Future Grasslands: Building Resilience Through Adaptation to Climate Change

A report for

NUFFIELD IRELAND
Farming Scholarships

by Zoe McKay

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1. Executive Summary

Demand for increased food production, combined with climate change, is placing growing pressure on agricultural production levels, costs and land availability. Over the past number of years, Ireland has experienced extreme weather events which have significantly affected grass growth and utilisation for grass-based livestock systems. Climate change predictions show an extended growing season along with substantial challenges for agriculture however, the effects will be region specific. For example, in 2024, a wet spring followed by a dry summer reduced national herbage production by 1.3 tonne (t) dry matter (DM)/hectare (ha) compared with the 10-year national average (PastureBase Ireland), while some farms particularly in the east of the country, experienced significant drought resulting in reductions in grass growth of up to 3 t DM/ha. This resulted in major implications for grass availability for grazing and silage conservation and many farmers experienced a feed deficit particularly in highly stocked grass-based systems that rely predominantly on grazed grass and have limited other feed buffers. With 92% of Irelands agricultural land under grassland, future proofing grass-based systems is essential in maintaining Ireland's competitive advantage while complying with legally binding environmental sustainability targets. Therefore, there is urgent need to identify strategies to build resilience into grass-based systems.

Therefore, the objectives of this report are to:

1. Establish the climate change challenges facing Irish grass-based livestock systems
2. Assess current resources in Ireland to address the impact of climate change on grass-based livestock systems
3. Assess international climate strategies to identify opportunities for adaptation and resilience to future proof grass-based livestock systems

To meet these objectives, a review of relevant literature on climate change and agriculture was conducted. Farm-level insights were gained through engagement with Irish farmers experiencing climate-related challenges. International perspectives were developed through study visits to eleven countries, enabled by this Nuffield Scholarship, and included participation in conferences, meetings and interviews with representatives from policy, research, education and farming sectors.

Key findings indicate that while Irish agricultural research has a strong focus on climate mitigation and sustainability, there is a significant gap in research and advisory support for climate adaptation in grassland systems. Changing rainfall patterns has emerged as the primary threat to total pasture productivity, number of grazing days and winter forage security. Current adaptation responses are limited, with little research beyond multispecies swards (MSS) and recommendations to increase silage reserves or consider stocking rate adjustments. International experience demonstrates that, where irrigation is constrained, farmer-led research programmes focused on risk planning, diversified home-grown forage and water management strategies are critical. Long lead times for the development of climate-resilient forage varieties highlight the urgency of immediate investment in long term trials under Irish conditions. Across all regions examined, strengthening farm business and the personnel resilience of farmers through risk assessment tools, planning frameworks and advisory supports was identified as essential to successful adaptation.

Collective action and national coordination across policy, research, advisory and industry stakeholders will be essential to support farmers adapting to climate change. This can be delivered through a National Grassland Climate Resilience Network, a farmer-led, nationally coordinated system that begins with the identification of on-farm challenges through an integrated farm-level resilience framework, and links these to targeted research, advisory support and industry engagement to deliver climate adaptation and ensure the long-term sustainability of grass-based livestock production systems in Ireland. This report recommends:

1. Develop climate risk and resilience tools: An integrated farm-level resilience framework should be developed to help farmers assess their climate vulnerability and plan appropriate data driven decisions and adaptations.
2. Farmer health and wellbeing: Farmer health and wellbeing should be supported to enable farmers to develop the skills needed to manage change, stress, uncertainty, increased workloads and financial pressures.
3. Research funding and infrastructure: Funding bodies should establish dedicated climate adaptation funding mechanisms and research facilities capable of

simulating future climate conditions and longer-term plot, and systems scale experiments.

4. Grass-fed standard: A review process should be established to quantify the market value of the Grass-Fed Standard and explore how it can be strengthened over time, while ensuring sufficient flexibility to respond to future industry challenges and opportunities.
5. Climate adaptation research: Multispecies swards are an important potential adaptation strategy and should be supported through further research. A future forages research programme should include long-term evaluation of alternative grass and winter forage species for grazing and conservation, alongside the breeding and assessment of plant varieties for climate tolerance, methane mitigation, pest and disease resistance, and nutrient-use efficiency.
6. Winter forages: A dedicated winter forage research programme should be re-established to develop resilient winter-feed options and explore sward diversification and collaborative approaches.
7. Water management: Water management systems should be assessed to determine whether water storage could become a viable adaptation option for farmers on dry soils.
8. Diversification for resilience: A holistic approach to land use is required to support competing demands, strengthen farm resilience and capitalise on opportunities for diversification. This should include tree integration, integrated crop-livestock systems, home-grown energy and protein, and complementary farm enterprises.

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3. List of Abbreviations

CO_2 = carbon dioxide

CSO = Central Statistics Office

DAFM = Department of Agriculture Food and the marine

DM = Dry matter

EPA = Environmental Protection Agency

EU = European Union

GHG = Green House Gas

Ha= Hectare

IFA = Irish Farmers' Association

IPCC = Intergovernmental Panel on Climate Change

LTA = Long term average

Mt CO2eq = Million tonnes carbon dioxide equivalent

MSS = Multispecies Swards

NGT = Non genomic techniques

PBI = PastureBase Ireland

PRG = Perennial Ryegrass

T = Tonne

VCU = Value for Cultivation and Use

UCD = University College Dublin

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To Michael and all our family in both Laois and Mayo, thank you for all your support and encouragement as I embarked on this new adventure. This Nuffield Scholarship has been one of the most incredible experiences of my life and has stretched me in so many ways, both personally and professionally. It has enabled me to meet people from all over the world and share in our ambitions to contribute to the future of agriculture. What was once a simple childhood hope, to travel the world and learn about agriculture, became a life-changing reality. I am incredibly proud and humbled to have been awarded this Scholarship, and I will always be grateful for the opportunities, experiences, friendships and memories it has given me.

5. Foreword

Growing up in Ballyfin, Co. Laois, I was involved in agriculture from a young age. I now live in Ballina, Co. Mayo, with my partner, where we primarily operate a dairy farm, retain all youngstock to finish, and run a small sheep flock. In 2015, I graduated with a BAgrSc from UCD and subsequently completed a PhD in dairy production in 2019. Following a period working in industry as a Ruminant Technical Specialist for Phileo UK and Ireland, I returned to UCD as an Assistant Professor of Grass and Forage Science within the School of Agriculture and Food Science. This is a diverse role encompassing both teaching and research, based at the University Farm (UCD Lyons Farm) near Newcastle, Co. Dublin. There, I lead on the grassland component of the Systems Dairy Herd, which examines the development of a higher-output, grass-based spring milk production system. Lyons Farm is a dry farm, receiving an average of 783 mm of rainfall annually. Over the past six years, changing rainfall patterns, summer droughts and changes to the Nitrate's Directive have significantly affected grass growth and utilisation. This is reflected nationally, with a five-year average grass growth of 12.3 t DM/ha compared to a 10-year average of 13.1 t DM/ha. In 2024, a wet spring followed by a dry summer reduced production by 1.3 t/ha, with some farms in the east experiencing losses of up to 3 t/ha. In contrast, climate change in the west of Ireland is creating challenges for grass utilisation, particularly during wetter autumn and spring periods, while suitable summer windows for achieving optimum silage conservation are also becoming increasingly constrained.

These conditions have led to feed deficits and challenges for silage conservation, particularly in highly stocked, grass-based systems with limited buffering capacity. My work at UCD Lyons Farm and our home farm has highlighted the contrasting impacts of climate variability on grass growth across regions of Ireland and the need for tailored tools and advisory. This has driven my interest in the need to build resilience in grass-based systems through adaptation to climate change. Through this Nuffield Farming Scholarship, I have had the privilege of visiting five continents and eleven countries which have informed the basis of this report on, "Future Grasslands: Building Resilience through Adaptation to Climate Change."

6. Introduction

The Irish agri-food sector is the country's largest indigenous export industry contributing €19 billion to the economy in 2025. Of this the dairy, meat, and livestock sectors account for €12.3 billion (Bord Bia, 2026). Irish livestock production is based on a grass-based system with 92% of Ireland's agricultural land under grassland (Central Statistics Office, 2023) with perennial ryegrass (PRG; *Lolium Perenne*) accounting for 95% of grass seed sales. Grassland dominance is driven by Ireland's temperate climate enabling the production of a high-quality home-grown feed that has facilitated a significant competitive advantage as evident though Bord Bia's Grass Fed Standard (Bord Bia, 2019, 2021). Climate change has led to rising temperatures, altered rainfall patterns, and more frequent extreme weather events which are already evident in Ireland. Significant mitigation and sustainability resources are in place to support Ireland's commitment to climate neutrality by 2050 (Climate Action and Low-Carbon Development Act 2021) however, fewer resources are available to develop tools to support farms impacted by climate change. Predictions suggest an extended growing season along with substantial challenges for agriculture, however, the effects will be region specific (Nolan et al., 2025). For example, in 2024, a wet spring followed by a dry summer reduced national herbage production by 1.3 t DM/ha compared with the 10-year national average, with some farms in the east experiencing reductions of up to 3 t DM/ha. This created significant feed deficits and had major implications for silage conservation, particularly in highly stocked grass-based systems that rely predominantly on grazed grass and have limited other feed buffers. Future proofing grass-based systems is essential in maintaining Ireland's competitive advantage while complying with legally binding environmental sustainability targets. Therefore, there is urgent need to identify strategies to build resilience into grass-based systems and adapt to climate change.

7. Objectives

The objectives of this research report are to:

1. Establish the climate change challenges facing Irish grass-based livestock systems
2. Assess current resources in Ireland to address the impact of climate change on grass-based livestock systems
3. Assess international climate strategies to identify opportunities for adaptation and resilience to future proof grass-based livestock systems

8. Research Approach and Methodology

This report began with a review of literature and policy to assess projected climate change in Ireland and its implications for grass-based livestock systems. It also evaluated policy measures and available resources to support farmers in adapting to these impacts. Engagement with Irish farmers and stakeholders helped identify current challenges and sector priorities. To incorporate international perspectives, this Nuffield Scholarship enabled research visits to Australia, New Zealand, Singapore, Taiwan, Zimbabwe, Romania, Poland, Chile, England, Belgium, and Portugal. These included conferences, meetings, and interviews with stakeholders across policy, research, education, and farming. Insights from this work have informed the report, with selected examples presented as case studies. The report is structured in three sections: first, the context of climate change and related policy, with a focus on agriculture (Section 9); second, an overview of current climate adaptation resources in Ireland (Section 10); and third, an examination of international developments and how these insights can be applied to futureproof and increase the resilience of grass-based livestock systems (Section 11).

Authors Note:

This first section of the report highlights the significant, complex and interrelated challenges that Irish agriculture will face under future climate change. Grassland ecosystems across Ireland's regions will be affected in different ways and at different times of the year, with climate projections indicating an increase in extreme weather events, including heavier rainfall and more frequent droughts alongside fewer frost and ice days. Given the breadth of this topic, climate change adaptation, the report will primarily focus on the implications of changing rainfall patterns resulting in periods of heavier rainfall in the autumn/spring and increased soil moisture deficits. Changing rainfall patterns will significantly affect forage availability in grass-based livestock systems, which rely on high grass growth and utilisation to support high stocking rates and conserve surplus grass over summer. Highlighting such challenges should inspire national action and support for farmers across Ireland in adapting to climate change. However, specific regions will be more significantly impacted by climate change and will require further targeted action and support across a variety of aspects of farm systems, including soil structure, nutrient management, infrastructure and heat stress.

9. Agriculture and Climate Change

"Europe is the fastest-warming continent"
European State of the Climate - Report 2025.

"We are living in a changed climate that is going to change more"
Padraig Flattery, Met Éireann.

9.1 Grass Based Livestock Systems

The Irish agri-food sector is the country's largest indigenous export industry. In 2025, exports reached a record €19 billion, a 12% increase on 2024. Dairy, meat and livestock accounted for €12.3 billion, with export growth of 14% and 18%, respectively (Bord Bia, 2026). Ireland's agricultural land spans 4,620,096 ha across 133,174 farms, with an average size of 34.7 ha. The primary agricultural sector is characterised by an ageing population, with 37.8% of farm holders over 65 and only 13.2% female (Central Statistics Office, 2023) with 109,300 people employed (Central Statistics Office, 2026).

Ireland's agricultural land is primarily grassland (92%), including permanent pasture, silage/hay ground, and rough grazing (Central Statistics Office, 2023). Ireland's temperate climate and geographic location make it ideally suited to growing grass, primarily PRG. Subsequently, grass seed sales in Ireland are dominated by PRG (95%) due to its rapid establishment, high yields of quality palatable herbage, tolerance for intensive grazing and cutting and its production response to fertile conditions and nitrogen fertiliser. Despite the advantages of a high PRG containing sward, less than 3% of grassland is reseeded annually with new grass varieties (Teagasc, 2024a).

As a result, grass-based livestock systems dominate, utilising grass to produce high-quality milk and meat products (Guyader et al., 2016). Production systems have evolved to maximise grass growth and utilisation by aligning animal nutrient demand with grass growth (Figure 1). The national target is to grow approximately 15 t grass DM/ha as the primary feed budget for profitable livestock systems characterised by low inputs, strong cost control, and relatively high stocking rates. These systems typically rely on c. 200 kg nitrogen per ha, to enable a ~300-day grazing season, with animals

housed for two to three months in winter. The development of farming systems based on utilising home-grown feed, such as grass, has been reported to be more profitable due to the availability of grass as a low-cost feed source (Finneran et al., 2012). This system aims to match the grass growth potential of the farm with the appropriate animal stocking rate (Roche et al., 2017), which can be maximised through effective grassland management technologies. Specialised farms adopting this system, may be more vulnerable to climate change due to their reliance on a long growing season to provide grazing and winter feed, while having limited buffers to mitigate periods of reduced grass availability.

