodiversity and development to support resilience building in other countries and throughout the international networks upon which Irish prosperity depends.

Transboundary climate risks to the island of Ireland[1]

Agriculture and food security	Risk severity
Risk to food affordability as a result of the cost-of-living crisis and climate-driven price inflation across a basket of food products.	High
Risk to nutrition security for low-income households and vulnerable groups – due to volatility in fresh fruit and vegetable supply chains.	Medium
Risk to farming, jobs and export-revenues in the dairy sector on the island of Ireland, due to climate-related disruption to feeds and other imports.	Medium
Risk to farming, jobs and export-revenues in the beef sector on the island of Ireland, due to climate-related disruption to feeds and other imports.	Medium (IE) Low (NI)
Infrastructure and trade	
Risk to energy security from damage to energy-critical infrastructure abroad from extreme weather and slow-onset climate change.	Low
Risk to energy security from climate impacts on transport and production infrastructure abroad, disrupting overseas supply of critical minerals.	Medium
Risk to businesses, financial sector and overall economy due to climate-related supply chain disruptions globally.	Moderate (IE) Low (NI)
Risk to business operations, jobs and export-revenues in the pharmaceutical industry from climate-related disruption to global supply chains.	High (IE) Moderate (NI)
Risk to public health from disrupted supplies of essential medicines and other drugs as a result of climate-related disruption to global supply chains.	Medium
Risk to business operations, jobs and export-revenues on the island of Ireland, due to climate-related disruptions to intra-island trade and with the UK.	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.	Low
Biophysical systems and ecosystem services	
Ecological risk to ecosystems and biodiversity from climate-induced changes in invasive species, movements of plants and animals, and infectious diseases.	High
Socio-economic risk to the blue economy from climate-induced changes to invasive species, movements of plants and animals, and infectious diseases.	Medium
Socio-economic risk to the forestry sector from climate-induced changes to invasive species, movements of plants and animals, and infectious diseases.	Low
Socio-economic risk to the agricultural sector from climate-induced changes to invasive species, movements of plants and animals, and infectious diseases.	Medium
Social risk to people and public health systems from a climate-induced rise in infectious diseases and cardiovascular and respiratory conditions.	Medium
Ecological risk to transboundary river basins and the ecosystems and biodiversity they support from climate-induced water stress.	Low
Socio-economic risk to water services from climate-induced stress on transboundary river basins.	Low

1 The evaluation of risk severity and policy readiness draws on the review of scientific and grey literature, insights from the stakeholder consultation, and the knowledge and expertise of the authors. The evaluations are therefore based on qualitative evidence and subjective judgements, which unavoidably require assumptions on the relative importance of different climatic and non-climatic risk drivers and the different systems and aspects of the society affected.

POLICY CONSIDERATIONS

Reducing transboundary climate risks is a novel challenge, so it is no surprise that public and private actors are not yet prepared to tackle it. Drawing on interviews with government officials and other national authorities, and review of key policy documents, below we list the main aspects of the challenge and offer suggestions for how to address them.

Context

The topic of transboundary climate risks has only recently emerged as a policy concern. As a result, many stakeholders are on a steep learning curve to understand both what constitutes a transboundary climate risk and what the implications may be for policy and practice. Nevertheless, most of our interviewees have an intuitive understanding of the subject and awareness of its importance.

Both jurisdictions on the island of Ireland acknowledge transboundary climate risks in official documents. In the Republic of Ireland, explicit references to such risks are included in the 2022 Review of the National Adaptation Framework, Ireland's Climate Change Assessment 2023, and the Climate Action Plan 2024. In Northern Ireland, the national summary of the UK's Third Climate Change Risk Assessment (CCRA) identifies several transboundary risks. National risk registers in both countries (last updated in 2023) identify climate change as a key strategic risk and note the role of climate change in driving other risks. Both countries are also in the process of developing new phases of adaptation planning, with new Sectoral Adaptation Plans in preparation in the Republic of Ireland, and the Third National Adaptation Programme underway in Northern Ireland. Nevertheless, there is a lack of specificity in existing documents on what is at stake on the island of Ireland from transboundary climate risks, and ownership of risks and responses remains unclear. Awareness of the topic has not yet resulted in much action.

Both jurisdictions are to some extent participating in adaptation processes that are being led at higher tiers of governance. For the Republic of Ireland this is the EU process, specifically the follow-up to the recently published first EU Climate Risk Assessment, which put a significant emphasis on transboundary risks. In Northern Ireland this is the five-yearly UK CCRAs and the National Adaptation Programme of the UK government. Both processes are likely to continue to emphasise transboundary climate risk. Both countries may find opportunities to examine the topic further as part of these multinational efforts.

Goals and priorities for Ireland

To ensure the resilience of the Irish way of life, despite the inevitable impacts of climate change at home and abroad, decision-makers will have to adopt and apply a transboundary lens to their operations. Policy and practice in Ireland will need to consider, and deal with, the transboundary climate change impacts that occur in other countries. Policy and practice in Ireland will also need to consider the potential transboundary effects on people elsewhere to avoid redistributing or exacerbating risks to others. By adapting effectively to both domestic and transboundary climate risks, Ireland will also contribute to the resilience of the global economy, because it would be acting as a reliable and predictable trade partner through ensuring safe and resilient ecosystems and as a responsible and thoughtful contributor to European and global governance.

This report highlights three main pillars that future resilience can be built upon. Each requires sustained public investment and prioritization in national policy. These pillars are:

- **Social cohesion.** A more unequal society will be more severely affected by mounting transboundary climate risks via cost-of-living crises, job losses and health impacts, among other factors. Investments in social protection, welfare, health, communities, education and wellbeing will increase Ireland's capacity to absorb and thrive despite transboundary climate risks.

- **Natural resilience.** The health and integrity of Ireland's natural capital will support adaptation to transboundary climate risks that arrive via changes to ecosystems on land and sea beyond its borders.
- **Resilient supply chains.** Ireland's import-dependent and export-reliant economy can continue to grow and deliver prosperity if there is a sufficient flow of risk data, effective risk management, and resilient infrastructure in trade, energy, information technologies and transport.

Challenges

- **A focus on "climate risks" is too narrow.** Overall, the challenge of building resilience cannot be met by focusing exclusively on "climate risks". Societal, economic and environmental resilience depend on a much broader problem framing and a broader policy agenda based on an understanding of transboundary climate risk.
- **Mitigation efforts currently overshadow adaptation**. Adaptation remains in the shadows of climate change mitigation as a policy objective and research field in Ireland, as elsewhere. Many initiatives and policies that explicitly acknowledge climate change still focus mainly if not exclusively on cutting emissions. Mitigation tends to be prioritized before adaptation in decisions about how to spend limited resources.
- **Complacency impedes progress.** There remains a sense of complacency around adaptation. Complacency also pervades thinking about supply chain resilience, which is either assumed to be a matter for private decision-makers, or a strategic concern handled at an EU level or in London, in the case of Northern Ireland. This leads to a lack of creativity and a lack of focus on the unique risk profile of Ireland in a rapidly changing risk landscape.
- **Many actors question the need for government intervention.** There is a pervasive but questionable assumption that markets will adequately price these climate risks, and that autonomous adaptation will deliver resilience without the need for state intervention. This assumption is slowly changing in the wake of the pandemic and, perhaps, driven in part by growing concerns with the dawn of artificial general intelligence and other novel risks, such as anti-microbial resistance.
- **Climate risks have yet to be embedded into strategies.** As an island, Ireland is accustomed to transboundary-oriented thinking and addressing matters of interdependence. These are concepts are prominent in the minds of policymakers and planners on both sides of the border. This was especially evident in our interviews. The main gap is the consideration of how future climate change impacts will drive and radically alter transboundary dynamics. There remains a lot to do to embed climate risk in existing north-south cooperation forums (as well as their east-west equivalents) and in broader international strategies on both sides of the border.
- **Climate risks are not yet adequately considered in "non-climate" fields.** When it comes to foreign affairs and Irish links to other countries, energy and trade interests dominate. Strategic risks resulting from climate change impacts in partner countries are – at best – an afterthought. While "non-climate" policies can deliver climate resilience on some matters (energy security, for example), the lack of explicit consideration of transboundary climate risk in these fields may produce ancillary costs, as well as benefits.
- **Risks are exacerbated by the reliance of Irish economies on a limited number of sectors.** Specialisation in pharmaceuticals, information technology, and food and drink concentrate exposure to transboundary climate risk. It is tempting for industrial and economic policy to reinforce this reliance to protect tax revenues, but this can result in policies that exacerbate risk exposure in ways that are not strategic.
- **Political uncertainties have slowed progress.** Recent political uncertainty in Northern Ireland linked to the UK's departure from the EU has slowed progress and distracted efforts to advance ambitious and strategic policy agendas on issues including adaptation and transboundary cooperation.

- **The uncertainties and complexities of transboundary climate risks make it difficult to convince sceptics about the need for policy action.** It is inherently complex to assess exposure to transboundary climate risk. High levels of uncertainty are inevitable. Interviews showed that this creates a hurdle for moving beyond a general awareness of the topic. Such complexities and uncertainties cloud decision-making about next steps and priorities – and the actions that flow from these. Uncertainty around transboundary climate risks is greater than for those resulting from direct impacts. Risks depend, potentially, on impacts in multiple locations outside Ireland, and to an even greater extent than normal on the *responses* of actors overseas on matters such as trade measures, or the success or failure of adaptation efforts at sources where impacts originate. It is difficult to make a robust case to convince sceptical stakeholders that specific risks will materialize in Ireland.
- **The networks of stakeholders who should be engaged in addressing such risks will need to expand.** In many cases, the ownership of transboundary climate risks might lie beyond the traditional network of stakeholders involved with climate change adaptation, for example in departments of trade or foreign affairs, or at the heart of government, or among supply chain managers in businesses. This stretching of the understanding of "adaptation" and "climate risk management" takes time, and it is currently in an early phase.
- **Governments' adaptation efforts tend to be led by departments with less influence and fewer resources.** Adaptation tends to be led and coordinated by environment departments that often lack the leverage and political and financial clout to drive changes in more powerful government departments. Transboundary climate risk suffers from a lack of champions and policy entrepreneurs inside government in Ireland, as in other countries.
- **Policies can be incoherent and poorly coordinated.** Transboundary climate risks invite a new strategic approach to policy integration. For example, multiple policy fields will be required to respond to risks emanating from a single pathway, such as the increase in invasive species: across farming, forestry, biodiversity, health, and more. The many risks identified in this report add to the complex field of systemic risks and global challenges facing small, open, globalised countries. Currently there is no centralised coordination of "the resilience agenda" in the heart of government.
- **One island; two distinct political systems.** Resilience to transboundary climate risks on the island of Ireland depends on making progress in two different political systems. Whilst the UK engagement with this topic is perhaps a few years ahead of that in the Republic of Ireland, both face similar challenges and limits to their spheres of influence. Risks cannot be managed "at source" across such a broad array of partner countries, nor can international systems, such as commodity markets, or long risk pathways, such as those related to vector-borne diseases, be controlled from Dublin, Stormont, London or Brussels. Coordinating across ministries to achieve coherent action on resilience remains a significant challenge.
- **Balancing social and economic vulnerabilities.** The severity and nature of transboundary climate risks – as well as their relative priority – depend to a large extent on the perspective taken; some framings suggest strategic economic risks to profitability in key sectors, whilst alternatives imply social cohesion and equity are more at stake. It is important to avoid the dominance of powerful perspectives, particularly in a field where evidence and data are thin, when setting early direction and priorities on government policy that might determine the course of adaptation strategy for years to come.

RECOMMENDATIONS

These recommendations have emerged from interviews with key stakeholders on the island of Ireland and from the analysis conducted by the authors.

Steps for leaders

- Organize a high-level event – on a theme such as "Reimagining Resilience in Ireland" – to gather stakeholders from government, business and research, catching the wave of heightened awareness among senior decision-makers in the wake of the pandemic and in response to growing geopolitical uncertainty about the fragility of global supply chains and mounting systemic risks.
- Prepare a briefing for the Department of the Taoiseach setting out the case for greater coordination of the "resilience agenda" across government departments.
- Commission an ambitious and innovative assessment of the economic costs of transboundary climate risk for the Irish economy.

Steps for governments, departments and offices

- Responsibility for leading the Republic of Ireland's broader resilience agenda should be clearly assigned to the Department of the Taoiseach. This agenda goes beyond existing emergency management provisions to include strategic preparedness, resilience-building and adaptation functions across government for all types of climate and non-climate risks.
- The division of labour between the Northern Ireland Executive and UK Cabinet Office on resilience planning in the wake of the UK's departure from the EU should be clarified and communicated clearly to stakeholders in Northern Ireland and beyond.
- National assessments (National Risk Assessment in Ireland, UK National Risk Registers in Northern Ireland) should more clearly account for the interaction between emerging, cascading and systemic risks, and clarify risk ownership for each identified risk within government.
- Governments on both sides of the border should launch a "strategic coherence for resilience" initiative across all government departments and policy domains. This should identify and assess key policy incoherencies. That is, the initiative should point out and evaluate any existing policies that are driving risk exposure in Ireland. This initiative should also clarify the objectives and primacy of specific policies and strategies for ensuring the resilience of the Irish and Northern Irish economies in the face of mounting critical supply chain risks, and other risks related to or exacerbated by cross-border climate change impacts. Moreover, this initiative should identify where shared policy objectives across different domains and departments could lead to greater inter-departmental cooperation on resilience and adaptation.
- Government capacity in foresight and horizon scanning exercises should be built, through a mix of staff development, training, recruitment and collaboration with external experts (such as the UK National Preparedness Commission). Such foresight exercises should integrate the assessment of transboundary climate risks with other "external" dynamics, such as artificial intelligence, cyber security, poorly managed migration and geopolitical rivalry.
- The Department of the Taoiseach should conduct or commission an economy-wide assessment of critical supply chain risks, highlighting the specific risks to sectors and segments of society in Ireland, and the options for risk management among relevant actors in government and the private sector.[2]

2 Lessons from the UK Department for Business and Trade's new Supply Chains Resilience Framework should inform the process. See: https://www.gov.uk/government/publications/supply-chain-resilience/dit-supply-chains-resilience-framework

- Relevant government departments should initiate a dialogue with Irish businesses to exchange views and clarify responsibilities on key supply chain risks affected by climate change impacts overseas. The dialogue should address matters that involve key sectors, including food and agriculture, pharmaceuticals, information technology, and cross-border critical infrastructure.
- A private-sector taskforce should be established to convene public sector actors, corporations and financial institutions to incentivise corporate action on climate adaptation in supply chains. The Republic of Ireland should also establish sectoral business coalitions to spur co-investment for resilience in shared and socially valuable supply chains.
- Governments on both sides of the border should initiate a consultation with vulnerable communities to incorporate their views on risk exposure and effective responses in light of transboundary climate risks described in this report.
- The Republic of Ireland should explore the feasibility of establishing a National Investment Fund for Resilience and Industrial Transition.
- The next iteration of Ireland's Industrial Strategy[3] should assess the options for and resilience benefits of economic diversification. The strategy should clarify the role of government in supporting "profitable redundancy" in critical supply chains and the strategic stockpiling of critical goods and inputs to the Irish economy.

Steps to advance the adaptation agenda

- The next iteration of each country's national climate change risk assessments should identify and assess transboundary climate risks and assign clear ownership for each risk.
- The next iteration of each country's national adaptation framework or plan should do the following: assess response options for each transboundary climate risk; allocate resources for adaptation; assess interactions between transboundary climate risks and between these risks and non-climate risks; clearly designate coordination responsibilities within governments to ensure coherence across the national adaptation framework; and describe the role of international action and cooperation for addressing transboundary climate risks in Ireland.
- Given that these next iterations may be years away, significant preparatory work is needed now to clearly assign risk ownership and advance understanding and capacity on "resilience" in government.
- As part of fulfilling Ireland's international obligations, including those under the Paris Agreement, national governments should highlight and describe actions to prevent "transboundary maladaptation" – that is, to point out the actions taken in Ireland to reduce climate risks and avoid exacerbating risks for people in other countries. These actions should be communicated in submissions to the UN, such as Adaptation Communications, Nationally Determined Contributions and biennial transparency reports.
- The Republic of Ireland and the UK should continue to contribute finance for adaptation in other countries. They should actively engage in the UN Framework Convention on Climate Change adaptation process and other international forums and political dialogues on trade, infrastructure, biodiversity and development to help build resilience in other parts of the world.

Steps to advance research and development

- The current gap in knowledge around the sources, scale and nature of Ireland's exposure to transboundary climate risk needs to be filled through investment in research, as well as the provision of decision-support tools and platforms.

3 Ireland's Industry 4.0 Strategy 2020-2025. See: https://enterprise.gov.ie/en/publications/publication-files/irelands-industry-4-strategy-2020-2025.pdf

- The Irish Government should explore the need for establishing a knowledge centre or research programme on transboundary climate risk exposure for Ireland and the UKPublic-private partnerships to coordinate the exchange of non-commercially sensitive data on risk exposure should be established between government and trade associations, particularly for key sectors such as pharmaceuticals, information technologies, and food and drink.
- The Shared Island Initiative should explore the feasibility of establishing research and greater knowledge exchange on "all of Ireland resilience", particularly on shared infrastructure, transboundary resources and seas, and mutually critical supply chains and industrial sectors.

1. INTRODUCTION

The island of Ireland is no stranger to the direct impacts of climate change, with cases of extreme temperatures up 35% within a generation and sea levels now rising 2.5 times faster than last century [1] [2, 3]. Of less prominence, but of equal if not greater threat, are the risks Ireland is exposed to because of the impacts of climate change in countries and regions beyond its borders. These so-called "transboundary climate risks" can cross continents and cascade across sectors, disrupting ecosystems, economies and societies from the local to the global scale.

While some conduits of transboundary climate risk, such as shared ecosystems and cross-border migration, have existed throughout history, the interconnected nature of our modern world means that risks now also propagate through global trade and financial flows. The island of Ireland boasts one of the world's most open economies, and transboundary climate impacts present a serious socio-economic risk to the trade, finance and workforce upon which both the Republic of Ireland and Northern Ireland depend.

Extreme weather events that are aggravated by climate change are already placing international supply chains under considerable strain and putting at risk the security of food, energy and many other commodities [4]. At the same time, climate change is altering and disrupting ecosystems the world over – driving the proliferation of invasive species and significantly impacting the emergence, prevalence and geographical distribution of vector-borne diseases. These factors, in concert, pose a growing threat to the ecology of the island and its services – from fisheries to forestry to food production.

Transboundary climate risks are also amplified by their interplay with non-climatic drivers, as demonstrated by the compounding impacts of droughts in the United States, Europe and Asia, and Russia's war in Ukraine, which together culminated in the rapid deterioration of food security experienced around the world in recent years [5, 6]. Transboundary risks can also be generated or exacerbated by countries' own adaptation responses: for example, imposing export controls in response to declining agricultural crop yields may seem like an effective adaptation response for one country, such measures tend exacerbate market effects, diminish global food supply, and undermine the resilience of the global food system as a whole. Adopting a transboundary lens when identifying and assessing climate risk, and in planning adaptation and effective policy responses, is therefore essential.

There is an emerging recognition among scientists, businesses and governments that interconnected risks require an interconnected response. The 2021 EU Adaptation Strategy, for instance, recognises that even local climate impacts can have global repercussions and encourages actions to address their transboundary effects. The 2024 European Climate Risk Assessment goes a step further, fully integrating transboundary climate risks and assessing the vulnerabilities that stem from Europe's interconnectivities as well as the socio-economic implications [4]. In addition to these regional developments, a growing number of countries are taking early but innovative steps to identify the national risks presented by transboundary climate impacts – and begin to consider these in adaptation planning processes – with Ireland a case in point.

The Environmental Protection Agency recently published a report that identified the transboundary climate risks facing the island of Ireland and described seven different pathways through which such risks propagate [7]. While the report broke ground in producing a "first pass" assessment of transboundary climate risks to the island, the report's authors called for a better understanding of the most prominent transboundary climate risks and the governance structures and what public policies would be most effective in managing them and strengthening systemic resilience.

Against this backdrop, the Irish Climate Change Advisory Council commissioned this study to further develop understanding of transboundary climate risks to the island of Ireland, via its agriculture and food security; infrastructure and trade; and biophysical systems. The study considers both the transboundary effects of climate change impacts originating in countries outside the island of Ireland, as

well as cross-border risks transmitted between the Republic of Ireland and Northern Ireland. As the methodology makes clear, this study falls short of a fully comprehensive risk assessment. But its purpose is to provide policymakers with sufficient information, indications of risk severity, and guidance to map out next steps – paving the way towards more effective policy and practice on transboundary climate risk management.

The study identifies and describes 17 transboundary climate risks with potentially serious ecological, economic and/or societal consequences for the island of Ireland (as a whole or to an individual jurisdiction), through the three risk pathways set out above. The study provides an indicative evaluation of the severity of each identified risk, considering the likelihood of its occurrence based on the latest available scientific evidence, and the magnitude of its impact in the context of the island's ecological and socioeconomic vulnerability. The methodological approach adopted for the evaluation is outlined in section 2. Sections 3 to 5 summarise the evidence base underpinning the evaluation for each of the three risk pathways. These sections also explore to what degree the existing policy landscape – at the global, regional and national level – ameliorates or exacerbates the identified risks and examine the current level of policy readiness to address them.

The final section distils a suite of policy recommendations on how authorities in the Republic of Ireland and Northern Ireland can leverage existing policy frameworks and institutional arrangements, and design new policy levers, to effectively manage the transboundary climate risks that pose a serious threat to the island of Ireland. The recommendations distil opportunities that are open to existing institutional bodies, both within and across the island's two jurisdictions, to better coordinate and collaborate to strengthen ecological, economic and societal resilience on the island of Ireland, in a manner that is inclusive and socially just.

Assessing climate risk through a transboundary lens and adopting a corresponding approach to adaptation provides an opportunity to demonstrate Ireland's strategic foresight and initiative. This presents an opportunity not only for Ireland to safeguard its own economic competitiveness, but to demonstrate how such actions fortify global resilience in an increasingly risky world.

2. METHODOLOGICAL APPROACH

This study is based on a comprehensive literature review and stakeholder consultations, both of which underpin the identification of specific transboundary climate risks to the island of Ireland within pre-determined risk transmission pathways. The study builds on the 2021 report Transboundary Climate Risks to the Island of Ireland [7]. It further develops three risk transmission pathways and indicates the severity of the risks identified. The study charts the relevant policy landscape and articulates promising mechanisms for policy development.

In accordance with instruction from the Irish Climate Change Advisory Council Secretariat, the study confined its coverage and analysis to transboundary climate risks that propagate through risk pathways relating to 1) trade, agriculture and food security, 2) infrastructure and trade, and 3) biophysical and ecosystem services. As a result, other potential transboundary climate risks to the island of Ireland, including those related to human mobility, migration and displacement and others raised during stakeholder consultation, are beyond the scope of the study but could usefully be the subject of further analytical attention in future. The authors conducted a review of scientific and grey literature to identify potential risks and examine their implications for both the Republic of Ireland and Northern Ireland. These risks included those originating from neighbouring regions (i.e. Great Britain and Europe) and more remote parts of the world. Semi-structured stakeholder consultations were held with 11 central government officials and 2 experts from national authorities spanning both jurisdictions, as noted in Table 1. (While subnational authorities and private-sector representatives were invited to consultation, it is regrettable that none were able to take part.) The consultations were used to augment the findings of the literature review with qualitative insights that were used to inform risk identification and prioritisation and formulate policy recommendations.

Table 2.1. List of government departments and national authorities on the island of Ireland consulted for the purpose of this study.

