Animal & Grassland Research and Innovation Programme

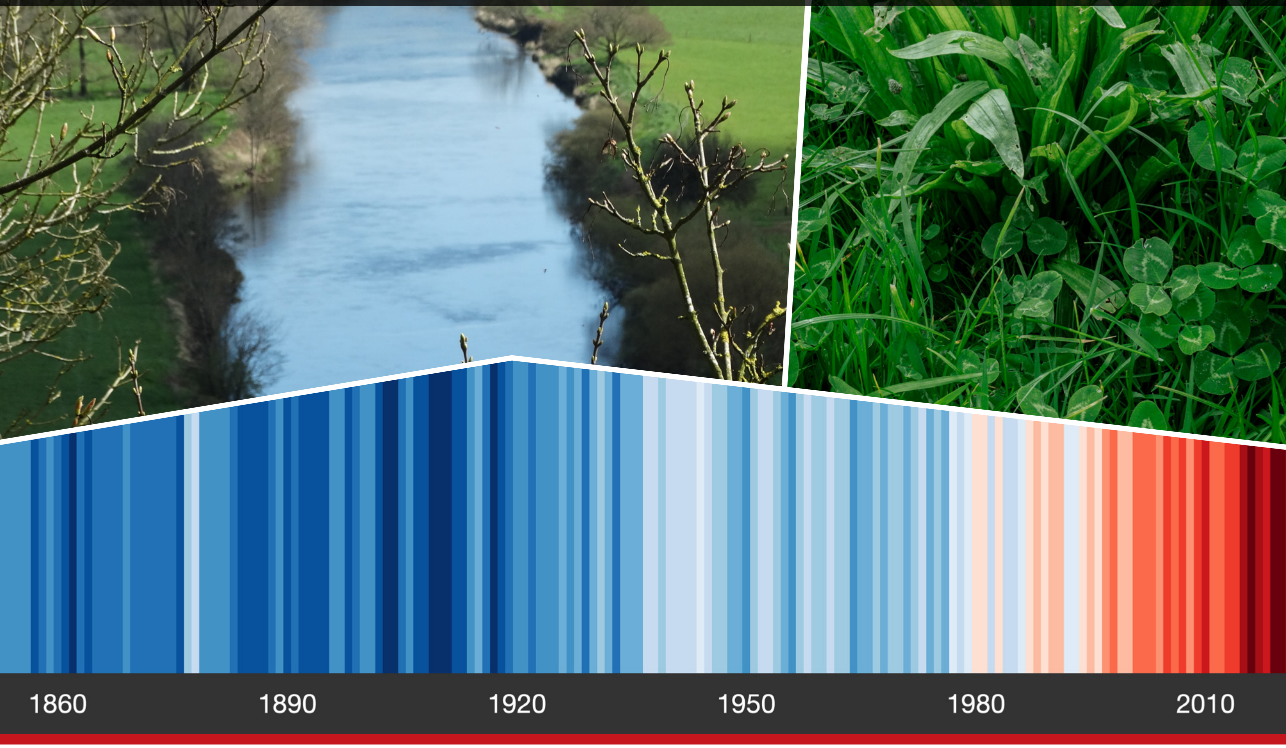
Moorepark

Climate Adaptation Conference

Conference Proceedings

Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

Tuesday 15th October, 2024



Teagasc
Agriculture and Food Development Authority

An Roinn Talmhaíochta, Bia agus Mara
Department of Agriculture, Food and the Marine

Teagasc Climate Centre

Climate Adaptation Conference

Conference Proceedings

Teagasc, Animal & Grassland
Research and Innovation Centre,
Moorepark, Fermoy, Co. Cork, Ireland

Tuesday 15th October, 2024

Edited by: Dr. Brian McCarthy and Dr. Michael Dineen

Sponsored by:

An Roinn Talmhaíochta,
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Department of Agriculture,
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Table of Contents

Conference Programme

What are the adaptations to be made to address the climate challenges in grassland?

Impacts of changing weather patterns

(Chair Michael Doran, ICBF Chairman)

8.30am **Registration** *(Tea/Coffee)*

8.45am **Conference opening**

9.00am **Setting the scene** – *Dr. Joe Patton*

9.15am **How weather patterns are changing, what are we adapting to** – *Dr. Padraig Flattery, Met Eireann*

9.45am **Feed costs - future scenario analysis** – Dr. Peter Doyle *and Dr. Tomas Tubritt, Teagasc*

10.05am **A decade of PastureBase Ireland - what do we know about grass growth on farms** – *Prof. Michael O'Donovan and Dr. Ciaran Hearn, Teagasc*

Climate adaptation challenges

(Chair Brian Murphy, DAFM)

10.35am **The Grazing Cow — A Carbon Paradox** – *Mr. Luc Delaby (INRAe)*

11.00am **Grass growth to 2040: the challenges ahead** – *Dr. Elodie Ruelle, Teagasc*

11.25am Coffee/Break

New species and the challenges

(Chair Fiona O'Donnell, Dairy Women Ireland/Dairy Farmer)

11.50am **Breeding for climate adaptation** – *Dr. Alan Stewart PGG Wrightson Seeds, New Zealand*

12.20pm **Plantain and multi species swards - their role in adaptation** – *Dr. Ellen Fitzpatrick, Dr. Philip Creighton, Dr. Brendan Horan and Mr. Kevin Dolan, Teagasc*

12.50pm **Grass/clover swards - adapting to the climate challenge** – *Dr. Michael Egan, Dr. Caitlin Looney, Teagasc and Mr. Mark Bateman (Dairy farmer)*

1.10pm **Discussion**

1.30pm **Summary/key messages/ new research areas** – *Dr. Deirdre Hennessy, UCC*

1.45pm **Lunch**

2.30pm **Visit Moorepark grassland studies**

- **Plantain grazing trial** – *Dr. Tomas Tubritt, Teagasc*
- **Grassland nutrition - plantain and clover impacts** – *Dr. Michael Dineen and Mr. Eoin Wims, Teagasc*
- **White clover cultivar evaluation** – *Ms. Ciara Carroll, Teagasc*
- **Moorepark grass-clover trial** – *Dr. Áine Murray, Teagasc*
- **Red clover evaluation trials** – *Ms. Sinead Kearney and Dr. Peter Doyle, Teagasc*
- **Initiatives on climate adaptation on Moorepark Farm** – *Dr. Jonathan Herron and Ms. Rachel Murphy, Teagasc*

Foreword: Managing grassland to adapt to climate challenges - The new reality

Michael O'Donovan

Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark Fermoy, Co Cork, Ireland

Irish grassland systems are experiencing challenges due to climate change. The incidence of intense precipitation events, soil moisture deficits and droughts and prolonged winter conditions are becoming increasingly frequent resulting in challenging conditions for Irish farmers. Feed deficits, resulting in the need to house animals for longer due to severe weather and soil conditions and moisture deficits/drought conditions mid-season, are becoming more frequent.

The world has just concluded its hottest decade on record, during which, the title for the hottest year on record was beaten eight times. The frequency and severity of climate and weather extremes is increasing. Europe is increasingly facing more frequent, severe, and longer lasting droughts. The economic losses caused by drought (~ €9 billion/year) mainly affect agriculture, the energy sector and the public water supply. Extreme droughts in Western and Central Europe in 2018, 2019 and 2020 caused considerable damage. In 2018 alone, agricultural damages amounted to some €2 billion in France, €1.4 billion in the Netherlands, and €770 million in Germany. If global warming increases the Earths average temperature by 3°C, droughts would happen twice as often and the absolute annual economic losses caused by drought would increase to €40 billion/year in Europe, with the most severe impacts in the Mediterranean and Atlantic Regions, including Ireland.

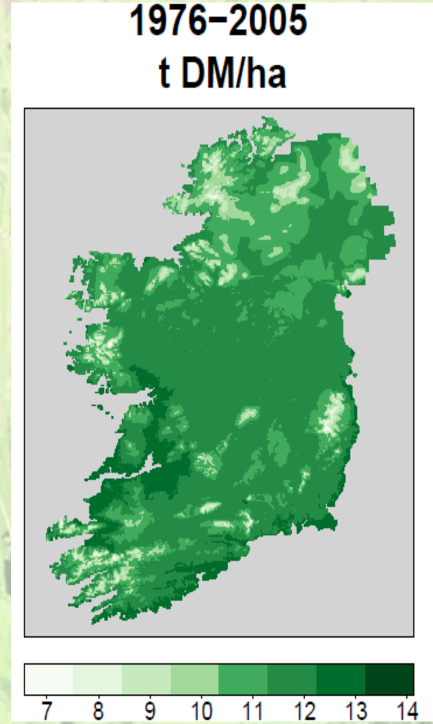
At an individual level, over 93% of Europeans consider that climate change is a serious problem, and 70% agree that adapting to climate change is positive. There is a consensus that climate adaptation needs to happen, not only just in agriculture.

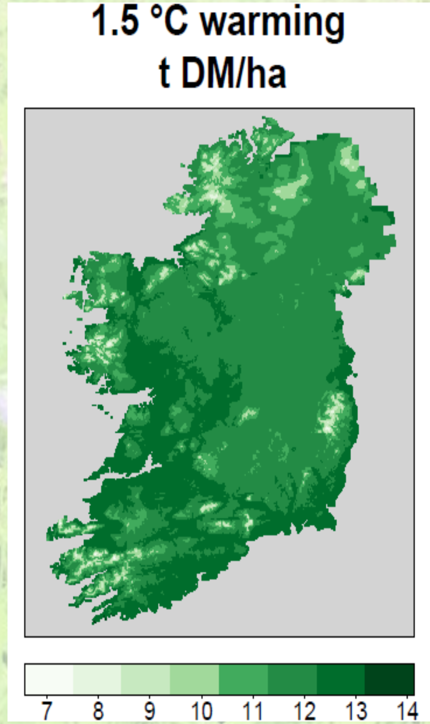
In July 2021, the Climate Action and Low Carbon Development Act 2020 was signed into law in Ireland. The Act commits the government to moving to a climate resilient and climate neutral economy by 2050. The European Union Green Deal (Farm to Fork) policy aims to reduce nutrient losses by 50% and fertiliser use in agriculture by 20% by 2030. The Water Framework Directive (WFD; EC 2000) requires at least good water quality in all European Union water bodies. Irish Agriculture has been proactive in this regard, with chemical nitrogen (N) input dropping substantially on Irish farms since 2022. The N fertiliser target is to reduce fertiliser use to 300,000 t by 2030, this was already achieved in 2023. Transitioning to lower N systems is a more prolonged path than some envisage, soil fertility improvement, legume incorporation, persistence and stability, and the threat of grass diseases are all major challenges, both short and medium term, that need to be overcome in the years ahead.

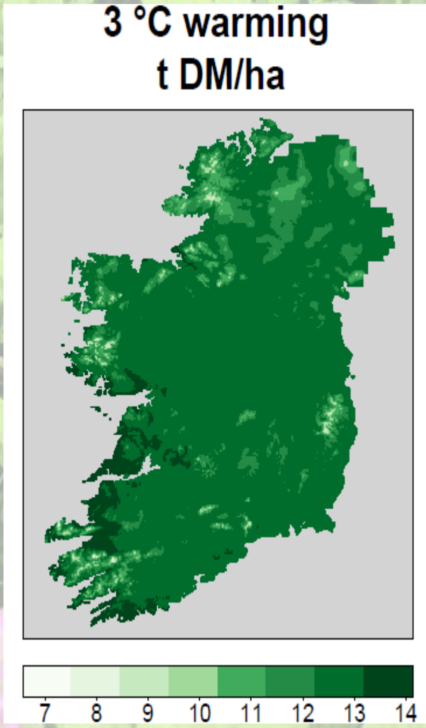
The conference objective is to identify the significant risks and opportunities of climate change for Irish grassland systems and to highlight the knowledge gaps that may exist which require an additional research focus. Key areas such as grass, clover and herb breeding for mixed species pastures, grassland and environmental modelling, weather and grass production trends as well as the latest research findings form part of the conference. The focus of the conference is to address ***key adaptations*** that Irish grassland will need to undertake in the years ahead in order to cope with climate change. An expectation of the conference outcomes will be to identify gaps in our Research and Knowledge Transfer programs to address the issues raised. It is a sign of the importance of this topic, that this conference has captured the interest and attention of delegates from a number of overseas countries. Teagasc welcomes delegates from New Zealand, Australia, United Kingdom and Europe as well as a range of multi-actor Irish delegates and of course grassland farmers.