This grass-based model also underpins Ireland's competitive advantage, with only about 10-15% of global milk production coming from grass-based systems (Shalloo et al., 2018). This advantage is reflected in Bord Bia's Grass-Fed Verified Standard, which supports the marketing of Irish beef and dairy products. The standard requires at least 90% of an animal's diet to be grass or grass forage (fresh weight basis), with dairy herds averaging 95% at processor level (Bord Bia, 2019; 2021).

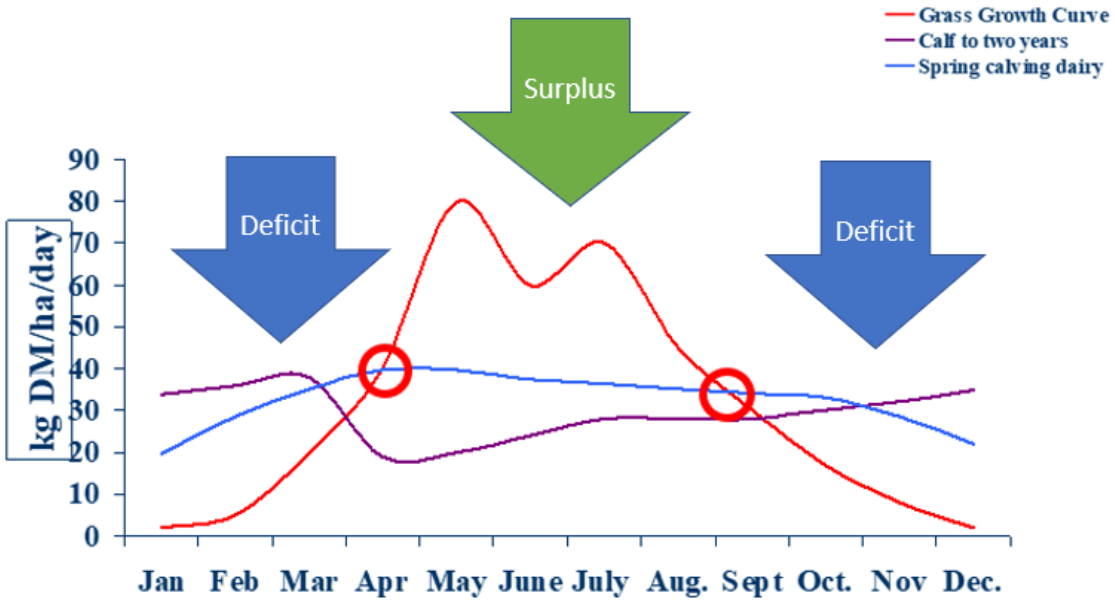


Figure 1: Average annual grass growth curve (-) and feed demand line for a spring calving dairy herd (-) and calf to two-year (-) system.

9.2 The Challenge of Climate Change

9.2.1 What is Climate Change

Climate change is defined by the United Nations as a long-term shift in climate driven directly or indirectly by human activity, altering the global atmosphere beyond natural variability (United Nations Framework Convention on Climate Change, 1992). Since the Industrial Revolution, climate change has been largely attributed to fossil fuel combustion, which releases carbon dioxide and other greenhouse gases (GHGs; Wuebbles et al., 2001). These gases (mainly carbon dioxide (CO_2), methane, and nitrous oxide) trap heat in the earth's atmosphere, leading to global warming. This results in rising temperatures, shifting rainfall patterns, and more frequent extreme weather, with major impacts on public health, water resources, energy, agriculture, and biodiversity. Climate extremes such as droughts, floods, and wildfires are becoming more common, affecting millions and disrupting food production (Rawat et al., 2024). Despite mitigation efforts, the World Meteorological Organization reports that 2025 was among the three warmest years on record, with the past eleven years the warmest recorded, highlighting the accelerating pace of global warming (Figure 2; World Meteorological Organization, 2026a).The recently published European State of the Climate - Report 2025 states that "Europe is the fastest-warming continent" and, has warmed by around 2.5°C compared to pre-industrial levels (World Meteorological Organization and Copernicus Climate Change Service, 2026b).

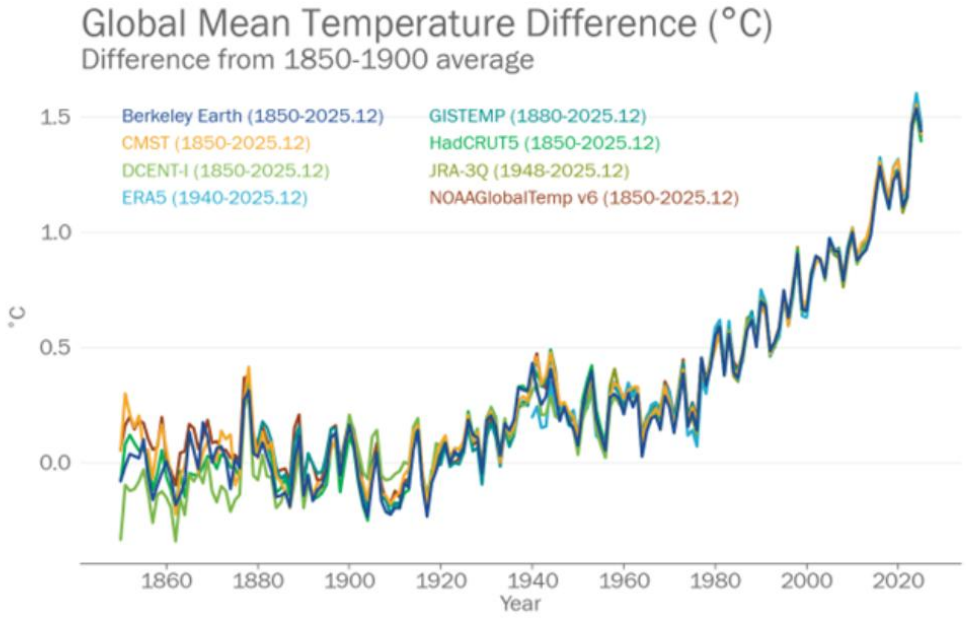


Figure 2: Annual global mean temperature anomalies relative to the 1850-1900 average shown from 1850 to 2025 for eight datasets (World Meteorological Organization, 2026).

9.2.2 International and National Policy

International climate frameworks have been in place since 1992, beginning with the United Nations Framework Convention on Climate Change (United Nations Framework Convention on Climate Change, 1992), followed by the Kyoto Protocol, which set the first legally binding GHG reduction targets for developed countries (United Nations Framework Convention on Climate Change, 1997). The 2015 Paris Agreement committed nearly all countries to limiting global warming to 1.5°C above pre-industrial levels (United Nations Framework Convention on Climate Change, 2015). Under this framework, the European Union (EU) submits updated Nationally Determined Contributions every five years and, in 2025, reaffirmed targets to cut emissions by 55% by 2030 and 66.25–72.5% by 2035, aiming for climate neutrality by 2050 (European Union, 2025). These targets underpin the European Green Deal, which Ireland must meet as an EU member.

Ireland's Climate Action and Low-Carbon Development Act 2021 aims for climate neutrality by 2050, including a 51% emissions reduction between 2018 and 2030 (Climate Action and Low-Carbon Development Act, 2021). This is implemented through carbon budgets and annual Climate Action Plans. Emissions, benchmarked against

1990 levels, peaked in 2001 and have since declined, with 2023–2024 levels (53.75 Mt CO_2eq) falling below 1990 levels (Climate Action Plan, 2025). Currently, emissions are dominated by agriculture (38%), transport (21.7%), and energy (13.3%) (Figure 3; Environmental Protection Agency (EPA), 2025).

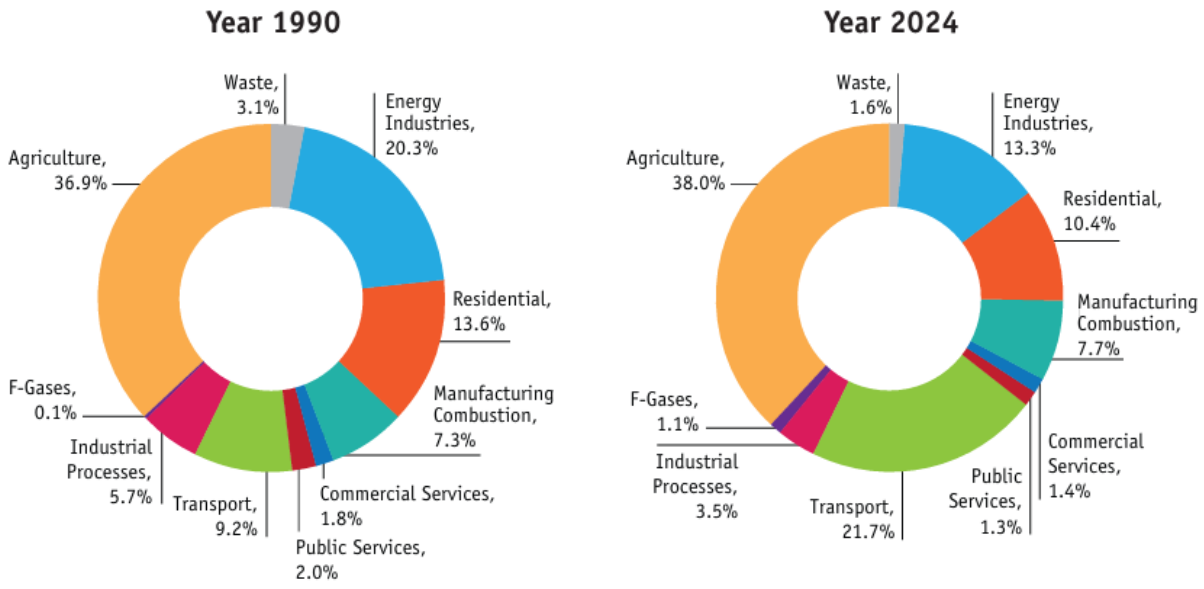


Figure 3: Profile of Irelands Greenhouse Gas Emissions (excluding land use, land-use change, and forestry) in 1990 and 2024 by Sector (EPA, 2025)

9.2.3 Agriculture's Contribution to Climate Change

Ireland accounts for 0.09% of global CO_2 emissions (Ritchie and Rosado, 2025) and ranks 13th in Europe for total GHG emissions by country (Figure 4). Within the EU, agriculture contributes 10.8% of total emissions (European Parliament, 2024). Ireland is unique considering it does not have a heavy industry sector, therefore agriculture accounted for 38% (20.4 Mt CO_2eq) of Ireland's national GHG emissions in 2024. Methane is the primary contributor (71.1%), largely produced through enteric fermentation from ruminants and manure management. Nitrous oxide accounts for a further 22.1%, mainly from manure management, agricultural soils, and fuel combustion. Carbon dioxide from liming, urea application, and fossil fuel use makes up the remaining 6.8% (Environmental Protection Agency, 2025). Methane from enteric fermentation alone contributes approximately 66% of agricultural emissions, reflecting Ireland's large cattle population and grass-based production system. In 2025, cattle

and sheep populations were estimated at 6.9 million and 5.1 million, respectively (Central Statistics Office, 2025).

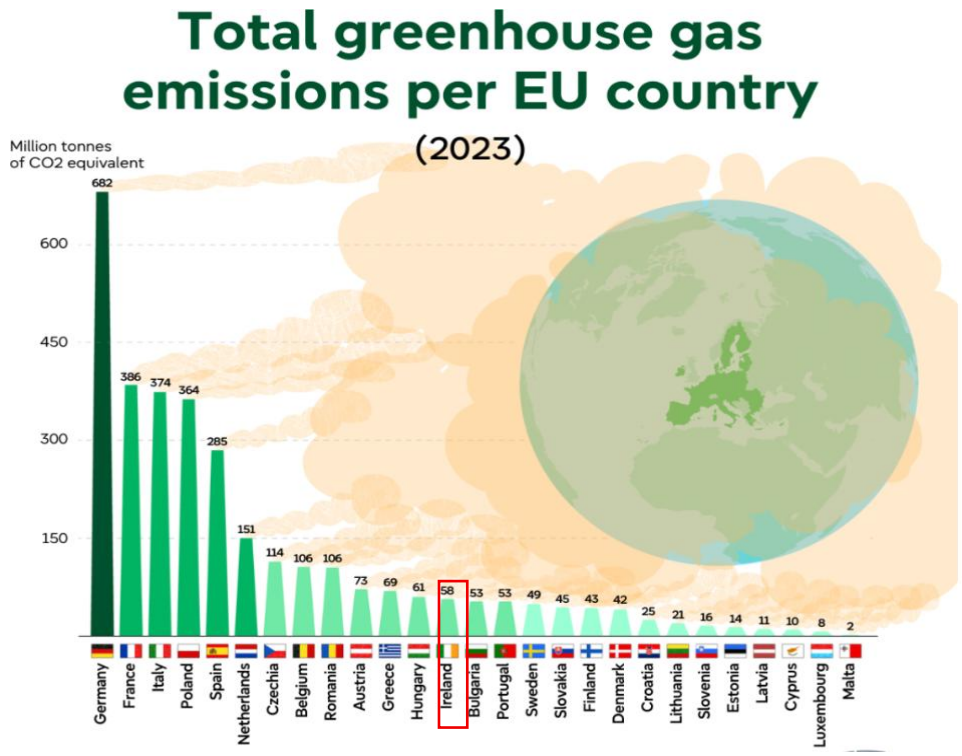


Figure 4: Total greenhouse gas emissions by EU country in 2023 (European Parliament, 2024)

9.3 Climate Change Challenges for Agriculture

9.3.1 Ireland's Current Climate

Ireland's ability to grow grass is the cornerstone of the agri-food sector and is driven by a temperate maritime climate, influenced by the North Atlantic and the Gulf Stream, which brings mild, moist conditions. As a result, Ireland receives high average rainfall (1,338 mm; Met Éireann, 2025) and moderate temperatures ideal for grass growth. Perennial ryegrass requires sunlight, water, and CO_2 for photosynthesis, and Ireland's climate supports yields of up to 15 t DM/ha depending on location and management. Growth is further influenced by soil type, nutrient availability (nitrogen, phosphorous, potassium and pH), temperature, topography, and management. These conditions enable a long growing and grazing season (240–300 days), providing a strong economic and competitive advantage. While Ireland has historically avoided extreme seasonal variability compared to countries of similar latitudes, the frequency and intensity of events such as storms, floods, and droughts have increased since the

1950s and are expected to continue rising (Nolan et al., 2025), in line with global warming trends (IPCC, 2022).