Government department/Institution	Jurisdiction
Department of Taoiseach	Republic of Ireland
Department of Public Expenditure, NDP Delivery and Reform	Republic of Ireland
Department of Finance	Republic of Ireland
Department of the Environment, Climate and Communications	Republic of Ireland
Department of Agriculture, Food and the Marine	Republic of Ireland
Department of Transport	Republic of Ireland
Department of Enterprise, Trade and Employment	Republic of Ireland
Department of Foreign Affairs	Republic of Ireland
Department of Health	Republic of Ireland
Met Eireann - Irish National Meteorological Service	Republic of Ireland
National Parks and Wildlife Services	Republic of Ireland
The Executive Office	Northern Ireland
Climate Northern Ireland	Northern Ireland

The stakeholder consultations probed government officials and other national authorities on the following:

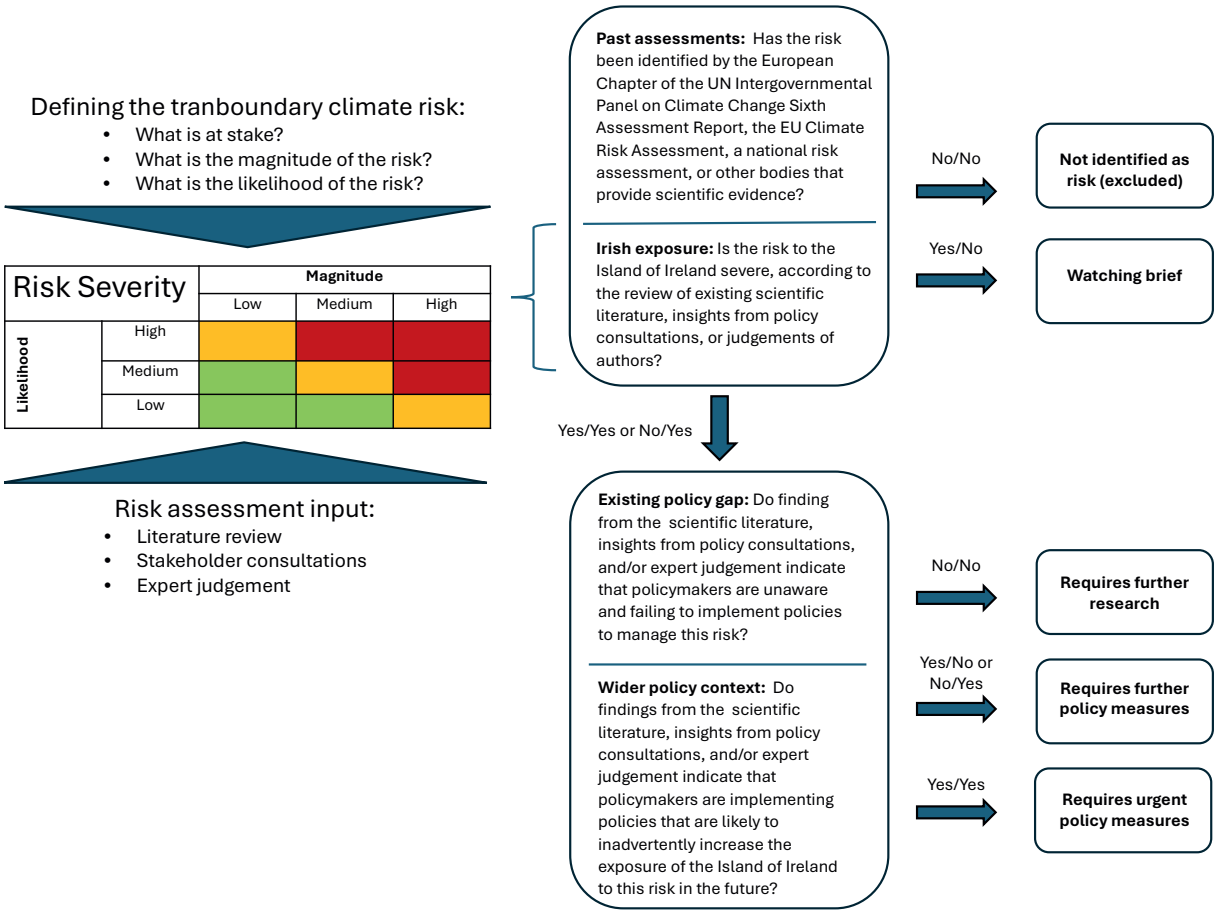
- the possible and/or probable transboundary climate risks to the island of Ireland as a whole or to an individual jurisdiction

- the economic, societal and environmental context of the island of Ireland as it shapes each jurisdiction's exposure and vulnerability to transboundary climate risks
- the existing policies that manage these risks, identifiable gaps, and assignment of risk ownership across relevant institutions and the governance landscape.

A bespoke methodology was developed to rank and prioritise the identified risks. The methodology used a two-stage approach to evaluate and determine risk severity and degree of policy readiness for each of the identified risks (see Figure 2.1). In the first stage, authors defined the risk generated by transboundary climate impacts by exploring what was at stake based on their expert judgement, the stakeholder consultation, and a review of the literature, including the European chapter of the UN Intergovernmental Panel on Climate Change Sixth Assessment Report [8], the European Climate Risk Assessment [9], and national risk assessments (among others). The authors also determined whether a given risk was applicable, and to what degree of severity, to the island of Ireland overall or to an individual jurisdiction specifically.

A conventional risk matrix was used to determine the overall severity of the transboundary climate risk through the subjective quantification of its likelihood[4] and magnitude[5]. A cut-off threshold was set so that all risks categorized with "high" or "medium" levels of severity were considered to require priority actions to manage them (in policy or research). Risks that failed to meet this threshold (i.e. those

Figure 2.1. An overview of the methodological approach to determine risk severity and policy readiness for each of transboundary climate risk (TCR), which depicts each stage and criterion for assessing risk severity and policy needs



4 Likelihood refers to "the chance of a specific outcome occurring, where this might be estimated probabilistically" [242].

5 Magnitude refers to "pervasiveness of the consequences, degree of change, irreversibility of consequences, potential for impact thresholds or tipping points, potential for cascading effects beyond system boundaries" [8].

with "low" severity) were considered "watching briefs" – a term used by both by the insurance sector and by the European Climate Risk Assessment to refer to issues that should be monitored but are not of immediate concern. The authors' ratings of likelihood, magnitude and overall severity are presented in risk tables in each of the three thematic chapters, alongside an indicative rating of policy readiness (see below). The level of confidence of the existing evidence base for a given transboundary climate risk is also indicated in these tables. However, the authors did not account for levels of confidence in determining the degree of risk severity.

In the second stage, the authors carried out a high-level evaluation of the level of policy readiness – at global, regional (EU) and national scales – for the management of each transboundary climate risk. This evaluation was based on the insights elicited from consultations with government officials and the review of existing legislative documents, policies and plans (and assessments thereof). The authors also considered the relevant location of risk ownership to account for the differential legislative responsibilities and policy landscapes of the Republic of Ireland and the EU Commission on one hand, and Northern Ireland authorities and the UK government on the other. The level of policy readiness was determined by considering the following two factors:

- **Existing policy gaps** – the awareness among policymakers of a particular transboundary climate risk and quality of existing (or planned) policy measures to manage it.
- **Wider policy context** – the existence of current or anticipated policies that are designed to deliver different objectives but inadvertently exacerbate the transboundary climate risk in question.

The authors grouped recommended policy actions into three categories as follows:

- **Requires further research** – This category indicates that the risk should be a priority for research action to determine the preparedness of existing policies to fully manage the risk. It was used in cases where the authors did not identify any significant policy gaps, where the broader policy landscape was considered conducive to reducing or managing a particular transboundary climate risk, or where the creation of an effective enabling environment in policy was foundational upon the formulation of new knowledge.
- **Requires further policy measures** – This category indicates that a risk is a priority for policy action. It applies to cases where authors determined there to be an existing policy gap *or* a broader policy landscape that failed to ameliorate a particular transboundary climate risk (or that unintentionally exacerbated the risk).
- **Requires an urgent policy response** – This category indicates that a risk is a high priority for policy action. It applies to cases where authors determined there to be both a serious policy gap *and* a broader policy landscape that failed to manage a particular transboundary climate risk (or that exacerbated the risk).

The evaluations of risk severity and policy readiness are based on the review of scientific and grey literature, insights from the stakeholder consultation and knowledge and expertise of the authors, relying on both quantitative and qualitative evidence. As such these evaluations rely on subjective judgements, which unavoidably require assumptions on the relative importance of different climatic and non-climatic risk drivers and the different systems and aspects of society affected.

3. TRANSBOUNDARY CLIMATE RISKS TO AGRICULTURE AND FOOD SECURITY

3.1 Introduction

The island of Ireland is dependent on imports for its food and nutrition security. Although Ireland's temperate climate supports a healthy agricultural sector, both the Republic of Ireland and Northern Ireland have increasingly embraced a liberal trade strategy for securing an affordable and diverse supply of food. As a result, the impacts of climate change on farms and supply chains in other countries will have significant effects on Ireland's food security in future.

Ireland is also home to extensive beef and dairy industries. These sectors are responsible for generating €10bn in export revenue [10]. Whilst plentiful rain and mild winters support world-leading quality pasture for feeding beef and dairy cattle, the sector has grown to such an extent that it also relies on significant imports of feed to maintain export volumes and earnings. Beef and dairy exports are at risk from climate change impacts on their international supply chains.

3.2 Food affordability and cost-of-living crisis

Risk	Likelihood	Magnitude	Risk severity
Risk to food affordability as a result of the cost-of-living crisis and climate-driven price inflation across a basket of food products.	High	Medium	High
Confidence	**Medium**		
Policy status	**Priority for policy action**		

Globalisation and the industrialisation of the global food system mean that most of the food that is consumed on Irish shores is the product of multi-tier international supply chains. Even a typical cooked Irish breakfast with products from local farms relies ultimately on several inputs from other countries. The maize starch in baked beans [11] – as well as the beans themselves – will have been imported from as far away as Brazil, or Canada, or Ukraine, all of which face increasing drought and pest risks in a changing climate [12]. Even locally sourced bacon and sausages come from pigs that will have been fed on a blend of imported wheat, barley, maize and soy, supplies of which are becoming more volatile as a result of climate change impacts on farms in major grain exporting countries in Latin America, North America and Russia [13] [14]. The same goes for the sugar in the marmalade, the tea in the mug and the fried tomatoes on the side: all are imported. Perhaps potatoes will be the only truly domestic, short supply chain product on the breakfast plate un-touched by transboundary climate risk.

The benefit of Ireland's complex, globalised food system is that food has become more affordable, and consumers enjoy a diverse choice of products. Trade liberalisation, EU membership and a busy, competitive market have ensured this. Businesses take care of the myriad daily sourcing decisions, exploring and administering supply chains to meet – and even to stoke – demand among Irish shoppers. Having access to multiple suppliers and markets also helps to smooth out minor variations in harvests. This facilitates "autonomous adaptation" to climate change; when flooding hits farmers in one country, supply chain managers quickly contract alternative suppliers to make up the shortfall. The government doesn't have to do anything. Nor do shoppers.

The downside is that the web of producers and suppliers upon which Irish consumers depend lie beyond the reach of Irish decision makers. Whilst supply chains offer flexibility during small shocks, they have evolved to deliver efficiency, not resilience. Concurrent or major shocks, like the war in Ukraine,

knock finely tuned supply networks out of kilter. Climate change is a driver of concurrent or compound shocks because it is playing out everywhere at once [15] [16]. It is also accelerating, and likely to produce and magnify major shocks in future [17].

Climate impacts on agriculture and food supply chains in other countries will increase, exposing the island of Ireland to heightened levels of risk. This risk has been identified in previous Irish and UK climate risk assessments, including the Transboundary Climate Risks for the Island of Ireland Report (Chapter 3 [18]), the Climate Change Adaptation Risks and Opportunities for Irish Businesses report [19], the Northern Ireland Summary of the UK Climate Change Risk Assessment (ID1, ID2, ID7) [20] and the European Climate Risk Assessment [21].

The price, availability and quality of food in Ireland will be directly impacted by climate change effects on farming abroad, but also by the reactions of other actors in those and intermediary countries. For example, in 2023 when droughts threatened rice harvests in India, their government banned exports to protect domestic consumers. This reaction continues to affect global rice prices today because it triggered a string of export restrictions and panic buying in other countries [22]. This pattern of climate events triggering market reactions will play out across commodity classes, throughout the global food system, leaving import-dependent countries like the Republic of Ireland and Northern Ireland at the mercy of volatile markets. As such, actors based in Ireland the UK are limited in their capacity to manage high levels of exposure to climate change risks emerging from the global food system.

Why does this matter? Can Irish supermarkets not work around poor harvests in supplier countries? Can Irish consumers not absorb higher prices while shocks last? Given the complexity of modern supply chains, and the pervasiveness of climate risk, shocks and price increases will become a fact of life in a climate constrained, globalised world. Many middle and high-income Irish households may indeed be able to accommodate higher food and drink prices without much effect. But low income and vulnerable households cannot.

The price of an average household's weekly food basket will go up as a result of transboundary climate risk. This is because the ingredients and "inputs" that are used to produce a wide range of modern food products will become more expensive as damaging climate impacts occur with increasing frequency and intensity throughout the supply network of the Irish food system.

Safe Food assessed the cost of a weekly minimum essential food basket in Ireland for different household types [23]. Table 3.1 below uses the categories from this report to briefly survey the transboundary climate risks associated with each food group.

Table 3.1. Transboundary climate risk profile for a typical weekly food basket.

Irish weekly food basket categories	% household expenditure (MESL) for an average Irish family[6]	TCR profile
Breads and cereals	10%	Medium – mostly imported from relatively-resilient UK and EU partners.
Meat	24%	High – price volatility expected due to the high level of embedded resources and water in meat.
Fish	5%	Low – some species at risk from climate change impacts in the seas; farmed fish will be impacted by supply chain risks to feed.

6 MESL stands for Minimum Essential Standard of Living. Average household is two adults and two children at primary school and secondary school age. Figures exclude 8% on "cafes and takeaways" and 2% on "social" (a category that includes hosting guests, and Christmas expenditure).

Irish weekly food basket categories	% household expenditure (MESL) for an average Irish family[6]	TCR profile
Milk, cheese and eggs	15%	Medium – prices will be impacted by cattle feed supply risks.
Oils and fats	1%	Low
Fruit	7%	High – impacts will reduce yields and disrupt harvests in southern Europe and tropical countries that supply Ireland.
Vegetables	15%	High – volatile supply chains affected by flooding, seasonal variability, drought and heat stress.
Sugar, jam, honey, etc.	1%	Medium – sugar prices will rise as global supply becomes less predictable; fruits less predictable, but freshness not important; honeybees somewhat sensitive.
Other food products	3%	Low
Coffee, tea and cocoa	2%	High – highly sensitive crops will become more and more expensive as impacts accumulate.
Soft drinks, juices, etc.	2%	Low – embedded sugar will gradually increase soft drink prices.
Snacks and treats	4%	Medium – highly processed snacks embed multiple commodities that will become more expensive.

Source: Safe Foods (2023) and author's analysis.

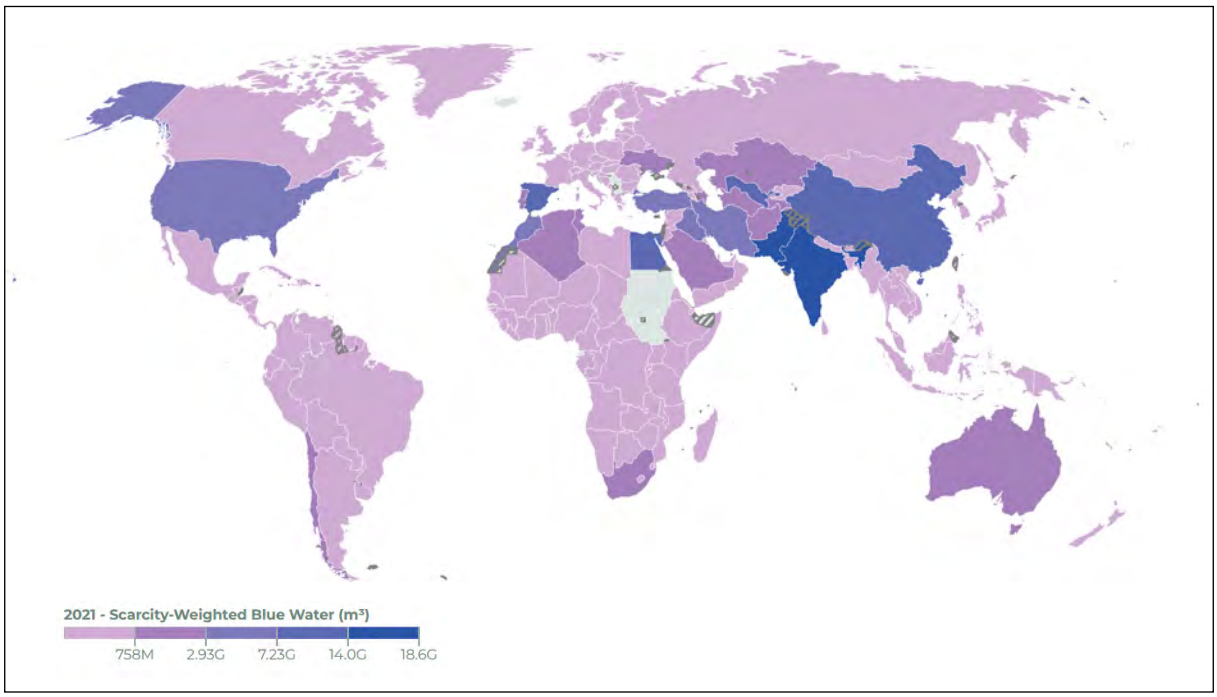
Food and drink that is consumed in Ireland has many commodities "embedded" in it. This means, for example, that a Snickers bar may have cocoa from West Africa (imported and processed via the EU), peanuts from the US, Turkey or India, sunflower oil from Ukraine, palm oil from Malaysia or Indonesia and sugar from Brazil. As such, the embedded water, meaning water that was used in the farming and production of the ingredients that went into the Snickers bar would have come from many different countries. This can be expressed as a water "footprint" – the total water use required to meet Ireland's consumption demands. The map in figure 3.1 shows the Republic of Ireland's water footprint, weighted for water scarcity, meaning it shows where Ireland is consuming embedded water from countries that are experiencing water scarcity, making them particularly vulnerable to the impacts of climate change, such as drought.

In the same way, Irish consumption has a land footprint. Figure 3.2 shows the area of land used for crops and other agricultural products embedded in the Republic of Ireland's consumption.

The Republic of Ireland's land and water footprints have been expanding in recent years[7], exposing consumers to ever higher levels of climate risk. The hotspots of water inputs into Irish consumption happen to be some of the areas with the highest vulnerability to climate change, for example India (116/185 most vulnerable countries in the world [24]), whereas its land footprint links Ireland with some of world's top exporters of climate risk via key agricultural commodity trade such as the US, China, Russia, Brazil and Argentina [14].

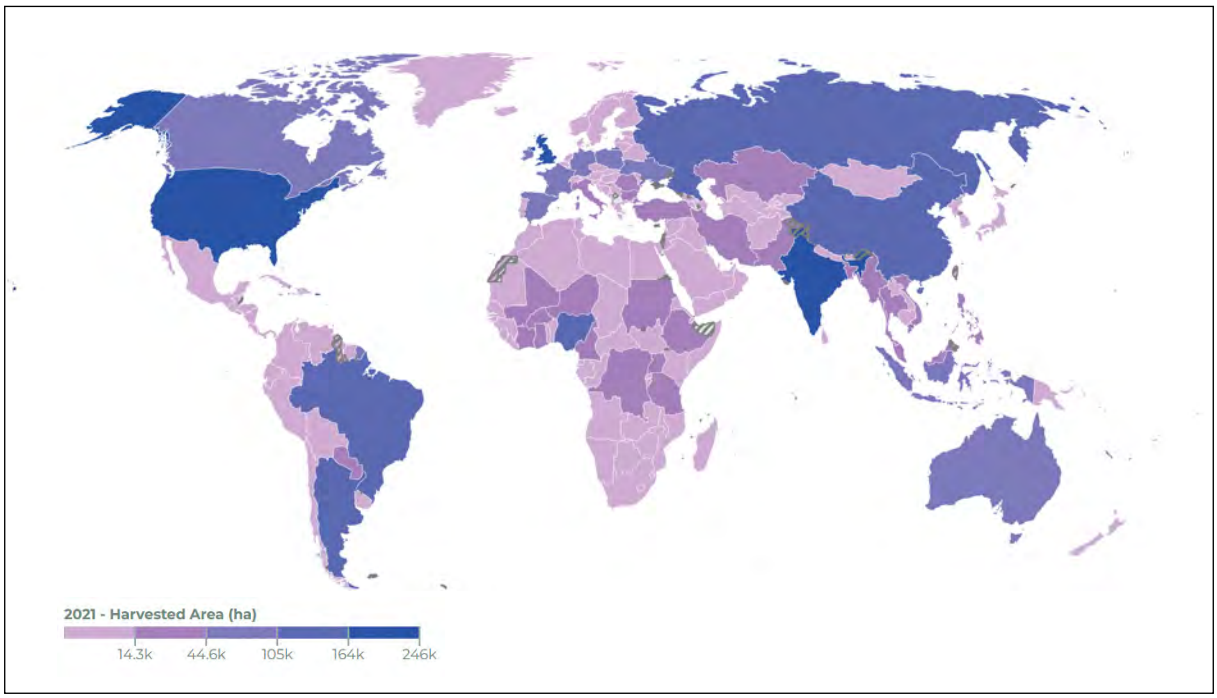
7 The Global Environmental Impacts of Consumption (GEIC) Indicator, data comparison from 2017–2021 (last available year of data) shows an increase in water footprint (blue water adjusted for water scarcity) from 62.4G metres cubed in 2017 to 126G metres cubed in 2021, and in land footprint (harvested area) from 1.74M hectares in 2017 to 3.06M hectares in 2021.

Figure 3.1. Republic of Ireland's water footprint to produce materials embedded in consumption (blue water, meaning surface and ground water) in cubic metres, adjusted for water scarcity



Source: https://commodityfootprints.earth/

Figure 3.2. Ireland's land footprint: harvested area (in hectares) for crops embedded in the Republic of Ireland's consumption



Source: https://commodityfootprints.earth/

As such, Ireland's exposure to transboundary climate risk is not the result of one or two key supply chains. It is the culmination of tens of thousands of inputs across a variety of different international markets. The risk is embedded in the ingredients and products that are to be found on supermarket shelves and markets on the island of Ireland. Climate change impacts in far off farmers' fields will lead to long term price increases for Irish food shoppers, putting pressure on the cost of living.

3.3 Risks to fresh produce

Risk	Likelihood	Magnitude	Risk severity
Risk to nutrition security for low-income households and vulnerable groups – due to volatility in fresh fruit and vegetable supply chains.	Medium	Medium	Medium
Confidence	**High**		
Policy status	**Priority for policy action**		

The majority of fresh fruit and vegetables consumed in Ireland was grown overseas, mostly in the EU (Spain and the Netherlands) and the UK, but also further afield, including North Africa and Central and South America. Imports have increased 42% since 1992: mostly of field vegetables, tropical fruit, apples and soft fruit [25]. The same picture applies in Northern Ireland; the UK imports roughly half of its vegetables and the vast majority of its fruit [26].

Farming, harvesting and transporting fresh horticultural produce are very climate sensitive processes. Extreme temperatures lead to heat stress in crops and fruit trees leading to reduced yield and lower quality [27]. Drought and flood events can disrupt fruiting periods, as well as disrupt harvests, increasing losses and reducing the quantity of fruit and vegetables that make it on to the market. Extreme weather, including heavy precipitation events, storms, wildfires and even heatwaves, can significantly disrupt time- and temperature-sensitive supply logistics, resulting in higher fruit and vegetable prices [28]. Prolonged growing seasons might increase yields in years when sufficient water and other conditions are conducive [27], but overall, the increasing variability of yields caused by climate change will result in more volatile prices for fresh produce. The nutritional value of imported fresh produce may also decrease as a result of climate change [27].

The share of fruit and vegetables imports from climate risk hotspots is increasing as competition to meet Irish and UK demands increases, bringing more developing countries into the reach of modern supply chains [29]. A UK assessment found that by 2050 over half of legume imports and 47% of fruit supply would come from climate-vulnerable countries, with an overall shortfall likely in the supply of fresh fruit and vegetables to meet UK dietary recommendations.

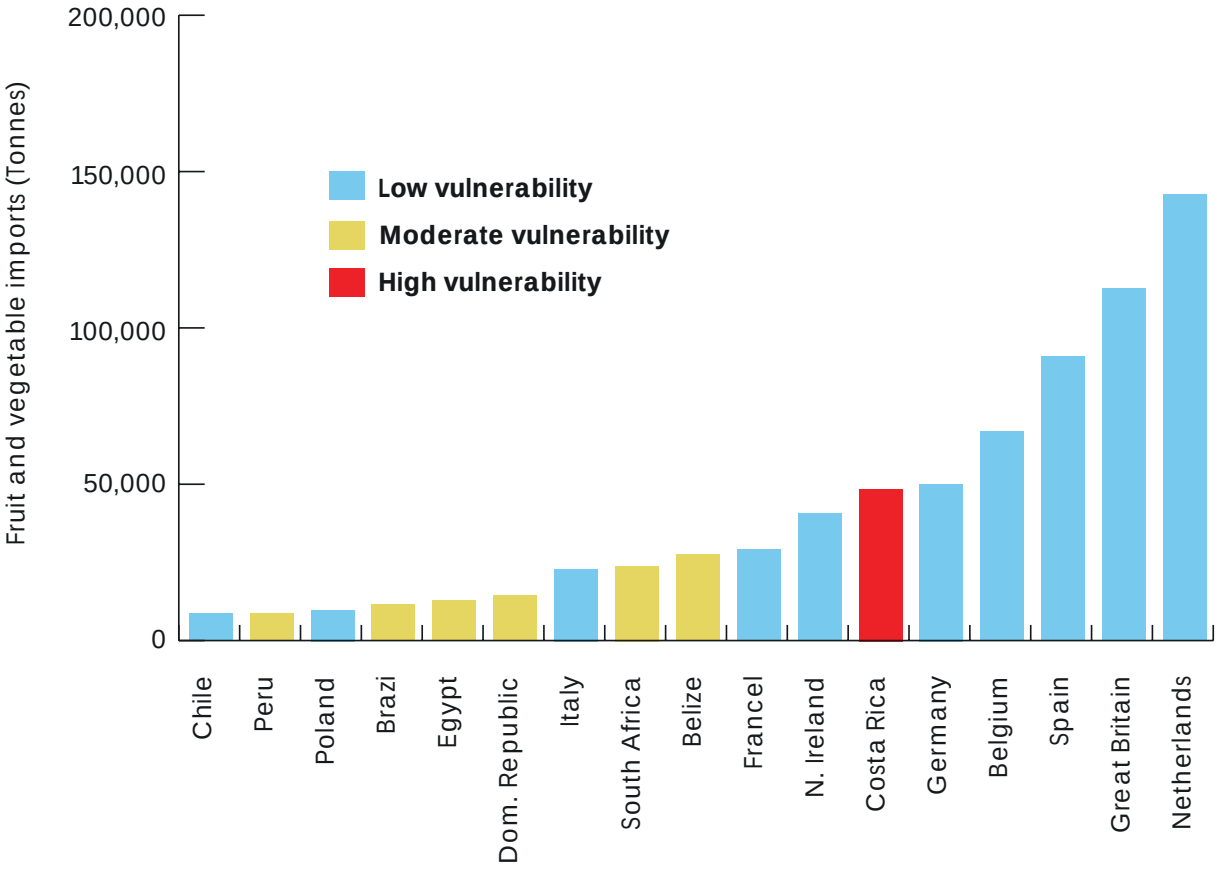
A study on Ireland's fruit and vegetable imports found that 22% of imports came from countries classified as climate-vulnerable in 2021. The majority of popular imported products like bananas (98%), pineapples (95%) onions (83%) and oranges (57%) are imported to Ireland from countries that are ranked as moderate or high in terms of climate vulnerability in the Notre Dame Global Adaptation Initiative Country Index (see [25]). Even countries assessed as having low vulnerability, such as Spain (due to their high capacity to adapt) will face extreme impacts from climate change that are very likely to disrupt horticulture [30]: low vulnerability ranking does not mean zero risk.