Success is never final; failure is never fatal. It's courage to continue that counts. – Winston Churchill

Impacts of changing weather patterns







How weather patterns are changing, what are we adapting to?

Pádraig Flattery,
Met Éireann, 65/67 Glasnevin Hill, Dublin

Summary

- Weather is what we experience day-to-day, climate is the long-term average of weather (typically reported over 30-year periods).
- Ireland's climate is 0.7°C warmer and 7% wetter (average period of 1991-2020, compared to 1961-1990).
- Due to climate change, rainfall associated with storms from October 2023 to March 2024 was 20% more intense, and 10 times more likely to occur.
- Due to climate change the wet period from Oct 2023 to March 2024 was 15% wetter and four times more likely to occur.
- Likely outcomes of further warming are: extended growing season, rainfall increasing in likelihood and intensity, prolonged heatwaves and droughts, higher extreme temperatures, fewer cold extremes.
- Climate change is already happening and affecting Irish weather, further change is inevitable, and the severity of change depends on global greenhouse gas emissions reduction targets being met.

Introduction

Ireland's climate is predominantly influenced by its geographical position in the northeast Atlantic Ocean, resulting in a temperate maritime climate. This produces mild winters and cool summers, with significant rainfall and frequent cloud cover. The Atlantic Ocean, along with the North Atlantic Current, ensures that sea temperatures around Ireland remain relatively high for its latitude, buffering the island from extreme seasonal fluctuations. Ireland's prevailing weather patterns are also impacted by the clash of air masses, which can bring about unpredictable shifts in weather, including strong winds and storms, particularly in the winter months.

Ireland's long-standing climate patterns are undergoing changes because of climate change. Rising global temperatures are increasing the likelihood and intensity of extreme weather events, such as heavier rainfall, which poses a challenge to Ireland's infrastructure, agriculture, and natural ecosystems. In this context, Ireland will need to adapt to both the gradual shifts in temperature and the more immediate consequences of erratic weather patterns. This paper will outline how Ireland's climate has changed and how it is likely to continue changing in the future.

Climate change in Ireland

Climate averages are the mean values of a climate variable over a standard reference period. The World Meteorological Organization (WMO) established that the length of the reference period should be 30 years, with a recommendation to update the climate averages every 10 years to provide representative reference values for recent climatic conditions. These averages include data such as temperature, rainfall, and wind patterns, which help provide a baseline for comparing current weather conditions to historical trends. Using climate averages allows scientists to identify deviations from expected patterns and track long-term changes in climate. Averages are essential for understanding shifts in regional weather patterns and for planning in sectors like agriculture, infrastructure, and disaster preparedness, where knowing average conditions is vital for effective decision-making.

In accordance with WMO guidelines, Met Éireann has compiled a set of climate averages for the period 1991-2020 for a range of parameters including air temperature, precipitation, sunshine and wind. Annual, seasonal, and monthly average values for the period 1991-2020 were compiled using quality-controlled data obtained from Met Éireann's observation network. Hundreds of weather stations across the country were used for analysis. Long-term averages for stations are then used to generate maps and gridded data at a 1 km resolution. Figure 1 shows how seasonal temperature has changed.

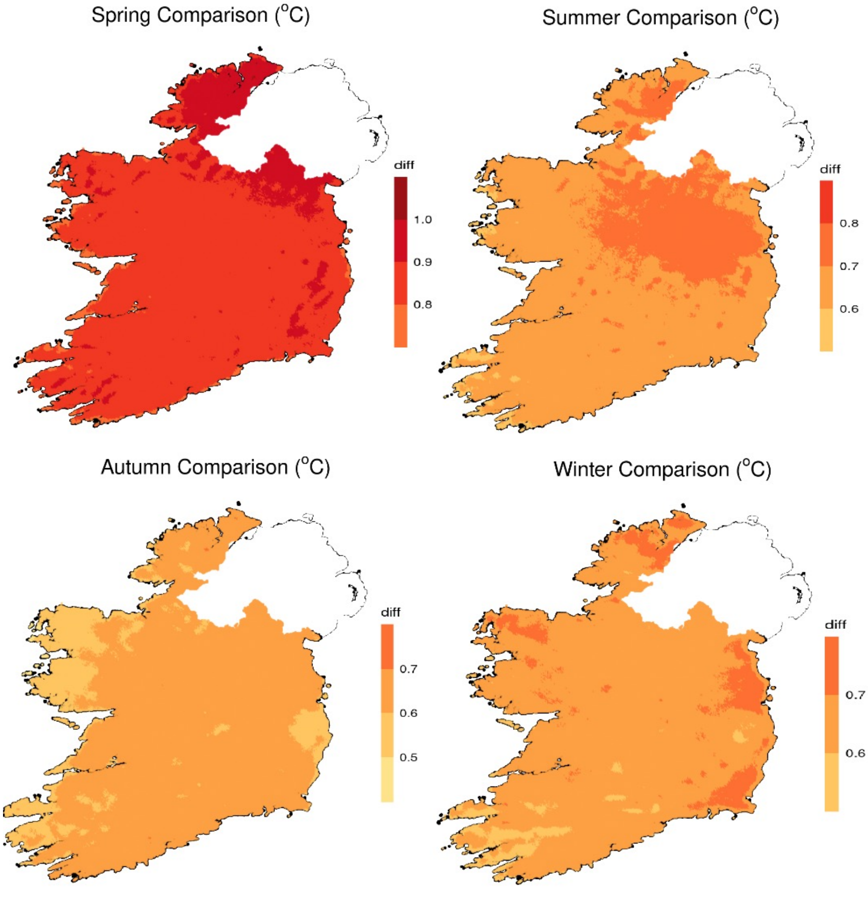


Figure 1. *Seasonal temperature change (°C) for the period 1991-2020 compared to 1961-1990*

Key highlights from 1991-2020 include a rise in Ireland's annual mean air temperature to 9.8°C, this ranges from approximately 8.5°C to 10.8°C. Due to the moderating influence of the sea, areas closest to the coast are generally warmest while areas at higher elevations are the coolest. The mean annual air temperature has increased by 0.7°C compared to 1961-1990. Spring temperatures increased by 0.8°C, summer and autumn temperatures increased by 0.7°C, and winter temperatures increased by 0.6°C.

Rainfall has also increased over the reference period; Ireland was 7% wetter in the 1991-2020 period compared to 1961-1990. Average annual rainfall in Ireland is now 1,288 mm, with much more rainfall falling in the west and at upper elevations. Figure 2 shows how rainfall has changed on a seasonal basis, with clear spatial differences in different seasons. Summer rainfall had the greatest relative change, increasing by 12%. Winter rainfall has increased by 7% on average, but notably increased strongly in the west and northwest of the country while declining in the east and southeast. Spring and autumn show increases of 3% and 4% on average, respectively.

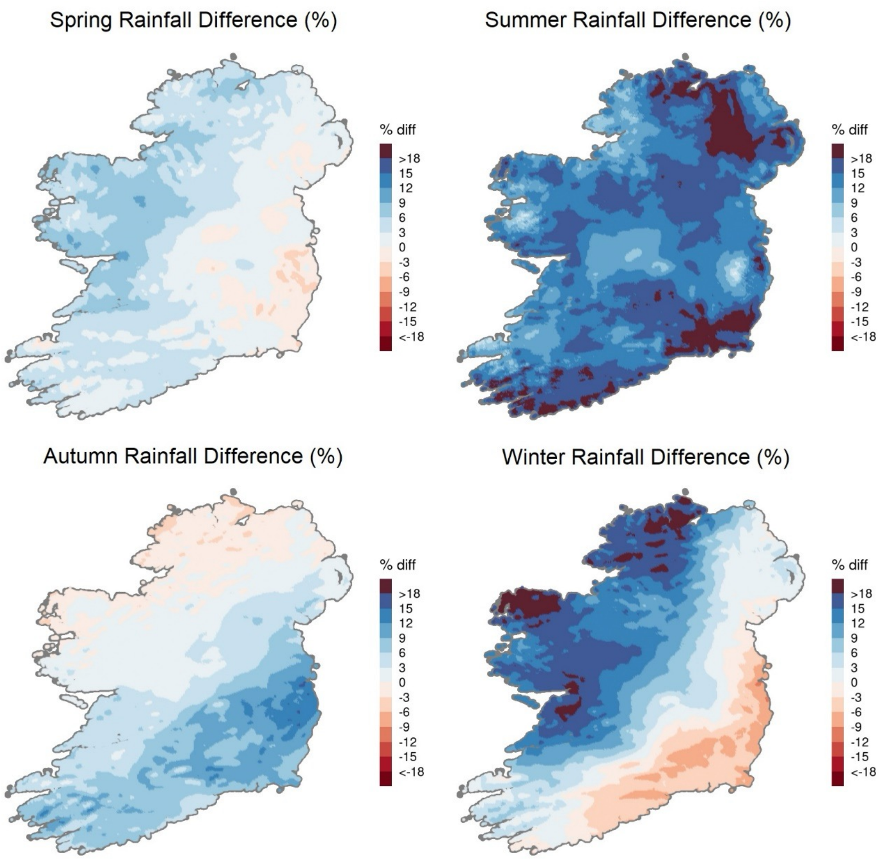


Figure 2. *Seasonal precipitation change (%) for the period 1991-2020 compared to 1961-1990*

There has also been a change in sunshine hours, with an average of 1,387.5 hours annually, an increase of 4.9% compared to the previous period. Wind speeds remain highest in the northwest, with Malin Head recording the strongest winds.

Storms and rainfall from October 2023-March 2024

A rapid attribution study by the World Weather Attribution group that involved Met Éireann scientists examined the links between climate change, storminess and rainfall in 2023/2024. The study found that rainfall associated with storms during this period was about 20% more intense and ten times more likely to occur compared to a pre-industrial climate. If warming reaches 2°C, as it is expected to in the 2040s or 2050s, unless emissions are rapidly halted, storm rainfall like we saw recently will become about 4% more intense again, and will be expected to occur about once every three years.

The study also examined the consistent wet weather over this period. In the cooler, pre-industrial climate, wet periods such as the 2023-24 October-March season occurred at most once every 80 years. However, in today's climate, they have become at least four times more likely, and are expected to occur about once every 20 years. The scientists estimate that climate change contributed to increasing the amount of total rainfall over the period by about 15%.

Future climate change

The TRANSLATE project, led by Met Éireann, is a collaborative initiative aimed at providing Ireland's first-ever standardised and bias-corrected national climate projections. These projections show how Ireland's climate will change under various global warming scenarios (1.5°C to 4°C), supporting informed adaptation strategies across key sectors. TRANSLATE projections are utilised in sectoral adaptation plans and provide data that can be used to produce climate services for a range of sectors including agriculture. Projections indicate future increases in temperatures annually, with drier summers and increased rainfall in winter projected as the climate continues to change. As the world warms, Ireland's temperature and rainfall will undergo more and more significant changes, for example in the worst-case scenario, average summer temperature could increase by more than 2°C, summer rainfall could decrease by 9% while winter rainfall could increase by 24%. The growing season is projected to start earlier and to last for longer.