The effects of climate change are already being felt on farms across the country. Most notably, the summers of 2018 and 2022 were characterised by extended periods of dry weather and heatwaves, which reduced grass growth to 11.6 and 11.5 t DM/ha, respectively, compared with the 10-year average of 13.1 t DM/ha (Looney, 2026 personal communication). This reduction in grass availability resulted in a greater reliance on supplementary feed. Similar impacts were observed in 2024, when a wet spring followed by a dry summer reduced national herbage production by 1.3 t DM/ha compared with the 10-year national average, with some farms in the east experiencing reductions of up to 3 t DM/ha. In spring 2026, Ireland experienced a period of exceptionally heavy rainfall, which significantly affected spring grazing management, delayed turnout, caused damage to heavy soils and resulted in an extended period of silage feeding (Teagasc, 2026c). This was followed by the second-warmest July since 1990 (Met Éireann, 2026), resulting in another significant dry period for farms in the east of the country. As of the end of August 2026, many farms in the east of the country are still awaiting sufficient rainfall to facilitate autumn grass growth and recovery. The Irish Farmers Journal (O'Brien, 2026a) and farm organisations such as the Irish Farmers' Association (IFA) have highlighted the on-farm costs and impacts being experienced by farmers through social media and RTÉ News, while also calling for national action and support for affected livestock farmers (IFA, 2026).

9.3.2 Ireland's Future Climate

The EPA regularly publishes Climate Projections for Ireland (Nolan et al., 2025) to assess future climate impacts and inform policy (Figure 5). Projections indicate increased extreme weather, including heavier rainfall and more frequent droughts, alongside fewer frost and ice days. These changes will have significant implications for agriculture. Positively, the growing season is projected to increase by 6.6% and 17.7% over the periods 2021-2050 and 2071-2100 respectively, with higher soil temperatures and more growing days. However, a warmer climate will also increase risks from pests and disease (Nolan et al., 2025). Impacts are likely to be greatest in lower rainfall regions, particularly the east and southeast. Notably, these regions account for 25% of

Ireland's cattle and sheep population (CSO, 2020), highlighting the potential consequences for grass-based livestock systems.

Bateman et al. (2026) modelled the impact of climate change on grass growth in Ireland under five warming scenarios (1.5–4.0°C). Grass growth increased under all scenarios, averaging 11.8–12.9 t DM/ha, depending on location (0.2–1.8 t DM/ha variation). The greatest seasonal impact occurred in August, where daily grass growth changes ranged from a reduction of 12.5 kg DM/ha/day (−24.4%) to an increase of 8.0 kg DM/ha/day (+13.5%), highlighting strong spatial variability. This will affect herbage supply and utilisation, with some farms more affected than others depending on location. Adaptation strategies and supports will be required to manage potential consequences, including longer winter housing periods, variable spring weather, challenges for grass utilisation in wetter spring/autumn periods, potential reduced grazing availability, challenges for silage production, and increased reliance on alternative forages.

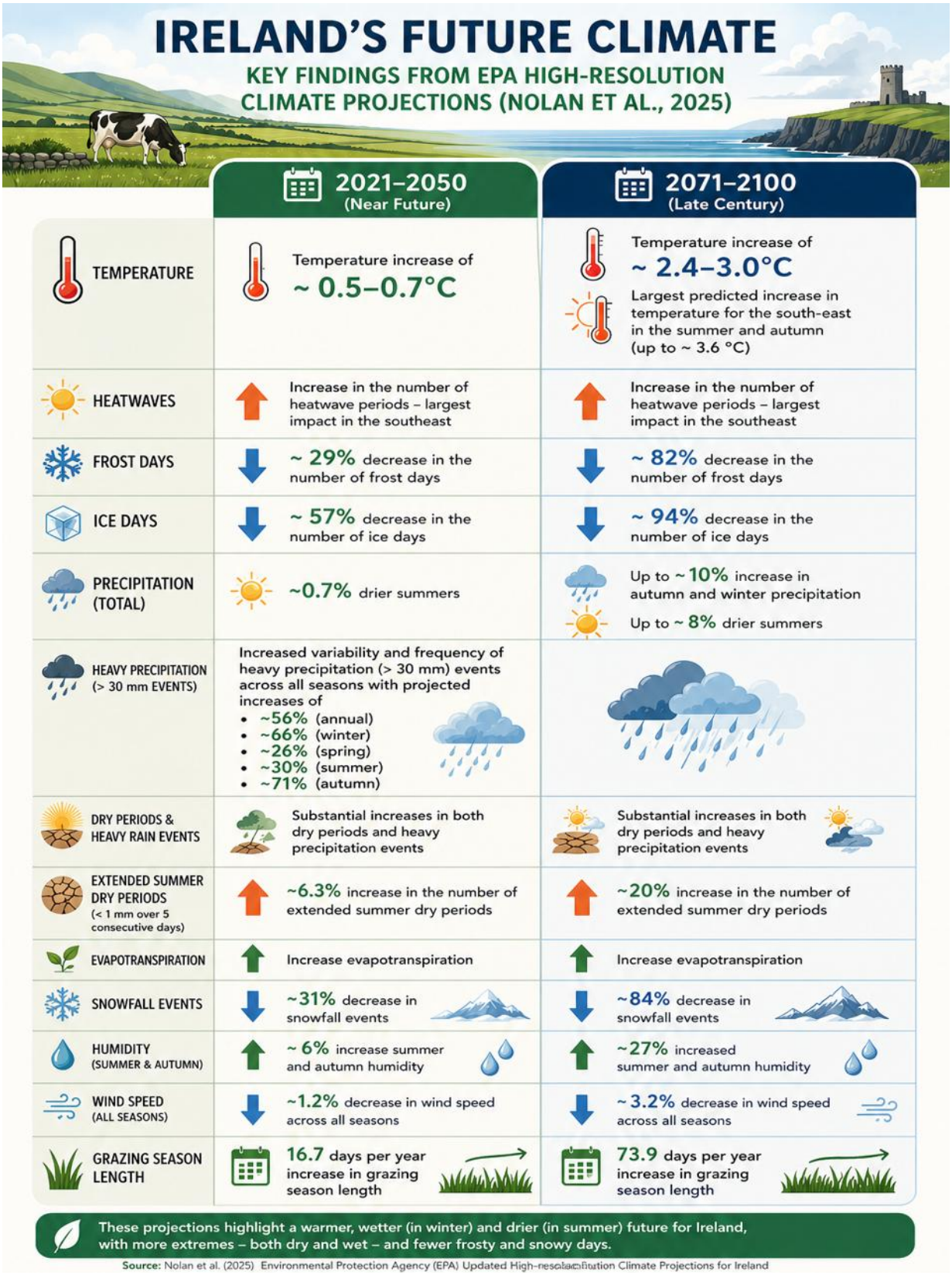


Figure 5: A summary of the key findings from the Environmental Protection Agency Updated High-resolution Climate Projections for Ireland (Nolan et al., 2025) over two selected time periods up to the end of the century (Infographic created using ChatGPT based on data from Environmental Protection Agency; Nolan et al., 2025).

9.4 Implications for Grass-Based Systems: Case Studies

Future climate projections for Ireland are particularly concerning, as grasslands remain heavily dominated by PRG. Perennial ryegrass has been selectively bred over decades for its high quality, persistence under grazing and cutting, and responsiveness to nitrogen application. However, it performs poorly under drought conditions, high temperatures, and low soil fertility, raising concerns about its resilience under future climate scenarios. Furthermore, changes to the Nitrates Directive (DAFM, 2025c) have reduced the chemical nitrogen allowances for grassland which will also impact yield unless an alternative such as clover is successfully established.

Climate impacts are already evident on Irish farms, particularly through wetter springs and drier summers, which are affecting both grassland performance and farmer wellbeing. National data, from farmers measuring grass and using PastureBase Ireland (PBI), indicates a decline in average annual grass production, from 13.1 t DM/ha (10-year average) to 12.3 t DM/ha (5-year average), with particularly low herbage yields recorded in 2018 and 2024 (11.6 and 11.8 t DM/ha, respectively; Figure 6; Looney, 2026, personal communications). Prior to 2018, national production averaged approximately 14.2 t DM/ha. In contrast, the recently published Dairy Roadmap 2030 has set a target of 11.4 t DM/ha of utilised grass (Teagasc, 2026a). At a utilisation rate of 75% (Grass10 target), this would require grass growth of 15.2 t DM/ha. While this level has been achieved by the top 100 PBI users (1.6% of users), it is driven by a strong focus on grassland management, soil fertility, extended grazing seasons, investment in infrastructure, sward rejuvenation, and the incorporation of clover (O'Donovan, 2025). Concerningly the average grass utilisation rate achieved on farms in 2022-2024 was only 7.8 t DM/ha (Teagasc, 2026a) reflecting how the uptake of grassland management tools and technologies remains limited due to barriers such as time constraints, labour availability, education, digital literacy, and the complexity of terminology (Garvey et al., 2018). Furthermore, best-practice grassland management is implemented on fewer than 5% of farms (Teagasc, 2023). Insufficient uptake of grassland management tools coupled with more challenging weather conditions provide little in terms of resilience for grass-based systems. Greater focus should be placed on encouraging and supporting farmers to utilise existing tools and technologies to build more resilient businesses. Establishing strong foundations in grassland management at farm level is essential for generating reliable data and identifying both

the challenges faced by farmers and their willingness and capacity to adapt. This information can help inform the development and adoption of future climate adaptation technologies. There will not be one single solution to the challenges posed by climate change; instead, a toolbox of strategies and technologies will be required, with options tailored to individual farm systems, enterprises, soil types and geographical locations.

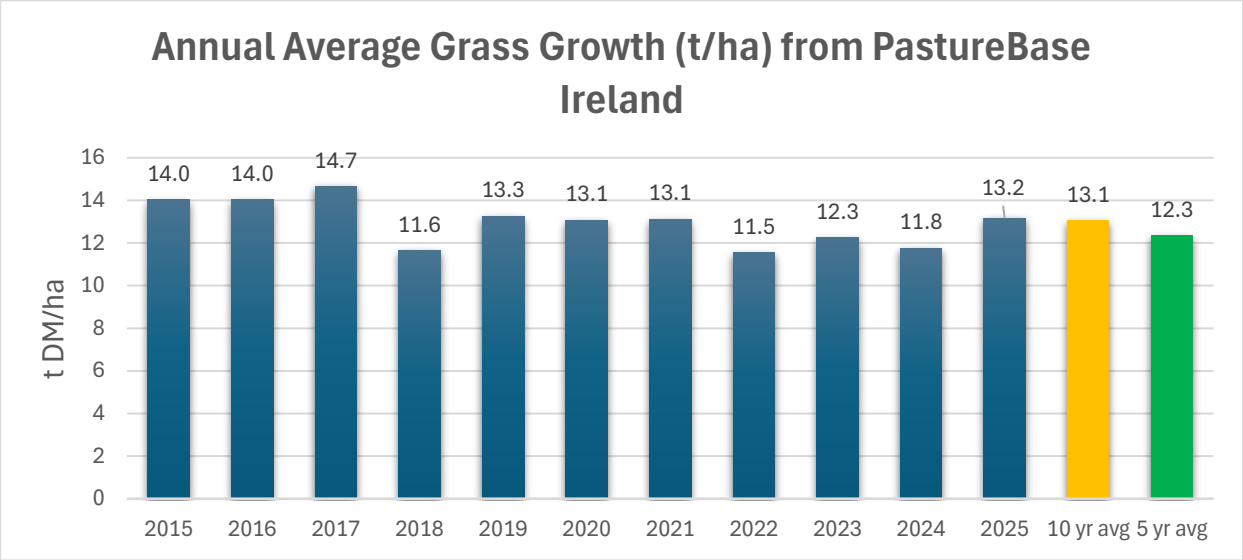


Figure 6: Annual average grass growth (t/ha) from PastureBase Ireland (Caitlin Looney, 2026)

Case Studies:

As part of this Nuffield research, visits were undertaken to commercial and research farms in the east and south of Ireland, where the impacts of extreme weather events, specifically drought, are already being experienced. The following section provides brief summaries to illustrate the challenges they are facing.

Case Study Farm 1: Curtin's Research Farm - Teagasc, Fermoy Co. Cork

Curtin's research farm is one of the Teagasc dairy research farms, specialising in sustainable dairy production research. Despite annual rainfall of 1,068 mm (10-year average), drier summer conditions (Figure 7) have significantly impacted total grass production in the last five years. In 2024 and 2025, average grass DM production was approximately 10 t DM/ha, compared with previous records of 14+ t DM/ha (Figure 8). As a result, stocking rates have decreased by 0.5 cows/ha, with increased reliance on purchased winter forage (+300 kg DM/cow) and additional concentrate feeding (+400

kg concentrate/cow. Although MSS have been established, this has not been sufficient, and summer cropping options are now being considered (Horan 2026, personal communication). This highlights that climate adapton is necessary and already happeneing at farm level.