While faith is often placed in the capacity of diversified supply chains and nimble sourcing models to avoid supply chain shocks, it is important to recall that most northern European countries have similar import-dependences as Ireland and the UK. As such, when production or logistics shocks occur in key producing regions, for example in response to a major drought and heatwave in southern Europe, traders from all importing countries will be scrambling for the same constricted supplies. In such a scenario, price shocks are inevitable, even where shelves can be stacked. Irish shoppers have already faced shortages linked to climate impacts [31] [32].

A highly likely outcome is that there will be an increase in the frequency and intensity of shocks in the supply of fresh fruits and vegetables into Ireland, leading to short term price increases for consumers.

Sudden price hikes will force shoppers on limited budgets to substitute fresh produce with other – probably less healthy – products. Household purchases of fruit, in particular, are sensitive to price in this way [33]. The nutrients and vitamins, and to some extent fibres, in fresh fruit and vegetables

Figure 3.3. Irish imports of fruit and vegetables (in tonnes, y-axis) from specific countries (x-axis) categorised based on their vulnerability to climate change (high, medium or low)



Source: Stanley et al, p.8. The figure shows that most of Ireland's imports come from relatively low-vulnerability countries in the EU, whilst several more vulnerable countries contribute specific products.

cannot be replaced with alternative, cheaper, albeit filling, food products. That means fruit and vegetables price shocks will result in poorer diets, especially in households on low incomes. The risk is acute for those in receipt of benefits, who have to spend half of their disposable income on food if they are to eat healthily [34].

Lower income households tend to consume fewer fruit and vegetables compared to higher income households anyway [35]. So the "climate-driven deficit in diets" will be even more pronounced in such groups. Fresh fruit and vegetable consumption is already lower than it should be in the UK and Ireland. For example, children and adolescents in Ireland need to increase their daily intake by over 80% in order to meet the World Health Organisation's recommended standard; for adults the required increase is 40% [25].

Poor nutrition can lead to lower levels of concentration in school and can therefore exacerbate underachievement [36]. It can also lead to long-term health impacts and contribute to obesity and related conditions that impair peoples' lifestyle and ability to work [37]. Together, the impacts of poor nutrition threaten to increase social inequality and reduce social mobility [34].

In summary, the health and wellbeing of low-income groups and children will be negatively impacted by transboundary climate risks to fruit and vegetables supply chains.

3.4 Globalised beef and dairy

Risk	Likelihood	Magnitude	Risk severity
Risks to farming, jobs and export-revenues in the dairy sector on the island of Ireland, due to climate-related disruption to animal feed and other imports.	Low	High	Medium
Confidence	**Medium**		
Policy status	**Priority for research action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to farming, jobs and export-revenues in the beef sector, due to climate-related disruption to feeds and other imports.	Low	IE: Medium	IE: Medium
		NI: Low	NI: Low
Confidence	**Medium**		
Policy status	**Priority for policy action**		

Ireland is famed for its high-quality beef and dairy exports from cattle grazed on plentiful and reliable lush pasture. However, the sheer scale of today's Irish beef and dairy herd means that imports are critical for the sector, chiefly in the form of imported feed.

Around 90% of beef and dairy production in Ireland is exported. The majority of exports go to the UK, EU and US – core markets that are responsible for the lion's share of recent growth in the sector. In 2022, dairy exports grew to €6.8 billion, and meat and livestock exports were worth €4 billion [38]. Those numbers dipped slightly in 2023 because of increased input prices (partly driven by weather events in sourcing countries), weather impacts in Ireland, which affected yields and pasture growth, and food inflation in Ireland's export markets dampening consumer demand [39]. Still, the food and drink sector in Ireland is worth well over €16 billion per year in exports and the beef and dairy sectors represent the core of those earnings, providing over 80,000 jobs in Ireland [40].

Cows in Ireland are mostly grass-fed but their diet, particularly in winter, is supplemented with barley, wheat, maize, soya, molasses, sugar beet, rapeseed meal or sunflower meal [41]. The vast majority of this feed is imported.

The Republic of Ireland imports between 4 and 6 million tonnes of animal feed per year [42] [43] [44], with around three quarters sourced from outside the EU, including vast quantities of grains and soy from breadbasket producers such as Brazil, the US, Argentina and Canada. Feed imports are increasing. Any future growth in the sector implies an increased reliance on feed imports.

The availability and price of these imported feeds will be negatively impacted by climate change. Ireland is particularly exposed because it relies upon major commodity markets that are vulnerable to compound climate events [45] and polycrises [46]. A study of climate risks in agricultural commodity trade found that Ireland is particularly exposed to risky imports of soy from the US, for example [14]. The commodities that are used to supplement cattle feed in Ireland are also in high – and growing – demand by consumers in other countries, inside and beyond the EU in emerging markets and China. Climate-related disruption to these markets may result in geopolitical tensions and market fragmentation [47]. There is little that a small country like the Republic of Ireland could do to guarantee access to stable and affordable grain and soy imports in such a scenario.

Hotter drier summers in Ireland might reduce silage production (as well as cereal production in Ireland), increasing the dependence of the beef and dairy sectors on imported feed. The risk of concurrent impacts on cereal and soy production in the Americas and Europe is non-trivial [48]. The risk to beef and dairy farmers of volatile feed prices is therefore a major issue for jobs and export earnings from these sectors.

If feed prices increase suddenly there will be short term drops in profits for Irish exporters. More acute cereal and soy supply crises might even lead to reduced production in the sector, causing reputational risks for traders and retailers sourcing Irish produce, and potentially even job losses at farm or processing facilities.

The marketability of Irish beef and dairy relies heavily on the sustainability and quality credentials associated with the Irish pasture, which has a low carbon footprint and strong brand. If this becomes less reliable as a result of climate change impacts within Ireland, the sector may have to rely more and more on imported feed, which could negatively affect brand value and the competitiveness or Irish exports, especially in premium markets.

Due to the high level of cross-border exchange within the dairy sector, in particular, these risks present specific challenges for north-south cooperation. For example, many farms in the north of the Republic of Ireland source feed that arrives in Northern Irish ports, for logistical reasons [49]. A significant proportion of Northern Irish milk is sent across the border to be processed in the south, due to insufficient processing capacity. As such, the fates of the dairy sectors in each country are intertwined. Collaborating on adaptation may present mutual benefits.

In the same vein, the agriculture and wider food and drink sector on the island of Ireland can also identify opportunities in the face of transboundary climate risks. Some, particularly milder, near-term impacts from climate change in other countries may result in occasional increases in harvests of agricultural inputs used by Irish producers, meaning their price might dip, as well as rise. The relative resilience of Irish pasture, given its temperate climate and the more severe projections of worsening climate conditions in other parts of the world, might mean that Ireland's competitive advantage is maintained or even enhanced vis-à-vis beef and dairy competitors in other countries. The costs of adaptation might be lower in Ireland than elsewhere.

The extent to which this translates into commercial advantage is hard to predict, particularly given that Ireland's food exports have become so import-dependent, linking farmers' fates to those of agricultural systems abroad, even when they also depend on relatively resilient domestic resources.

3.5 Current policy landscape and necessary measures

Agriculture is a heavily regulated sector. Regulators and stakeholders participate in an active ecosystem of market analysis, lobbying, research and monitoring and there is extensive policy coverage across most aspects of the food production system across the island of Ireland. Nevertheless, the wider food system upon which Irish consumers rely is less clearly governed. Risks to food affordability stemming from multiple international supply chains are hard to manage. Protecting low income and other vulnerable households is a matter of social policy as well as food policy. The policy landscape for managing transboundary climate risks to food security and the Irish food system is therefore quite broad.

The impacts of climate change on horticulture have already been identified as posing a health risk for the UK [50]. Related risks were highlighted in the Northern Ireland summary of the 3rd UK Climate Change Risk Assessment[8] and in the EU Climate Risk Assessment (Chapter 6 in [21]) and the Transboundary Climate Risks for the Island or Ireland report [51].

Adapting to impacts on food affordability could take various approaches. Incentivising more strategic risk management by private sector supply chain operators can be partially achieved by adopting more ambitious corporate risk disclosure regulations. Large companies in the Republic of Ireland are required to comply with the EU's new Corporate Sustainability Reporting Directive [52], which includes requirements to identify and report on measures for addressing physical climate risks to a company's

8 For example risks: H9: Food safety and food security; ID1: UK food availability, safety and quality; and ID7: international trade routes, see - see [20])

operations. This Directive incorporates many of the recommendations of the Taskforce on Climate-related Financial Disclosure [53], which have also been formally endorsed by the UK government. In theory, this will facilitate more disclosure and therefore action by businesses to reduce supply chain risks from climate change impacts, including those affecting food and feed imports vital for food and nutrition security on the island of Ireland.

In addition, the UK is developing a Critical Imports and Supply Chains Strategy [54], as well as the Department for Business and Trade's Supply Chain Resilience Framework [55]. Similar initiatives should be considered by the Republic of Ireland government. Inspiration may also be taken from other European governments, such as the Karlstad Declaration on Nordic co-operation for preparedness and robustness related to food supply and forestry [56].

Initiatives to improve supply chain resilience via public procurement have been initiated in Northern Ireland [57]. But a more comprehensive and overarching strategy for ensuring the resilience of critical food supply chains on the island of Ireland is probably warranted.

As such, supply chain resilience does not represent a policy gap: the agenda is widely recognised as important on both sides of the border. But there is still an undefined space between the traditional remits of private supply chain operators and the state when it comes to minimising risks to consumers.

A different way to manage the same set of risks is to seek to expand fresh fruit and vegetable production and supply chain capacity on the island of Ireland [58] [25]. Here an appropriate balance needs to be struck between investing in domestic capacity to reduce import-dependence, on the one hand, and benefitting from the flexibility and resilience-potential offered by trade with multiple supplier countries on the other. The Food Vision 2030 Report sets out various "missions" in this regard [59]. Implementing aspects of the National Strategy for Horticulture 2023-2027 would also contribute to this end [60].

Policies to improve nutrition security and health will also support adaptation to fresh fruit and vegetables price shocks [37]. One specific pathway is to ensure all school children have access to nutritious food via free school meals: a much-explored policy tool in both the Republic of Ireland and Northern Ireland [61].

There are also a range of opportunities for agriculture and the wider food system on the island of Ireland in a world impacted by transboundary climate risk. The resilience of Irish agriculture relative to other European countries, particularly those in southern Europe, means that, with sufficient adaptation to domestic impacts, food and drink exports from Ireland may become more competitive and more profitable in the EU market. If lower levels of inputs are needed to adapt in Ireland, compared to other countries, Irish agriculture exports – including beef and dairy – may also be able to market themselves as relying on shorter, less impactful, more sustainable supply chains.

Consumers in Ireland may be able to benefit from more stable locally produced horticulture products and thereby enjoy lower exposure to systemic risks in international markets, provided there has been sufficient investment and strategic management of the food system on the island of Ireland. Policies need to take into consideration the dynamic effects of transboundary climate risk in order to seize opportunities for Irish producers and consumers.

4. TRANSBOUNDARY CLIMATE RISKS TO INFRASTRUCTURE AND TRADE

4.1 Introduction

This section explores the risks to the economy and society of the island of Ireland that stem from climate change impacts on infrastructure, both on the island and around the world. It examines the implications of transboundary climate risks to infrastructure for three key areas: 1) energy security; 2) the economy, private-sector businesses and public health, with a focus on the trade and supply chain risks for key sectors (high-tech industries, financial services and pharmaceuticals); and 3) human mobility, including matters affecting residents and the tourism industry. It provides an overview of related policies that are in place and measures needed to help address risks.

A major climate threat that the island of Ireland faces is the impact of extreme weather events and slow-onset climate change on built infrastructure, on either side of the island's internal borders and in other countries. Damage to infrastructure caused by heat, droughts, storms and floods can compromise essential services, including energy provision, mobility of people, transportation of goods, communication systems and water access. The cascading effects of climate change through disrupted services of critical infrastructure can in some cases cause greater damage to the economy and wider society than the immediate and local climate impacts themselves [62]. The risk to critical infrastructure has also been highlighted as major threat to European countries in the Europe chapter of the Sixth Assessment Report of the UN Intergovernmental Panel on Climate Change and the European Climate Risk Assessment [63, 9].

Infrastructure assets are often highly interconnected and interdependent through networks. A failure of one infrastructure can cause widespread effects throughout the network and disrupt other infrastructure services, often across borders and sectors. The Republic of Ireland and Northern Ireland are therefore not only exposed to the effects on climate change on their own domestic infrastructure, but also to the cascading effect of climate impacts on infrastructure across internal and external borders with the UK and beyond. Moreover, the economic and societal repercussions to the island of Ireland from climate-related damage to critical infrastructure in Europe and globally can be exacerbated by the simultaneous disruptions of multiple infrastructure and services by a single climate-related event, as well as the compounding effects of multiple climate (and non-climatic) events that occur consecutively over a short period of time or simultaneously in different locations.

Indeed, the risk environment facing the built infrastructure across the world has changed dramatically over the last two decades, and the different climate hazards are increasingly testing the resilience of Europe's critical infrastructure. For instance, the extreme rainfall event in the catchments of the Meuse and Rhine rivers in the summer of 2021, resulted in devastating floods in Germany, Belgium and the Netherlands. The floods caused significant damage to railways, roads, electricity and gas networks, water and waste-water treatment plants, requiring months to years to recover [64]. The island of Ireland's closest neighbour, Great Britain, also experienced by its wettest day on record on 19th October 2023 when heavy rainfall led to power outages, disrupted rail services, and airport and port closures [65].

While World Bank analysis has emphasized the cost-effectiveness of investing in climate proofing infrastructure, much of Europe's infrastructure continues to age and deteriorate due to serious adaptation deficits and underinvestment [9, 66]. This neglect of infrastructure investment means that Europe's infrastructure – on which the island of Ireland depends for transportation of energy, goods and people – is particularly fragile and vulnerable to the effects of climate change. In fact, the annual damage to Europe's critical infrastructure is expected to grow tenfold by the end of this century due to climate change alone, with the industry, transport and energy sectors suffering highest losses [67].

Against this backdrop, the following sections explore the specific transboundary risks to which the island of Ireland's economies and society are exposed from the impacts of climate change on built infrastructure around the world. In particular, the sections examine the transboundary climate risks to the Republic of Ireland and Northern Ireland via international infrastructure on the industry, transport and energy sectors.

4.2 Risks to energy security

Risk	Likelihood	Magnitude	Risk severity
Risk to energy security from damage to energy-criticalinfrastructure abroad from extreme weather and slow-onset climate change.	Low	Medium	Low
Confidence	**Medium**		
Policy status	**Watching brief**		

Risk	Likelihood	Magnitude	Risk severity
Risk to energy security from climate impacts on transport and production infrastructure abroad, disrupting overseas supply of critical minerals.	Medium	Medium	Medium
Confidence	**High**		
Policy status	**Priority for policy action**		

Both the Republic of Ireland and Northern Ireland could be highly affected by the effects of climate change on energy critical infrastructure on either side of the border between them, as indicated in interviews with two government officials. This is because the island of Ireland operates an integrated energy system, with two transmission links connecting the electricity networks on across the internal border. There is also a considerable risk of cross-border effects from climate-related disruption to energy infrastructure on the island of Ireland because most energy production and storage facilities in the Republic of Ireland are in coastal areas and near rivers, exposing them to flooding from excess rainfall and sea-level rise [7]. The same risks affect many of Northern Ireland's thermal power plants. While the Irish Electricity and Gas Networks National Adaptation Plan acknowledges the risk from extreme weather on electricity networks, progress on adaptation efforts in this sector have been limited, as reported in the 2024 National Adaptation Framework report [68, 69]. However, in absence of a an "all-island" risk assessment for the energy system on the island of Ireland, it is difficult to determine the implications for such intra-island disruption to energy flow for energy security in each jurisdiction.

Perhaps of greater concern is the climate risk to energy-critical infrastructure that stems beyond the island of Ireland's external border, as emphasised by several government interviewees. The island of Ireland is linked to the European energy market via Great Britain through the East-West and Moyle interconnectors and two gas pipelines connected to Scotland. Several government officials stressed that any climate-related disruption to generation and transmission from these links could potentially have a serious implication for energy security on the island of Ireland and for the Irish and Northern Irish economies. These concerns may have some merit. A recent analysis showed around 60% of the UK's 4000 energy facilities examined are at risk from storm damage at a 1.6°C increase in global average temperatures [70]. The island of Ireland could also be affected by indirect ripples in the energy market, such as increased price volatility due to climate-related disruptions to wider European energy infrastructure, which the European Environment Agency expects to become increasingly affected by extreme heat (e.g. electricity generation and transmission) and inland flooding (e.g. electric substations, and oil and gas pipelines) in Europe, among other climate hazards [9].

Two government interviewees stressed the Republic of Ireland's particular vulnerability to the impacts of climate change on overseas energy infrastructure due to its high energy import dependency, with the lion's share of the country's primary energy demand being met with imported oil (48%) and natural gas (31%) [71]. Most imports of refined and crude oil products come from the UK and the US, respectively, whereas much of the gas is imported through a singular pipeline from Norway via Scotland. The high import dependency and concentration of supply mean that the Republic of Ireland faces a growing risk to energy security in the event of climate-related disruption to these oil and gas supplies as the integrity and reliability of oil and gas infrastructure is increasingly challenged by many climate hazards [72] [73]. These risks include damage to oil and gas pipelines due to flooding and melting permafrost, reduced oil refinery operations due to extreme heat, and disruptions to offshore oil and gas platforms due to hurricane and storms, among other risks [74] [75] [76]. Nevertheless, while the magnitude of such disruption of overseas energy supply would be high, it is fairly unlikely due to the relatively small number of energy infrastructure sites and high safeguards and protections in place around these assets in a highly regulated sector [77, 78].

To achieve their respective EU and UK climate targets, the authorities in the Republic of Ireland and Northern Ireland have both set out ambitious plans to boost the share of renewables in their energy supply to 80% by 2030, alongside measures aimed at accelerating the electrification of the transport sector [79, 80]. The share of renewable energy in Northern Ireland has already reached over 45% of demand. The Republic of Ireland, meanwhile, is expanding its wind generation with the aim to reach 8GW of onshore and 7GW of offshore wind over the next few years [81] [82]. As implementation of these policies continues, global demand is expected to soar for critical minerals that play a critical role in the production of wind turbines, solar panels and batteries. Thus, while this ramp-up of green technology is essential to mitigate climate change and address energy security, the island of Ireland will become increasingly exposed to the risks faced by these critical mineral-exporting countries – many of which are in climate-vulnerable regions. For instance, the EU imports around 98% of its rare earth metals and 94% of its magnesium from China, where many mining regions have experienced extreme rainfall and flooding on nearly an annual basis [83] [84]. At the same time, Chile, which holds the world largest lithium and copper reservoirs, has been severely affected by years of drought and water stress, increasing concerns for the country's water-intensive mining sector [85, 86, 87]. As such, the likelihood of climate-related disruptions of critical minerals is considerable given the dispersed and water-sensitive nature of the mining sector. Although such disruptions are unlikely to create acute risk to the security of the supply of needed minerals in the near term, they could create a serious hindrance to decarbonisation efforts on the island of Ireland and create some long-term risks for energy security.

4.3 Trade and supply chain risks

Risk	Likelihood	Magnitude	Risk severity
Risk to businesses, financial sector and overall economy due to climate-related supply chain disruptions globally.	Low	IE: High	IE: Medium
		NI: Medium	NI: Low
Confidence	**Medium**		
Policy status	**Priority for policy action**		

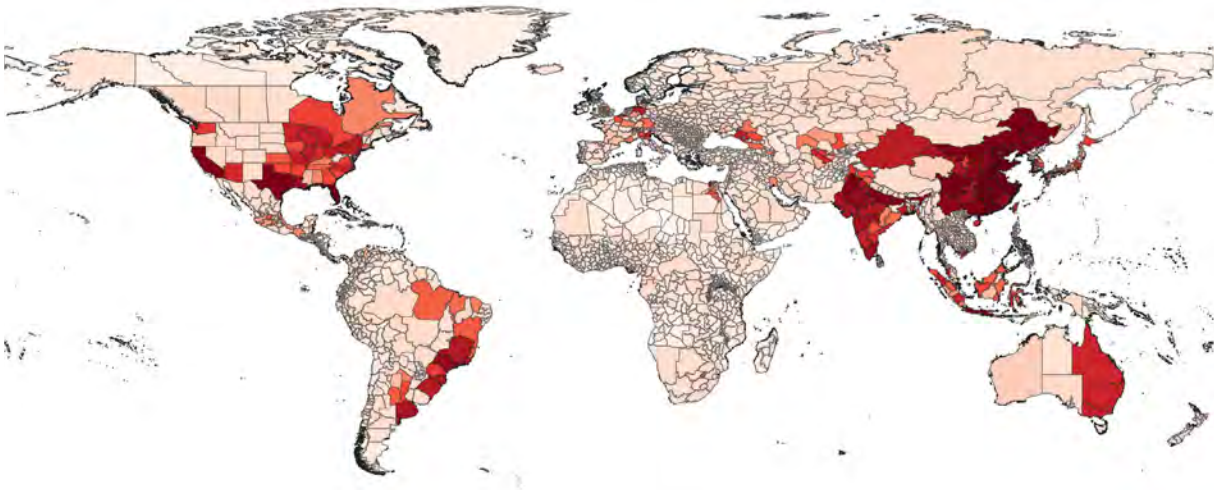
Risk	Likelihood	Magnitude	Risk severity
Risk to business operations, jobs and export-revenues in the pharmaceutical industry from climate-related disruption to global supply chains.	Medium	IE: High	IE: High
		NI: Medium	NI: Medium
Confidence	**Medium**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to public health from disrupted supplies of essential medicines and other drugs as a result of climate-related disruption to global supply chains.	Medium	Medium	Medium
Confidence	**Medium**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to business operations, jobs and export-revenues on island of Ireland, due to climate-related disruptions to intra-island trade and with the UK.	Low	Low	Low
Confidence	**Medium**		
Policy status	**Watching brief**		

The transboundary risks that the island of Ireland faces from climate-related disruptions to essential raw materials and components stretch far beyond those critical to the energy sector. Risks from extreme weather and slow-onset climate change to transportation and other built infrastructure, on the island and elsewhere could disrupt trade for many raw materials and components essential to the economies and wider societies of the island of Ireland. The impacts of heatwaves, droughts, storms and floods on roads, railways, seaports and airports around the world are already wreaking havoc on international trade and the global economy [9]. For example, recent analysis has shown that 86% of global ports are already highly exposed to multiple climate hazards, and that roughly 50% of them are exposed to extreme maritime conditions that could disrupt their operational capabilities [46]. With maritime routes accounting for around 80% of global trade [88], such disruptions could have serious ramifications for cross-border supply chains. The reliance on sea routes for commerce with the world means that island economies are likely to be particularly exposed. Both economies on the island of Ireland are certain to be affected by trade disruptions due to the climate impacts on supply chain infrastructure beyond their respective borders. However, there are notable distinctions in the scope and severity of the trade risks the two face, based on their own unique trade and economic vulnerabilities.