Conclusions

Ireland's climate is changing, we have warmed by 0.7°C and become 7% wetter over the period 1961-1990 to 1991-2020. This change has led to increased likelihood and intensity of rainfall associated with storms, and of prolonged wet periods in general. A warmer atmosphere carries more moisture (about 7% for each degree of warming) so this rainfall increase is consistent with what we could expect as the climate warms. The severity of future climate change depends on global greenhouse gas emissions reductions, the more warming we experience, the more severe the impacts will be.

Acknowledgements

Information in this paper comes from Met Éireann's research into climate averages (www.met.ie/climate/30-year-averages), the World Weather Attribution study into the extreme rainfall of 2023/2024 (www.worldweatherattribution.org/autumn-and-winter-storms-over-uk-and-ireland-are-becoming-wetter-due-to-climate-change/), and the TRANSLATE climate change projections (www.met.ie/science/translate).

Feed costs – Current situation and future scenario analysis

Peter Doyle[1], Michael O'Donovan[2], Paul Crosson[1] and Tomás Tubritt[2],

[1]Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Dunsany, Co. Meath;
[2]Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

Summary

- The Teagasc Grange Feed Costing Model was used to review the cost of producing commonly used feeds on livestock farms.
- Grass white clover swards remain the cheapest feed resource for Irish livestock farms, and this trend will continue into the future.
- Winter feeds will likely experience the greatest change in costs in the future compared to grazed pasture.

Introduction

In recent years, input prices in the agricultural sector have been very volatile, which makes it difficult for producers to assess the true cost of producing livestock feed on a multi-year basis. Future changes in market prices, policy, weather events and plant breeding will further shift the cost of home-grown livestock feed. Therefore, it is important to identify 'resilient feedstuffs' that are less prone to volatility in a fast changing world. The purpose of this paper is to outline the current cost of producing home-grown feeds on livestock farms and assess how this may change into the future due to changing input prices, policies, weather events and yields.

Grange Feed Costing Model

An agro-economic simulation model, "Grange Feed Costing Model" (GFCM) was developed to quantify the impact of management, market and biological factors on the production costs of ruminant livestock feed (Finneran *et al.,* 2010). This model was used to re-evaluate the cost of feed in 2024, and assess how this may change under different future scenarios. Table 1 lists the range of home produced feed crops evaluated and the assumed dry matter (DM) yields, DM concentration, energy content (Unitè Fourragère Lait (UFL), and inorganic nitrogen (N) fertiliser (kg/ha) applied for each feedstuff, which were derived from Finneran *et al.* (2012). Additional feedstuffs (zero-grazed grass and grazed multi-species swards containing herbs, legumes and grass) were added to the model and a dairy concentrate was included to allow a cost comparison with a concentrate supplement.

Total feed cost includes accounting costs plus the opportunity cost of the resources employed (i.e. annual land rental market price of €617/ha or €250/acre). The accounting costs includes all variable and fixed production costs, including processing, storage and feed-out costs, in addition to depreciation and interest on capital funding of fixed assets (e.g. reseeding, roadways, silage pits). Utilisation, harvesting losses etc. are also accounted for. Fertiliser prices were based on market prices prevailing in the first 6 months of 2024 for the purpose of this analysis. Likewise, machinery-contracting costs were based on the Farm and Forestry Contractors of Ireland (FCI) estimated 2024 costs and included VAT (FCI, 2024). Zero-grazing was estimated to cost €198/ha per cut, with seven cuts each year for a 13 t DM/ha crop. For the grazed white-clover and multi-species swards it was assumed that 20% and 33%, respectively, of the farm was over-sown each year costing €112/ha for the seed and over-sowing.

A sensitivity analysis was completed to evaluate the impact of future changes in market price and yields on the cost of home produced-feed. Key parameters investigated included a 20% change in fertiliser price, machinery contractor price, land price and total DM yield.

Cost of producing feeds in 2024

The result of the estimated feed costs for 2024 is presented in Table 1. Unless stated otherwise, prices described in the following text outline the cost of feed per tonne (t) DM grown and include land charge (€617/ha); prices excluding land charges are also presented in Table 1. Costs are presented in € per hectare, € per t DM grown, € per t DM utilised and relative to grazed perennial ryegrass swards on a unit of energy basis (UFL; Table 1).

It is well-established that grazed pasture is the cheapest feed resource in Ireland and primarily for this reason, it underpins Ireland's ruminant production systems. Based on the assumptions in this present analysis, a grazed grass sward costs €94/t DM (9.4 c/kg DM), or at 80% utilisation this equates to 11.7 c/kg DM utilised. Thus, it costs €1.99/day to feed one dairy cow 17 kg DM of grass. Fertiliser (predominantly N) accounts for 35% of the cost of producing grazed grass. Thus N fixing legume swards such as grass-white clover (€84/t DM) and multi-species (€86/t DM) are cheaper than grazed grass, with grazed grass-white clover having a small cost benefit over multi-species swards, due to a lower over-sowing rate and longer reseeding interval (10 vs. 12 years, respectively).

Zero-grazing is a feeding option being utilised by some Irish farmers allowing increased land area to be brought into the farming system. The cost of zero-grazing was assumed as the cost of producing the grass sward similarly to the grazed grass crop whilst also incurring the additional cost of mechanical harvesting and delivery to the cows. The mechanical intervention required in zero-grazing makes it more expensive than grazed grass (€198/t DM vs. €94/t DM) but slightly cheaper than grass silage.

On average across both cuts harvested in late-May and mid-July, grass silage (pit) costs €222/t DM grown (circa €48/t fresh weight). On average baled silage costs €252/t DM grown (€50 and €42/bale incl. and excl. land charge, respectively), with machinery contractor charges being the main cost element (€27/bale), followed by fertiliser (€10/bale). Red clover silage offers an alternative to reduce fertiliser N application on silage ground. However, red clover persistency in the sward is considerably lower at 5-6 years (Clavin *et al.,* 2017) and therefore would require more frequent reseeding than perennial ryegrass silage swards, raising fixed costs. Furthermore, red clover silage swards are typically operated on a 3-cut silage system instead of a 2-cut system as it is not suitable for grazing, which increases harvesting charges, and subsequently 3-cut red clover silage whilst growing an additional 3.5 t DM/ha has a similar cost to 2-cut grass silage at €217/t DM grown. Feeds such as maize silage (€238/t DM grown) and fodder beet (€248/t DM grown) cost relatively similar to grass silage (average of bale and pit) per t DM grown, however fodder beet remains more cost competitive when expressed on a unit of energy basis. An important point to consider is that maize and fodder beet often require additional supplementary protein and mineral supplementation, which is excluded in this analysis.

Based on current prices, grass silage (including land charge) and dairy concentrate at €355/t are 3.1 and 3.5 times more expensive than grazed grass per unit of energy (UFL) utilised, or if land charge is excluded, this rises to 5.0 and 7.1 times more expensive than grazed grass, respectively. This emphasises the importance of (1) producing sufficient quantities of home-produced feeds, especially forages and (2) using effective management techniques to maximise the proportion of grazed grass in the diet.

Sensitivity analysis

A sensitivity analysis was also conducted to evaluate the impact of a 20% change in DM yield and fertiliser, machinery contractor and land rental prices on feed costs (€/t DM grown). Within the sensitivity parameters investigated, a 20% change in DM yield and machinery contractor price resulted in the largest feed costs change, followed by land price, and lastly fertiliser price. For example, assuming the same inputs are applied, for a grazed grass crop producing only 10.4 t DM/ha annually (20% yield decrease), the cost increases to €111/t DM (18% rise). Similarly if DM yield dropped by 20% for silage production, the cost of first and second cut pit silage would increase by €35 per t DM/ha (+ 14%). Grazed forages will remain the best value feedstuffs for Irish livestock into the future, as even in a scenario where grazed forages yield 20% lower, and silages, maize and fodder beet yield 20% greater, grazed forages remain cheaper to produce, costing approximately €110/t DM grown compared to approximately €200/t DM for the other feed options. Increases/decreases in fertiliser price had the least effect on the cost of producing on farm feedstuffs, with a 20% price increase, raising the cost of all feedstuffs by €2-4. The results suggest that fertilisation of swards with sufficient levels of nutrients is a key management strategy in order to maintain low cost ruminant production systems. 'Winter feeds' (grass silage, red clover silage, maize silage and fodder beet), all have a high machinery dependence and higher overall costs, and therefore tend to experience the largest cost change in response to increasing input price changes, compared to grazed grass and grass white clover, with zero-grazing being intermediate (Table 1). Thus, any increases in future input costs will further increase the cost competiveness of grazed pasture, and management practices that maximise the proportion of grazed pasture in the diet of ruminants will help to reduce feed costs on Irish farms.

Conclusions

Home-produced feeds and grazed grass in particular, remain the cheapest feed resource for Irish farms, with grass-clover pastures being particularly cost-effective. Grazed grass will remain the biggest cost competitive advantage into the future, while 'winter feeds' will likely experience greater price volatility. Weather events that reduce the proportion of grazed grass in ruminant diets will significantly increase costs.

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Table 1. **Feed assumptions and estimated costs (€) to produce feed in 2024**

	Grazed grass	Grass+ white clover	Multi-species swards	Zero-grazing grass all year[1]	First + second cut pit silage[2]	First + second cut bale silage[2]	3-cut red clover silage[3]	Maize silage (open)[4]	Fodder beet[4]	Dairy nut @ €355/t
Feed assumptions										
DM yield (t/ha)	13	13	13	13	6 + 4	6 + 4	5.6 + 4.0 + 3.5	13	15	.
DM (%)	17.4	17.4	16.4	17.4	21.7	32.4	30	30	19	86
UFL/kg DM	1.03	1.02	1.02	1.03	0.82	0.82	0.82	0.80	1.12	1.08
Inorganic fertiliser N kg/ha[5]	225	100	100	225	87 + 69	87 + 69	0	112	114	.
Total fertiliser N kg/ha	250	125	125	250	115 + 82	115 + 82	0	145	145	.
Feed costs 2024										
Total costs/ha (incl. land charge) (€)	1,220	1,088	1,118	2,572	2,216	2,522	2,846	3,044	3,722	.
Total costs/t DM grown (incl. land charge) (€)	94	84	86	198	222	252	217	238	248	.
Total costs/t DM grown (excl. land charge) (€)	46	36	39	150	180	211	176	189	207	.
Total costs/t DM utilised (incl. land charge) (€)	117	105	107	247	286	296	287	273	308	.
Total costs/t DM utilised (excl. land charge) (€)	58	45	48	188	233	247	233	218	257	.
Relative cost to grazed grass per energy utilised (UFL) incl. land charge	1.0	0.9	0.9	2.1	3.1	3.2	3.1	3.0	2.4	3.5
Relative cost to grazed grass per energy utilised (UFL) excl. land charge	1.0	0.8	0.8	3.2	5.0	5.4	5.1	4.8	4.1	7.1
Sensitivity analysis (+/- 20%): impact on total cost (€)/t DM grown										
Fertilizer price (e.g. protected urea +/- €104/t)	4	2	2	4	4	4	2	4	2	.
Machinery contractor price (+/- 20%)	3	4	2	25	29	37	28	32	38	.
Land price (+/- €123/ha or €50/acre)	9	9	9	9	8	8	8	10	8	.
Total DM yield (e.g. grazed grass +/- 2.6 t DM/ha)	17	14	14	8	35	21	33	38	26	.
Fertilizer, contractor and land price combined	16	15	13	38	41	49	39	45	48	.

[1]Zero-grazing does not include the cost of handling extra slurry vs. grazing; [2]First- and second-cut silage were cut on 29 May and 17 July, respectively. [3]Slurry + the cost of 0-7-30 for the remainder of K requirements, no grazing is assumed, 6 year persistence; [4]The extra cost of feed protein supplementation required for maize and fodder beet is not included; [5]The remainder of N requirement was fulfilled via slurry (organic N) application. Land charge = €617/ha (€250/acre), protected urea = €520/tonne (t), 18-6-12 = €477/t, and dairy concentrate nuts = €355/t fresh weight. Pit silage complete job = €445/ha (€180/acre), mowing = €72/ha (€29/acre), tedding €42/ha (€17/acre), bale, wrap, stack and move (including plastic) = €23/bale, beet harvesting = €432/ha (€175/acre), and maize silage harvest (complete job) = €511/ha (€207/acre).