"The impacts of climate change on Irish grassland productivity on free draining soils have been significant, reducing grass production, quality and utilisation and we need to develop grazing strategies in terms of grazing practices and alternative feed options to protect the competitiveness of pasture-based systems".

– Dr Brendan Horan, Former Research Officer Teagasc.

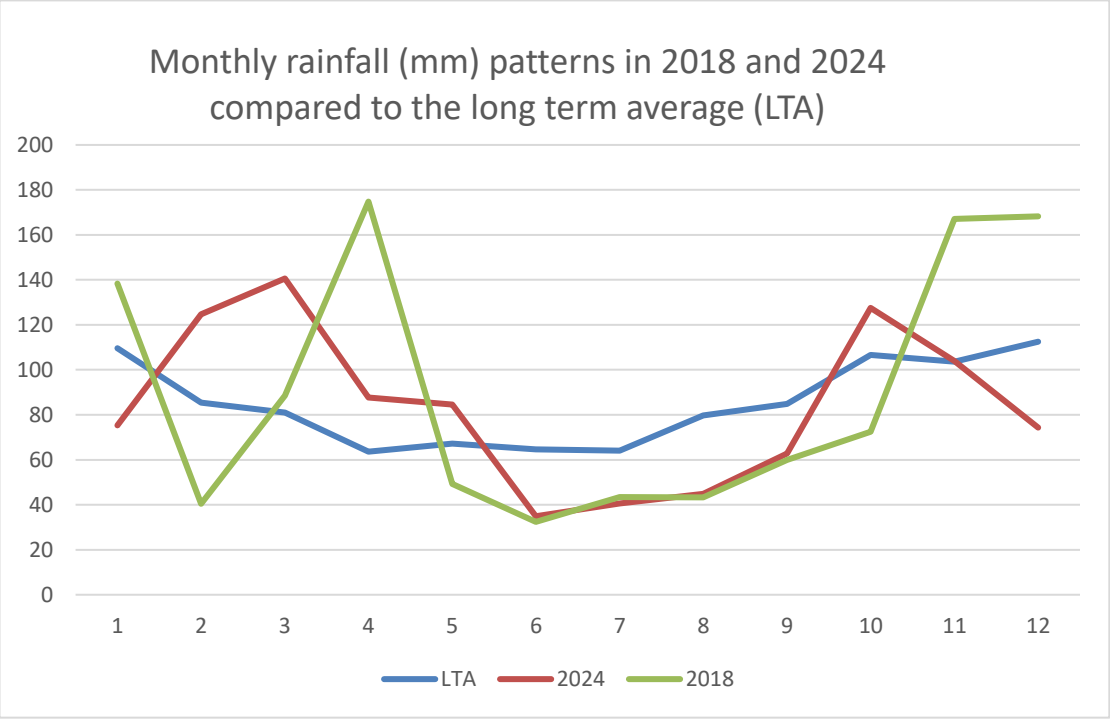


Figure 7: Teagasc Curtin's Farm monthly rainfall patterns in 2018 and 2024 compared to the long-term average (LTA)

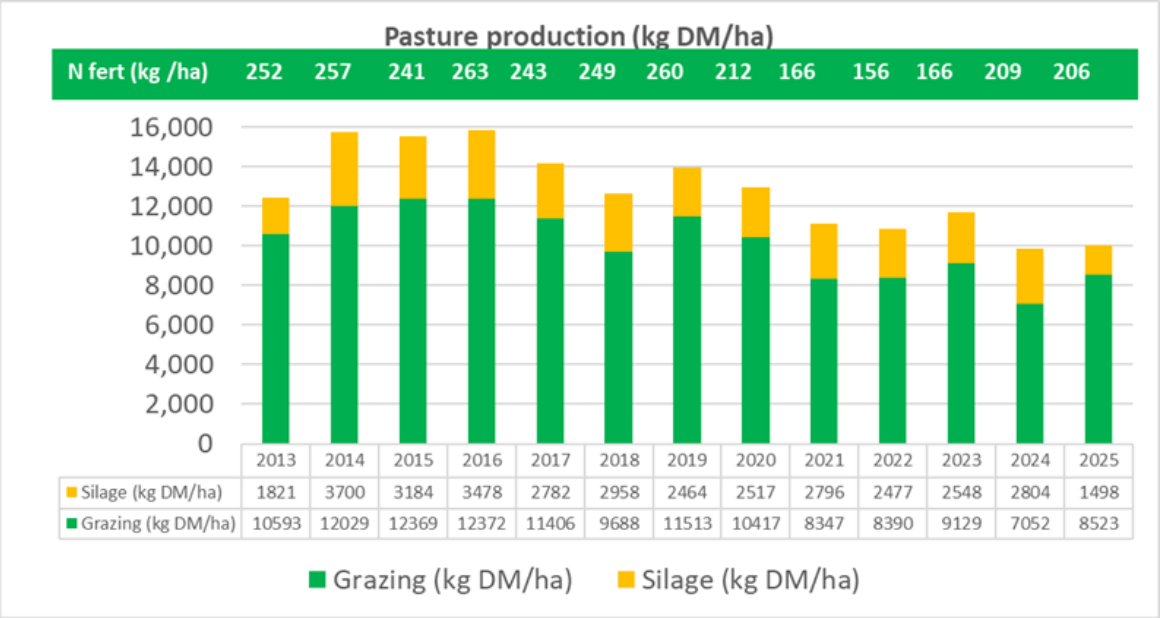


Figure 8: Annual average grass growth (t/ha) for Teagasc Curtin's Farm 2013-2025.

Case Study Farm 2: Gillian O'Sullivan, Dungarvan Co. Waterford

The O'Sullivan family milk 90 cows, producing on average 450 kg milk solids/cow/year on a challenging upland farm (650 ft above sea level) with low rainfall (1,000 mm/year) and shallow sandy soils, increasing the risk of soil moisture deficits. Gillian is very business focused when it comes to farm management and says it is important to have a clear plan, grow what feed they can and based on the figures, close the loop in the most sustainable way. Operating in such conditions has required Gillian to proactively trial a range of strategies to maintain herbage production and support a low-input system. Gillian has drawn on experience from New Zealand and Australia to develop resilience strategies for the farm. Key strategies include reduced stocking rate, a focus on forage self-sufficiency, high-quality bale silage, extended rotation lengths, and regular grass measurement. Emphasis is also placed on forage species selection, particularly rooting depth, to improve soil moisture retention. Diverse swards containing up to nineteen species, including grasses, legumes, herbs, brassicas, and cereals, have been established to provide multiple co-benefits, build on-farm feed reserves, and maintain a simple system which is important for the family as the farm, for them, can't be all consuming.

Case Study Farm 3: UCD Lyons Farm, Co. Kildare

UCD Lyons Farm is a relatively dry site, receiving an average annual rainfall of 783 mm (range: 670–878 mm), well below the national average of 1,338 mm (Met Éireann, 2025). Over the past decade, data has been collected as part of the Systems Herd research project, which examines the development of a higher-output, grass-based spring milk production system. Changing rainfall patterns have significantly affected herbage production (Figure 9), with a 5-year average of 11.6 t DM/ha compared to a 10-year average of 12.5 t DM/ha. It is important to note that reductions in chemical nitrogen allowances, driven by changes to the Nitrates Directive and efforts to encourage clover establishment, also contributed to reduced herbage production. This was particularly evident in 2018 and 2024, when rainfall levels were 658 mm and 671 mm, respectively, approximately 15% below the long-term average (783 mm). In both years, annual herbage production was reduced, falling to 9.27 t DM/ha in 2024, similar to Curtin's farm. As shown in Figure 10, rainfall distribution varied substantially in 2018 and 2024 compared with the long-term average, significantly affecting grass availability, grass quality, feed supply, and silage stocks.

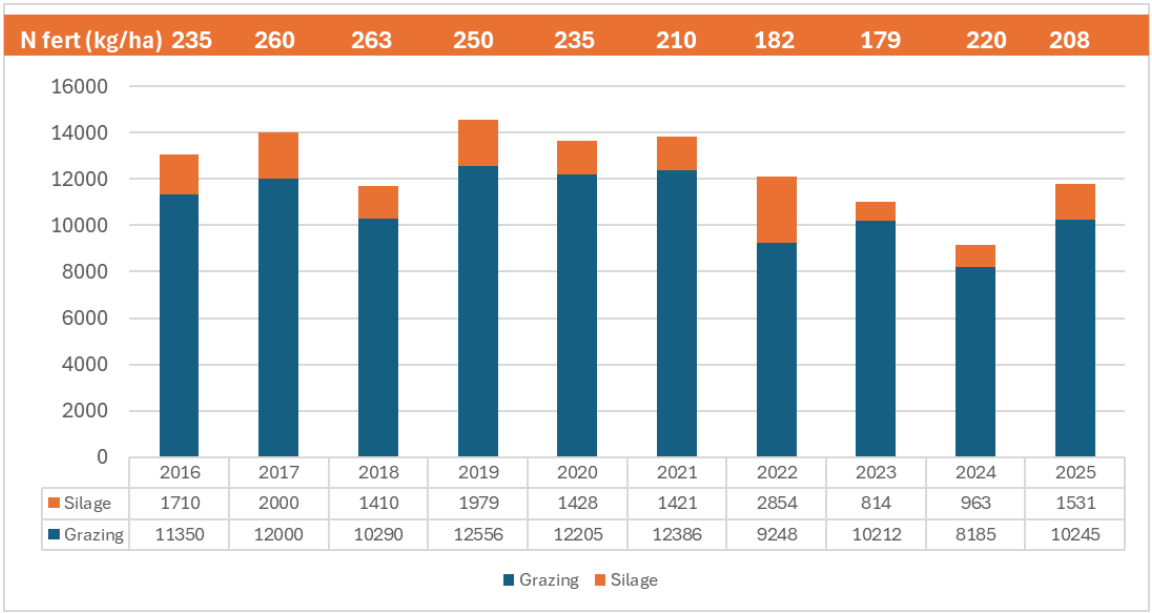


Figure 9: Annual average grass growth (t/ha) for UCD Lyons Farm 2016-2025

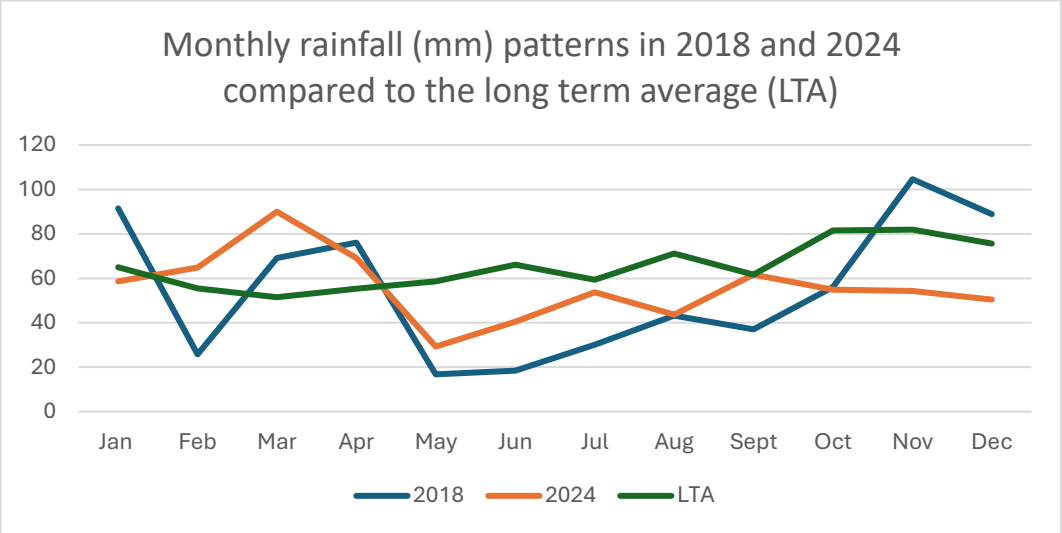


Figure 10: UCD Lyons Farm monthly rainfall patterns in 2018 and 2024 compared to the long-term average (LTA)

Case study Farm 4: Brian Maher Co. Kilkenny

Brian Maher is a dairy farmer running a 90-cow high-EBI herd in Co. Kilkenny, where summer drought has become a significant challenge. He notes, “something happened in 2018, we were not always dry but have gotten drier.” The farm’s exposure to wind and drought (June–August) now requires annual adaptation to maintain feed supply and quality, with a target of 700 kg milk solids/cow (653 kg achieved in 2024). Multispecies swards were trialled but proved unsuitable due to shallow topsoil and rocky areas. Instead, Brian invested in a diet feeder, providing greater flexibility in feeding systems. The high-EBI Holstein Friesian cows are described as having “good depth and capacity,” in other words a body confirmation that enables efficient feed conversion and supporting higher input levels. High-quality silage is a non-negotiable, but drought conditions mean that while a three-cut system is the goal, only one or two cuts are sometimes achieved, limiting winter forage reserves. To address this, Brian initially purchased maize silage and now grows it on farm, using it as a break crop when reseeding. Red clover silage is grown as a home-produced protein and energy source (Figure 11), improving system resilience. Key management strategies include regular grass reseeding for faster plant recovery from drought and pre-mowing during drought to maintain sward quality. Brian attributes improvements to experience, trial and error, and close collaboration with an innovative advisor.



Figure 11: Visiting the farm of Brian Maher

Farmer Perspectives on Climate Change Impacts:

Irish farmers experiencing the impacts of extreme weather events, particularly drought, face significant and often under-recognised challenges. Many describe feeling part of a minority group whose needs are not adequately acknowledged within the wider agricultural system. Across multiple discussions, there was a strong sense that their concerns are overlooked and insufficiently reflected in current research and advisory supports. This disconnect is evident in farmers' experiences with advisory services, with one noting, "the advisor dismissed the drought when I mentioned it, and said aside from that how are things going, not understanding that drought dictates everything here."