Figure 4.1. A global heat map showing comparison of aggregated damaged risk ratio across 2,600+ territories, based on modelled projections of damage to the built environment in 2050*



Notes: * The aggregated damaged risk ratio is the annual sum of damage in a state or province, where damage to all the buildings is aggregated. The coloured areas highlight states and provinces most at risk from climate change and extreme weather, as indexed by the extensive built-up areas coincide with exposure to climate change and extreme weather hazards.

Source: XDI's Gross Domestic Climate Risk Analysis [89].

Because the Republic of Ireland has a highly open and specialised economy, the country heavily depends on international trade and access to global finance, manufacturing and raw materials. These dependencies in turn, render its economy particularly exposed to disruptions to supply chains and financial flows caused by climate impacts on transport infrastructure – especially in key bottlenecks and manufacturing centres around the world. In fact, recent assessments show that much of the world's main supply chain infrastructure resides in high-risk locations for climate extremes (see Figure 4.1); the cost of climate-induced disruptions of global supply chains is expected to reach up to $25 trillion by 2060 [89, 90]. The likelihood of such disruption is therefore high. And with businesses largely unprepared to manage these climate risks, key industry sectors and the wider economy of the Republic of Ireland could be severely affected by these cross-border climate effects, with corporate value chains vulnerable to being upended by delivery delays, price spikes and shortages for a wide range of essential goods and services [91, 92].

High tech and financial service sectors are foundational to the Irish economy. Multinational and domestic corporates play an essential role, importing various raw materials and components from across the world and transforming them into high value-added goods and service. Repeated supply disruptions and sustained shortages due to climate change can therefore cause serious disruptions to business operations and even significant job losses in the long haul. Indeed, several government interviewees highlighted potentially serious economic ramifications of such disruptions in the pharmaceutical and IT sectors. More broadly, the lack of diversification in the Irish economy makes the country particularly vulnerable, as reflected by the fact that only five corporates accounted for 43% of the country's export value in 2022, with the pharmaceutical sector playing a dominant role [93].

Given the global and interconnective nature of corporate and financial networks, the projected economic cost from climate impacts on businesses, supply chains and their wider sectors could also adversely affect global investments and financial flows, with serious ramifications for the financial service sector and beyond. The projected economic implications of supply chain disruptions caused by extreme weather events could have a knock-on effect on Republic of Ireland's economy – leading to reductions in foreign direct investment and diminished tax revenues for the government as the result of poorer performance of multinational corporations. One government interviewee provided an example, noting that the growing threat of wildfires in California could impact Silicon Valley-based technology companies (e.g. Google, Meta) and that, given the significant corporate footprint of these companies in the Republic of Ireland, this could have cascading effects on the Irish economy. Market dynamics and the interplay with non-climatic drivers (e.g. disease pandemics and geopolitical tensions) can amplify the effects on these risks. Nevertheless, the complex and systemic effects that such supply chain disruptions can have upstream on the financial sector and global economy remain poorly understood [9]. Therefore, even though the magnitude of this transboundary climate risk has the potential to be high for the Republic of Ireland's economy, the much of the literature projects this risk to be moderate over the next two decades.

Northern Ireland also faces similar, serious risks from climate-related disruptions to global supply chains. Compared to the Republic of Ireland, however, the economy of Northern Ireland may stand more to lose from climate-related damages to infrastructure and severance of trade with its closest neighbours: the Republic of Ireland and the rest of the UK (i.e. Great Britain). The likelihood of disruptions to intra-island trade is considerable, given forecasts that extreme weather will increase in frequency and intensity and the vulnerability of critical infrastructure services in the Republic of Ireland and the UK to such events [103, 104]. The Republic of Ireland is Northern Ireland's largest export market – accounting for over 40% of the country's overall goods exports at a total value of £5.2 billion. Thus, any climate-inflicted disruption to the rail and road networks and flight connections that underpin cross-border trade on the island could seriously harm the country's export industries and revenues. One Northern Ireland government interviewee said that the country relies significantly on transport infrastructure south of its border because ports in Dublin and Cork have better infrastructure and expansion plans, and the Dublin airport often has more convenient and competitive flight options.

Box 1. The exposure of the pharmaceutical industry to climate-induced supply chain shocks

Although most economic sectors are at risk from the effects of climate change on international trade, the disruption of supply chains could be particularly severe for the thriving pharmaceutical industry on the island of Ireland. The pharmaceutical industry largely involves research and development and high-value manufacturing. The European Climate Risk Assessment has indicated that essential medicines and other drugs rely on supply chains that are most at risk of disruption, largely due to the geographical concentration of sourcing in climate-vulnerable regions and countries [9]. As a case in point, a recent study jointly authored by the pharmaceutical company Astra Zeneca and the World Wild Fund for Nature revealed that nearly 90% of global pharmaceutical manufacturing sites are already exposed to flood risks and a 25% to risks relating to water stress [94]. Another assessment from the US showed that nearly 70% of manufacturing site in the top 10 states for pharmaceutical production are in high-risk areas for tornadoes [95]. There is therefore at least a moderate likelihood of pharmaceutical shortages from supply chains disruptions that could significantly harm operations of pharmaceutical businesses and the sector at large in both jurisdictions.

The disruption to supply of medicine and pharmaceutical ingredients due to cross-border climate impacts, can be especially dire for the pharmaceutical industry in the Republic of Ireland, which employs over 24,000 people in the country and was ranked as the world's largest exporter of pharmaceuticals in 2022 [96, 97, 98]. Because the pharmaceutical sector in Ireland heavily relies on imports for a wide range of pharmaceutical ingredients (such as vaccines, blood, cultures and nucleic heterocyclic compounds), disruptions to upstream supply chains could inflict major harm on the Irish economy. Such disruptions could compromise businesses operations of pharmaceutical companies on a sector-wide scale and, in the long haul, lead to declines in export-driven economic growth, and, in turn, widespread job losses. Although to somewhat lesser degree, similar risks also apply to Northern Ireland where the pharmaceutical industry forms the backbone of a vibrant life science sector. This sector, valued at £2.4 billion, employed more than 19,500 people in 2019 and accounted for the country's third most exported commodity category [99]. The transboundary risks from climate changes to pharmaceutical supply chains also pose a growing threat to public health on the island of Ireland. Such disruptions could jeopardise the availability and access to essential medicines and other drugs. The disruption of pharmaceutical supply chain may not necessarily threaten the supply of life-essential drugs, and, in some cases, drug substitutions can address shortages. Nevertheless, the magnitude of such disruption could be considerable given the existing frailty of pharmaceutical supply chains [100, 101, 102], the rising prevalence of antimicrobial resistance, and the expected growth in infectious diseases due to climate change [9]. Such disruptions could be especially devastating if they coincide with a pandemic outbreak or other health ailments – which are expected to increase in the coming years due to climate change.

Yet transport infrastructure in other regions of the Republic of Ireland is particularly vulnerable to climate hazards due to longstanding underinvestment, as noted by many sources. For example, the EU Commission's Regional Competitiveness Index 2022 ranked Northern and Western Region of Ireland's transport infrastructure 218th out of 234 regions in Europe. A Northern Ireland government interviewee also expressed concern over the lack of infrastructure investments in recent years [105, 106, 107]. Another expert interviewed expressed concern about the lack of visibility of climate risk exposure and the resulting uncertainty about related vulnerabilities of rural transport networks in Northern Ireland. Other government interviewees pointed out the transport risks from climate change are geographically concentrated on the east coast, the location of urban and commercial centres of the Republic of Ireland and Northern Ireland and much of the road infrastructure on which cross-border freight transportation relies [108]. Recent plans by Irish authorities to conduct a thorough climate risk assessment of Irish transport infrastructure that has the potential to ameliorate some of these risks [109]. Moreover, any intra-island trade disruptions and economic impacts caused by an extreme weather event are likely to be relatively short-lived. Repair and restoration of land-based transport infrastructure usually can be undertaken relatively quickly. If road infrastructure damages are more severe, supply chains

can be reconfigured to use alternative mode of transport (e.g. via sea or air routes). As such, the magnitude of impact from such trade disruption on the overall economy is likely to be relatively modest.

Northern Ireland is considerably exposed to transboundary climate risks that may compromise the country's access to essential imports from Great Britain, which accounted for 57% of total imports in 2022 [110]. Damages inflicted by climate change to transport and other critical infrastructure in Great Britain could have detrimental effects on Northern Ireland's economy through reduction or halt in commodity flows with other UK trade partners. Risks relating to supply chain disruptions for Northern Ireland involve the agriculture sector (see Section 3), and the advanced manufacturing and engineering industry a major backbone of the Northern Ireland economy. This sector, which accounts for 11% of employment and 15% of gross value added, is especially vulnerable because of its high dependence on imports from Great Britain [111]. This vulnerability is underscored by the findings of the UK's Third Climate Change Risk Assessment and other recent analyses, which project a growing risk to the UK's rail and road, sea and airport infrastructure from extreme temperatures, flooding and other climate hazards [112, 113, 114]. Nevertheless, it is highly unlikely that damages to transport (and other critical) infrastructure in the UK from extreme weather events will cause any long-term paralysis in cross-border trade between the island of Ireland and the UK, or serious impact on their overall economies. As in the case of intra-island trade disruptions, critical infrastructure functions can be restored relatively quickly, and other transportation modes could be used as short-term substitutes. Furthermore, such trade risks may be somewhat lower for the Republic of Ireland because Irish businesses have begun to diversify their trade routes to circumvent the UK and avoid the challenging customs environment that arose following the UK's departure from the EU [115].

4.4 Risk to human mobility

Risk	Likelihood	Magnitude	Risk severity
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.	Low	Low	Low
Confidence	**Medium**		
Policy status	**Watching brief**		

Transportation infrastructure plays a vital role for the movement of people. Extreme weather events on the island of Ireland could significantly restrict people's ability to travel within either jurisdiction on the island and across the island's internal borders, potentially affecting whether people are able to go to businesses to work. However, the digital tools and platforms to support remote work that came into widespread use following the Covid-19 pandemic mean that the adverse effects of such disruptions to human mobility are likely to be relatively limited.

By contrast, the damages caused by climate change to transport infrastructure outside the island of Ireland's borders could have serious acute consequences on the tourism industries in the Republic of Ireland and Northern Ireland by hampering passenger travel from abroad. Prior to the Covid-19 pandemic, the tourism sector in the Republic of Ireland employed around 260,000 jobs across 20,000 businesses (mostly SMEs) and generated nearly £10 billion in revenues. In Northern Ireland, the sector employed approximately 71,000 people and contributed £1 billion to the local economy [116, 117].

The tourism sectors on the island of Ireland largely rebounded in the years following the Covid-19 pandemic – even against the backdrop of high inflation and cost-of- living crisis in Europe. However, the increased frequency and severity of extreme weather due to climate change are projected to have serious implications for the tourism sector in Europe and beyond in the coming years [118, 119]. More flight delays and cancellations and higher prices for air travel are likely. Air travel is more vulnerable

to risks from extreme weather and power failure than some other modes of transportation, largely because aviation relies heavily on computerised systems for air navigation, instrument landing procedures and passenger processing [120].

Moreover, a recent analysis has shown that UK airports are among the critical infrastructure likely to experience the most dramatic increase in climate risks, and that 30 UK airports are already at risk from major storms [113]. Disruptions to flight operations from the UK could have adverse effects on the tourism sector in the Republic of Ireland. Much of the air travel to and from the country involves UK airports. For example, one week's data from 2020 show between 117–153 flights per day between the UK and Ireland [121]. Northern Ireland also faces this same transboundary climate risk [122]. Indeed, the increased frequency and severity extreme weather events in the UK and beyond pose growing risks for both the airline industry and the tourism sectors for the island of Ireland [123]. Nevertheless, the overall effect on the tourism sectors and the wider economies on the island of Ireland is likely to be modest. Such disruptions are transient nature, and air travel routes can be reconfigured through unaffected airports. Climate change may also create opportunities for the tourism sectors on the island of Ireland, which could counterbalance some risks. For instance, several government interviewees mentioned that the growing prevalence and severity of heatwaves in southern Europe is expected drive an uptick in weather-related tourism in the northern parts of Europe, including the island of Ireland, as Europeans try to avoid and escape the extreme heat. For these reasons, the likelihood and magnitude of these infrastructure risks for the island's tourism sector may be modest.

4.5 Current policy landscape and necessary measures

To avoid and minimise the disruptive effects of extreme weather and slow-onset climate change on infrastructure services that are essential to the economies and society on the island of Ireland and beyond requires a suite of robust public policy measures and their strict enforcement. However, the global and international nature of these infrastructure risks means that many of the most effective policy levers to manage these risks are beyond the direct control of the governments of the Republic of Ireland and Northern Ireland. In this regard, strategic industrial and trade policies on national, EU and global levels can help lower transboundary climate risks by reducing the exposure of global transport infrastructure and other supply chain assets to climate hazards or the vulnerability of these assets to effects of these risks once realised. At the same time, to ensure that current and future infrastructure is built for a rapidly changing and increasingly volatile climate, policies on the island of Ireland must strengthen infrastructure resilience through improved spatial planning and set appropriate design and constructions standards for buildings and critical infrastructure. Broad-based adaptation policies are instrumental in enhancing risk awareness, building capacity and incentivising investments to climate-proof buildings and infrastructure.

On a global level, the Sendai Framework for Disaster Risk Reduction sets out a firm commitment by UN member countries to promote resilience of new and existing critical infrastructure through better urban and spatial planning, improved building codes and standards, increased public and private investments, and, in some cases, consideration of relocation of critical infrastructure from high-risk areas [124]. However, the non-legally binding nature of this agreement means that the level of ambition and degree of compliance are likely to vary across countries. Thus, the Republic of Ireland government and the Norther Ireland authorities should work together to leverage their joint diplomatic influence (including via the EU and the UK) to promote stronger implementation of the Sendai Framework globally. The EU has taken progressive steps in recent years to facilitate the climate-proofing of buildings and critical infrastructure through its latest adaptation strategy and wider policy frameworks [125]. Among the most important EU policy levers in this context is the recently adopted Critical Entities Resilience Directive, which obliges EU member states to conduct risk assessments (including for climatic hazards) for energy, transport and other critical infrastructure [126]. The recent revisions of the Trans-European Transport Network (TEN-T) and the Trans-European Networks for Energy (TEN-E) regulations

place stronger emphasis on risk assessment and adaptation measures to climate-proof key energy and transportation infrastructure networks across Europe. In addition, the EU has recently published technical guidance on climate proofing infrastructure 2021-2027 with the view to ensure a common and rigorous approach to mainstream climate adaptation into infrastructure projects funded by the EU. A range of other EU policies – the updated Eurocodes, the revised Energy Performance of Buildings Directive and the Renovation Wave, for example – is increasingly considering infrastructure risks from climate change.

Alongside the revised TEN-E regulations, EU regulations on risk preparedness in the electricity sector play an important role in enhancing the resilience of energy production facilities, storage and transmission infrastructure across EU member states. As a result, these policies will improve energy security for the island of Ireland by helping to address risks that stem from increasing climatic threats to energy-critical infrastructure in Europe. At the same time, national-level energy policies that facilitate increased domestic generation and diversification of supplies have an important role in minimizing transboundary climate risks to the energy sector. Examples include the planned interconnector between the Republic of Ireland and France and a second transmission link between the Republic of Ireland and the UK via Wales. Ireland's National Energy Security Framework also includes provisions around the important issue of strategic oil reserves (equivalent to at least 90 days of consumption, an important contingency in case of climate-related disruptions in oil supply) [127].

Energy security risks to the Republic of Ireland relating to its heavy reliance on overseas oil and gas (as well as electricity) are likely to diminish as the country continues its progressive shift towards domestic renewable energy sources, as pointed out by two government interviewees. However, one official indicated that the benefits of this green transition for the Republic of Ireland's energy security could be hampered by increased energy demand from data centres, should the Irish government continue to seek to attract them as a strategy to bring in foreign direct investment [128]. The International Energy Agency reports that data centres account for 17% of the energy consumption in the Republic of Ireland, and it indicates that this figure could double by 2026 [129]. As such, the government's industrial strategies must be developed in alignment with energy security objectives, as climate change may exacerbate the tensions between these competing policy demands.

The transition towards greater domestic production of renewable energy increases the exposure of the Republic of Ireland to climate-related supply chain disruptions; however, the EU has made significant efforts to safeguard supplies of critical minerals that are essential for the decarbonisation of the energy system on the Republic of Ireland and in other EU member states. The Critical Raw Materials Act adopted by the EU in 2024 sets ambitious 2030 targets to diversify EU supplies for critical raw materials and introduces various measures to enhance risk preparedness of supply chains [130]. The UK has also published a strategy to improve its capability to forecast and response to climatic (and non-climatic) shocks to global supply chains. This UK strategy is likely to help ameliorate such supply chain-related risks to Northern Ireland's energy security [131]. Overall, there is considerable awareness at both national and EU levels of the transboundary risks to energy security via existing energy critical infrastructure and essential supply chains for new low-carbon infrastructure. Nevertheless, policy efforts must increase to address the risks, particularly those related to essential supply chains.

Trade policies and industrials strategies on both EU and national levels also have an integral part to play in reducing transboundary climate risks – including threats to trade and energy security – for infrastructure beyond the Europe's external borders. Many public policies at EU and national levels in Europe have recently tried to address transboundary risks to supply chains by diversifying and shortening supply chains and establishing inventory buffers, albeit largely in response to non-climatic risks (i.e. pandemic or geopolitical tensions) [9]. However, one government interviewee expressed concerns that the EU's current emphasis on establishing strategic autonomy could in some instances create restrictions to supply chain diversification and make trade dynamics less agile to respond to climate shocks. These and other national policies that restrict trade and take isolationist approaches are also

likely to weaken the ability of inter-governmental bodies such as the World Trade Organization to introduce and employ policy levers that could address these trade risks more systemically. Moreover, although current prevailing policy prescription might prove relatively effective in managing transboundary risks from more localised and timebound threats, these measures alone might be less effective in addressing more systemic and sustained risks from climate change. As such, a greater recognition is needed among policymakers on the importance of increased investment in climate-proofing existing supply chain configuration.

Fortunately, the EU has begun to take steps to this end. The Corporate Sustainability Reporting Directive (CSRD) and the revised European Sustainability Reporting Standards (ESRS) that have recently been adopted by the EU will improve the transparency of European supply chains and may stimulate some adaption actions [9]. For instance, the ESRS will oblige larger companies to conduct materiality assessments, disclose the physical climate risks in their own operations and value chains, and report on adaptation policies and measures. Similar reporting obligations have been introduced by the UK government through its Climate-Related Financial Disclosure Regulation [132]. The resulting improvements in companies' risk management practices from these policies are likely to reduce climate-related risks to global supply chains.

The Republic of Ireland government is currently conducting an assessment of the country's trade dependencies to map sourcing locations and supply chain vulnerabilities. However, the prevailing policy approach adopts a generic resilience perspective and is at risk of neglecting the systemic and bespoke nature of climate risks. The Irish government and the authorities in Northern Ireland should therefore supplement these EU-level efforts by implementing policies on to specifically facilitate public- and private-sector investments into climate adaptation – especially in sectors that are strategically important and highly vulnerable to climate change. Among these sectors are agriculture, energy, and pharmaceuticals. Such policies could entail increasing access to adaptation finance (especially for small- and medium-sized companies) through corporate grants, loan guarantees and low-interest finance to enhance business agility and resilience to supply chain shocks. Public procurements can be leveraged to create market incentives. The Republic of Ireland government must also explore avenues to expand its industrial foundations to enhance the country's economic resilience through diversification, while recognising that the pursuit of industrial and trade policies that further increases the economic dependencies on vulnerable sectors, will potentially amplify the severity of transboundary climate risks to them.

With the island of Ireland already experiencing rapid changes in its climate [133], public policies and cross-border collaborations between the Republic of Ireland and Northern Ireland must be strengthened to more effectively manage the transboundary infrastructure risks from extreme weather and slow-onset climate effects within the island itself. In the Republic of Ireland, climate adaptation planning in the transportation sector has progressed well in recent years – especially with respect to risk identification and adaptation action, according to the Irish Climate Change Advisory Council's latest scorecard [134]. In the absence of freight train transportation, it is particularly important to ensure that motorways and major road networks on the island are designed and maintained to withstand increased risk from flooding and extreme temperatures. The high reliance on road transport, especially along key commercial routes, makes this vital [135]. By contrast, the scorecard shows that adaption planning for the Irish gas and electricity sectors has been inadequate across the board. Limited risk analysis has been undertaken for the sector. Existing electricity infrastructure has been found to be at considerable risk from climate hazards, such as flooding. Adaptation planning for other critical infrastructure, including communications networks and water-service infrastructure, has also been found to be lacking to varying degrees.

Both rail and road transportation infrastructure in Northern Ireland is at significant risk from climate change due to the absence of explicit adaptation targets and insufficient policies and plans, according to the UK Climate Change Committee (CCC) [135]. The CCC also concluded that the degree of climate

risk preparedness and adaptation planning for airports and seaports was too obscure to evaluate because of the lack of reporting procedures and assignment of risk ownership to private operators. It described the situation in the energy sector as especially bleak; risks to production facilities and network assets were only minimally integrated into existing policies and plans, and statutory responsibilities and oversight regarding the climate resilience of the energy system had yet to be established, it said. Thus, the government of the Republic of Ireland and the Northern Ireland authorities should leverage their complementary expertise and capabilities to strengthen cross-border collaboration and coordination to ensure greater actions and investments in the resilience of critical infrastructure and address other underlying vulnerabilities. As an example, the Republic of Ireland already has a strong working relationship with the UK in the energy sector as part of an existing memorandum of understanding on security of supply. This relationship should be leveraged further to undertake joint risk assessments and adaptation planning exercises to address shared climate risks and existing adaptation deficits in the sector.

More broadly, there is a need for the Republic of Ireland and Northern Ireland to engage in more active dialogue and take a joined-up approach to address the investment deficits in transport infrastructure on the island and boost investment in climate adaptation. A good example of an "all-island" approach in practice is the Republic of Ireland's government recently announced €800 million investment package, which includes transport infrastructure investments benefitting both jurisdictions [136]. As one government interviewee stressed, however, the package needs detailed risks assessments and a harmonised approach to adaptation to address the potential impacts of climate change on intra-island trade for each jurisdiction and cross-border effects. Such cross-border collaboration could entail conducting a cost-benefit analysis, creating contingency plans on an island-wide basis for such climate-related trade risks, and addressing some of the existing trade hurdles and risks of greater fragility of the island's supply chains caused by the UK's departure from the EU. Bilateral policy channels and political forums, such as the Irish-British Council, could also help stimulate pragmatic cooperation between the island of Ireland and the wider UK. For example, such efforts could help increase efforts to enhance the climate resilience of critical, cross-border infrastructure, such as airports, and encourage greater investment in adaptation in the aviation and shipping industries.

5. TRANSBOUNDARY CLIMATE RISKS TO BIOPHYSICAL SYSTEMS AND ECOSYSTEM SERVICES

5.1 Introduction

This chapter explores risks to Ireland's biodiversity, ecosystems and natural resources – as well as the socio-economic services they provide – from impacts of climate change that occur beyond its borders. We can think about the biophysical nature of transboundary climate risk manifesting in three ways:

- at origin: climate change impacts a biophysical system in one country and generates a socio-economic risk to another
- via transmission: climate change impacts a transboundary biophysical ecosystem that acts as a conduit for a risk between countries
- at end-point: climate change impacts a socio-economic system in one country and generates a biophysical risk to another [137].

The movement of species, pests or pathogens from one country or region to another may be considered an example of the first type of risk, and the transfer of water within a shared hydrological system an illustration of the second [138]. Land and air can also act as conduits for this second type of transboundary risk [139]. A reduction in a recipient country's biodiversity or conservation finance – from a donor reallocating such funds to manage their own climate impacts – may be considered an example of the third type of risk.

Except for risks transmitted through seas and oceans, the second type of transboundary climate risk will only link neighbouring countries. However, those facing risks of types one and three could be geographically distant from where the risk originates, if climate change disrupts an ecosystem in one country on which another depends for its services (such as global trade in timber) [138].

Ireland is exposed to all three types of risk. This summary will dive deeper into those transboundary climate risks identified as posing "a significant threat" to the island's ecosystems, biodiversity and natural resources [140]. It will further develop risk transmission pathways and indicate the severity of these risks, before setting out promising policy mechanisms for tackling them.

It is important to note that changes in ecosystems worldwide could present even greater cascading climate risks to the island of Ireland's socio-economic security than those explicitly considered. These could be catalysed by a global tipping point – a monsoon shift that induces largescale changes to agricultural markets, the dieback of the Amazon rainforest or a shift in Boreal forests, for example [212] – or a localised effect that nevertheless generates a highly specialised risk to either of the two jurisdictions. Such "grey swan" events may be hard to predict, but given the magnitude of their effect, require a transformative approach to resilience-building in the face of climate change [213].

5.2 Ecological risk: ecosystems and biodiversity

Risk	Likelihood	Magnitude	Risk severity
Ecological risk to ecosystems and biodiversity from climate-induced changes in invasive species, movements of plants and animals, and infectious diseases.	High	High	High
Confidence	**High**		
Policy status	**Priority for policy action**		

We identify a cluster of four risks to the island of Ireland from invasive species, movements of plants and animals, and infectious diseases. This section first describes an ecological risk to Ireland's diverse ecosystems and the biodiversity they support. We then highlight three socio-economic risks associated with the services such ecosystems supply, via the blue economy, forestry, and agriculture.