Grass growth and grazing management efficiency trends from PastureBase Ireland grassland farms

Michael O'Donovan, Ciarán Hearn and Anne Geoghegan,
Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

Summary

- Annual grass dry matter (DM) production has averaged 13.1 t DM/ha on PastureBase Ireland farms from 2014-2023.
- Spring is the least consistent grass growth season.
- The number of defoliation events has increased from 7.1 to 8.1 from 2014-2023.
- Average number of grazing days for this subset of farmers was 285 days (range of 274 - 296 days across years).
- The mean annual fresh grass allocation was 3.7 t DM/cow per year over the past 10 years and has remained static.
- In the past three years, both concentrate and forage inputs have increased.
- New avenues to increase grass production within the constraints of limited chemical nitrogen inputs need to be established.
- Grazing management tools need to be optimised to inform better grazing management and decision-making, as grass measurement on its own is not enough.

Introduction

PastureBase Ireland (PBI) is a web-based grassland management decision support tool that was first developed in 2013 for all Irish grassland farmers (Hanrahan *et al.*, 2017). The secondary purpose of PBI is to serve as the national grassland database for Irish grassland farmers. PastureBase Ireland is designed to allow grassland farmers to improve their grassland management on farm. It offers farmers 'grassland decision supports' and stores the data from dairy, beef and sheep farmers in a central national database. In 2024, there was over 14,000 farms registered on PBI. Approximately 50% of all grass covers are now uploaded from the PBI mobile application. Users with more than 25 annual covers on PBI use the mobile application for the majority of their data recording events. There has been a clear, continual increase in grassland measurement on dairy farms over time. The integration of the Moorepark St Gilles (MoSt) grass growth model into PBI started in 2023 and will be further developed in the coming years.

The objectives of using PBI on grassland farms is to focus on optimising grass utilisation across all ruminant sectors, improving farm productivity, promoting sustainable grazing practices and supporting evidence-based decision-making on Irish grassland farms. This paper describes data from a 10-year dataset of a sample of grassland farms (approx. 250 farms) taken from the PBI database; these farms completed a minimum of 35 covers each year from 2014 - 2023.

Grazing management performance

Annual grass growth has varied over the past 10 years (Table 1); on average dry matter (DM) production was 13.1 t DM/ha. Eight of the last 10 years have had less than 6% variation in grass DM production around this mean figure, which shows grass DM production is relatively consistent. Spring grass DM production is far more variable than either summer or autumn grass DM production, with autumn the most consistent season (Table 1). On average, over the 10 years, grass DM production was 1,817 ± 287 kg DM/ha, 6,209 ± 489 kg DM/ha and 5,299 ± 389 kg DM/ha for spring, summer and autumn, respectively. The average grazing days ranged from 274 to 296 days, with a mean of 285 grazing days. While these are not full time grazing days for the animals, it shows that grazing efficiency is increasing. The start date of the second grazing rotation has occurred three days earlier in the past three years than it did in the first year of this data set. The date that grass growth equals grass demand (magic day) is now seven days earlier. Previously, magic day was April 18 but is occurring on April 11 more recently.

Table 1. Seasonal and annual DM production (kg DM/ha) over ten years (2014-2023) on a sample of PBI farms

Year	Spring	Summer	Autumn	Annual	No. of grazing and silage events
2014	1,635	6,366	5,118	12,727	7.1
2015	1,709	6,430	5,458	13,215	7.5
2016	1,446	6,621	5,560	13,241	7.9
2017	2,163	6,527	5,588	13,990	7.9
2018	1,285	4,971	4,948	10,941	6.7
2019	2,059	6,629	5,214	13,685	7.9
2020	1,975	6,367	5,474	13,660	8.0
2021	2,075	6,146	5,741	13,887	8.4
2022	1,939	5,997	4,576	12,468	8.2
2023	1,886	6,039	5,316	13,193	8.1

The number of defoliation events has varied over the years, ranging from 6.7 - 8.4. The mean number of grazing events (7.2) and silage events (0.56) have increased over time. In the first three years of the data set, the mean pre-grazing yield was 1,611 kg DM/ha; however, in the last three years the mean pre-grazing yield across the season has reduced to 1,474 kg DM/ha, which is in line with recommendations (O'Donovan *et al.,* 2022).

Grazing management improvements

Grazing stocking rates have increased slightly on these farms over the 10-year period. The grazing area was stocked at 2.8 cows/ha in 2014, this figure increased to 3.0 cows/ha up to 2019, with no increase since. Grazing stocking rates were 2.2 ± 0.11 cows/ha, 3.9 ± 0.16 cows/ha and 2.9 ±- 0.13 cows/ha for spring, summer and autumn, respectively. The grass allowance to herds has been maintained, as the average fresh grass allocation was 3.7 t DM/cow over the past 10 years, with very little variation. Over the 10-year period, the supplement feeds allocated per cow during the grazing season averaged 423 kg DM/cow and 748 kg/cow for conserved forage and concentrate, respectively (Table 2). In the past three years, there has been a tendency for both concentrate (+ 171 kg/cow) and conserved forage inputs (+ 114 kg DM/cow) to increase. In two of the last 10 years, concentrate input averaged > 1 t/cow.

The weekly grass growth for farms from 2014-2024 (year to date) is shown in Figure 1. Daily grass demand was approximately 40 kg DM/ha per day over the 10-year period. Within the year, the mid-season period (01 April - 01 September) had the highest daily grass demand of approximately 60 kg DM/ha per day. While there has been an increase in the variation in daily grass growth figures in recent years, largely induced by prolonged alternating periods of high and low rainfall, the increased level of supplementary feed in Irish grazing systems is unexpected. Compounding the issues created with variation in grass growth is the increasing trend for pushing the boundaries of spring grass growth. In many cases, both first and second grazing rotations are now starting earlier. These changes create more demand for grazed grass earlier in the farming year and substantially increases the risk of feed deficits in late spring and early summer. The practice of only measuring farm cover is not sufficient to improve farm grassland management; grassland managers need to embrace the use of MoSt grass growth predictions, autumn and spring grass budgeting and effective planning of annual nutrient applications to achieve grazing targets. All the effective grassland management tools are currently available on PBI, although farmer uptake has been limited.

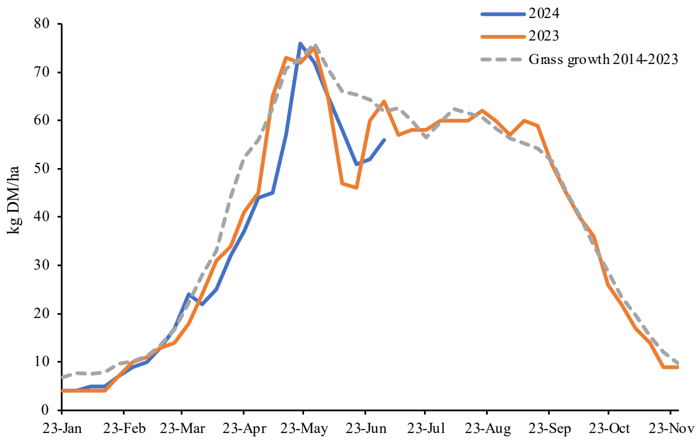

Figure 1. *PastureBase Ireland grass growth curve 2014 - 2024*

Reducing chemical nitrogen (N) application on grazed swards is now the norm in grassland farming and is leading to a lot more instability in grass growth; improvements in grassland management can alleviate this issue. As part of an increased awareness around N fertiliser use and reduction, clover is now more widely used in reseeding. Over-sowing white clover into established swards has become more common to increase clover levels on many farms. The level of white clover used on farm has doubled in the last two years. The awareness around targeted use of chemical N fertiliser to optimise sward clover content needs to increase to fully realise the potential benefits of clover on farm.

Table 2. The annual and seasonal grass demand, as well as, concentrate and forage input over the grazing season from 2014 to 2023

Year	Annual grass demand (kg DM/ha)	Spring grass demand (kg DM/ha)	Summer grass demand (kg DM/ha)	Autumn grass demand (kg DM/ha)	Concentrate offered (kg/cow)	Conserved forage offered (kg DM/cow)
2014	41	23	60	39	400	261
2015	43	27	63	41	464	262
2016	43	22	65	41	587	325
2017	45	30	64	43	622	315
2018	35	19	51	39	1,122	566
2019	43	27	60	43	750	356
2020	42	27	58	41	799	519
2021	42	27	59	42	857	474
2022	39	26	58	36	1,009	599
2023	42	25	56	42	892	538

Summary and conclusions

The primary objective of PBI is to enhance the management of grass on Irish farms. From this dataset, there has been a number of grazing management efficiency improvements in the last 10 years. The level of grassland measurement on farms has increased from 631 to > 14,000 farms. The number of grazing days and the number of defoliation events (grazing + silage) have increased, while pre-grazing yields have decreased in line with best practice guidelines. However, there are some concerns; while annual grass DM production is relatively static, daily grass growth within years has become more variable, especially in spring. The lack of increase in grass allowance per cow is concerning, given that concentrate and forage input has increased in the last four years. Some of the policy changes around N management, delayed application of spring N and the restriction on total N usage is likely influencing annual grass output. The real challenge of future grassland systems will be to explore and find avenues to increase grass DM production with moderate N application levels, whilst maintaining an efficient grassland system.

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Climate adaptation challenges

The grazing cow – A carbon paradox

Luc Delaby

INRAE, l'Institut Agro, UMR Pegase, 16 Le Clos, 35590 Saint Gilles, France

Summary

- Ruminants, due to enteric methane emissions, contribute to global warming but also play an important role in grasslands utilisation and high-quality food production. This is the carbon (C) paradox.
- The role of agriculture and ruminants in climate change has to be considered relative to other sectors and the evolution of their contribution since the beginning of the 20th century.
- Grasslands have the potential to sequester C, which helps to reduce global warming, and provide many other ecosystem services.
- A large part of these ecosystem services are closely linked to the presence of ruminants and grazing.
- Looking beyond climate change, considering other issues that are vital to the future of the planet encourages the maintenance of ruminant livestock farming that makes the most of grassland.

Introduction

Current climate change and its acceleration over the last decade are the result of the increase in greenhouse gas (GHG) emissions (IPCC, 2023). The three main GHG are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), which account for 75%, 18% and 4% of total global emissions respectively in 2020, expressed in CO_2eq (IPCC, 2023). Since 1970, GHG emissions have increased by a factor of 2.18, from 27 to 59 Gt CO_2eq. A large proportion of these emissions and their increase are the result of human activity, particularly fossil fuel consumption (transport, residential and industry). As a significant part of total CH_4 comes from the enteric digestion of forage by livestock and this GHG is included in national inventories, ruminants are often blamed for global warming. Ruminants also have the ability to transform pastures and forages into high-quality foodstuffs, which are of great importance for human consumption and global food security. In addition, grasslands, which cover 40% of the earth's surface, are both organic matter rich soils that need to be preserved and interesting potential carbon (C) sinks that need to be encouraged (O'Mara, 2012). That is the C paradox of the grazing cow.

The impacts of ruminant livestock on GHG emissions and other environmental impacts

There is no point hiding the facts: ruminants play a role in GHG emissions. Nevertheless, their absolute influence, which is often amplified by the media, should be put into perspective in relation to other sectors emissions. The evolution of their contribution to the considerable increase in GHG emissions since the beginning of the 20th century also needs to be considered. The most important GHG caused by ruminant farming is enteric CH_4 (Table 1). As a proportion of the total agricultural sectors GHG emissions, enteric CH_4 represents 63% (France) and 70% (Ireland), respectively, and 8% and 22%, respectively, of the total GHG emissions of these two countries. These emissions should be compared with the weight of fossil fuel emissions, which are 73% and 56%, respectively, in France and Ireland, and 74% on a global level.