For these farmers, the summer months, especially June through August, bring sustained pressure and uncertainty. The lack of clear, drought-specific support and strategies leaves them managing farms without helpful tools. As one farmer expressed, reflecting the emotional toll of these conditions, "it's easier to be depressed in wellies." This highlights not only the practical difficulties but also the mental strain associated with exposure to climate-related stress.

While many farmers remain engaged in discussion groups, they report diminishing value from these groups. A recurring theme is that peers who are less affected by drought often struggle to fully understand its impact, reducing the relevance of shared advice. Despite this, affected farmers continue to participate, largely out of a sense of commitment to others showing their personal resilience rather than for personal

benefit. As one participant noted, “I got more out of my discussion group years ago, but not when the system changed away from the grass-only blueprint.”

A clear gap exists in both research and advisory services tailored to drought-prone areas. Farmers emphasise the need for proactive, rather than reactive, guidance and support that is available to help plan for the challenge before it escalates. There is also a call for a broader shift in mindset within the sector. Reliance on a single system model is seen as increasingly inadequate in the face of climate variability. As one farmer explained, “we grow grass when we can, but the forage that won’t let us down is in a pit and ensures profitability even during drought.”

Overall, farmers do perceive a lack of joined up thinking across the industry. Addressing climate resilience should not be framed as a choice between systems; instead, there is a need for flexible, diversified approaches supported by multiple advisory “blueprints” that reflect the realities of changing conditions.

These case studies highlight the significant regional challenges of climate change currently being experienced by Irish farmers. The reductions in herbage production at Curtin’s (−3 t/ha) and UCD (−2 t/ha) exceed the projections of Bateman et al. (2026), emphasising the localised nature of climate impacts and the need for targeted adaptation and resilience strategies and wellbeing support. They also demonstrate the value of on-farm data (e.g. weather stations and grass measurement) in monitoring change, identifying challenges, and supporting informed decision-making.

10. Agri-Food Strategy and Future Direction

Within the context of this Nuffield report, building resilience through adaptation to climate change, the following section provides an overview of national policy, the direction of the agri-food sector and existing available resources.

10.1 Food Vision 2030

Food Vision 2030 (Department of Agriculture Food and the Marine, 2020) is a ten-year strategy positioning Ireland as a leader in sustainable food systems, built on its natural competitive advantage and the three pillars of sustainability. It confirms that growth will continue to be driven by grass-based livestock systems and outlines 218 actions to achieve this vision. While “climate change” (26 references) and “grass” (44 references) feature prominently, the strategy lacks specific actions to safeguard the grass-based advantage under increasing climate variability and extreme weather. It does however say that Ireland’s agri-food sector will remain a “grass-based livestock production wherein lies Ireland’s natural competitive advantage” however, there is no action as to how this will be maintained in the context of climate change.

10.2 Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan 2025

Sector specific climate change adaptation plans were recently published by the Department of Agriculture, Food and the Marine (Department of Agriculture, Food and the Marine, 2025a). The Agricultural plan aims to identify sector risks and opportunities and strengthen resilience to climate change through an “Impact Screening and Prioritisation exercise” which highlights the knowledge gaps. Suggested measures include improved grazing infrastructure, increased silage and high-quality winter feed stocks (including an additional month’s supply), diverse or drought-resistant swards, realistic stocking rates, and winter feed budgeting. Areas requiring further research include system flexibility, farm planning, pest and disease monitoring, development of more resilient grass varieties, and ongoing Value for Cultivation and Use (VCU) trials for PRG and clover. However, this plan is high level and does not provide on farm strategies for farmers to implement today.

10.3 Grassland and Climate Resilience Research

10.3.1 Grassland Management

Advancements in Irish grassland research over the past 60 years have significantly increased herbage production and utilisation, driven by improved understanding of soil and plant nutrition, grass varieties, ruminant nutrition, and forage management (O'Donovan et al., 2022). Through improved tools and technologies, dairy farmers now grow an average of 13.2 t DM/ha (2014–2024), with the top 100 achieving 15.2 t DM/ha (O'Donovan et al., 2025). Between 2010 and 2024, €312 million was invested in agriculture and food research through DAFM funding programmes. Of this, €66.6 million supported animal production, €52.1 million sustainable resource management, and €28 million grass, clover, forage crops, and horticulture (Department of Agriculture, Food and the Marine, 2025b). With agriculture accounting for 38% (20.4 Mt CO_2eq) of Ireland's GHG emissions in 2024, research has focused strongly on mitigation and sustainability. It is clear from the literature that there is a significant gap in research on adaptation or resilience to climate change strategies compared to research on herbage production, utilisation, mitigation, efficiencies and sustainability. Furthermore, climate adaption or resilience is not a research theme under which funding is allocated (Department of Agriculture, Food and the Marine, 2025b). There is an urgent need to invest in research that builds resilience into grass-based livestock systems through adaptation to climate change.

10.3.2 Teagasc Climate Centre

In December 2022, the Teagasc Climate Centre (Teagasc, 2024b) was established to coordinate climate and biodiversity research and accelerate technologies to reduce GHG emissions and enhance biodiversity. This centre has a strong focus on mitigation (reduce nitrogen and methane emissions, increase carbon capture, enhance biodiversity, increase diversification), however, one of the six pillars is to enhance adaptation and develop resilience to climate change. For example, the AgriAdapt project (Teagasc, 2026b), led by climate adaptation scientist Dr Elodie Ruelle, supports farmers in adapting to climate change through grass growth predictions, identification of practical adaptation measures, grass disease monitoring and the development of weather warning systems with Met Éireann.

10.3.3 Alternative Species Swards

Cera et al. (2025) identify increasing heatwave frequency as a major challenge for livestock systems, highlighting the need for alternative species better suited to warmer, drier conditions to build climate-resilient, grass-based livestock systems. Research on MSS (grasses, legumes, and herbs) shows that greater plant diversity can improve productivity, drought tolerance, biodiversity, and animal performance, while reducing nitrogen inputs (Finn et al., 2018; Grace et al., 2019; Baker et al., 2023).

However, most studies focus on mixtures of six common species. Aside from Moloney (2020), research has largely centred on grazing swards and animal performance (Grace et al., 2018, 2019; Boland et al., 2022; Baker et al., 2023; Jezequel et al., 2024; Woodmartin et al., 2025; Connolly et al., 2026). While this demonstrates the significant potential of sward diversification, it remains limited, with little exploration of a broader range of species or winter forage options suited to future climate predictions. Baker et al. (2025) reports the farmers' perspectives on the adoption of MSS and highlights both the benefits observed on farm (biodiversity, soil health, drought resilience and reduced nitrogen use) and the knowledge gaps, (tailored support, peer learning, demonstration farms and practical guidance on establishment and grazing) for increased adoption of MSS.

10.3.4 Adaptation Strategies

Climate adaptation scientist at the Climate Centre Teagasc, Dr Elodie Ruelle, leads the FarmAdapt project, which is currently conducting a systematic review and synthesis of climate adaptation research for Irish agriculture, alongside gap analysis and prioritisation. Early findings highlight the potential of MSS to improve drought resilience (Misra and Ruelle, 2025). However, speaking with Dr Ruelle, the review also identifies a significant lack of research on adaptation strategies in Ireland beyond measures such as increasing silage quantity and quality, expanding winter slurry storage, adjusting stocking rates, and addressing challenges for clover under wetter conditions. Furthermore, there is a lack of funding, funding mechanisms and research facilities to simulate future climates and longer-term experiments to enable adaptation strategy development.

11. Strategies for Future Proofing Grass Based Livestock Systems

During this Nuffield Scholarship, travel was undertaken across five continents, to Australia, New Zealand, Singapore, Taiwan, Zimbabwe, Romania, Poland, Chile, England, Belgium, and Portugal. Insights were gained from discussions and observations of the strategies and tools used internationally to build resilient agri-food systems and address climate change. This included attending conferences and meeting stakeholders across policy, research, education, and farming. With the challenges of grass production in a changing climate in mind, the scholarship identified key gaps and areas for consideration for Ireland. Drawing on these experiences, this section outlines and discusses five main emerging themes, supported where relevant by international examples.

11.1 Risk Management and Resilience Tools

"We need to be able to change quickly and have freedom to do that, as the only constant is change" Nigel Weller, Managing Executive, National Foods Limited Zimbabwe.

"Nature and climate will not wait for us to have these arguments over how" Maria Chiorean, Executive Director of ANZ's Sustainable Finance team in Singapore.

Climate change impacts, such as unpredictability, increased workload, and financial pressure, are shown to negatively affect farmers' mental health and wellbeing (Brennan et al., 2022; Batool et al., 2025). As these pressures are compounded by wider local and global factors, strategies must support both farm systems and the people within them. Given this complexity, resilience has become a central concept in research and policy (Darnhofer, 2014). As Rogier Schulte, Professor at Wageningen University in the Netherlands, states, "resilience is the new efficiency." It refers to the ability to withstand, adapt to, and recover from challenges, supporting long-term sustainability (Alexander,

2013; Asresehegn et al., 2025). Resilience operates at both individual and collective levels, highlighting the role of personal coping capacity alongside support from the wider community and industry (Folke, 2006; Norris et al., 2008).

Given the uncertainty associated with climate change, tools to assess farm business risk and resilience, particularly to events such as changing rainfall patterns and drought, would provide valuable support to farmers in affected regions. In Australia, the Victorian Drought Resilience Adoption and Innovation Hub at the University of Melbourne's Dookie campus (Figure 12) is funded by the Australian Government to help communities prepare for extreme drought. The hub brings together farmers, researchers, and industry to co-develop locally tailored solutions. Adoption officers work one-to-one with farmers to support decision-making and encourage technology uptake. A key focus is proactive planning; as adoption coordinator Rhiannan McPhee notes, there is a need to move away from a "when it breaks, I'll fix it" mindset. Mental health is also recognised as a priority, with peer support groups providing both social connection and practical knowledge. Building resilient people is considered as important as building resilient farm businesses, enabling both to plan, adapt, and thrive.



Figure 12: Visiting Rhiannan McPhee (Adoption Coordinator) and Dr. Sara Hely (Director) of the Victoria Drought Resilience Adoption & Innovation Hub at the University of Melbourne's Dookie campus

At a national level, climate risk has been assessed under the Agriculture, Forestry and Seafood Climate Change Sectoral Adaptation Plan 2025. While this identifies risks and outlines high-level actions (e.g. funding, stakeholder engagement, research, and education), it does not translate into practical, farm-level strategies for those already experiencing climate impacts. Although the report acknowledges the stress caused by extreme weather, there is a clear need for enhanced research, advisory support, farm-level risk assessment tools, and practical adaptation plans. Such frameworks would help farmers make informed decisions and build resilience within their farm businesses.

There have been significant developments in Ireland in tools that support farm sustainability and efficiency by assessing inputs, outputs, and contributions to GHG mitigation (e.g. AgNav, PastureBase Ireland, and the Bord Bia Sustainability Survey). Similarly, planning tools are widely used for business planning, farm safety risk assessment, and financial management. However, Ireland lacks an integrated, farm-level resilience framework to support structured decision-making. Such a framework could include:

- Establishing a farm baseline (current performance, available data, and tools)
- Identifying farm-specific climate risks (e.g. grass growth, winter forage supply, heat stress, policy constraints)
- Evaluating performance in a “bad” year (weather patterns, growth rates, feed budgets)
- Assessing resilience capacity (buffering, system flexibility, infrastructure)
- Implementing adaptation strategies
- Summarising outcomes through a resilience scorecard or checklist

11.1.1 ABCD of Resilience

Grass-based livestock systems are vulnerable to climate shocks due to limited diversity (e.g. specialised dairy systems) and a strong reliance on grass growth within low-input production models. While these systems maximise efficiency, they offer limited buffers when unexpected challenges arise. In Ireland’s seasonal system, where 95% of milk comes from spring-calving herds, shocks can affect many farms simultaneously, intensifying competition for resources and reducing overall resilience, particularly under future climate pressures on grass growth. A meeting with Rogier Schulte of

Wageningen University, who leads the Global Network of Lighthouse Farms, highlighted approaches to building resilience. This network brings together innovative farms worldwide to demonstrate sustainable food production and identify strategies to anticipate shocks. Their work has led to the development of the ABCD (Agencies, Buffers, Connectivity, and Diversity) framework, which could inform the development of an integrated farm-level resilience framework as demonstrated in Figure 13.

11.1.2 International Climate Resilience Tools

Briefly, other examples of on farm assessments include the Self-Evaluation and Holistic Assessment of Climate Resilience of Farmers and Pastoralists (SHARP) published by the Food and Agricultural Organisation of the United Nations (Food and Agricultural Organisation, 2026) as part of their land resource and planning toolbox. Similarly, the EU has developed an impact assessment toolbox of resilience-enhancing strategies on farming systems while this is more focused on data modelling it highlights the importance of the area at EU level (European Union, 2026).

Barriers will exist for the use of theses tool by farmers (aging population, time, education etc.) hence it would be important to support the use and adoption of such tools through discussion groups or farming for the future workshops to create space for affected farmers to highlight their needs from research and advisory, work together to identify ways to reduce volatility and try adaptive strategies to build resilient grass based livestock systems.