There is a high likelihood that climate change will generate an ecological risk to the island of Ireland's ecosystems and biodiversity through an upsurge in invasive species, movements of plants and animals (i.e. shifts in their range, migratory patterns and/or population dynamics) and infectious diseases. The magnitude of this risk is also assessed as high and deemed to be particularly acute because of the island's geography, with limited opportunities for redress once some risks materialise (e.g. the establishment of invasive species).

Climate change creates cascading consequences for invasive species [141] and cultivates conditions that drive their establishment, growth and spread. Introductions of alien species are reported to be rising at "unprecedented rates" and now total over 37,000 around the world, 3500 of which are classified as harmful [142]. Invasive non-native species can generate severe ecological risks to nature, catalysing dramatic changes to ecosystems and representing one of the top five direct drivers of biodiversity loss worldwide [142]. A global meta-analysis finds decreases in species richness associated with biological invasions of 41% among birds, 27% in terrestrial habitats and 21% in aquatic habitats [143].

The cumulative effect of invasive species does not stop with the sectors that directly rely on ecosystem services (such as fisheries, forestry and agriculture), but percolates throughout a country's economy and society to "reach every place, every priority, and every agency" [144, p. 1]. IPBES estimates the global economic cost of invasive species to exceed US$423 billion each year, with costs quadrupling every decade since 1970 [142].

The IPCC finds that longer growing seasons in Northern Europe and western Central Europe, and increasing sea temperatures, will support the introduction and establishment of terrestrial and marine invasive species, respectively [145]. There are already 1,277 non-native species recorded on the island of Ireland, with 193 species classified of high and medium impact or singled out under EU Regulations [146][9]. The threats invasive species pose to Ireland have recently made headlines [147] and awareness of them was high among our interviewees – including their effects on complex ecosystems – though many also emphasised insufficient understanding and integration (in policy) of the effect of climate change on invasive species and consequences for the island's nature reserves and national parks. The 2024 IPBES Invasive Alien Species Assessment finds that their effects are most acute on islands: alien species have played a key role in 60 percent of global plant and animal extinctions, with 90 percent of these reported from islands, and alien plants now outnumber native plants on over a quarter of islands worldwide [142].

The European Climate Risk Assessment [21] reports that climate change, alongside other factors, is also causing a wide variety of plants and animals in Europe to move and/or expand their geographical ranges north (and uphill), resulting in a "redistribution of biodiversity" across the continent [145]. Such shifts could see the movement of species from the Republic of Ireland to Northern Ireland: the potential for a north-east shift of Ireland's waterbirds' ranges has already been recognised [148]. Changes in species composition are already being observed in Europe and present disruptions to the functioning of ecosystems at origin and endpoint. Changes in the distribution of major tree species are projected for all European regions at 1.7°C of global warming and northward distribution shifts of marine populations and communities are already evident across all European sub-regions (including some species redistributions) [145]. Climate change is also catalysing changes in the phenology[10] and distribution of migratory species [149]. These effects are particularly prevalent within Ireland's aquatic environments

9 Some sources report much higher estimates for the UK, although lack of data and definitional clarity lead to a wide range of estimates.

10 Phenology refers to natural phenomena that recur periodically in plants and animals and the relationship between these phenomena and seasonal or climatic changes [240].

(see below). But with the island's unique positioning (on the western edge of many waterbirds' wintering range), and with climate change creating more hospitable wetlands further north (reducing the need for birds to fly as far south), the effects may be particularly acute: in the last two decades, populations of Ireland's wintering waterbirds have fallen 40 percent, with shifting migration patterns causing cascading effects on ecosystem services through climate-induced "phenological mismatches" [18] [150] [151].

Such phenological mismatches – related to the different responses of species to climate change – also suggest increases in the volume and geographic distribution of pest outbreaks [152]. The European Climate Risk Assessment reports on the "unprecedented incidences" of insect outbreaks documented in Europe and the direct and indirect ways such outbreaks contribute to biodiversity loss (through the increased need for pesticides, for example) [21]. Its island geography may offer Ireland some protection from such outbreaks, but not from the increased risk of imported pests via international trade. All three dynamics – geographical changes in species' range, migratory patterns and population outbreaks – could manifest as transboundary climate risks to the island's ecosystems and biodiversity. Apart from insect outbreaks, however, they could also present ecological and socio-economic opportunities that warrant further investigation.

Infectious diseases in plants and animals are another conduit for transboundary climate risk. Researchers are increasingly documenting evidence of the impacts of climate change on pathogens and their vectors – including extensions in their geographic range – and the new risks to animal [153] [154], plant [155] [156] and human health [157] they present in places hitherto unaffected [158]. This includes Europe [21].

The IPCC finds with high confidence that climate change "alters the prevalence, distribution and load of pathogens and their vectors" [145]. While globalised trade and human mobility are two of the most significant drivers of this risk across borders, infectious diseases can also spread through migrating animals – birds or fish heading south from Scandinavia or north from Africa, for example. They can manifest in an ecological risk directly (by introducing an infectious disease) or indirectly (by reducing the number that migrate). An outbreak of avian flu among Irish seabird colonies in 2023, for example, was deemed "alarming and unprecedented" [159], reflecting a trend in virus evolution and dynamics that could be linked to climate change [160]. The EU Climate Risk Assessment also articulates the detrimental impacts of climate change on the health of pollinators, whose diversity is in sharp decline, driven also by the effects of invasive species [21]. While infectious diseases in plants and animals catalyse biodiversity loss, a recent meta-analysis indicates the reverse also holds true: biodiversity loss, climate change and the introduction of non-native species were found to be the most significant environmental drivers of infectious disease outbreaks [161].

Some of the above risks may transmit between the two jurisdictions within the island of Ireland. The highly invasive floating pennywort, for example, was cited in research for this study as posing a major risk to native biodiversity, ecosystems and conservation goals in the Republic of Ireland, if it were to spread across the border from Northern Ireland. Others may originate from Great Britain, Europe or further afield. One interviewee drew attention to the transboundary transmission of diseases such as ash dieback and Dutch elm disease, exacerbated by low afforestation levels and the need to import significant quantities of timber: "*90% of Ireland's ash is going to die because of the consignment of imported disease … So having a lack of self-sufficiency makes Ireland very vulnerable to such situations*." Fireblight is another disease that has recently made headlines [162]. Cross-border trade is a significant conduit for these risks and highlights the need for coherence across biodiversity, trade and forestry policies and practices.

The threats posed to ecosystems and society by climate-induced species invasions is one of 36 risks identified in the European Climate Risk Assessment and is rated as "substantial" in the current/near term (2021–2040) [21]. A further risk to food web dynamics and related ecosystem services due to phenological changes and species distribution shifts is also rated as "substantial" [21]. The future

magnitude of risks from pests, pathogens and invasive species to terrestrial and freshwater species and habitats in Northern Ireland is assessed as being medium by mid-century, but with high urgency, indicating new, stronger or different government action is required. Colonisation by new species is classified as a potential opportunity [163]. The need to prioritize research to better predict the impacts of pests and diseases is highlighted in the Third Climate Change Adaptation Scorecard [164].

5.3 Socio-economic risks, the blue economy, forestry and agriculture

The blue economy

Risk	Likelihood	Magnitude	Risk severity
Socio-economic risk to the blue economy from climate-induced changes to invasive species, movements of plants and animals, and infectious diseases.	Medium	Medium	Medium
Confidence	**Low**		
Policy status	**Priority for policy action**		

The likelihood that climate change will generate a socio-economic risk to the island of Ireland via the blue economy – through an upsurge in invasive species, movements of fish stocks (i.e. shifts in their range and migratory patterns) and infectious diseases – is assessed as medium. The magnitude of this risk is also assessed as medium – with the potential for detrimental impacts in part mitigated by the potential to harness new opportunities.

Climate change poses the single greatest threat to marine ecosystems [165], with cascading risks for the blue economy and the sectors that it constitutes, such as fisheries, aquaculture, tourism, transport and energy. It is forecast that climate-induced declines in ocean health could cost the global economy US$428 billion per year by 2050 [166]. Shifts in the spatial distributions of economically important marine species are already affecting these sectors [167] [168]. Fish stocks are experiencing an expansion in range and a poleward shift, with an average northward expansion of over 140 km per decade registered in the north-east Atlantic Ocean [145] [21]. Cold-water species, such as cod and herring, are at the southern limits of their range in Irish waters, and their replacement with warm-water species is expected to continue [163]. Relative to many other parts of the world, high concentrations of alien marine species are also established in waters off the Irish coast [142] and consultations suggest that many future risks of invasive species are likely to be aquatic [18]. Interviewees cited declining populations of various species of fish, oysters and native crayfish as examples of concern.

Threats to marine ecosystems from climate change in combination with other anthropogenic drivers are classified as "critical" in the current/near term by the European Climate Risk Assessment [21]. The future magnitude of risks from pests, pathogens and invasive species to marine species and habitats in Northern Ireland is assessed as increasing from medium at present to high in future, with new, stronger or different government action required.

These risks have potentially significant economic implications for both the Republic of Ireland and Northern Ireland. The 200 miles of Ireland's exclusive economic zone houses nursery and fishing grounds for both Ireland's fleet and other EU fleets. The seafood industry, supported by 2,000 fishing vessels and aquaculture sites, was reported to contribute €1.26bn to the Irish economy in 2021 and sustain 16,000 jobs. €37.3m was allocated in 2023 for capital projects in Ireland's six fishery harbour centres [169], while multi-million pound investments are also being considered in Northern Ireland's three key fishing harbours [170]. Ireland currently holds significant quota share for various cold-water species whose populations may experience dramatic declines in Irish waters [18]. On the other hand, the Irish Sea is projected to experience large increases in hospitable habitats [171], while indications suggest warm-water species such as hake, anchovies, bluefin tuna and sardine may experience

increases in population off the Irish coast [18]. Ireland currently has only small quota shares for such species [18]. Understanding and weighing the risks and opportunities will require granular assessments and public-private cooperation. The IPCC concludes that redistribution of the fixed allocation scheme for total allowable catches will be a major governance challenge for adaptation in Europe [145]. The need to better understand fish stock distribution is also noted in the Third Climate Change Adaptation Scorecard [164].

It is not only export industries that face a risk from shifting fish stocks, but also imports of fish and seafood to the Republic of Ireland and Northern Ireland from similar phenomena happening worldwide. The shifting of open-ocean fish stocks has been identified as a global transboundary climate risk [139]. Multiple interviewees noted the potential devastating ecological, economic and social impacts of climate-induced tipping points – such as a diversion or dramatic change of the Gulf Stream and Atlantic Meridional Overturning Circulation (AMOC), or significant melting of the Greenland iceshelf or in the Antarctic, as a result of climate change.

Forestry and agriculture

Risk	Likelihood	Magnitude	Risk severity
Socio-economic risk to the forestry sector from climate-induced changes to invasive species, movements of plants and animals, and infectious diseases.	Medium	Low	Low
Confidence	**Low**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Socio-economic risk to the agricultural sector from climate-induced changes to invasive species, movements of plants and animals, and infectious diseases.	Medium	Medium	Medium
Confidence	**Low**		
Policy status	**Priority for policy action**		

The likelihood that climate change will generate a socio-economic risk to the island of Ireland via both the forestry and agricultural sectors – through an upsurge in invasive species, movements of plants and animals (i.e. shifts in their range, migratory patterns and/or population dynamics) and infectious diseases – is assessed as medium. The magnitude of this risk is assessed as low for the forestry sector, and medium for the agricultural sector, given their relative importance to the economies of both jurisdictions.

Invasive species present risks to the productivity of both the forestry and agricultural sectors in the Republic of Ireland and Northern Ireland. In a report prepared for An Fóram Uisce, Lucy et al. estimate that invasive species cost the Republic of Ireland €2.1 billion in 2020 (a tenfold increase in a 2013 estimate) and that the annual cost could reach €26.5 billion by 2030 [172]. The annual cost of invasive species for Northern Ireland was estimated to be £150m in 2021, including £85m in annual costs to the forestry sector (a 2942 percentage change since 2013) and £40m in annual costs to the agriculture sector [173]. Eschen et al. find that invasive species now cost the UK economy an estimated £4bn annually – up 135 percent from a 2010 assessment – with impacts not only on agriculture and forestry, but on construction, development and infrastructure, and tourism and recreation too [173].

One fifth of forest biomass loss across Europe is caused by insect outbreaks that the European Climate Risk Assessment finds are likely to worsen under future climate predictions [21]. A 2021 report finds that

33.4 billion tonnes of Europe's forest biomass is at risk from fires, windthrows and insect outbreaks under a changing climate [174]. As such outbreaks expand geographically (facilitated by trade, travel and the shifting distributions of plant pests), they may present a transboundary risk to the forestry sectors of both national jurisdictions, with significant economic consequences: a 2022 report estimates that the forestry and wood sectors contribute more than €2 billion to the Irish economy each year [175]. Interviewees cited the rising risk of bark beetle associated with droughts and warmer temperatures in particular [176]: *"our state forestry company has nightmares about bark beetle and what it will do to conifers in this country; they understand it is marching across Europe at present and people are felling forests in advance of it"*. The IPCC find that >3.4°C of global warming would make large parts of Europe – including western Central Europe – suitable for pests such as wood beetles and increase economic losses for the forestry industry [145].

The potential effects of climate change on agricultural insect pests have also long been recognised [177]. The European Climate Risk Assessment distils some of their effects for the agricultural sector in Europe, including the destruction of crops, increased requirement for pesticides, and detrimental effects on livestock [21]. Across the world, up to 40 percent of crops are lost annually to plant pests and diseases, costing US$220 billion [178]. Around 137,500 farms produce over €8.2 billion in output in Ireland across 4.5 million hectares of land [179]. Gross output of Northern Ireland agriculture was estimated at £3.07 billion for 2022 [180]. The dependence of the Irish economy on agricultural output increases the magnitude of the risk associated with insect outbreaks, while a rise in infectious diseases of plants and animals will also hit both sectors hard [181] [182] [183]. The IPCC finds, with high confidence, that climate change is leading to the expansion in range of pests, weeds and diseases that have a detrimental effect on the health of European crops [145].

Ireland's Great Famine was, of course, caused by a disease that spread from continental Europe and destroyed the potato crop, but interviewees also raised threats to livestock and poultry. These include risks from established diseases such as liver fluke, whose rise is linked to climate change [184] and is reported to cause annual losses to the livestock and food industries of €2.5 billion worldwide, including €90M to Ireland [185]. They also include projected risks, posed by the Bluetongue virus, for example, as it moves further north (with the changing climate) in Europe. Northern Ireland's climate risk assessment cites the implications of climate-related expansions in parasites on the lambing industry, and the potential for changing wind patterns to blow over vectors from continental Europe [163]. Migration also plays a role. Avian flu (also discussed above) has reportedly led to the culling of over half a billion farmed birds since 2021 [186]: while Ireland has so far avoided the substantial losses other countries have faced, a 2024 assessment of its incursion into Northern Ireland poultry flocks rates the risk level as "medium" [187].

The European Risk Assessment classifies the risk to forest ecosystems and the carbon sink from more severe and frequent hot-dry events and related insect pest outbreaks as "substantial" in the current/near term [21]. The risk of large-scale cascading impacts across sectors from such forest disturbances is also rated as "substantial" [21]. The future magnitude of risks from pests, pathogens and invasive species to both forestry and agriculture in Northern Ireland are assessed as increasing from medium at present to high in future, with new, stronger or different government action required.

Collectively, the socio-economic risks caused by transboundary climate impacts on the blue economy, forestry and agricultural sectors could be significant. The agri-food sector in Ireland, which includes primary production in farming, fishing and forestry, as well as the processing and manufacture of food, beverages and wood products, exported goods valued at €18.98 billion (9%) in 2022 and employed 165,000 people [188].

Total gross output for agriculture in Northern Ireland was £2.87 billion in 2023, generating £341 million in total income, while fishing and seafood industries are reported to create an annual turnover of £135 million and the Forest Service generate £13.9 million of income (2022–2023) [189] [170] [190].

5.4 Ecological and socio-economic risks: water systems and services

Risk	Likelihood	Magnitude	Risk severity
Ecological risk to Ireland's transboundary river basins and the ecosystems and biodiversity they support from climate-induced water stress.	Low	Low	Low
Confidence	**Low**		
Policy status	**Watching brief**		

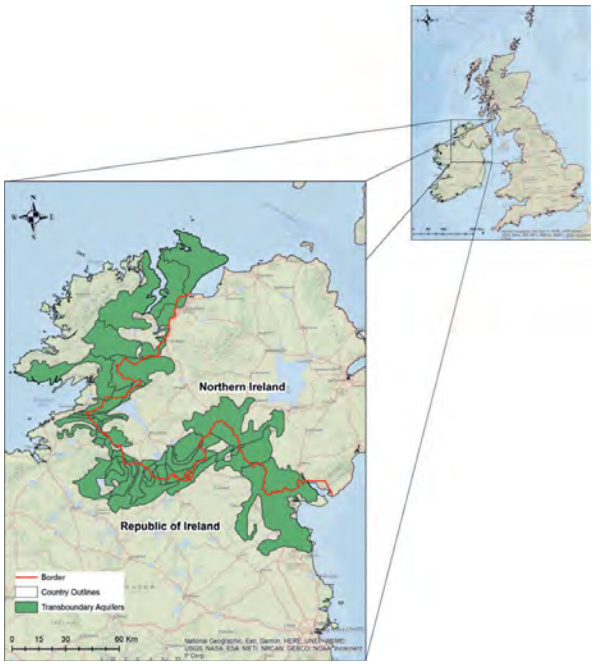
Risk	Likelihood	Magnitude	Risk severity
Socio-economic risk to water services from climate-induced stress on transboundary river basins.	Low	Low	Low
Confidence	**Low**		
Policy status	**Watching brief**		

We identify two transboundary climate risks to the island of Ireland from increased water stress on the island's three shared river basins and 34 groundwater bodies: an ecological risk to the island's transboundary river basins and the ecosystems and biodiversity they support, and a socio-economic risk via impacts on the island's water services.

Invasive non-native species and the changes in species distribution noted above are also known to affect inland water sources [148], but this section focuses on the wider threats to water security and services.

The likelihood that climate change will generate an ecological risk to the island of Ireland's transboundary river basins or generate a subsequent socio-economic risk from the impacts of climate-induced stress on water services, is deemed low. The magnitude of both risks is also assessed as low, although further research may be required to assess potential impacts on Ireland's transboundary hydrology, as may action to integrate climate projections into cooperative arrangements and management plans.

Figure 5.1. Transboundary aquifers shared between Northern Ireland and Republic of Ireland



Source: Third UK Climate Change Risk Assessment Technical Report: Summary for Northern Ireland (Climate Northern Ireland, 2023).

Globally, climate change is intensifying the hydrological cycle, making floods and droughts more likely and/or more severe, and generating water-related risks that are projected to increase with every degree of global warming [191]. A new assessment for Ireland – covering 37 catchments – projects increased flows in winter and reduced flows in summer, together with large reductions in annual low flows [192]. This correlates with other evidence suggesting seasonal droughts are likely to become more frequent and severe [193] [194]. By the end of the century, 40 percent decreases (or more) in river flows and groundwater could be experienced during Irish summers. These projections correlate with observed trends in Ireland and across Europe and generate upstream effects (e.g. on saltwater intrusion) that cascade downstream [145]. And yet, with a projected 20 percent increase in the volume of water flowing through rivers by mid-late century overall, and an anticipated rise

in extreme rainfall events, increases in flood frequency and intensity are also anticipated [195]. The European Climate Risk Assessment rates the risk to the population, infrastructure and economic activities from pluvial and fluvial flooding as substantial now and in the near term [21].

In light of such impacts, there are two shared river basin districts – Neagh Bann and North Western – that could act as conduits for transboundary climate risk between Northern Ireland and the Republic of Ireland. They present both an ecological risk – the degradation of ecosystems downstream and disruption of habitat connectivity, for instance – and a socio-economic risk, given the challenges for water management such trends and forecasts represent.

Across the island, these risks could take the form of water supply shortages (75–80 percent of Ireland's potable water is drawn from surface water sources) and reduced water quality (from increased eutrophication, algae blooms and pollution due to drought or stormwater run-off) [194] [148]. More granular analysis of the cascading effects of such impacts on each transboundary catchment area is required, but several interviewees for this study noted the potential for transboundary climate risks to arise related to droughts and floods within shared basins and potential implications for water abstraction policies across the two jurisdictions. Others cited the impacts of climate change on freshwater bodies across Europe and beyond, as well as the shifting water cycle globally, arguing how little is known about the potential disruptions to Ireland as a result.

The impacts of climate change on water bodies and river basins across the island are likely to cascade to other sectors: from food, agriculture and inland aquaculture to energy, infrastructure and the built environment [21]. The European Climate Risk Assessment cites that "rivers and lakes are at the top of ecosystem services' value when considering euros per km^2 of ecosystem extent" [21, p. 119]. It also finds that enhancing cross-border cooperation and research given the impacts of climate change on shared waters is required, as supported by the Water Convention and its Task Force on Water and Climate [21] [196]. Interviewees noted the future cross-border implications of diminishing groundwater bodies on the island, and Fraser et al. raise the prospect of increased pressure for abstraction in times of water stress and the risk of cross-border conflict that may result [197]. UN Water note that "transboundary cooperation is needed to address climate impacts that cross national boundaries. . . [and also] to avoid maladaptive consequences from a basin perspective" [198, p. 5].

5.5 Human health risks

Risk	Likelihood	Magnitude	Risk severity
Social risk to people and public health systems from a climate-induced rise in infectious diseases and cardiovascular and respiratory conditions.	Medium	Medium	Medium
Confidence	**Low**		
Policy status	**Priority for research action**		

We identify a social risk to the people of Ireland and the island's public health sectors resulting from the interaction between the biophysical environment and human health, specifically from infectious disease and cardiovascular and respiratory conditions.

The likelihood that climate change will generate a health risk to the people of Ireland and their public health system – as a result of a climate-induced rise in infectious diseases and cardiovascular and respiratory conditions – is assessed as medium, with the magnitude of the risk also deemed medium in light of its potentially grave effects. The rapid pace with which this risk could escalate, coupled with insufficient understanding of the nature and scale of risk, make this risk an urgent candidate for research.

According to a review article in the Lancet, "We are witnessing widespread increases in the emergence, spread, and re-emergence of infectious diseases in wildlife, domestic animals, plants, and people."

[199]. This statement infers the cascading risk to *human* health – in the form of zoonotic disease – created by increased disease in plants and animals. Evidence suggests this risk is exacerbated by biodiversity loss: the spread of human disease and infection is overwhelmingly mediated through our ecosystems [200].

Climate-sensitive infectious diseases are a growing global concern, and the environmental suitability for the transmission of all infectious diseases is increasing [201]. The UK and Europe are no exception [202]. Coastlines suitable for the spread of the Vibrio bacteria[11], for example, have extended by 329 km every year since 1982. Europe faces a particularly high threat from the bacteria, that can lead to illness and death, with 1.4 billion people at risk globally [203]. Climate change is also expanding the geographic range of tick vectors: Lyme disease and tick-borne encephalitis are the most likely infections to emerge in the UK as a result [204] [205]. Vector-borne disease outbreaks, that lead to the deaths of 700,000 people a year globally [206], are also a rising risk.

As illustrated in Figure 5.1, Europe is likely to face increased local outbreaks of malaria, dengue and West Nile fever, including in previously unaffected areas of northern and western Europe [202]. The UK Health Security Agency draws particular attention to the potential introduction of invasive mosquito species, including Aedes albopictus that can carry dengue, chikungunya and Zika: most of the UK's habitats could become suitable for its establishment in the second half of the twenty-first century [205]. Mosquitoes capable of carrying the West Nile virus are already established in parts of the UK [205]. People working in agriculture, forestry or emergency services face highest exposure, and the elderly, young children, and those with compromised immune systems face highest vulnerability to such risks [202].

Infectious diseases are a globally recognized transboundary climate risk [139]. Europe and Great Britain both present a source of risk to the island of Ireland in this regard, particularly through animal vectors such as mosquitos, midges and ticks [163]. Other countries further afield are also a source of risk, as disease cases rise worldwide and travel to the island through tourism and trade: imported malaria cases to England, Wales and Northern Ireland exceeded 2000 cases in 2023 [207]. The risk to Ireland could also raise exponentially in the future: experts say with "overwhelming evidence that climate change is fuelling disease outbreaks and epidemics . . . it is not a matter of if, but when, such events will precipitate another pandemic" [208].

Transboundary climate risks to public health could also result from the impacts of climate change on water services, with the European Climate Risk Assessment emphasizing that foodborne and water-borne diseases will increase in coming decades [21]. The IPCC find that climate change has been linked to a higher incidence of campylobacteriosis outbreaks across the EU [145]. The UK Health Security Agency also cite the increasing risk of acute gastrointestinal illness (from Salmonella, Campylobacter, and Vibrio spp.) [205], and its correlation with flooding in Ireland has been recently assessed [209]. These risks were also noted by interviewees. While the European Climate Risk Assessment rates the severity of risk from geographic expansion and increased transmission of infectious diseases as "limited" in the current/near term [21], one interviewee noted the limited geographic scope for bio-surveillance and low monitoring of pathogen vectors as a risk for Ireland's public health system. The future magnitude of risk from vector-borne disease to public health in Northern Ireland is rated low at present, rising to medium in all the future scenarios, but with further investigation required.