Table 1. Various quantities of GHG emissions (expressed in CO_2eq) in the World, France and Ireland (EDGAR, 2024)

Mt CO_2eq	World	France	Ireland
Total	52,963	385.5	57.8
Fossil origin	39,024	282.4	32.5
Fossil (% total)	73.7	73.3	56.2
Agriculture sector	6,488	68.6	22.3
Agriculture (% total)	12.3	17.8	38.6
CH_4 from agriculture	4,611	43.0	15.7
CH_4 (% agric)	71.1	62.7	70.4
CH_4 enteric	3,300	32	13
CH_4 enteric (% CH_4 agric)	71.6	74.4	82.8
CH_4 enteric (% total)	6.2	8.3	22.5

In terms of the evolution of the relative contribution, it is original to illustrate and compare the number of cows and cars per inhabitant over the age of 18 in Europe between 1950 and 2023. France and Ireland will be used here as examples (Table 2). This comparison is interesting because the direct emissions (CO_2 due to petrol for cars or CH_4 by digestion for cows) expressed in CO_2eq by the cow and the car are frequently described as similar (between 2.5 and 3.0 t CO_2eq).

Table 2. Evolution between 1950 and 2023 of the number of cows and cars by 1000 inhabitants older than 18 years (from various sources compiled by the author)

/1000 inhabitants	France		Ireland	
	1950	2023	1950	2023
Inhabitants (> 18 years '000)	30,520	52,840	1,965	3,989
Cows	268	132	610	584
Cars	76	736	153	575

Between 1950 and 2023, in France, the number of cows (dairy and beef) per 1,000 inhabitants (>18 years old) halved, while at the same time the number of cars increased tenfold. During the same period, in Ireland, the number of cows per 1,000 inhabitants has remained virtually stable, while the number of cars has increased by a factor of 3.75. Over the last century, other activities such as transport, housing and industry have had a significantly greater impact than the livestock sector. In addition, let us not forget that during this period, agricultural productivity per inhabitant has risen sharply thanks to genetic improvement and improved livestock rearing practices. As a result, GHG emissions per unit of product have fallen sharply, as illustrated by the dairy sector in France and Ireland, from 1984 to the present day (Table 3).

Table 3. Evolution of enteric methane emissions per cow and per kg of milk at national level in France and Ireland between 1984 and 2022

	France			Ireland		
	1984	2000	2022	1984	2000	2022
Dairy cows ('000)	7,195	4,425	3,250	1,535	1,260	1,500
Milk yield ('000 tons)	22,750	24,250	23,900	5,600	5,265	9,100
Average DMI /day (kg)	16.0	19.0	22.0	15.0	16.5	18.0
CH_4 enteric/year (kg)[(1)]	117	139	161	110	120	131
CH_4 /kg milk (kg CO_2eq)[(2)]	0.86	0.71	0.61	0.84	0.81	0.61

[(1)]*assuming an average 20 g of CH_4 per kg of dry matter intake.* [(2)]*with a conversion factor of 28*

In addition to GHGs, ruminant livestock farming, and especially beef production, is often criticised for its cost in terms of water and surface area, its inefficiency in producing protein, its contribution to air and water pollution and sometimes even its harmful effects on human health. Generally speaking, in European countries, where daily food supplies are virtually guaranteed for everyone, ruminant farming is being called into question and is the subject of numerous scenarios and studies aimed at reducing its numbers and its contribution to food production on the basis of protecting the environment.

The role of grasslands and ruminants in the future of the Earth

A large part of ruminant GHG emissions is included in the natural C cycle, unlike other sectors, which draw mainly on fossil energy stocks (oil, coal, etc.). In this unique situation, permanent grassland offers the opportunity to fix C and increase soil organic matter content. This will help to partially offset ruminant GHG emissions and, above all, limit global warming. On average, and although this is still a matter of debate due to the wide variations observed between specific situations (Klummp, 2022), around 0.5 t of C is sequestered each year in long-term grassland. The most important thing remains to avoid releasing the stored C and, consequently, to maintain or, better still, to extend the area of grasslands.

Grasslands have other benefits for the environment and these benefits, known as ecosystem services, need to be accounted for in the overall assessment of ruminant production systems. These services can be classified into various categories, as proposed by the Millennium Ecosystem Assessment (2005): provisioning, supporting/regulating and cultural services. Grasslands contribute to a large number of these services, as recently described by Richter *et al.* (2024) or by Isselstein and Kayser (2014). Some of these services are of critical importance to Earth and humanity and should at least be preserved and better promoted. We can cite water and nutrients (nitrogen (N), phosphorous, C) flux regulation, water purification, pesticide use reduction, erosion control and natural hazard prevention, pollination and biodiversity preservation among these attributes. Meadows are often associated with hedges, embankments and copses of trees or shrubs, creating the bocage network that is favourable to birds, small and large fauna and flora and serves as a larder and protective area. These landscapes also contribute to cultural services, and are really appreciated by the citizen-consumers, for recreation or simply as a pleasure for the eyes.

A large part of these services depends directly or indirectly on ruminants, and in particular, the use of pastures for grazing. Provisioning services are interesting if ruminants enhance the biomass of human food as milk and meat. Regulating services are most effective and relevant if ruminants graze. Grazing herds or flocks contribute largely to the agreeability of this landscape, as demonstrated in opinion surveys carried out in different European countries. Good management practices in ruminant farming and grazing at adequate stocking rates will further improve the positive impact of certain ecosystem services. Reducing the use of chemical N by introducing legumes and broadleaf plants to pastures helps to limit GHG (N_2O) emissions and promote floral diversity. In less intensive grass-based systems, delaying harvesting of certain paddocks to protect birds nesting, or allowing flowering to take place, will be favourable to support such ecosystem services. In ley-farming systems, such as in organic farming systems, pastures for improving soil C content, atmospheric N fixation and ruminants, for their contribution to recycling nutrients N-phosphorous-potassium (linked with dung and urine patches at grazing, and slurry or manure production indoors) play an essential role in soil fertility and the long-term sustainability of these farming systems.

Conclusion

Because of the total area they cover and their functionality, grasslands have a major influence on many biological processes that are essential to the planet's equilibrium, both locally and globally. To quote the title of Bengtsson *et al.* (2019), "*Grasslands are more important for ecosystem services than you might think*". The emergency associated with the climate change crisis has put the spotlight on ruminants as being responsible for GHG emissions. How do we maintain grasslands functions without ruminants? That is the C paradox of the grazing cow. Given all the ecosystem services attributed to grasslands, the need to produce more food with fewer inputs and less environmental impacts, and to protect and encourage biodiversity, our future depends in part on our ability to combine grasslands and ruminant farming for a win-win solution.

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Grass growth to 2040 and beyond: the challenges ahead

Elodie Ruelle,
Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork

Summary

- TRANSLATE data was used with the MoSt grass growth model to predict the impact of possible future climates on grass growth in Ireland.
- Preliminary work is showing that an increase in Earth's average temperature of 1.5 °C could lead to an increase in national average annual grass yield of 2.5% and a 3 °C increase an average increase of 8.5%.
- When looking at the monthly data, the increase in grass growth will be mainly for the winter and spring months (especially April, October and November) while a decrease is forecasted for the summer and autumn months (especially August).
- In addition, an increase in the variability between years is forecasted for the months of July, August and September.
- Better farm infrastructure and increased high quality forage stocks will be necessary to adequately adapt to future climate.

Introduction

The temperate climate of Ireland allows for an extended grazing season with grass growing for most of the year and relatively low occurrence of drought conditions. However, the climate is changing and in order to be able to adapt to the future challenges and find relevant adaptation strategies it is important to know what will be the likely impact of future climate scenarios. This paper will use weather projections from the TRANSLATE project and the Moorepark St Giles grass growth (MoSt GG) model to predict the impact of future climate scenarios on grass growth in Ireland.

Model description

The MoSt GG model is a dynamic and mechanistic model that was developed in Teagasc Moorepark in collaboration with INRAE (France). The model uses inputs such as weather data (min and max air temperatures, rainfall and solar radiation) as well as management information (fertiliser and grazing) and soil type to predict grass growth and nitrogen (N) leaching among other things. The model is currently widely used to predict grass growth on 84 farms each week in Ireland and has also been used to analyse scenarios for the renewal of the Nitrates Derogation Action Plan for Ireland.

Data inputs

The data that have been used in this paper are part of the TRANSLATE climate projections data (Met Éireann). Two types of data were used for the two case studies (simulations) that are presented in this paper. The first case study utilised CMIP5 gridded data, which are used to highlight the average impact a global warming of 1.5 °C or 3 °C would have across the country of Ireland compared to the baseline weather of 1976-2005. For the second case study, a specific location (Moorepark) was simulated at different warming severities using six weather projection models. Different climate time series are presented, a historical series (1976-2005), and two projection periods: 2021-2050 (centred on 2035) and 2041-2070 (centred on 2055) at Representative Concentration Pathways (RCP) of either 4.5 (moderate emission scenario) or 8.5 (high emissions scenario) representing a total of 750 years simulated. For both case studies, 220 kg of N per ha was applied in six applications at fixed dates and grass was grazed each time the paddock height reached 10 cm. Trafficability was not taken into account in the management rules. Simulations were run on a free draining soil.

National average impact of 1.5 °C or 3 °C warming

Assuming the same management for each part of Ireland and an unrealistic uniform free draining soil type, a 1.5 °C warming could result in a median increase in average annual grass growth of 438 kg dry matter (DM)/ha (ranging from -8 to 1,106 kg DM/ha). This corresponds to an increase of 3.4% in annual grass growth (Figure 1). Going up to a 3°C increase would lead to a further median increase of 599 kg DM/ha but with more variability and some parts of the country seeing a slight decrease in annual growth.

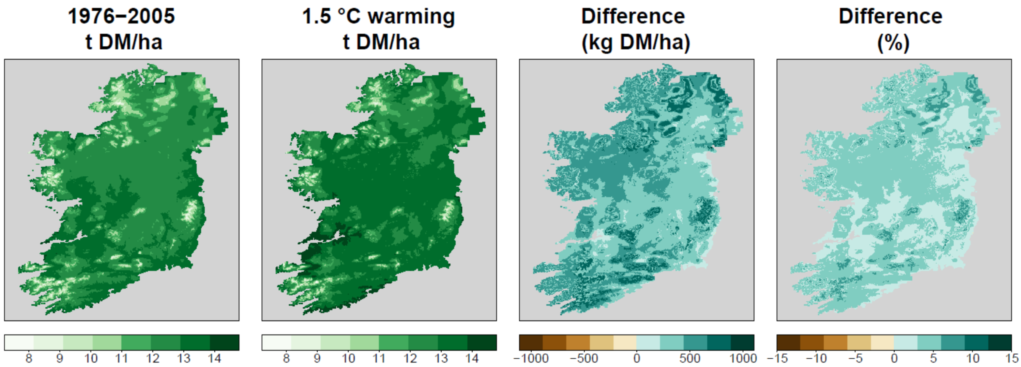

Figure 1. *Annual cumulative grass growth simulated by the MoSt GG model for the historical year (1976-2005), 1.5 °C warming, difference between the two and percentage difference*

Looking at the monthly output, the results are more variable. Overall, simulations demonstrated an increase in grass growth for most months except August and September, in particular (Figure 2). For the months of June, July, August and September, a decrease in growth was predicted, especially for the eastern part of the country (up to -213 and -219 kg DM/ha in August and September, respectively, in parts of the country). The east coast is predicted to see a slight decrease in growth for the early months of the year but not during summer. The biggest increases are projected for the months of December, with a median increase of 111 kg DM/ha, as well as April, with a median increase of 97 kg DM/ha. At 3 °C warming, the trend was the same but more severe, with an important median predicted decrease in growth for the months of July and August (-40 and -200 kg DM/ha, respectively; with a range of up to -294 and -563 kg DM/ha). There was also a greater predicted increase in spring growth for the country, with a median increase of 308 kg DM/ha during April. It should be noted that these simulations were performed using an average weather year and do not represent any variability between years or extreme years.