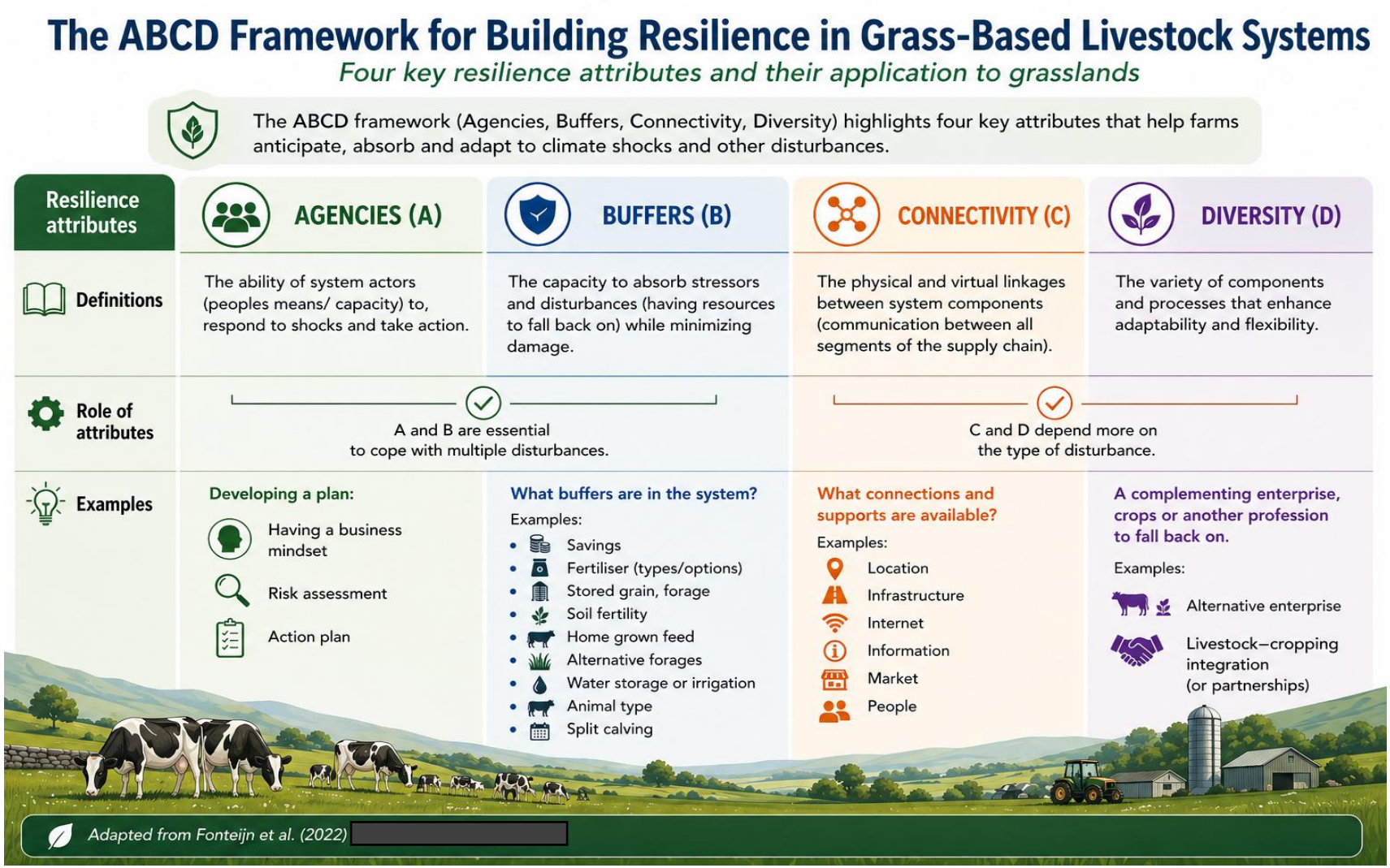


Figure 13: Four key resilience attributes and their application to grasslands (adapted from Fonteijn et al., 2022). (Infographic created using ChatGPT based on the ABCD Framework of Fonteijn et al. (2022) and insights developed form this Nuffield research study).

11.2 The Grass Fed Standard

Capitalising on Ireland's green image and grass-based competitive advantage has been central to the growth of its export market. The Bord Bia Grass Fed Standard provides a robust, data-led framework supporting Ireland's grass-fed reputation. This is evident in the success of Ornua, owner of Kerrygold and Ireland's largest dairy exporter. At the Nuffield Ireland Briefing Days in January 2025, Communications Director Jeanne Kelly highlighted the importance of maintaining the grass-fed advantage to ensure product quality and meet consumer expectations, while noting that climate change and its impact on grass availability could threaten both the standard and the market access it supports.

Reductions in grass availability for grazing and silage in some regions will create feed budget deficits and increase reliance on alternative supplementation (concentrates or forage). Over the past five years, the national average Grass-Fed value has remained between 94.6–94.9% (personal communication, Mick Houlihan, Senior Manager, Bord Bia). The standard already includes buffers that provide resilience in poorer grass-growing years:

1. At processor level, they must ensure the milk pool averages 95% grass-fed, creating a buffer when some suppliers fall below target due to poor grass growth (minimum 90% at farm level). However, if more farms are affected by drier conditions, there is very little margin before the milk pool falls below the standard, potentially creating logistical and cost challenges for processors.
2. Verification is based on a three-year rolling average, which helps smooth the impact of poor individual years.
3. The standard includes a 0.7% allowance for alternative forages (e.g. maize, whole crop, silage crops, brassicas, and summer crops). While this does not disqualify a farm, it does not contribute to the 90% grass and grass-forage requirement, despite some being home-grown.

Similarly, the New Zealand dairy industry operates a Grass-Fed Administrative Standard stating that cows "enjoy a diet consisting of on average of 90% grass" and are "free to roam 340 days of the year, for at least eight hours per day." However, "grass" is broadly defined, covering thirty eight feed types, including triticale, wheat, barley (baleage and green feed), and crops such as kale, lucerne, and fodder beet

(Ministry for Primary Industries, 2025). This broad definition, which largely reflects home-grown forage use, can be misleading to consumers as recently experienced by Fonterra (Dairy Reporter, 2026) so care must be taken when used in marketing. However, it does provide flexibility for farmers operating across diverse climate zones, once correctly labelled. In contrast, the Irish dairy standard specifies grass or grass forage only which may limit farmers and processors in the future. Consideration should be given to broadening this definition to explicitly include legumes, MSS and brassicas, which also meet grass-fed principles but are not clearly recognised. The beef standard already includes grazed grass and legumes (pasture) and grass/legume forages (silage, haylage, hay).

For now, buffers within the Grass-Fed Standard help accommodate fluctuations in grass availability due to climate change. However, the standard should be future-proofed and adaptable to changing conditions. Key considerations include:

- A review process should be established to quantify the market value of the Grass-Fed Standard and explore how it can be strengthened over time, while ensuring sufficient flexibility to respond to future industry challenges and opportunities.
- The data generated through Bord Bia audits presents an opportunity for regular analysis at national, regional and local levels to better understand emerging farm-level trends, such as changes in feed budgets, and support evidence-based decision-making.
- Assess the potential future balance between maintaining the Grass-Fed Standard and opportunities to diversify feed inputs.
- Broadening definitions to explicitly include other grazing species such as legumes, herbs and brassicas.
- Reconsidering the 0.7% allowance for alternative forages, potentially increasing and integrating it into the grass/grass-forage category as “home-grown feed” to reduce pressure in drier regions and encourage greater integration with the tillage sector, rather than reliance on imported concentrates.

It is important to note that the Grass-Fed Standard is an industry standard facilitated by Bord Bia Grass Fed Standard. Over time, and as climate impacts intensify, an industry-level discussion may be required on what the standard should include and

what is realistically achievable for Irish farmers. Future challenges also need consideration, including potential regional divergence, as the east and southeast are likely to be more affected by summer drought than other parts of the country. For example, in August 2026, Brian Harte nutritionist with Tirlán, based in the south-east, reported that 93% of their suppliers had little or no fresh grass available and 77% will face a winter fodder crisis as a result of summer drought and early utilising of winter feed (O'Shea, 2026). This may drive future demand for alternative forages or, from a processing perspective, greater interest in reducing summer feed demand and flattening the milk supply curve. In addition, the current standard may limit diversification, including the use of alternative species for biodiversity or more integrated crop-livestock systems that could reduce reliance on imported protein and feed. While the standard is important for market access and consumer communication, it may also unintentionally constrain on-farm adaptation of new technologies.

11.3 Grass and Forage Research

As outlined in Section 10, there is limited research in Ireland on grassland resilience buffers in grass-based system to support adaptation to climate change. The European Grassland Federation's Grazing Working Group, through its Grazing in Europe survey, identified climate change as the key challenge and highlighted the need for more drought-resilient species (personal communications, Agnes van den Pol van Dasselaar, 2026). Countries facing greater drought exposure are more advanced in this area. The following section presents international examples of grassland research responding to climate change and highlights relevant considerations for Ireland.

"Different things growing in different places for different reasons" Karrinjeet Singh-Mahil Western Victorian dairy farmer.

"We need to invest in research to grow grass in a different way…a better-way-to-grow-grass club" James Mann, former Board Chair of Dairy Australia and South Australian dairy farmer.

11.3.1 Alternative Species

Recent research with MSS has highlighted the potential of sward diversification in Ireland, but this is limited and excludes other plant species. Alternative species swards also play an important role in increased on farm biodiversity. In the last decade there has been a loss of almost one third of Ireland's semi-natural grasslands and a decline in over half of Ireland's native plants (Department of Housing, Local Government and Heritage, 2024).

In New Zealand, both researchers and farmers are exploring the role of alternative grass species such as tall fescue (*Lolium Arundinaceum*), cocksfoot (*Dactylis Glomerata*), timothy (*Phleum Pratense*), and annual ryegrass (*Lolium Multiflorum*), in improving system resilience. In Northland, where summer drought is severe and irrigation is not feasible, farmers including Donal Watson and Alistair McCahon collaborate at the Northland Agricultural Research Farm (Figure 14). This farmer-owned initiative, overseen by the Northland Dairy Development Trust and researcher Kim Robinson (AgFirst Agribusiness), focuses on adapting farm systems to drought. The farm runs system-scale trials using alternative species in place of PRG, aiming to generate practical, transferable knowledge for forage production. The study evaluates profitability, production, environmental outcomes, and labour. For local farmers, this work is essential, as "perennial ryegrass is no longer fit for purpose… it has to be oversown every year" (Donal Watson). Annual rainfall is similar to Ireland (1,300 mm); however, higher evapotranspiration and the concentration of rainfall during winter and early spring contribute to significant summer drought. Tower and Nugar fescues have performed particularly well, yielding up to 12 t DM/ha (compared to the regional average of 8–9 t/ha) with improved tolerance to both drought and waterlogging. To navigate extreme weather events (drought and heavy rainfall), Donal Watson has built a system around strategic feed planning, diverse pastures, and water management. While against the norm in New Zealand, split calving helps flatten the farm's feed demand curve, aligning it more closely with seasonal pasture supply. During dry summers, this approach maintains milk flow, while in wet winters it reduces the need for high-intensity stocking on fragile soils.

In Ireland, PRG will remain dominant but is likely to perform at lower levels (Section 9.3.2). It will therefore need to be supported by alternative species to improve yield, nitrogen use, water tolerance and drought resilience. Currently, resilience is limited,

with PRG accounting for 95% of grass seed sales. Given the long lead times required to develop and adopt resilient forage varieties, research must begin now to identify suitable alternative and companion species and varieties under Irish conditions.
Further to this, there is a lack of funding mechanisms to support longer-term research experiments that extend beyond the typical four-year funding cycle which allows for only two years of production data. Longer-term assessments are important for developing and refining effective adaptation strategies.



Figure 14: Northland Agricultural Research Farm; Mixtures of fescues, chicory and clovers performing well compared to Kikuyu and Italian ryegrass in surrounding pastures.

11.3.2 Summer Cropping

Anthony Pollock milks 230 Kiwi-cross cows on 82 ha in Hamilton, New Zealand, and is no stranger to summer drought, despite the farm receiving 1,132 mm of rainfall annually. High evapotranspiration rates mean that “in the ten years prior to the last two, we had eight droughts, one lasting eighteen months.” As irrigation is not an option, Anthony has adapted his system by bringing calving forward by six weeks, reducing stocking rate, focusing on output per cow, and incorporating alternative forages and summer crops (Figure 15a). A mixed-species approach has proven far more reliable than monocultures, which often fail under dry conditions. Diversity improves soil structure, moisture retention, and nutrient cycling, while spreading risk across species. Effluent is returned to these areas, providing a low-cost nutrient source, with only around 120 kg of nitrogen applied. Anthony describes it as a “cheap crop” that fits well within the system. He grows forage crops suited to different soil types, including maize,

summer crops, and annuals, creating a rotation that delivers a combined annual yield of 13–14 t DM/ha. In the region, drought reduces grass-only production to 7–8 t/ha; however, by combining 8–9 t/ha from summer crops with 4–5 t/ha from annual grasses, he maintains yields close to the regional norm of 15–16 t/ha in non-drought years. This significantly increases the proportion of home-grown feed in the system. For Anthony, success comes from prioritising home-grown feed and balancing short-term output with long-term resilience: “Do I want 16 tonnes for a few years, or 14 tonnes that will last 10 years? I’ll take the latter.” His system demonstrates how observation, strategic crop selection, and flexibility can transform a drought-prone dairy farm into a productive and sustainable enterprise.



Figure 15 a) Mature summer crop on the farm on Anthony Pollock (oats, chicory, plantain, white, red and persian clover, rape, brassica, turnip, vetch, linseed, kale, millet, sorghum, red shank, sunflowers); **b**) Mixed species sward on the Dryland Pastures Programme at Lincoln University New Zealand.

Research and advisory support from universities and Dairy NZ facilitate the uptake of such new technologies and offer technical advice for utilising alternative forages. For example, Dr Alister Black at Lincoln University is running a research programme specifically on Dryland Pastures which explores the use of varying mixtures (such as legumes, brassica, annual ryegrass, green feed cereals, lucerne, herbs) under regenerative agricultural practices on herbage and animal performance (Figure 15b).