The European Climate Risk Assessment [21, p. 100] finds that "wildfires are increasingly affecting areas that have not been considered fire-prone in the past" and Ireland is no exception [18]. Transboundary climate risks could (in theory) arise if wildfires spread between the Republic of Ireland and Northern Ireland, fuelled by Ireland's "flammable landscape" and extended periods of drought [210]. But they could also (and arguably more likely) manifest in the form of detrimental impacts on air quality [145]

11 The Vibrio bacteria lives in certain coastal waters and usually infects people through the consumption of raw or under-cooked shellfish but also open-wound contact. Vibrio infections usually result in vomiting, diarrhoea and fevers, and in some cases life-threatening conditions [241].

Figure 5.2. An overview of the impacts and risks of climate sensitive infectious diseases in Europe, that considers the main drivers of hazards, vulnerability and exposure, direction of change in climate suitability of observed changes and at 1.5°C and 3°C, and the overall infectious disease risk across Europe

Impact/Risk	Hazards: Climatic hazards	Hazards: Interacting non-climatic hazards	on / to Affected systems and processes		Direction of change by regions: Europe	SEU	WCE	EEU	NEU
Reduction in habitat availability of cold-adapted groups	Warming, heatwaves, drought	Land-use change, habitat fragmentation	Rare, cold-adapted, endemic species, low dispersal capacity groups	Observed	▲	▲	▲	◆	◆
				Proj. +1.5°C	△	△	△	◇	◇
				Proj. +3.0°C	▲	▲	▲	◇	◇
Reduction in biodiversity of cold-adapted groups	Warming, heatwaves, drought	Land-use change, habitat fragmentation	Rare, cold-adapted, thermosensitive and drought-sensitive species, endemic species, low dispersal capacity groups	Observed	▲	▲	▲	◆	◆
				Proj. +1.5°C	△	△	△	◇	◇
				Proj. +3.0°C	▲	▲	▲	◇	◇
Range shifts	Warming, change in precipitation	Land-use change, habitat fragmentation	Northward shifts and altitudinal movements of species and populations.	Observed	▲	▲	▲	◆	◆
				Proj. +1.5°C	△	△	△	◇	◇
				Proj. +3.0°C	▲	▲	▲	◇	◇
Changes in phenology	Warming		Species and populations	Observed	▲	▲	▲	▲	▲
				Proj. +1.5°C	▲	▲	▲	▲	▲
				Proj. +3.0°C	▲	▲	▲	▲	▲
Decrease in ecosystem production	Warming, heatwaves, drought	Land-use change	Ecosystem productivity, and nutrient and carbon cycling	Observed	◆	◆	◆	◆	◆
				Proj. +1.5°C	◇	▲	◇	◇	◇
				Proj. +3.0°C	◇	▲	◇	◇	◇
Rising incidence of fire	Warming, heatwaves, drought	Land-use change, management	Ecosystems	Observed	◆	◆	◆	△	◆
				Proj. +1.5°C	△	△	△	△	△
				Proj. +3.0°C	▲	▲	▲	▲	▲
Reduced pollination services	Warming, heatwaves, drought	Land-use change, management	Pollination and crop yields	Observed	◆	◆	◆	◇	◆
				Proj. +1.5°C	◇	◇	◇	◇	◇
				Proj. +3.0°C	◇	◇	◇	◇	◇
Increased soil erosion	Warming, heatwaves, drought, precipitation	Land-use change, management	Soil erosion	Observed	◆	◆	◆	◆	◆
				Proj. +1.5°C	◇	◇	△	na	△
				Proj. +3.0°C	◇	◇	△	na	△

Direction of change: △ Increase ▽ Decrease ◇ Both na = no evidence

Confidence level: Observations — Low, Medium, High

Confidence level: Projections — Low, Medium, High

- Northern Europe (NEU)
- Eastern Europe (EEU)
- Western and Central Europe (WCE)
- Southern Europe (SEU)

Source: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Bednar-Friedl, et al. 2022).

– and therefore to public health, in the form of cardiovascular and respiratory conditions – from increased wildfires and megafires across Europe. Fires already affect more than 400,000 hectares in the EU each year and could increase across all regions of Europe at global warming levels of 1.5°C and 3°C (with medium to high confidence) [145]. This risk is likely to become more probable with planned afforestation and reforestation. The European Climate Risk Assessment reports that the pledge to plant at least 3 billion additional trees under the EU biodiversity strategy for 2030 could "increase wildfire risk through increased fuel load and connectivity" [21, p. 253] [211]. New geographic distributions of plants, such as the invasive common ragweed in Europe [145], are also likely to affect aeroallergens across Ireland, with implications for respiratory conditions such as asthma and hay fever [18].

5.6 Current policy landscape and necessary measures

Several existing policies are helping to reduce and manage the risks outlined above, either intentionally or implicitly. At an umbrella level, these include commitments under the Paris Agreement, Global Biodiversity Framework and Sustainable Development Goals, and the implementation of regional policies, such as the European Union's Biodiversity Strategy for 2030, Nature Restoration Law and Habitats

Directive (in addition to the EU Adaptation Strategy and 8th Environment Action Plan). For the Republic of Ireland, such umbrella policies include Ireland's 2024 Climate Change Assessment, the 2024 Climate Action Plan, the 2024 National Adaptation Framework (with forthcoming updates to Sectoral Adaptation Plans), the 4th National Biodiversity Action Plan (2023 to 2030), and the broader 2023 National Risk Assessment. For Northern Ireland, the 2021 Third UK Climate Change Risk Assessment (Northern Ireland summary), Third UK National Adaptation Programme (2023 to 2028) (until such a time as the third Northern Ireland Climate Change Adaptation Programme is published) and 2023 UK National Risk Register are salient. The first Climate Action Plan and the updated Biodiversity Strategy for Northern Ireland are yet to be published.

An assessment of these national policies[12], for their coverage of the risks articulated in this summary, draws the following conclusions:

- Responses to the risks considered in this summary are encouraging. Of all the risks considered, invasive species has the strongest policy coverage, closely linked to the spread of pests and pathogens. This holds true not only in climate-related policies but also Ireland's biodiversity action plan. Altered river basin flows have the weakest coverage, arguably reflecting the respective ranking of these risks.
- The transboundary nature of each risk is only implicitly considered. Both assessments acknowledge transboundary climate risks, although Northern Ireland's assessment integrates them more extensively, and the UK's Adaptation Programme reflects this in proposed actions, with more frequent references to collaboration and cooperation across borders.
- Given the risks generated to a range of sectors by a single phenomenon, it is encouraging to see these are acknowledged in national risk assessments and registers that go beyond the climate and environment realm. Repeated calls for monitoring and surveillance suggest a cross-sectoral and cross-jurisdictional approach is likely to be more efficient, effective and coherent.

The implementation of these policies, and updates thereof, presents opportunities to strengthen management of the transboundary climate risks considered in this summary. The Taoiseach's Shared Island Initiative also offers largely untapped potential to the same end.

Migrating and invasive species and infectious diseases in plants and animals

The risks associated with invasive species appear well-covered in policy formulation at multiple scales. For the Republic of Ireland, at a regional level, EU Regulation 2014/1143 contains specific provisions on invasive alien species, while the European Climate Risk Assessment identifies a further eight relevant frameworks and initiatives [21]. At the national level, and in addition to the policies noted above, Ireland has an Invasive Alien Species Soil and Stone Pathway Action Plan, and Sectoral Adaptation Plans for Biodiversity and for Agriculture, Forestry and Seafood, that all contain actions, measures and recommendations aimed at reducing this risk. The Draft River Basin Management Plan for Ireland (2022–27) highlights actions targeted at freshwater invasive species, while Bord Iascaigh Mhara has established a cross-department and inter-agency working group with a mandate to assess the risk of invasive species to aquaculture. The initiative to create an "MPA regime" (expanding Ireland's network of marine protected areas) may also offer scope for collaboration to safeguard transboundary marine species that are at risk from invasive species, also with the UK and Europe [140]. The role of the National Horticulture Strategy in developing more biological and environmental resilience to pest and diseases has also been noted [164].

Information on invasive species is nationally coordinated and managed by the National Biodiversity Data Centre, which hosts and maintains Ireland's National Invasive Species Database and develops comprehensive profiles for species classified of high and medium impact or singled out under EU

12 With the exception of Sectoral Adaptation Plans

Regulations [146]. A series of 2013–14 assessments formed these classifications, covering both established and potential non-native species, leading to the creation of a watch list and more detailed risk assessments of the 41 species prioritised [146]. Bord Iascaigh Mhara has also produced reporting guidelines for invasive species risk assessments [18], while various programmes – such as the cross-border initiative under PEACEPLUS [214] – support the implementation of these efforts.

For Northern Ireland, an Invasive Alien Species Strategy, (revised) Implementation Plan, and Rapid Response Contingency Plan, as well as Widely Spread Species Management Measures and Standard Operating Procedures for Invasive Non-Native Species Control, set out various mechanisms to manage and mitigate the risks posed by invasive species and have (according to assessments) been making steady progress towards their objectives [163]. The Northern Ireland Environment Agency host an Invasive Non-Native Species Team and dedicated website documenting specific species and the risks they present (both established and potential), as well as relevant legislation and management options. A 2019 order enshrines obligations in law.

The risks associated with infectious diseases in plants and animals also appear well covered in policy, though arguably with less prominence. The Republic of Ireland has a Plant Health & Biosecurity Strategy (2020–2025) and a National Farmed Animal Biosecurity Strategy (2021–2024), as well as an Animal Health Surveillance Strategy (2023–2028), for example. EU regulations in plant and animal health and the EU Birds Directive are also relevant risk reduction measures. The UK's Plant Biological Security Strategy, National Plant Monitoring Scheme and Risk Register (supporting localised and real-time risk identification) and Animal Health and Welfare Common Framework offer complementary vehicles for Northern Ireland, in addition to its own regulations. Some all-island initiatives also exist: a Catalogue of Pests and Pathogens of Trees on the Island of Ireland, for instance. Authorities already recognise the need for bilateral agreement on communications, preparedness and operational responses to pest and disease outbreaks: *"this is essential, given the shared land border, and recognises the island of Ireland as a single epidemiological unit"* [215].

A number of sectoral policies are also relevant for the management of risks driven by invasive species, pests and pathogens, such as:

- **Marine frameworks and initiatives.** For the Republic of Ireland, these include the National Marine Planning Framework and Monitoring Programme and the National Strategic Plan for Sustainable Aquaculture Development, as well as various EU policies (such as the EU Marine Strategy Framework Directive, Maritime Spatial Planning Directive, Common Fisheries Policy, and associated action plans, and the European Maritime, Fisheries and Aquaculture Fund Seafood Development Programme). For Northern Ireland, this includes the forthcoming Marine Plan for Northern Ireland. At an international level, this includes policies under the Convention for the Protection of the Marine Environment of the North-East Atlantic. Various joint initiatives on Marine Protected Areas and conservation management also present opportunities to manage transboundary climate risks to fish stocks in Irish waters.
- **Forestry strategies and regulations.** For the Republic of Ireland, these include Ireland's Forest Strategy and its Implementation Plan, the Shared National Vision for Trees and Forests and Forestry Programme (2023–2027) and the New Coillte Strategic Vision, as well as EU policies such as the EU Forest Strategy for 2030 and proposed Forest Monitoring Law. Up-to-date forestry policy for Northern Ireland appears lacking.
- **Agricultural policies.** For the Republic of Ireland, these include the CAP Strategic Plan and ACRES scheme and EU policies (such as the Common Agricultural Policy and Farm to Fork Strategy) more broadly. For Northern Ireland, this includes the Future Agricultural Policy. It also includes other policies discussed elsewhere in this report.

Progress towards the adaptation of the agriculture, forestry and seafood sector is rated as "moderate" in the Third Climate Change Adaptation Scorecard, with evidence of a substantive research focus on

climate change, supported by the launch of the Teagasc Climate Action Strategy, inclusion of adaptation in departmental studies and the development of the National Marine Research and Innovation Strategy [164]. Risk owners include an Internal Adaptation Steering Group, Climate Action Management Board and Seafood Climate Action Group. This broader enabling environment bodes well for the management of transboundary climate risks to these sectors. But much depends on increasing awareness and understanding of transboundary climate risks among relevant actors, and the implementation of policies, further mainstreaming of adaptation, and continued monitoring and review more broadly. Given a "limited focus" on adaptation measures in fisheries and aquaculture, this sector should be prioritised [164].

While coverage of the risks catalysed by migrating and invasive species and infectious diseases in plants and animals appears comprehensive, the following recommendations would strengthen the management of this risk:

- Prioritise adaptation of the biodiversity sector as a policy objective, noting the limited progress reported in relevant assessments, and addressing capacity and programmatic constraints (harnessing opportunities such as the newly established Directorates of Scientific Advice and Research and Conservation Measures in the Republic of Ireland) as well as research and data gaps [164].
- Mainstream climate projections into all invasive species and biosecurity policies, assessments and databases and put in place measures to ensure their regular update given the rapidly changing nature of this risk; use this same opportunity to strengthen coherence across the range of actions and policies aiming to manage this risk and identify any gaps in relation to recommendations from experts as well as significant incoherences (e.g. with trade policies, given international trade represents a major driver of these risks) [172].
- Increase accountability for implementing actions already identified in policies (such as increased bio-surveillance and security) by ensuring all risks have identified owners and regular reporting mechanisms.
- Harness structures and capacities established on invasive species to strengthen risk identification, surveillance and management related to pests and pathogens more broadly – working towards a more holistic understanding of the threats transboundary climate risks pose to Irish ecosystems and biodiversity.
- Establish or support cross-ministerial and cross-jurisdictional working groups. These should convene biodiversity and climate change experts to explore adaptation solutions to transboundary climate risks where the implementation of existing actions falls short. This should be done in dialogue with sectoral representatives from fisheries, forestry and agriculture, and could include risks generated by the movement and migration of species.

Water stress

Transboundary risks affecting shared hydrological systems on the island of Ireland are well recognised in policy. At an international level, the UK is a signatory to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, and the Republic of Ireland is subject to provisions under various EU policies, such as the Water Framework Directive, Groundwater Directive and Floods Directive (among others: the European Climate Risk Assessment identifies 13 relevant frameworks and initiatives [21]). At the national level in the Republic of Ireland, the Draft River Basin Management Plan for Ireland (2022–2027) (soon to be called the Water Action Plan, published later this year), Water Quality and Water Services Infrastructure Sectoral Adaptation Plan, the National Water Resources Plan and Biodiversity Action Plan by Irish Water, and four Regional Water Resources Plans could all be relevant to the management of transboundary climate risks to the island's shared water systems – either informally, through their implementation, or more formally, through explicit consideration as they are updated in the future. North of the border, the Draft 3rd cycle River Basin Management Plan (2022–2027) and Northern Ireland Water Climate Change Strategy present complementary opportunities.

Both national jurisdictions also have flood risk policies and management plans in place. Implementation of the EU Floods Directive is carried out on an all-island basis and interviewees pointed to decades of deep cross-border engagement on transboundary flooding and shared water-related risks. The Third Climate Change Adaptation Scorecard rates progress in the flood risk management sector as good overall, led by the Office of Public Works and supported by effective cross-sectoral engagement and leadership buy-in [164]. Development of a Predictive National Flood Risk Assessment is ongoing, alongside the implementation of several relevant policies (such as the Climate Change Adaptation Schemes Programme and National Coastal Change Management Strategy, Nature-Based Solutions Catchment Management Strategy and Biodiversity Action Strategy). There is "significant evidence" of adaptation mainstreaming [164]. Progress in adaptation of the water quality and water services infrastructure was rated slightly lower (moderate) with "limited evidence of the use of risk identification and prioritization and modelling predicted climate changes that will affect the sector" [164, p. 25]. Significant research gaps, limited implementation, monitoring and evaluation of adaptation actions, weak mainstreaming of adaptation, and a lack of systematic coordination will all hinder the recognition and response to transboundary climate risks to water services [164].

The Northern Ireland's Department for Infrastructure and the Republic of Ireland's Office of Public Works already collaborate on cross-border catchment areas and seek to avoid transboundary maladaptive effects: cooperation is reported as "close and lasting" [216]. Shared water bodies are managed jointly through the EU Water Framework Directive. The two authorities use shared templates and conduct joint monitoring of shared groundwater sites, transitional and coastal waters, and transboundary rivers and lakes. This cooperation is reflected in shared River Basin Management Plans, programmes of measures and information systems for each of the shared districts. Cross-border groups include the official North/South Water Framework Directive Coordination Group as well as unofficial stakeholder bodies and technical implementing groups, committees and forums. Several cross-border projects (such as Source to Tap [217]) have also been initiated. Importantly, cooperation also crosses scales: the two jurisdictions are currently working on a "shared waters" publication, and the North-South Ministerial Council has water listed as an area for cooperation. Interviewees cited high levels of interaction between local authorities within the border region, including on adaptation – noting that Dublin and Belfast probably have much to learn given they share as many risks.

While transboundary cooperation of shared water resources is exemplary, the following recommendations would strengthen the management of this risk:

- Assess the extent to which shared River Basin Management plans are accounting for the projected impacts of climate change, potentially led by the new project delivery office. The former Northern Ireland Climate Change Adaptation Programme (2019–2024) called for such plans to account for the latest climate risk assessments, and for programmes of measures to address potential impacts [163], but there may be gaps in applying downscaled climate projections (at basin level) to cross-border catchments, and assessing the potential risks (today and under future climate scenarios) to water systems and the services they supply. The Third Climate Change Adaptation Scorecard notes that such plans incorporate climate resilience, but only to a limited degree [164]. National adaptation plans should reflect these needs and those with climate change and adaptation expertise should support these efforts [218].
- Explore the extent to which it is feasible and desirable to extend integration and cooperation to cover transboundary marine and coastal monitoring [216].
- Appraise potential challenges to effective cooperation to manage shared water resources in the future: one interviewee noted the different policy and regulatory approaches to water quality and supply between the two jurisdictions as a risk, with "potential regulatory divergence and more complex arrangements for cross-border cooperation and consultation" following Brexit [219, p. 18]. This may require investment to develop standardized baselines, indices and methodologies to assess future outlooks on net water availability.

Human health

In the wake of Covid-19, transboundary risks to human health are moving up the policy agenda globally. At a regional level, EU Regulation 2022/2371 on serious cross-border threats to health indicates the high level of priority given by the EU to the threat of infectious disease. Several EU policies also appear relevant for the effective management of this risk by the Republic of Ireland, including the EU Global Health Strategy, EU4Health programme and RescEU. These efforts are supported by the Health Emergency Preparedness and Response Authority, the European Climate and Health Observatory and European Centre for Disease Prevention and Control. The latter carries out threat prioritization exercises (including those of environmental origin) with a view to generating medical countermeasures, and are developing the Athina (Assessment of Threats and Intelligence) platform for data collection on risks and responses. But the European Climate Risk Assessment notes the need for a more coherent approach to surveillance, incorporating climate, animal and environmental indicators, and stronger coordination between Member States and the EU to drive more systemic action [21].

Both the Republic of Ireland and Northern Ireland have relevant national policies, such as the Health Protection Strategy 2022–2027 and the forthcoming Public Health Bill, respectively. The Republic of Ireland has a Health Protection Surveillance Centre that could help predict emerging risks, and the UK's Biological Security Strategy is a flagship initiative to protect the UK and its interests from significant biological risks, including future infectious disease outbreaks. Northern Ireland also has an infectious disease incident/outbreak plan. But the Third Climate Change Adaptation Scorecard rates progress towards the effective adaptation of the health sector as limited, with "limited use of risk identification and prioritization and the use of projections and impacts of climate change to influence actions and decisions" [164, p. 26]. The HSE Climate Action Strategy and National Clean Air Strategy in the Republic of Ireland, as well as the establishment of a Climate Change Oversight Group, could provide useful vehicles, but increasing awareness and understanding of transboundary climate risks is a crucial first step, in conjunction with the implementation of policies, further mainstreaming of adaptation, and continued monitoring and review more broadly.

While there is extensive monitoring of transboundary risks to public health, the following recommendations would strengthen the management of this risk:

- Invest in research to better understand the links between climate change and communicable disease (responding to calls by the World Health Organization [220]).
- Convene experts to design a precautionary process to regularly and effectively assess the transboundary climate risk to the health of the Irish people, on an all-island basis.

General recommendation – adopt a holistic approach

A final recommendation to strengthen adaptation to biophysical transboundary climate risks cuts across all types of risk articulated above: the need to adopt a holistic approach. To avoid siloed and fragmented approaches, some (including interviewees) have called for the design of an all-island conservation strategy for biodiversity protection and nature restoration in addition to mainstreaming transboundary climate risks within the existing policy ecosystem.

Such an approach risks policy proliferation but could help avoid potential trade-offs (e.g. between vector control to reduce infectious diseases in plants and animals and wetland restoration to reduce flood risk) [21], while strengthening policy integration and coherence. The All-Island Climate and Biodiversity Research Network (AICBRN) may be a useful resource in formulating the strategy, but the adequate resourcing and empowerment of a lead government department – to oversee and implement actions across sectors – would be critical.

CONCLUSIONS

This report has identified and assessed the most severe transboundary climate risks facing the island of Ireland under three pre-defined categories: agriculture and food security, infrastructure and trade and biophysical systems and ecosystem services. It is clear from this brief scoping exercise that these risks – and others – will not occur in isolation; they can be expected to occur simultaneously as climate change unfolds throughout the world. Climate change impacts cannot be contained within sectoral or national borders. As such, the island of Ireland's true exposure is to a series of inter-related, inter-acting, compounding and cascading cross-border risks, driven by climate change and other socio-economic dynamics.

The interactions between the risks identified and assessed in this report have not been considered in any detail. In many cases, it will not be possible to anticipate the specific timing and nature of risk interactions. It is therefore important to embark on a process of iterative risk assessment so that new knowledge and perspectives can be used to inform planning for Irish resilience.

The report has also focused on risks and responses at the national level in the Republic of Ireland and Northern Ireland. Yet transboundary climate risks pose a number of challenges for local government, as we as private actors at a range of scales, from small and medium enterprises to multinational firms based on the island of Ireland. It is important that these actor groups are brought into climate risk assessment and adaptation processes. Dissemination of the report's main findings to these groups may facilitate dialogue and engagement.

The recommendations in the opening section of this report are intended to illuminate the first steps in a resilience-building process on the island of Ireland that explicitly recognises the interdependence between these jurisdictions and the rest of the world. This report aims to be a useful guide as that journey begins.

REFERENCES

[1] S. Flood, S. Paterson, E. O'Connor, B. O'Dwyer, H. Whyte, MartinLeTissier and J. Gault, "National Risk Assessment of Impacts of Climate Change: Bridging the Gap to Adaptation Action," Environmental Protection Agency, Wexford, 2020.

[2] D. Healy, J. Tawn, P. Thorne and A. Parnell, "Inference for extreme spatial temperature events in a changing climate with application to Ireland," The Royal Society, London, 2024.

[3] S. F. Kew, M. McCarthy, C. Ryan, J. S. Pirret, E. Murtagh, M. Vahlberg, A. Amankona, J. O. Pope, F. Lott, F. Lott, B. Coonan, I. Pinto, I. Pinto and S. Philip, "Autumn and Winter storms over UK and Ireland are becoming wetter due to climate change," Grantham Institute for Climate Change, London, 2024.

[4] European Environment Agency, "European Climate Risk Assessment," European Environment Agency, Copenhagen, 2024.

[5] World Food Programme, "War in Ukraine Drives Global Food Crisis - Hungry world at critical crossroads," World Food Programme, Rome, 2022.

[6] World Bank Group, "What You Need to Know About Food Security and Climate Change," World Bank Group, 17 October 2022. [Online]. Available: https://www.worldbank.org/en/news/feature/2022/10/17/what-you-need-to-know-about-food-security-and-climate-change. [Accessed 22 August 2024].

[7] C. Murphy, K. Leonard, R. Moore and S. Flood, "Transboundary Climate Risks for the Island of Ireland," Environmental Protection Agency, Wexford, 2024.

[8] IPCC, "Climate Change 2022 — Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change," Cambridge University Press, Cambridge and New York, 2022.

[9] European Environment Agency, "European Climate Risk Assessment," European Environment Agency, Copenhagen, 2024.

[10] Board Bia, "Future Focused: Export Performance and Prospects Report 2023-24," Irish Food Board, Dublin, 2024.

[11] The Grocer, "The Grocer," 27th October 2022. [Online]. Available: https://www.thegrocer.co.uk/supply-chain/branston-struggling-to-supply-baked-beans-due-to-disruption-linked-to-ukraine-war/672912.article. [Accessed July 2024].

[12] K. Li, J. Pan, W. Xiong, W. Xie and T. Ali, "The impact of 1.5 °C and 2.0 °C global warming on global maize production and trade," *Sci Rep 12,* vol. 17268, no. https://doi.org/10.1038/s41598-022-22228-7, 2022.