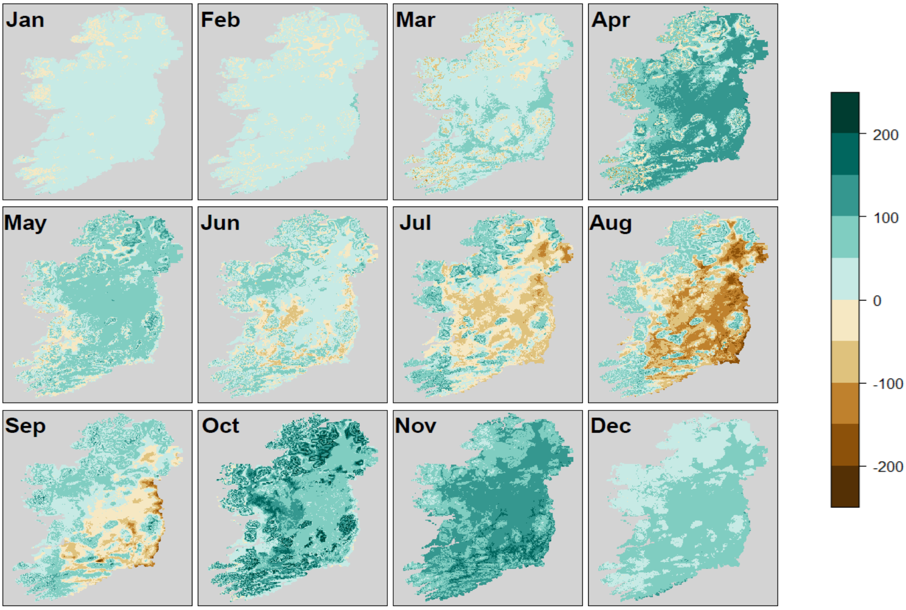

Figure 2. *Monthly cumulative grass growth difference between a 1.5 °C warming simulation and the baseline simulation (1976-2005)*

Year to year variability: The Moorepark example

A total of 750 years were simulated for the specific location simulation [30 years historical (1976-2005), two different RCP (4.5 and 8.5), six model projections for each of the RCP at two future time periods (2021-2050 and 2041-2070)]. Looking at the prediction as a whole, no statistical difference was detected between the simulated historical annual grass yield (1976-2005) and the future projected annual grass yield during either time period (2021-2050 or 2041-2070) or RCP. However, most model simulations projected some extreme individual years with very low or very high grass growth compared to the baseline, with the extreme years even more likely at the higher RCP. In terms of seasonality, once again the simulations showed a grass growth increase for the shoulders of the year and in spring (November to May) and a decrease for the months of July to September (Figure 3). This trend increases with the 2041-2070 time period and for the RCP 8.5 compared to the RCP 4.5. Although the marginal difference in growth does not seem to be important (Figure 3A) the possible year to year variation will be increasing in the months of August and September (Figure 3B). Some individual simulations showed also a very rare possibility of a total absence of growth for the months of August and September, which were not present in the historical data. This highlights once again the projected increase in grass growth variability.

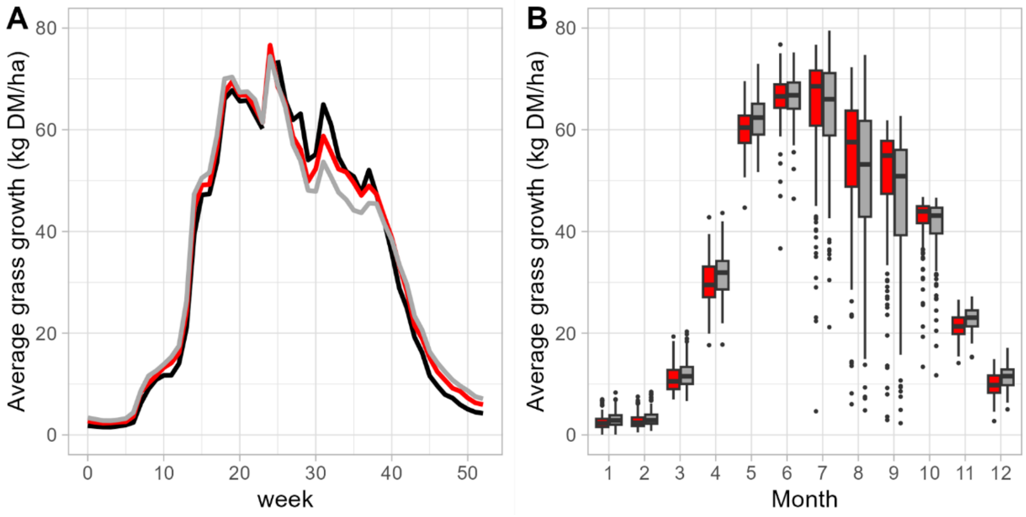

Figure 3. *Predicted average weekly (A) and monthly grass growth variation (B) for the time period 1976-2005 (black; only shown in A), 2021-2050 (red) and 2041-2070 (grey) using climate projections at the Moorepark location at RCP 8.5 on a free draining soil*

The challenges ahead

This preliminary work shows that no major changes are forecasted for the 50 years ahead. However, the increase in variability and the change in seasonality will bring some challenges. It may not be possible to take advantage of the increase in growth in the spring months, through increased grass utilisation, if soil conditions restrict grazing. On-farm grazing infrastructure will have to be improved to ensure good access to paddocks early in the year especially if the increase in spring growth is also associated with an increase in rainfall. On the other hand, the decrease in growth in the summer combined with an important increase in the variability during the months of July to September will lead to increased challenges for summer and autumn grassland management. This could have repercussions and cause difficulty in creating adequate forage stocks for winter feeding. However, the projected increase in growth for the months of October and November could help extend grazing (weather conditions permitting) and help reach target closing and opening farm covers. Some extreme years will be associated with very poor or potentially even no growth in some of the summer months, those years, while rare, might become more frequent in the future. Farmers will need to increase their silage and forage stocks to ensure adequate buffer feed is available during those periods. It will also be important that the forage is of high quality to maintain milk yields. The switch to more diverse swards or more drought resistant grass could also help in the adaptation to drier summers. In the future, more locations, soil types and weather projections will be analysed. Early results indicate that the increase in variability on heavier soils should be less pronounced in the summer due to their ability to retain water. Trafficability was not examined in this paper, although it could have a major impact if grass cannot be grazed or fertiliser applied due to high rainfall levels.

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New species and the challenges

Breeding for Climate Change

Alan Stewart,
PGG Wrightson Seeds Ltd, New Zealand

Summary

- Pasture breeding is a long-term process with any breeding commencing today not coming to market until the 2030's and this cultivar may still be sold in 2050.
- Breeding for resilient pastures in the face of climate change is crucial. Improvements in yield, quality, disease resistance and persistence remain paramount.
- Pasture diseases will increase; breeding resistant material is a key priority.
- As multispecies pastures become increasingly used, breeding of clovers compatible with grass swards is crucial, there is opportunity for breeding red clovers that have improved tolerance to grazing.
- Research needs to be undertaken to maximise opportunities for breeding for environmental traits that reduce nitrogen leaching, nitrous oxide and methane emissions.
- Breeding programs will become more complex as breeders add additional traits, with greater emphasis on breeding for disease resistances, performance in mixed swards and environmental mitigation.

Introduction

Plant breeding is a long-term process taking 10-15 years to develop and thoroughly test a cultivar, with the cultivar then potentially being sold for 10-20 years beyond that. Therefore, it is essential to understand what future farming systems may look like. We need to be looking 30 years or even 50 years out. These time scales suggest rather frightening changes in climate and, consequently considerable change in pastures and farming systems, much of which may be difficult to predict. We know climate change will cause warmer temperatures and shorter winters, but it will also mean a greater frequency of extreme climatic events such as increases in winter storms, floods, droughts, heat waves and surprisingly, cold winter events may still be problematic requiring winter hardiness in a cultivar.

The Challenges

The challenge for breeders is primarily one of ensuring that we have resilient cultivars for future climate scenarios and farm systems. However, where possible breeders should try to incorporate traits that minimise a cultivars impact on greenhouse gas (GHG) emissions resulting from its use on-farm. Market demand for sustainable products may drive the need for reduced impact on the environment even more than government regulations. Breeding resilient cultivars to maximise farm production will always require improvements in yield, disease resistance, quality and persistence of pastures.

Yield

Breeding to improve yield will continue to be a primary objective and well-designed robust breeding programs are required, utilising the best modern breeding techniques such as those outlined for perennial ryegrass (*Lolium perenne* L.; PRG) by Conaghan and Casler (2011). The implementation of genomic selection and other techniques continue to be refined in several commercial programs (Bornhofen *et al.*, 2022; Byrne *et al.*, 2024). The gains in yield from breeding using genomic selection are predicted to be greater than those achieved in the past, although the caveat to this is that as more traits are added to a program the added complexity will reduce progress. In addition, many of these techniques are expensive and pasture breeding programs are limited in their funding when compared to major animal and crop breeding programs.

Disease

With warmer and wetter conditions, we are already seeing the expansion of rust, *Dreschlera* and mildew on PRG pastures in Ireland. These diseases were previously only common in milder conditions of southern Europe. It will be important to understand the increasing impact of these diseases on pasture yields and quality. Breeding PRG for resistance to these diseases generally requires field screening where diseases regularly and reliably occur. International companies with breeding programs throughout the world are well positioned for this type of breeding as they can screen in appropriate countries where diseases are present. Disease breeding in PRG must become an immediate priority, particularly as we are already seeing expansion in diseases and development times for cultivars are not fast.

Quality

Breeding for quality is likely to become more important as increased summer temperatures will increase lignification. However, breeding a cultivar that can maintain its quality when grazing is delayed will allow greater flexibility of grazing in the farm system and this may be more important than quality *per se*. In addition to breeding for quality we now know that breeding cultivars with improved palatability and animal intakes is crucial. Measurements of palatability and animal intakes within a breeding and testing program requires grazing trials where pre- and post-grazing yields are monitored. This adds another level of complexity to breeding as many programs have relied upon cutting trials in the past, ignoring animal preferences.

Persistence

The frequency of extreme climatic events is likely to increase, and potentially, one of the more devastating could be droughts. Any increase in pasture pests is also likely to exacerbate drought impacts and depending upon which pest is present the use of safe endophytes in PRG may offer a solution as it does in New Zealand and Australia.

Environment

Pastures can impact climate through ruminant emissions of methane and nitrous oxide. The impact of different cultivars on GHG emissions is the subject of much research currently with some factors showing potential reductions in the order of 5-10%. Although this seems small, by combining a number of these pasture traits together, with technologies applied to ruminants, such as animal breeding, feed additives and vaccines, significant reductions in GHG emissions could potentially be achieved.

The high crude protein content of many pastures results in inefficient nitrogen (N) utilisation by the rumen and in excess losses of N in urine through leaching or nitrous oxide. Any trait that reduces N concentration in the urine, dilutes the urine or results in more effective uptake of N can reduce these losses. These include grasses with a high WSC-protein ratio, modern cultivars with improved N use efficiency, any plants with high moisture content and plants with biological nitrification inhibition such as plantain.