11.3.3 Winter Forage

As part of the Nuffield Scholarship travels a visit was also made to Hooibeekhoeve in the Province of Antwerp, Belgium, a research and demonstration farm focused on

building resilience in integrated dairy and arable systems (90 cows on 60 ha). Although it operates as a high-output indoor dairy system, its objective is to maximise forage production and quality using home-grown feed (Figure 16). The farm grows a wide range of forages and crops in rotation, including grasses, clovers, herbal leys, maize, cover crops, cereals, beans, fodder beet, and sorghum, producing a variety of high-quality silages. Species are selected to enhance biodiversity and resilience, with some sown to flower at different times of the year. Crop rotation plays a central role in maintaining soil organic carbon, improving soil structure, and spreading climate risk. Technology plays a critical role on the farm with all machinery fitted with GPS tags, while near-infrared (NIR) sensors are used on slurry tanks to measure nutrient application in real time. However, according to Hooibeekhoeve researchers Katrien Geudens and An Schellekens, a key challenge in assessing silage quality in diverse mixtures, as NIR analysis can underestimate nutritional value compared to animal performance. Heat stress management is also a major concern during summer. Flemish legislation requires outdoor animals to have access to shade from trees or shelters, while housed animals must be continuously monitored for temperature and humidity. Fans and misting systems are activated above 28 °C to safeguard animal welfare and manage limited water resources. Hooibeekhoeve demonstrates that diversification, technology and proactive climate adaptation can be integrated to improve resilience, resource efficiency and animal welfare, while maintaining a strong focus on forage quality and home-grown feed production.



Figure 16: Conserved and fresh forage at Hooibeekhoeve Belgium

11.3.4 Grass Breeding and National Variety Testing

Future traits of importance

A visit to AgResearch in Palmerston North, New Zealand, included meetings with Dr Marty Faville, a researcher in genomics and plant breeding, and Dr Nick Roberts, Principal Scientist and founder of the High Metabolisable Energy ryegrass programme. Their research focuses on developing PRG varieties better adapted to soil moisture deficits and with higher energy content (Figure 17a and b). Alan Stewart, Chief Scientific Officer at PGG Wrightson Seeds, emphasised that plant breeding must take a long-term perspective, anticipating future requirements such as pest and disease resistance, heat tolerance, forage quality, methane reduction potential, and tannin content to support resilient grass-based livestock systems. This forward-looking approach is needed not only for PRG but also for alternative forage species and crops, which have received far less attention to date.

In Ireland, this area of research remains underdeveloped. For example, only recently, through the AgriAdapt project, has on-farm monitoring of disease in PRG swards begun (Mulkerins, 2026), however, disease risk is not reported on the National Recommended List. The importance of evaluating species under future climate scenarios was also highlighted at the European Grassland Federation Symposium on MSS. Dr Raj Whitlock of the Buxton Climate Change Impacts Lab, the longest-running climate change experiment in the UK, presented research assessing grassland species under conditions of elevated winter temperatures, summer drought, and irrigation. However, from an Irish perspective such research is limited as there is a lack of national research facilities to simulate future climates and utilise new non genomic techniques (NGT's) which are now permitted for use in the EU. Such techniques will enable faster more targeted genetic changes that would have occurred naturally (European Commission, 2026). Such techniques may facilitate the breeding of more resilient crops to challenges such as climate change (cold, heat, wet, drought tolerance), pests, disease, nutrient use efficiencies and water use efficiencies.

National Variety Testing

For PRG and white clover varieties to be marketed in the EU, they must be included on a National Recommended List, with trials in Ireland conducted by the DAFM through the National Herbage Variety Evaluation Programme. Varieties must demonstrate

distinctness, uniformity and stability (DUS), as well as value for cultivation and use (VCU), a process that takes approximately six years from sowing to recommendation. In Ireland, the Recommended List currently focuses on monocultures of PRG (evaluated under high inorganic nitrogen input c.315 kg N to account for the absence of animal manure) and white clover, with red clover only recently (2024) included. There is a need to expand this work to assess a wider range of species and traits under a lower nitrogen rate and on farm conditions. While a substantial dataset exists for PRG across five trial sites under both simulated grazing and cutting conditions, its potential is not fully utilised. As an initial step, site-specific and regional performance data should be analysed and reported to highlight how varieties perform under different conditions (e.g. west versus east of the country). In addition, greater emphasis should be placed on disease monitoring and more comprehensive quality assessments. Increased collaboration is needed to better leverage existing trial data, alongside further research to evaluate a broader range of grass and forage species and varieties under future climate scenarios.



Figure 17 a) Drought research on PRG AgResearch New Zealand; **b)** High ME grass breeding in AgResearch New Zealand

11.3.5 Data Management to Enable Innovation

Data is a powerful tool that enables planning and decisions making. On many of the international farms and business visited during this Nuffield Scholarship programme, the use and generation of data was much more advanced than in Ireland. This was particularly evident from a weather data perspective where on farm weather stations provided site specific data and enabled rainfall and soil moisture monitoring. From the Irish farm visits, the availability of information was poor with no on farm rainfall data

and the closest weather station not capturing the local microclimate. Technology, precision agriculture and tools that improve efficiency, data collection and evidence-based decision making will be central to climate adaptation.

Another example is the poor uptake of grass-measuring technology on Irish farms. Significant resources have been allocated to grassland research over the past 60 years (O'Donovan et al., 2022); however, best-practice grassland management is still implemented on fewer than 5% of farms (Teagasc, 2023). Farmers often describe limitations such as time constraints, labour availability, education, digital literacy, and the complexity of terminology as primary barriers to technology uptake (Garvey et al., 2018). In Australia, Kevin Smith, Professor of Pasture Agronomy and Breeding, and his team at the University of Melbourne are developing drone technology to measure pasture biomass, with the vision that, in the future, local advisory services could work with farmers to generate weekly grass-walk data. Such technologies should be considered in Ireland as they could significantly reduce the time and labour involved in grass measurement and potentially make best-practice grassland management more accessible to already time-constrained farmers.

"We want to be innovative in our own right…. create the vision and set a path to inspire and innovate" Professor P.J. Mathews UCD.

Consideration needs to be given to the species combinations and practices that will make up Irelands grassland in the future to enable sustainable forage production under reduced inputs and more challenged weather conditions. This should include the establishment of a future grasslands dry soil programme of research and advisory services. Currently Teagasc run the Heavy Soils programme aiming to "improve the profitability of grassland farms on heavy soils through the adoption of key technologies".

11.4 Water Management

"Looking at this space (water management) is an absolute need"
Matthew Craig, Hydrometric & Groundwater Programme Manager, Environmental Protection Agency, Ireland.

Climate change is expected to reduce summer rainfall and increase the frequency of extended dry periods (<1 mm precipitation over five consecutive days). Soil moisture deficit is a complex and serious threat to plant productivity, leading to reduced leaf size, restricted root growth, lower water-use efficiency (Bhattacharya, 2021), and decreased herbage production (Grant et al., 2014). As was evidenced by this author's Nuffield Scholarship travels, in countries such as New Zealand, Romania, Zimbabwe, and Chile, irrigation is commonly used to manage soil moisture deficits where groundwater resources allow (Figure 18a and b). The South Island of New Zealand is well known for irrigation use, while in parts of the North Island (e.g. Hamilton and Northland), uptake is limited by topography, infrastructure costs, water charges, and water table constraints. In these systems, the viability of irrigation is clear, and farmers have access to tailored guidance depending on their situation. In Ireland, farmers will increasingly need to consider how to maintain forage production during drier summers. While discussion around irrigation is emerging, it remains a very sensitive issue in a traditionally rain-fed grass-based system. Nevertheless, the question remains whether irrigation could or should have a role in drought-prone regions, or whether greater emphasis should instead be placed on alternative forages for grazing and winter feed.



Figure 18 a) Irrigation system in Romania; **b**) water storage in New Zealand

The Irish EPA has begun assessing the impact of climate change on national water resources. According to Matthew Craig, Manager of the Hydrometric and Groundwater Programme, climate change poses a major threat to Ireland's water supply through intensification of the water cycle and shifting weather patterns. Although Ireland has high rainfall, water is not effectively stored, limiting system resilience. Around 80% of Ireland's water supply comes from surface water and 20% from groundwater (Department of Agriculture, Food and the Marine, 2024), the reverse of many EU countries where groundwater predominates and enables irrigation. Groundwater abstraction has only been regulated since 2018, introduced as a reactive response to extended summer droughts, alongside increased permissions for well drilling. In contrast, rainwater harvesting is exempt from regulation as it ultimately re-enters the water system. With climate change expected to increase both heavy rainfall and summer soil moisture deficits, improved water-use efficiency and storage nationally will be essential however, the wider ecosystem and biodiversity impacts must also be considered (European Environment Agency, 2021). As Matthew Craig notes, "solutions are going to be all about storage," as the natural environment alone cannot buffer future water variability for Ireland.

The use of stored rainwater is already evident on Irish golf courses, where ponds are being developed for irrigation. Climate change will also likely increase regional disparities in rainfall, with wetter western areas and drier eastern regions. In Chile, a prolonged "mega drought" has led to national debate on inter-regional water transfer and sectoral prioritisation. Similar controversy has emerged in Ireland, for example around the proposed Shannon Pipeline project. These issues highlight the need for a systems-based approach, as increased rainfall variability will create simultaneous water demand across sectors. Agriculture accounts for only around 1% of national water use with approximately 85% of this supporting pasture production (Upton et al., 2017).

Regions, co-operatives, and farmers exposed to changing rainfall patterns may choose to proactively plan water resources through on-farm storage solutions such as tanks, covered lagoons, or lined ponds to reduce evapotranspiration and build resilience. However, any future approach must be underpinned by a national assessment of water resources, including the long-term implications of water storage for Ireland's natural

resources, ecosystems and biosecurity (European Environment Agency, 2021). Such resources are being sought after by vegetable growers in Ireland following the 2026 summer drought, and agricultural should be considered in any national conversations on water availability (O'Brien, 2026b). With increased slurry and soiled water storage requirements under the Sixth Nitrates Action Plan (2026–28), there may be an opportunity to take a longer-term, integrated approach to farm yard water and slurry storage. This could also support the development of smart, solar-powered, data-driven systems to improve water use efficiency, similar to irrigation technologies used by vegetable producers. International examples from New Zealand and Zimbabwe encountered through this Nuffield Scholarship highlight the potential for integrated irrigation systems, where water, slurry, and fertiliser are applied through a single infrastructure. Such systems support precision agriculture while reducing machinery traffic and associated soil compaction.

There are significant challenges associated with water storage and use, and for most farmers, additional storage will not be environmentally or economically sustainable in the long term. A clear national strategy is needed to assess the future role and sustainability of water management in Ireland. However, the most likely outcome is that greater emphasis will need to be placed on breeding alternative grass species and crops better suited to drier conditions. In relation to building resilience to climate change, this represents a "fork in the road" decision: either water management is a strategy that can be used to support continued production of PRG for grazing and conservation during summer months, or alternative forage systems will need to be developed.

11.5 Opportunities for Farm Resilience

Food Vision 2030 states that while grass-based production of milk, beef, and sheep will remain the dominant part of agri-food output, greater integration is needed, including dairy–beef and dairy–tillage linkages. This highlights the importance of viewing grass-based systems holistically within national strategy and resilience planning. The sector cannot be considered in isolation, given overlapping policy areas such as the Crops 2030 Strategic Plan (Teagasc, 2020), Ireland's 4th National Biodiversity Action Plan (Department of Housing, Local Government and Heritage, 2024), the Forestry Strategy (DAFM, 2023), and competing land uses such as energy

production (Department of Climate, Energy and the Environment, 2023). The Grass-Fed Standard may unintentionally limit diversification, as it requires the baseline diet to consist solely of grass and grass forage. Under future climate scenarios, where grass growth for grazing and silage is constrained due to changing rainfall patterns, alternative strategies will be required. Concentrates provide a short-term response to feed deficits but are costly. In 2024, an average of 1,338 kg/cow was fed on farms stocked at 2.0 LU/ha, compared with a 2030 target of 800 kg/cow (Teagasc, 2025; 2026a). However, Ireland is only 21% self-sufficient in concentrate feed ingredients and imported approximately 3.4 million tonnes annually between 2014 and 2018 (Teagasc, 2020). While the availability of Irish feed ingredients is a limitation, opportunities exist for both tillage and livestock farmers as recent Irish research has highlighted that replacing imported feed ingredients with locally sourced cereals and faba beans maintains the same level of milk production from grazing dairy cows (McCarthy et al., 2026).

Competition for land in Ireland is increasing across agriculture, environmental protection, biodiversity, housing, and renewable energy. The Programme for Government committed to a land-use review in 2022 to support national strategy (DAFM, 2023). Competing and sometimes conflicting policy targets are adding further pressure on land use decisions. Farm diversification options need to be considered as possible strategies for developing resilient adaptive systems that also offer multiple co-benefits.

11.5.1 Systems Integration

Longer-term resilience planning could include the use of alternative crops and forages better suited to drought conditions, grown collaboratively between livestock and tillage farmers to supply local, home-grown energy feed crops and support both sectors' targets. The Crops 2030 Strategy promotes greater sector integration, which could also strengthen livestock systems by improving access to stored high-quality winter forage and reducing the risk of fodder shortages, a key climate risk (EPA, 2024). Given the specialised nature of farming in Ireland, fodder supply agreements and cross-sector partnerships should be considered, alongside consideration of how out-blocks or farms, which typically have lower annual production than the home block, could be better utilised.