[13] Irish Farmers Journal, " The fall and rise of the Irish pig sector," [Online]. Available: https://www.farmersjournal.ie/focus/pigs/the-fall-and-rise-of-the-irish-pig-sector-805338. [Accessed July 2024].

[14] K. Adams, M. Benzie, S. Croft and S. Sadowski, "Climate change, trade, and global food security: A global assessment of transboundary climate risks in agricultural commodity flows," Stockholm Environment Institute, Stockholm, 2021.

[15] J. Verschuur, A. Murgatroyd, Y. Vittis, A. Mosnier, M. Obersteiner, C. Godfray and J. Hall, "The impacts of polycrises on global grain availability and prices," https://www.researchsquare.com/article/rs-3969801/v1, Vols. https://doi.org/10.21203/rs.3.rs-3969801/v1, 2024.

[16] J. Hedlund, H. Carlsen, S. Croft, C. West, Ö. Bodin, E. Stokeld, J. Jägermeyr and C. Müller, "Impacts of climate change on global food trade networks.," *Environmental Research Letters,* https://doi.org/10.1088/1748-9326/aca68b, 2022.

[17] S. Seneviratne, X. Zhang, M. Adnan, W. Badi, C. Dereczynski, A. D. Luca, S. Ghosh, I. Iskandar, J. Kossin, S. Lewis, F. Otto, I. Pinto, M. Satoh, S. Vicente-Serrano, M. Wehner and B. Zhou, "Weather and Climate Extreme Events in a Changing Climate. 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," Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2021.

[18] C. Murphy, L. Heaphy, T. Quinn and E. a. N. P. O'Brien, "IRELAND'S CLIMATE CHANGE ASSESSMENT Volume 3: Being Prepared for Ireland's Future Climate," Environmental Protection Agency, 2023.

[19] K. Deignan, A. O'Hora, O. Delargy, L. Heuston and C. Morrow, "Climate Change Adaptation: Risks and Opportunities for Irish Businesses," SustainabilityWorks, 2019.

[20] Climate Northern Ireland, "Evidence for the third UK Climate Change Risk Assessment (CCRA3) Summary for Northern Ireland," 2023.

[21] EEA, "European Climate Risk Assessment," 2024.

[22] J. Glauber and A. A. Mamun, "India's export restrictions on rice continue to disrupt global markets, supplies, and prices," 2024.

[23] Safe Food, "What is the cost of a healthy food basket in Ireland in 2022?", 2023.

[24] University of Notre Dame, "Notre Dame Global Adaptation Initiative Index, Country rankings," [Online]. Available: https://gain.nd.edu/our-work/country-index/rankings/.

[25] I. Stanley, O. Doyle, C. Elliott-Kingston, B. McNulty and C. Murrin, "The irish Fruit and Vegetable System: A summary of production, trade and consumption".

[26] Energy and Climate Intelligence Unit, " Climate impacts on UK food imports: spotlight on climate-vulnerable countries," 2023.

[27] M. Bisbis, N. Gruda and M. Blanke, "Potential impacts of climate change on vegetable production and product quality – A review," *Journal of Cleaner Production,* vol. 170, no. 1, pp. 1602-1620, 2018.

[28] R. Tchonkouang, H. Onyeaka and H. Nkoutchou, "Assessing the vulnerability of food supply chains to climate change-induced disruptions," *Science of The Total Environment,* vol. 920, 2024.

[29] P. Scheelbeek, C. Moss, T. Kastner, C. Alae-Carew, S. Jarmul, R. Green, A. Taylor, A. Haines and A. Dangour, "UK's fruit and vegetable supply increasingly dependent on imports from climate vulnerable producing countries," *Nat Food 1,* 2020.

[30] M. Jiménez-Donaire, J. Giráldez and T. Vanwalleghem, " Impact of Climate Change on Agricultural Droughts in Spain," *Water,* vol. 12, no. 11, 2020.

[31] Irish Examiner, "Shortage of fruit and vegetables 'a wake-up call' on impact of climate change," 22 February 2023. [Online]. Available: https://www.irishexaminer.com/news/arid-41076908.html.

[32] Irish Examiner, "Horticultural crops in danger of further decline if support is not put in place, IFA warns," 22 February 2023. [Online]. Available: https://www.irishexaminer.com/farming/arid-41077799.html.

[33] T. Andreyeva, M. Long and K. Brownell, "The impact of food prices on consumption: a systematic review of research on the price elasticity of demand for food," *Am J Public Health,* vol. 100, no. 2, pp. 216-222, 2010.

[34] The Food Foundation, "The Broken Plate: The State of the Nation's Food System," 2023.

[35] J. Mackenbach, S. Brage, N. Forouhi, S. G. N. Wareham and P. Monsivais, "Does the importance of dietary costs for fruit and vegetable intake vary by socioeconomic position?", *Br J Nutr.,* vol. 114, no. 9, pp. 1464-1470, 2015.

[36] L. Levy, "School Food and Attainment - Review of the literature," 2013.

[37] J. Harrington, C. Leydon, C. Twohig and S. Vandevijvere, "Policies for Tackling Obesity and Creating Healthier Food Environments in Ireland: Food-EPI 2020. Current policies and priority actions," 2020.

[38] Bord Bia, "Export Performance and Prospects Report 2022 – 2023," 2023.

[39] Bord Bia, "Future Focused: Export Performance and Prospects Report 2023 – 2024," 2024.

[40] Teagasc, "The Irish Dairy Beef Industry," The Agriculture and Food Development Authority, [Online]. Available: https://www.teagasc.ie/animals/beef/dairy-calf-to-beef/#:~:text=The%20Irish%20Dairy%20Beef%20Industry&text=It%20supports%20in%20excess%20of,processing%2C%20distribution%20and%20transport%20sectors.

[41] National Dairy Council, "National Dairy Council," [Online]. Available: https://ndc.ie/accordion/what-do-irish-cows-eat/#:~:text=Due%20to%20our%20climate%20and,to%20300%20days%20each%20year.

[42] "2.3m tonnes of imported animal feed was genetically modified," AgriLand, 23 November 2022. [Online]. Available: https://www.agriland.ie/farming-news/2-3-m-tonnes-of-imported-animal-feed-was-genetically-modified/.

[43] The Irish Farmers Journal, "Feed Imports into Ireland rise in 2022," 8 March 2023. [Online]. Available: https://www.farmersjournal.ie/tillage/news/feed-imports-into-ireland-rise-in-2022-752234#:~:text=Ireland%20needs%20to%20import%20large,into%20the%20Republic%20of%20Ireland.

[44] The Journal, "'Dining on deforestation': Irish meat and dairy may be linked to Amazon forest clearance," 18 December 2023. [Online]. Available: https://www.thejournal.ie/overseas-impact-soy-imports-deforestation-6248437-Dec2023/#:~:text=Soy%2C%20mainly%20grown%20in%20South,that%20stock%20Ireland%27s%20supermarket%20shelves.

[45] J. Zscheischler, S. Westra and B. v. d. Hurk, "Future climate risk from compound events," *Nature Clim Change,* vol. 8, p. 469–477, 2018.

[46] J. Verschuur, E. E. Koks, S. Li and J. W. Hall, "Multi-hazard risk to global port infrastructure and resulting trade and logistics losses," *Communications Earth & Environment,* vol. 4, 2023.

[47] International Monetary Fund, "World Economic Outlook: Navigating Global Divergences, Chapter 3 – Fragmentation and Commodity Markets: Vulnerabilities and Risks," 2023.

[48] R. B. Kerr, T. Hasegawa, R. Lasco, I. Bhatt, D. Deryng, A. Farrell, H. Gurney-Smith, H. Ju, S. Lluch-Cota, F. Meza, G. Nelson, H. Neufeldt and P. Thornton, "Food, Fibre, and Other Ecosystem Products," [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.), 2022.

[49] House of Lords European Affairs Sub-Committee on the Protocol, Northern Ireland Grain Trade Association (NIGTA), "Written evidence (NIP0030)".

[50] UK Health Security Agency, "Health Effects of Climate Change in the UK, Chapter 9: Climate change and food supply," 2023.

[51] C. Murphy, K. Leonard, R. Moore and S. Flood, "Transboundary Climate Risks for the Island of Ireland," Environmental Protection Agency, Wexford, 2024.

[52] EC, "CSR Directive," [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464.

[53] TCFD, "TCFD Recommendations," [Online]. Available: https://www.fsb-tcfd.org/recommendations/.

[54] UK Government, "UK Critical Imports and Supply Chain Strategy," [Online]. Available: www.gov.uk/government/publications/uk-critical-imports-and-supply-chains-strategy/critical-imports-and-supply-chains-strategy-html-version#annex.

[55] UK Department for Business and Trade, "DBT Supply Chain Resilience Framework," [Online]. Available: https://www.gov.uk/government/publications/supply-chain-resilience.

[56] Nordic Council of Ministers, "The Karlstad Declaration on Nordic co-operation for preparedness and robustness related to food supply and forestry," [Online]. Available: https://www.norden.org/en/deklaration/karlstad-declaration-nordic-co-operation-preparedness-and-robustness-related-food.

[57] "Public Procurement Note 03/21 on Supply Chain Resilience," [Online]. Available: https://www.finance-ni.gov.uk/publications/ppn-0321-supply-chain-resilience.

[58] C. Lascurettes, "Why don't we grow more plant-based food in Ireland?", Cúl Dara Consultancy, 2024. [Online]. Available: https://culdaraconsultancy.ie/march-2024-newsletter.

[59] Department of Agriculture, Food and the Marine, " Food Vision 2030," 2021.

[60] Department of Agriculture, Food and the Marine, "National Strategy for Horticulture 2023-2027".

[61] Northern Ireland Assembly, "Effect of Free School Meals Nutrition on Educational Attainment," 2010.

[62] M. Mullan, L. Danielson, B. Lasfargues, N. C. Morgado and E. Perry, "Climate-resilient Infrastructure: Policy perspective. OECD Environment Policy Paper N. 14," OECD, Paris, 2018.

[63] B. Bednar-Friedl, R. Biesbroek and D. N. Schmidt, "Europe. 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 University Press, Cambridge, 2022.

[64] E. E. Koks, K. C. H. v. Ginkel, M. J. E. v. Marle and A. Lemnitzer, "Brief communication: Critical infrastructure impacts of the 2021 mid-July western European flood event," *Natural Hazards and Earth System Sciences,* vol. 22, no. 12, p. 3831–3838, 2022.

[65] M. Kendon, "Storm Babet, 18 to 21 October 2023," Met Office, Exeter, 2023.

[66] S. Hallegatte, J. Rentschler and J. Rozenberg, "Lifelines: The Resilient Infrastructure Opportunity," World Bank, Washington DC, 2019.

[67] G. Forzieri, A. Bianchi, F. B. e. Silva, M. A. M. Herrera, A. Leblois, C. Lavalle, J. C. Aerts and L. Feyen, "Escalating impacts of climate extremes on critical infrastructures in Europe," *Global Environmental Change,* vol. 48, pp. 97-107, 2018.

[68] Department of the Environment, Climate and Communication, "National Adaptation Framework: Planning for a Climate Resilient Ireland," Government of Ireland, Dublin, 2024.

[69] The Department of Environment, Climate and Communications, "Electricity and Gas Networks Sector: National Adaptation Plan," Government of Ireland, Dublin, 2019.

[70] T. Moore, "Revealed: How rising temperatures will affect our airports, rail network and power stations," Sky News, 8 December 2023. [Online]. Available: https://news.sky.com/story/revealed-how-rising-temperatures-will-affect-our-airports-rail-network-and-power-stations-13025028. [Accessed 25 May 2024].

[71] Sustainable Energy Authority of Ireland, "Energy in Ireland - 2023 Report," Sustainable Energy Authority of Ireland, Dublin, 2023.

[72] C. V. Mikellidou, L. M. Shakou, G. Boustras and C. Dimopoulos, "Energy critical infrastructures at risk from climate change: A state of the art review," *Safety Science,* vol. 110, p. 110þ120, 2018.

[73] A. Antoniou, A. Dimou, E. Zacharis, F. Konstantopoulou and P. Karvelis, "Adapting oil and gas infrastructure to climate change," in *Pipeline Technology Conference 2020*, Berlin, 2020.

[74] United States Government Accountability Office, "Energy Infrastructure Risks and Adaptation Efforts," United States Government Accountability Office, Washington DC, 2014.

[75] A. M. Cruz and E. Krausmann, "Vulnerability of the oil and gas sector to climate change," *Climate Change,* vol. 121, p. 41–53, 2014.

[76] Asian Development Bank, "Climate Risk and Adaptation in the Electric Power Sector," Asian Development Bank, Mandaluyong City, 2012.

[77] M. Khan, "Critical Infrastructure safety and security: Oil & Gas as the ideal example," Axis Communications - Newsroom, 8 January 2023. [Online]. Available: https://newsroom.axis.com/blog/securing-critical-infrastructure. [Accessed 15 August 2024].

[78] B. E. Humphreys, "Critical Infrastructure Risk Management: Securing the Oil and Gas Supply Chain," Congressional Research Service, Washington DC, 2013.

[79] Department of the Environment, Climate and Communications, "Climate Action Plan 2023 - Changing Ireland for the Better," Government of Ireland, Dublin, 2022.

[80] Minister for Agriculture, Environment and Rural Affairs, "Climate Change Act (Northern Ireland) 2022," Northern Ireland Assembly, Belfast, 2022.

[81] E. O'Donnell and E. McGrath, "Green Metals: Demand Arising from Decarbonisation of Energy and Transport Sectors," Geological Survey of Ireland, Dublin, 2023.

[82] Statistics Information, Analysis & Research Branch, Department for the Economy, "Electricity Consumption and Renewable Generation in Northern Ireland," Northern Ireland Government, Belfast, 2024.

[83] K. v. Wieringen and M. F. Álvarez, "Securing the EU's supply of critical raw materials," European Parliamentary Research Service, Brussels, 2022.

[84] L. Woetzel, D. Pinner, H. Samandari, H. Engel, M. Krishnan, C. Kampel and J. Graabak, "Could climate become the weak link in your supply chain?", McKinsey Global Institute, 2022.

[85] F. Cambero, "Focus: Chile's parched mines race for an increasingly scarce commodity: water," Reuters, 6 May 2022. [Online]. Available: https://www.reuters.com/world/americas/chiles-parched-mines-race-an-increasingly-scarce-commodity-water-2022-05-06/. [Accessed 05 July 2024].

[86] J. Dinneen, "Drought, not lithium mining, is drying out Chile's largest salt flat," New Scientist, 4 November 2022. [Online]. Available: https://www.newscientist.com/article/2345815-drought-not-lithium-mining-is-drying-out-chiles-largest-salt-flat/. [Accessed 5 July 2024].

[87] S. Bochanski, E. Cox and L. P. Low, "Preparing for climate risks to key commodities: What businesses should know," PwC, 2024.

[88] UNCTAD, "Review of Maritime Transport 2022.," United Nations, Geneva, 2022.

[89] XDI, "XDI Gross Domestic Climate Risk," XDI Benchmark Series, 1 March 2024. [Online]. Available: https://archive.xdi.systems/xdi-benchmark-gdcr/. [Accessed 23 July 2024].

[90] Y. Sun, S. Zhu, D. Wang, J. Duan, H. Lu, H. Yin, C. Tan, L. Zhang, M. Zhao, W. Ca, Y. Wang, Y. Hu, S. Tao and D. Guan, "Global supply chains amplify economic costs of future extreme heat risk," *Nature,* Vols. 627, p. 797–804, 2024.

[91] World Economic Forum, PwC and Stockholm Environment Institute, "Taking Stock of Business of Business Efforts to Adapt to Climate Change," World Economic Forum, Geneva, 2023.

[92] S. Boyson, M. D. Gerst, L. Guntuka, T. Linton, G. Muraski, B. Vakil and S. Vakil, "How Exposed Is Your Supply Chain to Climate Risks?", Harvard Business Review, Boston, MA, 2022.

[93] Central Statistics Office, "Ireland's Trade in Goods 2022," CSO statistical publication, Dublin, 2023.

[94] R. Dobson, "Diagnosing current and future water risks facing the pharmaceutical sector," WWF, Berlin, 2021.

[95] M. Rumrill and C. Rossi, "How vulnerable is your pharma facility to natural disaster?", Pharma Manufacturing, 8 January 2024. [Online]. Available: https://www.pharmamanufacturing.com/facilities/article/33017109/how-vulnerable-is-your-pharma-facility-to-natural-disaster. [Accessed 26 July 2024].

[96] Observatory of Economic Complexity, "Ireland [Country Profile]," Datawheel, Massachussets, 2024.

[97] T. a. E. Department of Enterprise, "Trade and Investment Report 2022," Department of Enterprise, Trade and Employment, Dublin, 2024.

[98] Irish Pharmaceutical Healthcare Association, "Contribution to the Irish Economy," Irish Pharmaceutical Healthcare Association, 2023. [Online]. Available: https://www.ipha.ie/about-us/contribution-to-the-irish-economy/. [Accessed 2 July 2024].

[99] Fraser of Allander Institute, "The Economic Contribution of the Pharmaceuticals Sector in Northern Ireland," University of Strathclyde - Business School, Glasgow, 2022.

[100] Irish Pharmacy Union, "How Pharmacists' Efforts in Managing Medicine Shortages Protect Patients," Irish Pharmacy Union, 2024. [Online]. Available: https://ipu.ie/members-support/medicine-shortages/. [Accessed 15 August 2024].

[101] K. Zafeiropoulos, N. Morfonios and J. Louloudi, "Why Europe is running out of meds, again," European Data Journalism Network - EDJNet, 8 March 2023. [Online]. Available: https://www.europeandatajournalism.eu/cp_data_news/why-europe-is-running-out-of-meds-again/. [Accessed 15 August 2024].

[102] European Parliament, "Medicine shortages in the EU: causes and solutions," European Parliament, 16 July 2020. [Online]. Available: https://www.europarl.europa.eu/topics/en/article/20200709STO83006/medicine-shortages-in-the-eu-causes-and-solutions. [Accessed 15 August 2024].

[103] C. Murphy, L. Heaphy, T. Quinn and E. O. a. P. Nolan., "Ireland's Climate Change Assessment: Volume 3 - Being Prepared for Ireland's Future Climate: Summary for Policy Makers," Environmental Protection Agency, Wexford, 2023.

[104] Department for Environment, Food & Rural Affairs, "UK Climate Change Risk Assessment 2022," UK Government, London, 2022.

[105] L. Dijkstra, E. Papadimitriou, B. C. Martinez, L. d. Dominicis and Matija Kovacic, "EU Regional Competitiveness Index 2.0 - 2022 edition," The Publication Office of the European Union, Luxembourg, 2023.

[106] HM Treasury, "Country and regional analysis: 2018," UK Government, London, 2018.

[107] I. Henry, "Investing in infrastructure is key to economic recovery," Newsletter, 20 April 2021. [Online]. Available: https://www.newsletter.co.uk/business/consumer/investing-in-infrastructure-is-key-to-economic-recovery-3205966. [Accessed 27 July 2024].

[108] Transport Infrastructure Ireland, "National Roads Network Indicators 2023," Transport Infrastructure Ireland, Dublin, 2024.

[109] Transport Infrastructure Ireland, "Climate Adaptation: Proposed Methodology for Detailed Climate Risk Assessments - Version 3," January 2024. [Online]. Available: https://www.tii.ie/media/vh2g3tgk/tii-detailed-climate-change-risk-assessment-methodology-2024.pdf. [Accessed 23 July 2023].

[110] Northern Ireland Statistics and Research Agency, "Overview of NI Trade with GB - 4th April 2023," Northern Ireland Statistics and Research Agency, Belfast, 2023.

[111] Invest Northern Ireland, "Advanced manufacturing and engineering," Invest Northern Ireland, 2023. [Online]. Available: https://www.investni.com/international-business/our-sectors/advanced-manufacturing-and-engineering. [Accessed 24 July 2023].

[112] UK Climate Change Committee, "Transport Briefing," UK Climate Change Committee, London, 2021.

[113] T. Moore, "Revealed: How rising temperatures will affect our airports, rail network and power stations," Sky News, 9 December 2023. [Online]. Available: https://news.sky.com/story/revealed-how-rising-temperatures-will-affect-our-airports-rail-network-and-power-stations-13025028. [Accessed 23 July 2024].

[114] Associated British Ports, "Climate Change Adaptation Report - 2021 update," Associated British Ports, London, 20.

[115] E. Burke-Kennedy, "Up to 20 new trade routes to continent in use after Brexit," The Irish Times, 23 March 2022. [Online]. Available: https://www.irishtimes.com/business/economy/up-to-20-new-trade-routes-to-continent-in-use-after-brexit-1.4834224. [Accessed 23 July 2024].

[116] Irish Tourism Industry Confederation, "The Competitiveness of Irish Tourism - Review & Outlook," Irish Tourism Industry Confederation, Dublin, 2023.

[117] Department for the Economy, "Tourism," [Online]. Available: https://www.economy-ni.gov.uk/topics/tourism#:~:text=In%20Northern%20Ireland%2C%20our%20tourism,731%20million%20in%20export%20earnings. [Accessed 26 July 2024].

[118] Egis and UK Met Office, "Climate Change Risks for European Aviation," Eurocontrol, Brussels, 2021.

[119] S. Pek and B. Caldecott, "Physical climate-related risks facing airports: an assessment of the world's largest 100 airports," University of Oxford, Oxford, 2020.

[120] C. Doll, S. Klug and R. Enei, "Large and small numbers: options for quantifying the costs of extremes on transport now and in 40 years," *Natural Hazards,* vol. 72, p. 211–239, 2014.

[121] J. Pearson, "Did You Know? There Are Up To 153 Daily Flights Between the UK & Ireland This Week," Simple Flying, 3 December 2022. [Online]. Available: https://simpleflying.com/153-daily-uk-ireland-flights-this-week/#:~:text=Separated%20by%20the%20Irish%20Sea,117%20and%20153%20flights%20daily. [Accessed 22 July 2024].

[122] Northern Ireland Statistics and Research Agency, "Northern Ireland Air Passenger Flow Statistics up to 22 March 2024," 22 March 2024. [Online]. Available: https://www.nisra.gov.uk/publications/northern-ireland-air-passenger-flow-statistics-22-march-2024. [Accessed 12 August 2024].

[123] Department for the Economy, "Tourism," Department for the Economy, [Online]. Available: https://www.economy-ni.gov.uk/topics/tourism#:~:text=In%20Northern%20Ireland%2C%20our%20tourism,one%20in%20every%2012%20jobs. [Accessed 22 July 2024].

[124] United Nations Office for Disease Risk Reductin, "The Sendai Framework for Disaster Risk Reduction 2015-2030," United Nations, Geneva, 2015.

[125] EU Commission, "Forging a Climate-Resilient Europe—the New EU Strategy on Adaptation to Climate Change. COM(2021) 82 final," EU Commission, Brussels, 2021.

[126] European Commission, "Directive (EU) 2022/2557 of the European Parliament and of the European Council of 14 December 2022 on the resilience of critical entities and repealing Council Directive 2008/114/EC," The Publications Office of the European Union, Luxembourg, 2022.

[127] Department of the Environment, Climate and Communications, "Energy Security in Ireland to 2030," Government of Ireland, Dublin, 2023.

[128] Department of Business, Enterprise and Innovation, "Government Statement on The Role of Data Centres in Ireland's Enterprise Strategy," Government of Ireland, Dublin, 2018.

[129] International Energy Agency, "Electricity 2024 - Analysis and forecast to 2026," International Energy Agency, Paris, 2024.

[130] EU Commission, "Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/17," The Publication Office of the European Union, Luxembourg, 2024.

[131] Department for Business and Trade, "Critical imports and supply chains strategy," UK Government, 2024, 2024.

[132] Department for Business, Energy and Industrial Strategy, "Mandatory climate-related financial disclosures by publicly quoted companies, large private companies and LLPs," UK Government, London, 2022.

[133] W. C. A. C. García, N. Dwyer and J. Gault, "Climate Status Report for Ireland 2020," Environment Protection Agency, Wexford, 2021.

[134] Climate Change Advisory Council, "Third Climate Change Adaptation Score Card," Climate Change Advisory Council, Dublin, 2023.

[135] Climate Change Committee, "Adapting to climate change: Progress in Northern Ireland," Climate Change Committee, London, 2023.

[136] Department of the Taoiseach, "Unprecedented funding of over €800 million for Shared Island investment priorities including A5 road," Irish Government, 20 February 2024. [Online]. Available: https://www.gov.ie/en/press-release/2c23e-unprecedented-funding-of-over-800m-for-shared-island-investment-priorities-including-a5-road/. [Accessed 10 August 2024].

[137] S. Talebian, M. Benzie, K. Harris, Ł. Jarząbek, P. Magnuszewski, T. Carter and N. and Obermeister, "A conceptual framework for responding to cross-border climate change impacts (Version 01)," 2023. [Online]. Available: https://doi.org/10.5281/zenodo.7817615.