Farm systems utilising high quality locally grown forages with efficient animals is essential to reduce methane emissions. A very limited range of fodder plants have been shown to reduce methane emissions compared to grazed PRG pastures, most notable are the annual crops, forage rape and fodder beet. Various traits, which may reduce methane emissions from ruminants grazing pastures, are under research for breeding within pastures species and these include lipids, condensed tannins, saponins and phenolic compounds. Many of these may be capable of providing small improvements and some may only work under certain farm conditions but anything providing a reduction can be useful.

The use of GMO technologies could lead to even greater reductions in methane emissions. In New Zealand, AgResearch have two GMO projects that are each predicted to reduce methane emissions by around 15-20% as well as providing potential improvements in animal production. These involve a high lipid PRG and a high condensed tannin white clover. Any resultant cultivar will have to pass a rigorous series of tests including under grazing animals before commercialisation is likely, which appears to be 5-10 years away, or more.

Future breeding

Although Ireland and the European Union (EU) do not currently allow the growth of GMO or gene-edited plants, they do allow import and consumption of many genetically modified foods and animal feeds. In the future, it is likely that gene-editing, particularly gene-knockouts, could become deregulated in the EU, and this should provide opportunity for further genetic improvements in pastures. Although it may be relatively simple to knockout a gene, the knowledge of where in a pathway and which gene to knockout is not simple and in many cases pasture breeders will follow the lead from breeding advances made in the major world crops such as maize, rice, barley or wheat. At the same time, the exploitation of natural genetic variation is central to making progress for any trait and environmental targets are no different. Genetic resources for heat tolerance are likely to be required in the future and great care will be required internationally to preserve germplasm collections from hotter climates, notably from North Africa, the Mediterranean and even subtropical regions as many of these resources are threatened by climate change.

Multispecies swards

The use of multispecies pastures, where the N fixed by clovers drives production and the grasses provide resilience to a farm system, are crucial for environmental sustainability. Clovers improve pasture quality and milk yield and their ability to substitute for synthetic N fertilisers, developed through the energy intensive Haber-Bosch process, reduces GHG emissions. The use of multispecies pastures can also influence methane emissions and N losses, and this is the subject of current research.

With the increased use of multispecies pasture, breeders will need to breed cultivars that mix well together, particularly white and red clovers that are compatible with PRG. Currently much of the clover breeding in the northern hemisphere is done in pure swards and it is likely that improvements in compatibility are possible by breeding within grazed PRG swards. In New Zealand, breeding and testing of white clover has been done in mixed PRG swards for many years while it is only in the last twenty years that red clover has been bred in this manner. This has resulted in more prostrate red clover cultivars with improved persistence in mixed PRG swards (Ford and Barrett, 2011). Grazing tolerant lucerne may also find a place in drier pastures. Herbs such as plantain can be used in mixed pastures as a tool to reduce N leaching and nitrous oxide emissions. Like clover, breeding plantain within mixed PRG swards is likely to result in greater compatibility with PRG. Breeding in mixed swards and adding additional traits for selection will make breeding programs more complex and genetic gain in yield will be potentially slower.

Conclusions

In the next 10-20 years, Irish pastures may not appear very different from today's multispecies pastures. Yet farmers and breeders will need to be prepared for the warmer conditions and more erratic nature of the climate that will mean more disease pressure on pastures, poorer pasture quality in summer, more floods, potential droughts and associated pests. However, on the positive side there may be more potential for greater winter growth, less dependency upon silage and options for more winter Brassica crops. Multispecies pastures will likely still contain PRG, white and red clover and plantain. Where PRG fails in drier summers, shorter-lived and more winter active hybrid and Italian ryegrass cultivars may find a role as could grazing tolerant lucerne. The use of multispecies pastures, increased disease pressure and need to breed not only for yield and conventional traits but also for environmental factors will make plant breeding and evaluation systems more complex. Despite this, there appears to be good potential to breed more resilient pastures with some capacity to reduce current GHG emissions.

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Plantain and multispecies swards – their role in adaptation

Ellen Fitzpatrick[1], Brendan Horan[2], Kevin Dolan[2] and Philip Creighton[3],

[1]Teagasc, Johnstown Castle, Co. Wexford, Ireland; [2]Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co Cork, Ireland; [3]Teagasc, Animal & Grassland Research and Innovation Centre, Mellows Campus, Athenry, Co. Galway, Ireland.

Summary

- One of the main challenges facing ruminant livestock production is maintaining pasture production and quality, while addressing sustainability challenges such as reducing chemical fertiliser inputs.
- When clover and herbs (plantain and chicory) are incorporated into swards of perennial ryegrass (PRG), there is an opportunity to improve animal performance, at reduced chemical nitrogen (N) application rates.
- Despite a number of farm scale experiments determining that multispecies swards (MSS) can outperform PRG swards, there is still concern among farmers about the persistency and management of these more diverse swards.

Introduction

In intensive ruminant grazing production systems in temperate regions, the focus on simple and productive forages combined with chemical nitrogen (N) fertiliser has led to a limited range of plants being used in grazing swards, and a predomination of perennial ryegrass (*Lolium perenne* L., PRG) monocultures. Such swards are capable of high levels of productivity and nutritional value over a long growing season but are reliant on high levels of chemical N fertiliser application and adequate moisture availability (Grange *et al.,* 2020). One of the key factors in addressing the sustainability challenges associated with ruminant livestock production is reducing reliance on inputs of chemical fertilisers. This is reiterated in European Union climate policy. The challenge of maintaining pasture productivity within such limits requires the successful incorporation of legumes such as white clover (*Trifolium repens* L.; WC) and red clover (*Trifolium pratense* L.; RC) within PRG dominated pastures. More recently, a growing body of scientific evidence has shown that the inclusion of a limited number of additional dicotyledonous complementary species in PRG-WC swards (i.e. multispecies swards (MSS)), can further enhance both productivity and sustainability, and improve the overall resilience of grazing systems (Grange *et al.,* 2020; McGrane *et al.,* 2023). These species, selected for their agronomic performance, include chicory (*Cichorium intybus* L.; CH) and plantain (*Plantago lanceolata* L.; PL). This paper focuses on recent Teagasc investigations of MSS from a dairy, beef and sheep enterprise prospective, and the role they have in climate adaptation.

Pasture production and nutritive value

A key component of MSS is their ability to maintain and enhance the production of high quality pasture for grazing livestock. There is a growing body of research that shows MSS with reduced chemical N fertiliser application rates, can produce similar, or slightly greater pasture dry matter (DM) yields as PRG-only swards receiving higher N fertiliser application rates. Hearn *et al.* (2024), who investigated different combinations of pasture species and N fertilisation rates in grazed plots, reported that over three grazing seasons, a PRG-WC-PL sward was the most productive. It produced 11.7 t DM/ha across all N rates (ranging from 10.1 t DM/ha with zero N to 11.4 t DM/ha with the application of 200 kg N/ha) compared to 8.8 t DM/ha for a PRG-only sward across all N rates. In a grazing system experiment, utilising dairy cows, Jezequel *et al.* (2024a) observed no significant difference in annual pasture yield (13 t DM/ha) between three sward types (PRG-only, PRG-WC and MSS) during a two year study, despite large differences in fertiliser N application (243, 128, 127 kg N/ha for the PRG, PRG-WC, and MSS treatments, respectively). Similarly, in a dairy calf to beef system Fitzpatrick *et al.* (2024) reported similar DM yields of 11.9, 11.5 and 11.4 t DM/ha, respectively for PRG (150 kg N/ha), PRG-WC+RC (75 kg N/ha) and MSS (75 kg N/ha). An important finding from the reported studies is the similar annual DM yields for the different sward types, which implies that the inclusion of legumes and improved species diversity can reduce the need for chemical N application without compromising pasture production. However, despite, agronomic and performance benefits of more species-rich swards, the long-term persistency of clover and herbs can often be an issue and a deterrent to farmers as the benefits of these more diverse swards may only be evident for five years or less. Both Hearn *et al.* (2024) and Jezequel *et al.* (2024a) reported that although WC and PL remained relatively stable in the sward, RC and CH, in particular, declined significantly over time. The variation in sward clover and herb content over time can have a significant effect on the results observed. It is widely reported in the scientific literature that PRG-WC and MSS can deliver swards of similar or improved nutritive value compared to PRG-only swards (Grace *et al.,* 2018; McClearn *et al.,* 2019). Based on a detailed evaluation of sward nutritive value over each rotation during a two year period, Jezquell *et al.* (2024a) reported no significant effect of sward type on sward nutritive value parameters (CP, NDF or ADF contents of 220, 403 and 207 g kg/DM, respectively). The effect of sward type on ash content was greater for MSS (114 g kg/DM) compared to both PRG and PRG-WC (97 and 102 g kg/DM, respectively) while OMD content tended to be lower for MSS (799 g kg/DM) compared to both PRG and PRG-WC (812 and 808 g kg/DM, respectively).

Animal Performance

Jezequel *et al.* (2024b) observed that sward type had a significant effect on total lactation milk production. The greatest milk and milk solid (MS) production was observed for MSS during the three year study period (5,296 and 476 kg/cow per year, respectively), with PRG least (5,018 and 452 kg/cow per year, respectively), while PRG-WC was intermediate (5,138 and 463 kg/cow per year, respectively). Recent research at Teagasc Johnstown Castle (Fitzpatrick *et al.,* 2024) has shown that overall lifetime growth performance of early-maturing dairy-beef heifers consuming PRG plus RC and WC swards (CLOVER) and MSS was similar, but greater than PRG swards. Calves consuming MSS swards grew an additional 0.17 kg/day compared to the CLOVER and PRG (0.79 vs. 0.62 kg/day) calves during their first grazing season. During the second grazing season, heifers grazing CLOVER and MSS pastures had significantly greater average daily gains over that of the PRG treatment group (0.92, 0.87, and 0.81 kg/day, respectively). This resulted in a greater number of heifers finished at pasture for the CLOVER and MSS treatments compared to the PRG treatment (86% vs. 75% vs. 68%, respectively).

Results from McGrane *et al.* (2023) show that the addition of a companion forage (WC, RC, PL or CH) significantly improved lamb performance, particularly in the post-weaning period. Lambs grazing a mixed sward type gained an additional 17-31 g/day, reached the appropriate slaughter weight 16-28 days faster and received significantly less concentrate feeding relative to lambs grazing a PRG-only sward. These results confirm the findings of previous studies suggesting that sward diversification is a good opportunity to increase animal performance across dairy, beef and sheep systems while significantly reducing the requirements and costs associated with chemical N fertilizer application within such systems.

The role of MSS in climate adaptation

As discussed in the previous sections, increasing plant diversity in sown grasslands can yield better environmental performance without any reduction in pasture productivity, whilst increasing animal performance, even when there is a reduction in farm inputs (largely in the form of chemical N fertiliser). Moreover, as climate change is leading to more extreme weather events such as summer drought, MSS have shown better drought resistance than monoculture swards in several studies (Grange *et al.,* 2021). When forbs are included, MSS have also been shown to increase carbon sequestration and provide greater pasture stability against weed invasion, thereby facilitating a reduced reliance on herbicides.

Clover and herb inclusion can also play a role in mitigating some greenhouse gas (GHG) emissions. Results from studies by Woodmartin *et al.* (2024a; b) show that the inclusion of any companion forage (WC, RC, PL, CH) with PRG increased dry matter intake (Woodmartin *et al.* 2024a) and reduced methane (CH_4) yield (g/kg dry matter intake), relative to a PRG-only sward. Methane production (g/day) was lowest with WC inclusion, with animals having 14% lower CH_4 production (g/day) than those consuming PRG-only swards. In contrast, in a study with dairy cows, no difference in CH_4 yield was found when cows grazed PRG-WC swards compared to PRG-only swards (Dwan *et al.,* 2024). Data on CH_4 emissions from MSS is limited and further research in this area is warranted. Woodmartin *et al.* (2024b) also reported that the inclusion of CH or PL reduced urinary N concentration by 13% and 34% on average, relative to PRG-only and PRG-WC treatments, which were similar. Similarly, Wims *et al.* (2024) reported a 41% decrease in urinary N concentration, and a 36% and 27% increase in urine weight and urination events, respectively, resulting in a 25% reduction in total urinary N excretion when a PRG-WC-PL sward was fed to cows compared to a PRG-only sward. Plantain has also been shown to promote a reduced rate of soil nitrification associated with secondary compounds found in urine excreted by grazing animals and from root exudates (Pinxterhuis *et al.,* 2024). These factors, can result in significant reductions in N leaching, which would be particularly useful in a scenario where climate change results in higher rainfall during the winter months, when most leaching occurs.