In Australia, integrated crop-livestock systems and on-farm diversification are key strategies for drought resilience. During this Nuffield study, farms and research institutions in Victoria and South Australia were visited to explore drought adaptation strategies. Although conditions are more extreme, the approaches provide useful insights for resource efficiency, sustainability, and resilience. Mark Wootton, owner of Jigsaw Farm, emphasises the importance of “controlling your controllables” to build resilience. His diversified enterprise includes sheep, cattle, and agroforestry and operates as a carbon-neutral business (Doran-Browne et al., 2018). This diversification provides flexibility, multiple income streams, and environmental co-benefits, including carbon sequestration, livestock shelter, improved water and climate regulation through crop diversity, and enhanced resource efficiency via solar energy and strategic water use (Figure 19).



Figure 19: Mark Wootton, Jigsaw Farms Victoria South Australia.

11.5.2 Silvopasture

"Farming in the shelter of trees"

Professor Jim McAdam (Director Irish Agroforestry Forum).

Agroforestry is defined by the Agroforestry Forum as "land use practices where trees are combined with crops and/or livestock on the same unit of land." Presentations at the National Agroforestry Conference highlighted the role of integrating trees into grassland to improve resilience. However, the Department of Agriculture, Food and the Marine currently support tree integration primarily through afforestation grants (e.g. 400 trees/ha), which result in permanent land-use change (Olave et al., 2025). This lack of flexibility is a significant barrier for farmers, as it removes future options to change enterprise. While integrating trees into grassland systems will reduce grass growth, it offers significant system benefits, including extended growing seasons, carbon sequestration, improved animal welfare through shelter, reduced evapotranspiration under shade, enhanced biodiversity, better nitrogen use efficiency, reduced nitrate leaching, and greater resilience to drought and flooding (Jose and Dollinger, 2019; Baker et al., 2025). With rising temperatures and more frequent extreme weather events, policy must better support tree establishment on farmland. This should go beyond traditional agroforestry models by enabling lower-density, strategically placed trees while ensuring land remains eligible under the Basic Payment Scheme and Nitrates Action Plan regulations.

Irish grassland is typically defined by the absence of trees and with only 6.9% of the landscape under hedgerows (Green, 2010) this offers limited shade and shelter for livestock. Climate change models predict increasing temperatures and more extreme weather events. To maximise the welfare of grazing animals, shade and shelter will be required as heat stress can have significant implications including metabolic and digestive functions (Gauly et al., 2013) reducing milk production and quality and reproductive efficiency (Kadzere et al., 2002; Das et al., 2016).

Silvopasture, a form of agroforestry where widely spaced trees coexist with grazing livestock, offers a useful model. In Portugal, systems such as the Montado integrate livestock with trees like cork oak and olive delivering environmental and production benefits, including wildfire mitigation. Observations from farms in Portugal and

Australia highlight the importance of shade (Figure 20a), with livestock consistently seeking tree cover even at moderate temperatures (c.25 ˚C; Figure 20b). Greater consideration is needed for forward-looking, long-term approaches to practical systems that “put trees into fields, not fields into forests” (John Casey, Forestry Development Officer, Teagasc). As trees take many years to establish, immediate action through policy, research and training of advisors is essential to ensure future climate resilience while maintaining agricultural productivity.



Figure 20 a: Sheep utilising the shade of a single tree in South Australia; **b**: Silvopasture (Montado) sheep grazing under Cork Oak trees Portugal.

11.5.3 Agrivoltaics

Solar energy is a rapidly growing sector in Ireland, with ambitious targets to support the clean energy transition (Department of Climate, Energy and the Environment (2023). However, its expansion has raised concerns and prompted calls for a national land-use dialogue (Morrissey, 2025), driven by the loss of productive agricultural land to solar developments and long-term leasing at high prices. Agrivoltaics, the dual use of land for both agriculture and solar energy, aims to improve land-use efficiency by combining food and energy production. In Ireland, most solar installations use ground-mounted photovoltaic panels, raising questions about their compatibility with productive farming systems such as sheep grazing. While dual-use systems may offer benefits, they could also provide farmers with additional income streams. More broadly, agrivoltaics could support a more integrated approach to sustainable intensification by creating a symbiotic relationship between agriculture and renewable energy production.

While in Belgium, KU Leuven's TRANSfarm facility was visited, a research farm powered entirely by renewable energy and featuring a purpose-built agrivoltaics system integrated into an arable farming system (Figure 21). The visit highlighted both the potential of agrivoltaics and key challenges, including cost, permitting, land-use regulation, and public acceptance. The system is designed for research on a 2,000 m² area, with elevated solar panels allowing machinery access and crop management beneath. Around 30% of the ground area is shaded at any time, and early results show winter wheat yields reduced by 20–30%. Despite these limitations, such systems demonstrate alternative designs that could better integrate cropping, livestock grazing, and solar energy. Current research is exploring horizontal versus vertical panel layouts, crop suitability, and the integration of elevated structures with grazing livestock. Emerging technologies such as semi-transparent panels may also improve light penetration.



Figure 21: KU Leuven's TRANSfarm facility Agrivoltaics site

12. Conclusions

The objectives of this report were to establish the climate change challenges facing Irish grasslands, assess available adaptation resources and to identify strategies and opportunities for adaptation and resilience building to future proof grass-based livestock systems. This report concludes:

The Climate Change Challenges

- The climate change projections highlight a warmer, wetter (in winter) and drier (in summer) future climate for Ireland with more climate extremes and fewer frost and snow days.
- Perennial ryegrass dominates Irelands grasslands and the National Recommended List; however, it performs poorly under drought conditions, high temperatures, and low soil fertility, raising concerns about its resilience under future climate scenarios.
- Climate change and changes to the Nitrate's Directive have changed grass growth trends, with a notable decline in average annual grass production, from 13.1 t DM/ha (10-year average) to 12.3 t DM/ha (5-year average).
- The changes in grass growth on farms in some areas exceeds climate projections, emphasising the localised nature of climate impacts and the need for targeted adaptation and resilience strategies and wellbeing support.
- Climate change is already being experienced on farms across the country and is a serious threat to the profitability and sustainability of grass-based livestock systems.

Current Available Resources

- National strategy is focused on continued capitalisation of Irelands competitive advantage to grow grass however; there is a significant lack of strategy of how this will be achieved with climate change.
- Sector risk assessments for climate change impact have been carried out and highlight the significant knowledge and infrastructure gaps, however not the path forward.
- Suggested strategies include improved grazing infrastructure, increased silage and winter feed stocks (including an additional month's supply), diverse or drought-resistant swards, realistic stocking rates, and winter feed budgeting.

- Research with MSS have demonstrated the significant potential of sward diversification. However, it remains limited, with little exploration of plant breeding opportunities, consideration of a broader range of species (grazing and winter feed) with future climate tolerance and supports for farmers to implement existing and new technology successfully.

Opportunities For Adaptation and Resilience

- Introduce climate risk and resilience tools: an integrated farm level resilience framework should be developed to help farmers evaluate their farms climate vulnerability and plan adaptations.
- Farmer wellbeing must be supported to develop resilient people and businesses.
- Consideration should be given to broadening the Grass Fed Standard definition to include legumes, multispecies swards and brassicas. While the standard is critical for market access, it may unintentionally limit diversification (alternative species or more integrated crop-livestock systems) and on-farm adaptation.
- Climate Adaptation Research: MSS are an important strategy for adaptation and should be supported however; further research is required. A future forages research programme is needed and should include evaluations of alternative grass and forage species, the assessment of plant varieties for drought, methane mitigation, pest and disease resistance and the establishment of a dry soils research and advisory programme.
- Technology, plant breeding, precision agriculture, grassland management and weather tools that improve efficiency, data collection and evidence-based decision-making must be supported and encouraged at farm level as they will be central to climate change adaptation
- Water Management: Consideration needs to be given to water management systems for farmers farming very dry soils. This will significantly impact the path forward and determine what other strategies will be required.
- Diversification for resilience: A holistic approach to land use is required to support competing demands, enable buffering and resilience strategies, and capitalise on opportunities through farm diversification and the integration of complementary technologies.

13. Recommendations

Collective action and national coordination across policy, research, advisory and industry stakeholders will be essential to support farmers adapting to climate change. This can be delivered through a National Grassland Climate Resilience Network, a farmer-led, nationally coordinated system that begins with the identification of on-farm challenges through an integrated farm-level resilience framework, and links these to targeted research, advisory support and industry engagement to deliver climate adaptation and ensure the long-term sustainability of grass-based livestock production systems in Ireland. This report recommends:

1. **Develop climate risk and resilience tools**: An integrated farm-level resilience framework should be developed to help farmers assess their climate vulnerability and plan appropriate data driven decisions and adaptations. As demonstrated by the Victorian Drought Resilience Adoption and Innovation Hub in Australia, farmers, researchers and industry should be brought together to co-develop locally tailored solutions and support the uptake of tools and technologies such as precision agriculture, grassland management and weather monitoring systems. Establishing strong foundations in grassland management at farm level is essential for generating reliable data, identifying the challenges faced by farmers and assessing capacity to adapt.

2. **Farmer health and wellbeing**: Farmer health and wellbeing should be researched and supported through a behavioural science pillar in the National Grassland Climate Resilience Network, enabling farmers to develop the skills needed to manage change, stress, uncertainty, increased workloads and financial pressures. Building resilience in both people and farm businesses must be a key component of climate adaptation and could be delivered through climate adaptation specific discussion groups and future farm workshops.

3. **Research funding and infrastructure**: Funding bodies should establish dedicated climate adaptation funding mechanisms and research facilities capable of simulating future climate conditions. Investment should support new plant-breeding technologies and longer-term plot, and systems scale experiments to develop

practical adaptation tools and inform future policy. Further opportunities exist for collaborative research initiatives to assess potential co-benefits and synergies across livestock, tillage, forestry and energy systems.

4. **Grass-fed standard**: A review process should be established to quantify the market value of the Grass-Fed Standard and explore how it can be strengthened over time, while ensuring sufficient flexibility to respond to future industry challenges and opportunities. The data generated through Bord Bia audits presents an opportunity for regular analysis at national, regional and local levels to better understand emerging farm-level trends, such as changes in feed budgets, and support evidence-based decision-making. The Grass-Fed Standard could also be broadened to include legumes, multispecies swards and brassicas, which align with grass-fed principles, while providing greater continuity between the current dairy and beef grass-fed standards.

5. **Climate adaptation research**: Multispecies swards are an important potential adaptation strategy and should be supported through further research. A future forages research programme should include long-term evaluation of alternative grass and winter forage species for grazing and conservation, alongside the breeding and assessment of plant varieties for climate tolerance, methane mitigation, pest and disease resistance, and nutrient-use efficiency. A dry-soils research and advisory programme should also be established. Substantial datasets already exist that could be better utilised to assess climate impacts, including National Variety Testing data and county/regional-level data from PBI. These could provide valuable local and regional insights and be monitored over time. Greater research collaboration is needed to leverage existing datasets, alongside research evaluating a broader range of grass and forage species and management strategies under future climate scenarios.

6. **Winter forages**: Research on silage production, silage quality and alternative winter feed types in Ireland has been limited in recent years. A dedicated research programme should be re-established to develop resilient winter-feed options and explore sward diversification and collaborative approaches between tillage and livestock systems to produce home grown winter forage under future climate

conditions. Research is also required on assessing silage quality in diverse mixtures, as NIR analysis can underestimate nutritional value compared to animal performance.

7. **Water management**: Water management systems should be assessed to determine whether water storage could become a viable adaptation option for farmers on very dry soils. This will have significant implications for future land-management strategies and help determine which additional adaptation measures may be required.

8. **Diversification for resilience**: A holistic approach to land use is required to support competing demands, strengthen farm resilience and capitalise on opportunities for diversification. This should include tree integration, integrated crop-livestock systems, home-grown energy and protein, and complementary farm enterprises. As trees take many years to establish, action through policy, research and advisor training is needed now to build future climate resilience and provide animal shade while maintaining agricultural productivity.

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15. Plain English Compendium Summary

As part of the Final Report requirements, authors need to provide a one page, plain English Compendium summary along with each Final Report in electronic and hard copy format. A template for the summary can be found below, following the completed example.
Note that this summary will be read by people without expertise in the field of study. It should be written in plain English and stand-alone as a summary of the research.

Project Title:	**Name of project**
Scholar: Address: Phone: Email:	Zoe McKay Melodale Farm, Gortogher, Cloghans, Ballina, Co. Mayo 0872054097 zoe.mckay@ucd.ie
Objectives	1) Establish the climate change challenges facing Irish grass-based livestock systems 2) Assess current resources in Ireland to address the impact of climate change on grass-based livestock systems 3) Assess international climate strategies to identify opportunities for adaptation and resilience to future proof grass-based livestock systems
Background	Climate change and rising food demand are increasing pressure on Irish agriculture. Extreme weather has reduced grass growth, causing feed shortages and making winter feed conservation more difficult. As 92% of Ireland's agricultural land is grassland, improving the resilience of grass-based systems is essential to maintaining grass-fed milk and meat production while meeting environmental targets.
Research	Relevant research on climate change and agriculture was reviewed, alongside discussions with Irish farmers about climate-related challenges. Through the Nuffield Scholarship, eleven countries were visited to gather international perspectives from farmers, researchers, educators and policymakers through conferences, meetings and interviews.
Outcomes	Irish research prioritises emissions reduction over climate adaptation for grassland farming. Summer drought threatens grass growth, grazing and winter feed. Adaptation requires mixed-species grasslands, better feed planning, flexible animal numbers and improved water management. Irish trials of drought-resistant forages, supported by stronger farm planning and advice, are needed now.
Implications	Collective action and national coordination are essential to help farmers adapt to climate change. A National Grassland Climate Resilience Network could connect farmers, researchers, advisors, policymakers and industry. It would identify farm-level challenges and link them to targeted research, advice and practical solutions to strengthen the long-term resilience of Irish grass-based livestock systems.