[138] T. R. Carter, M. Benzie, E. Campiglio, H. Carlsen, S. Fronzek, M. Hildén, C. P. O. Reyer and C. and West, "A conceptual framework for cross-border impacts of climate change," *Global Environmental Change,* Vols. 69, 102307, 2021.

[139] A. a. M. A. K. [. Anisimov, "The Global Transboundary Climate Risk Report," The Institute for Sustainable Development and International Relations and Adaptation Without Borders, 2023.

[140] C. Murphy, K. Leonard and R. a. F. S. Moore, "Transboundary Climate Risks for the Island of Ireland (TCRII) (2021-CE-1043)," EPA Research Report Prepared for the Environmental Protection Agency by Irish Climate Analysis and Research UnitS (ICARU), 2021.

[141] J. Hellmann, J. Byers and B. a. D. J. Bierwagen, "Five Potential Consequences of Climate Change for Invasive Species," *Conservation Biology,* vol. 22, pp. 534-543, 2008.

[142] H. E. Roy, A. Pauchard, P. Stoett, T. Renard Truong, S. Bacher, B. S. Galil, P. E. Hulme, T. Ikeda, K. V. Sankaran, M. A. McGeoch, L. A. Meyerson, M. A. Nuñez, A. Ordonez, S. J. Rahlao, E. Schwindt, H. Seebens, A. W. Sheppard and V. Vandvik, "Summary for Policymakers of the Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services," IPBES, 2023.

[143] G. Mollot and J. a. R. T. Pantel, "The Effects of Invasive Species on the Decline in Species Richness: A Global Meta-Analysis," *Advances in Ecological Research,* vol. 56, pp. 61-83, 2017.

[144] ISAC, "Invasive Species Threaten the Success of Climate Change Adaptation Efforts," 2023. [Online]. Available: www.doi.gov/sites/default/files/documents/2024-02/isac-climate-change-white-paper-november-2023.pdf.

[145] B. Bednar-Friedl, R. Biesbroek, D. Schmidt, P. Alexander, K. Børsheim, J. Carnicer, E. Georgopoulou, M. Haasnoot, G. Le Cozannet, P. Lionello, O. Lipka, C. Möllmann, V. Muccione, T. Mustonen and D. a. W. L. Piepenburg, "Europe," 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 University Press, p. 1817–1927.

[146] "Invasives.ie - Invasive Alien Species in Ireland," [Online]. Available: https://invasives.ie/about/catalogue.

[147] BBC, "Ash sawfly: Invasive insect threatens NI's native trees," [Online]. Available: https://www.bbc.com/news/uk-northern-ireland-65884272.

[148] C. a. C. G. o. I. The Department of the Environment, "National Adaptation Framework Planning for a Climate Resilient Ireland," 2024.

[149] B. Martay, K. Macphie, K. Bowgen, J. Pearce-Higgins, R. Robinson and S. a. W. J. Scott, "Climate change and migratory species: a review of impacts, conservation actions, indicators and ecosystem services. Part 1 – Impacts of climate change on migratory species," JNCC, 2023.

[150] B. Burke, L. J. Lewis, N. Fitzgerald, T. Frost and G. a. T. T. D. Austin, "Estimates of waterbird numbers wintering in Ireland, 2011/12 – 2015/16," *Irish Birds,* vol. 41, pp. 1-12, 2018.

[151] A. Wingler, F. Cawkwell, P. Holloway, G. Misra and R. a. S. C. de la Torre Cerro, "PhenoClimate: Impact of Climate Change on Phenology in Ireland," EPA - Report 404 (2018-CCRP-MS.54), 2018.

[152] A. Lackey, P. Deneen, G. Ragland, J. Feder and D. a. P. T. Hahn, "Simulated climate warming causes asymmetric responses in insect life-history timing potentially disrupting a classic ecological speciation system," *Ecology Letters,* vol. 26, p. 1407–1418, 2023.

[153] P. Daszak and A. a. H. A. Cunningham, "Anthropogenic environmental change and the emergence of infectious diseases in wildlife," *Acta Tropica,* vol. 78, no. 2, pp. 103-116, 2001.

[154] M. M. Rojas-Downing, A. P. Nejadhashemi, T. Harrigan and S. A. Woznicki, "Climate change and livestock: Impacts, adaptation, and mitigation," *Climate Risk Management,* vol. 16, pp. 145-163, 2017.

[155] M. Hunjan and J. Lore, "Climate Change: Impact on Plant Pathogens, Diseases, and Their Management," in *Crop Protection Under Changing Climate*, Springer, 2020.

[156] B. Singh, M. Delgado-Baquerizo and E. e. a. Egidi, "Climate change impacts on plant pathogens, food security and paths forward," *Nat. Rev. Microbiol.,* vol. 21, p. 640–656, 2023.

[157] C. Mora, T. McKenzie and I. e. a. Gaw, "Over half of known human pathogenic diseases can be aggravated by climate change," *Nat. Clim. Chang.,* vol. 12, p. 869–875, 2022.

[158] R. Baker and A. M. I. e. a. Mahmud, "Infectious disease in an era of global change," *Nat. Rev. Microbiol.,* vol. 20, p. 193–205, 2022.

[159] BBC, "'Alarming and unprecedented' Irish bird flu warning," [Online]. Available: https://www.bbc.com/news/articles/cglyrzx8rz7o.

[160] D. Prosser, C. Teitelbaum and S. e. a. Yin, "Climate change impacts on bird migration and highly pathogenic avian influenza," *Nat. Microbiol.,* vol. 8, p. 2223–2225, 2023.

[161] M. Mahon and A. A. O. e. a. Sack, "A meta-analysis on global change drivers and the risk of infectious disease," *Nature,* vol. 629, p. 830–836, 2024.

[162] I. Times, "Irish hedgerows face 'wide-scale' threat after outbreaks of fireblight disease," [Online]. Available: https://www.irishtimes.com/environment/2024/03/05/irish-hedgerows-face-wide-scale-threat-after-outbreaks-of-fireblight-disease/.

[163] C. N. Ireland, "Evidence for the Third UK Climate Change Risk Assessment (CCRA3): Summary for Northern Ireland," 2021. [Online]. Available: www.ukclimaterisk.org/wp-content/uploads/2021/06/CCRA-Evidence-Report-Northern-Ireland-Summary-Final.pdf.

[164] C. C. A. Council, "Third Climate Change Adaptation Scorecard," Climate Change Advisory Council, 2023.

[165] I. Wåhlström, L. H. D. P. J. Hammar, E. Almroth-Rosell, C. Dieterich, L. Arneborg, M. Gröger, M. Mattsson, L. Zillén Snowball, G. Kågesten, O. Törnqvist, E. Breviere and S.-E. a. J. P. R. Brunnabend, "Projected climate change impact on a coastal sea—As significant as all current pressures combined," *Global Change Biology,* vol. 28, p. 5310–5319, 2022.

[166] H.-O. Pörtner, D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold and B. a. W. N. M. Rama, "IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.," IPCC, 2019.

[167] S. Gaines, R. Cabral and C. a. G. Y. Free, "The Expected Impacts of Climate Change on the Ocean Economy," World Resources Institute, 2019.

[168] IIED, "Climate change and the blue economy," IIED, 2022.

[169] F. a. t. M. Department of Agriculture, "Minister McConalogue announces investment of €37.3 million in capital projects in Ireland's six fishery harbour centres," [Online]. Available: https://www.gov.ie/en/press-release/bbd0b-minister-mcconalogue-announces-investment-of-373million-in-capital-projects-in-irelands-six-fishery-harbour-centres/.

[170] E. a. R. A. Department of Agriculture, "Multi-million pound investment in fishing harbours moves step closer - Poots," [Online]. Available: https://www.daera-ni.gov.uk/news/multi-million-pound-investment-fishing-harbours-moves-step-closer-poots.

[171] B. Townhill, E. Couce and C. a. P. J. Lynam, "Investigating Climate Change Resilience of Vulnerable Marine Species around the UK," 2021.

[172] F. Lucy and J. a. D. J. Caffrey, "Invasive alien species in the Republic of Ireland: policy recommendations for their management," The Water Forum, 2021.

[173] R. Eschen, M. Kadzamira, S. Stutz, A. Ogunmodede, D. Djeddour, R. Shaw, C. Pratt, S. Varia and K. a. W. F. Constantine, "An updated assessment of the direct costs of invasive non-native species to the United Kingdom," *Biological Invasions,* 2023.

[174] G. Forzieri, M. Girardello and G. e. a. Ceccherini, "Emergent vulnerability to climate-driven disturbances in European forests," *Nat Commun,* vol. 12, no. 1081, 2021.

[175] F. S. Ltd. and H. Phillips, "Economic Activity and employment levels in the Irish forest sector," CONFORD, 2022.

[176] Z. J. Robbins, C. Xu, B. H. Aukema, P. C. Buotte, R. Chitra-Tarak, C. J. Fettig, M. L. Goulden, D. W. Goodsman, A. D. Hall, C. D. Koven, L. M. Kueppers, G. D. Madakumbura, L. A. Mortenson and J. A. a. S. R. M. Powell, "Warming increased bark beetle-induced tree mortality by 30% during an extreme drought in California," *Global Change Biology,* vol. 28, p. 509–523, 2022.

[177] J. Porter, M. Parry and T. Carter, "The potential effects of climatic change on agricultural insect pests," *Agricultural and Forest Meteorology,* vol. 57, no. 1–3, pp. 221-240, 1991.

[178] FAO, "Plant Production and Protection," [Online]. Available: https://www.fao.org/plant-production-protection/about/en.

[179] F. a. t. M. Department of Agriculture, "Agri-Food and the Economy," [Online]. Available: https://www.gov.ie/en/publication/e2273-agri-food-and-the-economy/#:~:text=The%20agri%2Dfood%20sector%20is,60%25%20of%20indigenous%20manufactured%20exports.

[180] E. a. R. A. Department of Agriculture, "Statistical Review of Northern Ireland Agriculture 2022," NISRA, 2022.

[181] M. Pautasso and M. a. H. O. Schlegel, "Forest Health in a Changing World," *Microb. Ecol.,* vol. 69, p. 826–842, 2015.

[182] C. Godde, D. Mason-D'Croz, D. Mayberry and P. a. H. M. Thornton, "Impacts of climate change on the livestock food supply chain; a review of the evidence," *Global Food Security,* vol. 28, 2021.

[183] R. Lahlali, T. Mohammed, S.-E. Laasli, G. Gachara, R. Ezzouggari, Z. Belabess, K. Aberkani, A. Assougeum, A. Meddich, M. El Jarroudi and E. Ait Barka, "Effects of climate change on plant pathogens and host-pathogen interactions," *Crop and Environment,* 2024.

[184] S. Shrestha, A. Barratt, N. J. Fox, A. B. Vosough and M. R. Hutchings, "Financial Impacts of Liver Fluke on Livestock Farms Under Climate Change–A Farm Level Assessment," *Frontiers in Veterinary Science,* vol. 7, 2020.

[185] T. A. H. I. P. C. T. W. Group, *Liver Fluke - The Facts; Parasite Control Leaflet Series, Vol. 5, Ver. 2,* Animal Health Ireland, 2021.

[186] CIWF, "Bird Flu: Only Major Farm Reforms Can End It," Compassion in World Farming International, 2023.

[187] H. Bishop, "What is the risk of incursion of notifiable avian influenza into Northern Ireland poultry flocks during the 2023/24 winter migratory period?", DAERA, 2024.

[188] E. a. P. Division, "Annual Review and Outlook for Agriculture, Food and the Marine 2023," Department of Agriculture, Food and the Marine, 2023.

[189] DAERA, "Northern Ireland agricultural incomes in 2023," [Online]. Available: https://www.daera-ni.gov.uk/news/northern-ireland-agricultural-incomes-2023#:~:text=Aggregate%20Agricultural%20Income,%C2%A3341%20million%20in%202023.

[190] F. S. Agency, "ANNUAL REPORT AND ACCOUNTS 2022-23 For the year ended 31 March 2023," DAERA, 2023.

[191] M. Caretta, A. Mukherji, M. Arfanuzzaman, R. Betts, A. Gelfan, Y. Hirabayashi, T. Lissner, J. Liu, E. Lopez Gunn, R. Morgan and S. a. S. S. Mwanga, "Water. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group," Cambridge University Press, 2022.

[192] H. Meresa, S. Donegan, S. Golian and C. Murphy, "Simulated Changes in Seasonal and Low Flows with Climate Change for Irish Catchments," *Water,* vol. 14, no. 1556., 2022.

[193] P. Leahy, L. Hermida Gonzalez, K. Hickey, G. Kiely, M. Allen and P. a. P. A. Nowbakht, "ClimAtt: Tools for Climate Change Attribution of Extreme Weather Events," EPA, Research Report No. 384, 2016.

[194] F. a. M. B. O'Loughlin, "Projected climate change in Ireland and associated risk to water quantity; a review of national policies, governance and plans for future proofing Ireland's water supply," University College, 2023.

[195] EPA, "Hydrology," [Online]. Available: https://www.climateireland.ie/impact-on-ireland/future-climate-of-ireland/hydrology/.

[196] H. A. Munia, J. H. A. Guillaume, Y. Wada, T. Veldkamp, V. Virkki and M. and Kummu, "Future transboundary water stress and its drivers under climate change: A global study.," *Earth's Future,* vol. 8, 2020.

[197] C. Fraser and J. a. K. R. M. Brickell, "Post-Brexit implications for transboundary groundwater management along the Northern Ireland and the Republic of Ireland border," *IOP Publishing: Environmental Research Letters,* 2020.

[198] U.-W. E. G. o. W. a. C. Change, "Climate Change and Water: UN-Water Policy Brief," UN Water, 2019.

[199] A. e. a. Pfenning-Butterworth, "Interconnecting global threats: climate change, biodiversity loss, and infectious diseases," *The Lancet.,* 2024.

[200] F. a. O. R. S. Keesing, "Impacts of biodiversity and biodiversity loss on zoonotic diseases," *PNAS,* vol. 118, no. 17, 2021.

[201] M. e. a. Romanello, "The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future," *The Lancet,* vol. 398, no. 10311, pp. 1619 - 1662, 2021.

[202] A. Kaźmierczak, "Climate change as a threat to health and well-being in Europe: focus on heat and infectious diseases," EEA, 2022.

[203] W. H. Organization, "Lancet Countdown report calls for climate-driven health action," [Online]. Available: https://www.who.int/news/item/15-11-2023-lancet-countdown-report-calls-for-climate-driven-health-action.

[204] J. C. e. a. Semenza, "Climate change and infectious disease in Europe: Impact, projection and adaptation," *The Lancet Regional Health – Europe,* vol. 9, no. 100230.

[205] UKHSA, "Health Effects of Climate Change in the UK: State of the evidence 2023," 2023.

[206] WHO, "Vector-borne diseases," [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases.

[207] UKHSA, "How we protect the UK from vector-borne diseases," [Online]. Available: https://ukhsa.blog.gov.uk/2023/12/11/health-effects-of-climate-change-the-health-threat-from-vector-borne-diseases/.

[208] T. a. T. H. de Oliveira, "Will climate change amplify epidemics and give rise to pandemics?", *Science,* vol. 381, no. 6660, 2023.

[209] M. e. a. Boudou, "Flood hydrometeorology and gastroenteric infection: the winter 2015–2016 flood event in the Republic of Ireland," *J. Hydrol.,* vol. 599, no. 126376, 2021.

[210] I. Times, "Ireland's 'flammable landscape' must be managed to avoid increased wildfire risk, expert says," [Online]. Available: https://www.irishtimes.com/ireland/2024/04/17/irelands-flammable-landscape-must-be-managed-to-avoid-increased-wildfire-risk-expert-says/.

[211] V. e. a. Hermoso, "Tree planting: A double-edged sword to fight climate change in an era of megafires," *Global Change Biology,* vol. 27, no. 13, p. 3001—3003, 2021.

[212] R. McSweeney, "TIPPING POINTS Explainer: Nine 'tipping points' that could be triggered by climate change," 2020. [Online]. Available: https://www.carbonbrief.org/explainer-nine-tipping-points-that-could-be-triggered-by-climate-change/.

[213] T. G. Benton, C. Bieg, H. Harwatt and R. a. W. L. Pudasaini, "Food system impacts on biodiversity loss: Three levers for food system transformation in support of nature," Chatham House, 2021.

[214] S. E. P. Body, "PEACEPLUS PROGRAMME 2021 – 2027 Programme Overview," [Online]. Available: https://www.seupb.eu/sites/default/files/2023-05/PEACEPLUS_Overview_24052023.pdf.

[215] Defra, "Safeguarding our animals and plants," 2019. [Online]. Available: https://assets.publishing.service.gov.uk/media/5fe21ad5e90e07452ec36f1f/animals-plants-biosecurity-narrative.pdf.

[216] R. (. B. S. O. Povilanskas, "Integrated trans-boundary river basin and transitional water management in Ireland – NI/IE," [Online]. Available: www.balticlagoons.net/artwei/wp-content/uploads/2011/04/Integrated-trans-boundary-river-basin-and-TW-management-in-Ireland.pdf.

[217] EU, "Source to Tap," [Online]. Available: https://www.sourcetotap.eu/.

[218] C. a. C. The Department of Environment, "Review of the National Adaptation Framework," Government of Ireland, 2022.

[219] L. G. a. H. The Department of Housing, "Draft River Basin Management Plan for Ireland 2022 - 2027," Government of Ireland.

[220] P. e. a. Klepac, "Climate change, malaria and neglected tropical diseases: a scoping review," *Transactions of The Royal Society of Tropical Medicine and Hygiene,* 2024.

[221] A. J. Kettle, "Storm Kyrill and the storms of mid-January 2007: Societal and Energy Impacts in Europe," *Advances in Geoscience,* vol. 58, pp. 135-147, 2023.

[222] R. Pearce and S. Evans, "Mapped: How the UK generates its electricity," Carbon Brief, London, 2015.

[223] Sustainable Energy Authority of Ireland, "Energy Security in Ireland: A Statistical Overview," Sustainable Energy Authority of Ireland, Dublin, 2016.

[224] M. Coté and M. A. Mikaelsson, "White Paper on European Climate Risk and Trade in Europe," Stockholm Environment Institute, Stockholm, 2024.

[225] M. A. Mikaelsson and A. Dzebo, "Impacts and Risks from Climate Change on Trade Infrastructure," Stockholm Environment Institute, Stockholm, 2023.

[226] Q. Wang, K. Liu, M. W. E. Koks and H. Wang, "Exposure of Global Rail and Road Infrastructures in Future Record-Breaking Climate Extremes," *Earth's Future,* vol. 12, no. 1, pp. 1-15, 2024.

[227] E. E. Koks, C. Z. M. T. M. V. S. A. F. J. W. H. J. Rozenberg and S. Hallegatte, "A global multi-hazard risk analysis of road and railway infrastructure assets," *Nature Communication,* 2019.

[228] E. E. Koks, J. Rozenberg, C. Zorn, M. Tariverdi, M. I. Vousdoukas, S. A. Fraser, J. W. Hall and S. Hallegatte, "A global multi-hazard risk analysis of road and railway infrastructure assets," *Nature Communication,* vol. 10, 2019.

[229] E. Burke-Kennedy, "Up to 20 new trade routes to continent in use after Brexit," The Times of Ireland, 23 March 2022. [Online]. Available: https://www.irishtimes.com/business/economy/up-to-20-new-trade-routes-to-continent-in-use-after-brexit-1.4834224. [Accessed 23 July 2024].

[230] EU Commission, "Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks," The Publication Office of the European Union, Luxembourg, 2007.

[231] European Parliament and the Council of the European Union, "REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on Union guidelines for the development of the trans-European transport network, amending Regulations (EU) 2021/1153 and (EU) No 913/2010 and repealing Regulation (EU) No 1315/2013," The Publication Office of the European Union, Luxembourg, 2024.

[232] M. Kiss, "Revision of the trans-European transport network guidelines: Briefing," European Parliamentary Research Service, Luxembourg, 2024.

[233] G. Hughes, P. Chinowsky and K. Strzepek, "The costs of adapting to climate change for infrastructure," The World Bank, Washington DC, 2010.

[234] E. Poloczanska, C. Brown and W. e. a. Sydeman, "Global imprint of climate change on marine life," *Nature Clim Change,* vol. 3, p. 919–925, 2013.

[235] C. a. M. H. Murphy, "HydroPredict: Ensemble River Flow Scenarios for Climate Change Adaptation," Environmental Protection Agency, 2024.

[236] EPA, "Ireland's Climate Change Assessment," Environmental Protection Agency, 2023.

[237] A. Best, "Northern Ireland Agri-Food Sector Key Statistics," DAERA, 2022.

[238] ONS, "Woodland natural capital accounts: 2022," [Online]. Available: https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/woodlandnaturalcapitalaccountsuk/2022.

[239] C. Murphy, K. Leonard, R. Moore and S. Flood., "Transboundary Climate Risks for the Island of Ireland (TCRII)," Environmental Protection Agency, Wexford, 2024.

[240] M. Keller, "Chapter 2 - Phenology and growth cycle," in *The Science of Grapevines (3rd edition)*, Cambridge, Academic Press, 2020, pp. 61-103.

[241] U.S. Centres for Disease Control and Prevention, "About Vibrio Infection," U.S. Centres for Disease Control and Prevention, 14 May 2024. [Online]. Available: https://www.cdc.gov/vibrio/about/index.html. [Accessed 03 September 2014].

[242] M. D. Mastrandrea, C. B. Field, T. F. Stocker, O. Edenhofer, K. L. Ebi, D. J. Frame, H. Held, E. Kriegler, K. J. Mach, P. R. Matschoss, G.-K. Plattner, G. W. Yohe and F. W. Zwiers, "Guidance note for lead authors of the IPCC fifth assessment report on consistent treatment of uncertainties," IPCC, Geneva, 2010.

APPENDIX

Risk	Likelihood	Magnitude	Risk severity
Risk to food affordability as a result of the cost-of-living crisis and climate-driven price inflation across a basket of food products.	High	Medium	High
Confidence	**Medium**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to nutrition security for low-income households and vulnerable groups – due to volatility in fresh fruit and vegetable supply chains.	Medium	Medium	Medium
Confidence	**High**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to farming, jobs and export-revenues in the dairy sector on the island of Ireland, due to climate-related disruption to animal feed and other imports.	Low	High	Medium
Confidence	**Medium**		
Policy status	**Priority for research action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to farming, jobs and export-revenues in the beef sector, due to climate-related disruption to feeds and other imports.	Low	IE: Medium	IE: Medium
		NI: Low	NI: Low
Confidence	**Medium**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to energy security from damage to energy-critical infrastructure abroad from extreme weather and slow-onset climate change.	Low	Medium	Low
Confidence	**Medium**		
Policy status	**Watching brief**		

Risk	Likelihood	Magnitude	Risk severity
Risk to energy security from climate impacts on transport and production infrastructure abroad, disrupting overseas supply of critical minerals.	Medium	Medium	Medium
Confidence	**High**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to businesses, financial sector and overall economy due to climate-related supply chain disruptions globally.	Low	IE: High	IE: Medium
		NI: Medium	NI: Low
Confidence	**Medium**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to business operations, jobs and export-revenues in the pharmaceutical industry from climate-related disruption to global supply chains.	Medium	IE: High	IE: High
		NI: Medium	NI: Medium
Confidence	**Medium**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to public health from disrupted supplies of essential medicines and other drugs as a result of climate-related disruption to global supply chains.	Medium	Medium	Medium
Confidence	**Medium**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Risk to energy security from climate impacts on transport and production infrastructure abroad, disrupting overseas supply of critical minerals.	Low	Low	Low
Confidence	**Medium**		
Policy status	**Watching brief**		

Risk	Likelihood	Magnitude	Risk severity
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.	Low	Low	Low
Confidence	**Medium**		
Policy status	**Watching brief**		

Risk	Likelihood	Magnitude	Risk severity
Ecological risk to ecosystems and biodiversity from climate-induced changes in invasive species, movements of plants and animals, and infectious diseases.	High	High	High
Confidence	**High**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Socio-economic risk to the blue economy from climate-induced changes to invasive species, movements of plants and animals, and infectious diseases.	Medium	Medium	Medium
Confidence	**Low**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Socio-economic risk to the forestry sector from climate-induced changes to invasive species, movements of plants and animals, and infectious diseases.	Medium	Low	Low
Confidence	**Low**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Socio-economic risk to the agricultural sector from climate-induced changes to invasive species, movements of plants and animals, and infectious diseases.	Medium	Medium	Medium
Confidence	**Low**		
Policy status	**Priority for policy action**		

Risk	Likelihood	Magnitude	Risk severity
Ecological risk to transboundary river basins and the ecosystems and biodiversity they support from climate-induced water stress.	Low	Low	Low
Confidence	**Low**		
Policy status	**Watching brief**		

Risk	Likelihood	Magnitude	Risk severity
Socio-economic risk to water services from climate-induced stress on transboundary river basins.	Low	Low	Low
Confidence	**Low**		
Policy status	**Watching brief**		

Risk	Likelihood	Magnitude	Risk severity
Social risk to people and public health systems from a climate-induced rise in infectious diseases and cardiovascular and respiratory conditions.	Medium	Medium	Medium
Confidence	**Low**		
Policy status	**Priority for research action**		

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