Conclusion: Future work and challenges to adaptation

It is evident from the studies discussed in the current paper, that more diverse swards have positive implications for animal performance and pasture production with reduced chemical N fertiliser applications. Future pasture-based systems research should aim to further investigate optimum combinations of species and optimum inclusion rates for sward mixtures for use in dairy, beef and sheep production systems. Breeding more grazing tolerant varieties of RC to enhance their persistency in grazing systems would be of significant benefit, given the animal performance benefits of RC inclusion reported by McGrane *et al.* (2023). Furthermore, evaluation of herb varieties is also an area in which further research is required, in terms of their persistency, seasonal pasture quality and growth. This data would be particularly useful in the future development of recommended lists for herb incorporation on farm. Additionally, adoption on Irish farms would be significantly supported by the development of appropriate establishment and grazing management advice.

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Grass-clover swards – adapting to the climate challenges

Michael Egan, Mark Bateman,and Caitlin Looney,
Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Co. Cork

Summary

- Incorporating white clover into swards and reducing chemical nitrogen (N) fertiliser application according to sward clover content can maintain system performance and reduce farm gate N surplus.
- A 30% reduction in chemical N fertiliser due to the inclusion of clover in swards can reduce national GHG emissions by 0.42 – 0.67 Mt CO_2 eq.
- There can be large variations in clover content from year to year.
- Soil fertility, grazing management and climatic conditions all play a key role in clover persistency and stability.

Introduction

Pasture-based production systems in Ireland consist of perennial ryegrass (*Lolium perenne* L.) that requires chemical nitrogen (N) for pasture production. In the last 10-15 years, the use of chemical N fertiliser has received a lot of focus, particularly in terms of the negative impact on water quality as well as greenhouse gas (GHG) emissions, resulting in reductions in the permitted application rates. More recently, the increased cost of chemical N fertiliser has also resulted in an increased focus on reducing chemical fertiliser use in pasture-based production systems. As a result, there has been a growing awareness and adoption of legumes, in particular white clover (*Trifolium repens* L.) and red clover (*Trifolium pratense* L.), in pasture-based systems. White and red clover swards can make an important contribution to the future sustainability of ruminant production systems in Western Europe (Peyraud *et al.*, 2009). They have the potential to reduce N input from purchased chemical fertiliser through N fixation. This paper explores the role of clover in Irish pasture-based production systems, examining the benefits of clover, its incorporation into grassland farms, and how it can aid climate adaptation.

Benefits of legumes

Research from Teagasc has shown significant benefits of including white clover in grazing swards, with 7% more milk solids (Egan *et al.,* 2018), 10% more live weight gain in beef cattle and 25% more in lambs (Creighton *et al.,* 2022), derived from a 10% increase in dry matter (DM) intake due to improved sward quality. Additionally, legumes can increase or at least maintain pasture production, particularly at lower N application rates. Research at Teagasc Moorepark shows that grass-white clover swards, receiving 100 kg N/ha less chemical N fertiliser than a grass-only sward, produced similar levels of pasture (13.4 t DM/ha) over an eight year period. Similarly red clover silage swards receiving zero chemical N had similar production to grass-only swards receiving up to 412 kg N/ha per year (Clavin *et al.,* 2017). Many experiments have quantified the level of N fixation of white clover, however, the rate of N fixation is largely influenced by sward clover content (Figure 1a), with a sward containing 25% white clover having the potential to fix 90 kg N/ha (Burchill *et al.,* 2014). Chemical N fertiliser supply also affects the rate of N fixation (Figure 1b; Enriquez-Hidalgo *et al.,* 2018). Typically, the higher the level of chemical N application and lower level of sward clover content the lower the quantity of N fixation from clover swards. While red clover has the ability to fix up to 250 kg N/ha per year under optimal conditions (Ledgard *et al.*, 2009).

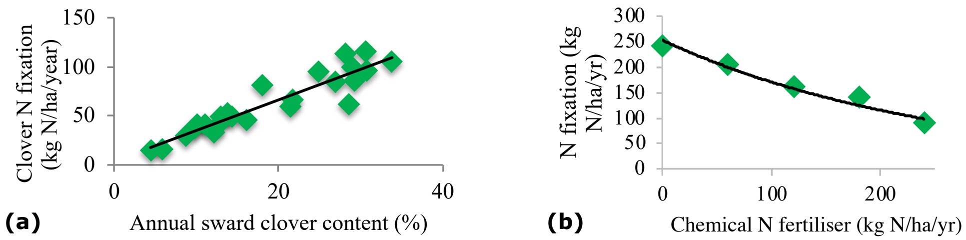

Figure 1. *(a) The relationship between sward white clover content and N fixation (Burchill et al., 2014) and (b) the relationship between chemical N fertiliser application and N fixation (Enriquez-Hidalgo et al., 2018)*

Incorporating white clover on commercial farms

In 2020, a group of 36 farmers from across the country were enrolled in the 5-year Clover150 programme. The farms included a range of land types, geographical spread, climate conditions and farming enterprises. White clover was established on the farms through a combination of reseeding and over-sowing. In 2020, the Clover150 farms had clover on <10% of their milking platform area and by the end of 2023, 64% of the milking platform area had clover, with an average clover content of 23%. Data from the Clover150 farms (Table 1) shows that chemical N fertiliser application in 2020 was 232 kg N/ha and pasture production was 14.4 t DM/ha. By 2023 chemical N fertiliser application declined by 76 kg N/ha and pasture production was 12.9 t DM/ha. In 2020, farm gate N surplus and N utilisation efficiency (NUE) were 194 kg N/ha and 31%, respectively. By 2023, the farm gate N surplus had reduced by 54 kg N/ha (to 140 kg N/ha), while farm gate NUE had increased to 36%. It is vital, however, that reductions in N fertiliser do not compromise total pasture production on farm, resulting in other forms of purchased N (concentrate and silage) replacing chemical fertiliser.

Table 1. Four year on farm performance (2020 – 2023) for the Clover 150 programme

Year	Average clover %	Average clover area %	DM yield (kg DM/ha)	Nitrogen (kg N/ha)	NUE%	N surplus (kg N/ha)
2020	10%	<10%	14.4	232	31%	194
2021	12%	45%	14.1	206	33%	180
2022	18%	61%	13.2	159	39%	139
2023	23%	65%	12.9	156	36%	140

Role of clover in adaptation to climate change

There is a clear requirement to reduce chemical fertiliser to improve water quality and reduce GHG emissions. Agriculture in Ireland accounts for 90% of national nitrous oxide (N_2O) emissions, with chemical fertilisers accounting for 38% of N_2O emissions. There are clear economic benefits to reducing chemical fertiliser use, but there are also significant environmental benefits, in relation to decreasing N_2O emissions from pasture-based systems. Herron *et al.* (2022) reported that a 30% reduction in N fertiliser, through the incorporation of clover in swards, would reduce national GHG emissions by 0.42 – 0.67 Mt CO_2 eq. Gilliland (2022) reported that due to the extensive and definitive research evidence on clover, the majority of Irish grassland farmers with good grass growth potential, should optimise clover swards as a priority. The Clover150 programme has shown a successful blueprint for the establishment of clover on commercial farms and the significant improvements that can be achieved in farm gate N surplus and NUE. These benefits can be achieved when the desired levels of clover (average 20-25%; Egan *et al.*, 2018) are attained. However, there are agronomic instability concerns around the consistency and persistency of clover from year to year. There are multiple factors that can determine the proportion of clover in grazing swards; Murray *et al.* (2022) cited 1) soil fertility, 2) grazing management and 3) climatic conditions as key factors in maintaining sward white clover proportion and persistency.

- It has long been established that soil fertility (pH, phosphorous (P) and potassium (K)) need to be at optimum levels for white and red clover swards to persist and contribute (Chapman *et al.,* 2017); optimum soil pH and P levels increase taproot growth and nodulation in the establishment year (Rangeley and Bolton, 1986). The petiole and lamina growth of legume plants have a major requirement for K, resulting in reduced levels of stolon development in white clover and taproot length in red clover in K deficient soils (Bailey and Laidlaw, 1998). Currently, the soil fertility status of soils in Ireland is sub-optimal, with only 18% (20% dairy and 13% drystock) of soils optimal for P, K and pH (Teagasc, 2023). This will challenge the ability of farmers to establish and maintain the long term persistency of clovers. Optimum soil fertility remains fundamental to the success of clover; below minimum levels greatly diminish establishment, growth, and makes management to improve sward persistency less effective.
- Stolons are an integral part of white clover and its persistency and are influenced by light availability to the base of the sward (Black *et al.,* 2009). Defoliation management (pasture mass and post-grazing residuals) is the main factor that determines light availability to the base of the sward. It has been reported that increasing pre-grazing pasture mass (> 1,750 kg DM/ha; Black *et al.,* 2009), greater grazing residuals (> 4 cm) and more silage cuts (> 1.6 cuts/year; Murray *et al.,* 2022) can result in a rapid decline in sward white clover content over time. Additionally, autumn closing date/spring opening farm cover (OFC) can have an impact on clover content. Murray *et al.* (2022) reported that swards with an OFC > 900 kg DM/ha reduced clover content compared to paddocks with an OFC of <700 kg DM/ha. While in red clover swards defoliation height < 6 cm and crown damage through compaction or poaching (Teagasc, 2009) reduce red clover proportion and persistence. This emphasises the importance of defoliation management practices to provide favourable conditions for clovers to persist. However, it is vital that any management decision made on farm, does not compromise the ability of a farm system to meet herd feed demand. Defoliation management practices, therefore, need to strike a balance between being favourable for clover growth (light to base of the sward) and feeding the herd.
- It is clear that Irelands climate is changing in recent years, with 2023 on record as the wettest year (1,511 mm), 2024 the coldest summer (13.9°C) in the last 10 years. This has placed significant challenges on Irish farmers, and particularly on grass and clover growth, as average annual pasture DM production was 12.4, 10.5 and 11.6 t DM/ha on dairy, beef and sheep farms, respectively, in 2023. It is widely accepted that both white and red clover favours warm, dry, and bright growing conditions, and when deficiencies in these key meteorological factors occur, it significantly impacts the ability of clover to persist in swards. Red clover plants due to their deep taproot are relatively drought tolerant, which if used strategically in drought prone soils for silage production, may negate potential fodder shortage as experienced in 2018. The large changes in meteorological conditions that occur from year-to-year, can result in significant fluctuations in clover persistency, no more so than in the last 2 years. When this occurs and clover content declines, as in the spring of 2024 (Clover150 data) there needs to be an adaption in on farm management (fertiliser and grazing/cutting) to ensure clover content can recover, but also that grass growth doesn't decline as a result of lower clover content and a reduction in N fixation.

Conclusions

In conclusion, clover will play a significant role on grassland farms in improving the economic and environmental sustainability of pasture-based systems. However, achieving and maximising these benefits requires careful management and consistently achieving and maintaining optimal clover contents (20-25%). The Clover150 programme has shown a successful blueprint for the establishment of clover on farms. However, maintaining clover on farms long term will require improving soil fertility, strategic chemical fertiliser application and grazing management practices that allows a balance between maintaining clover content and meeting herd feed demands. White and red clover have the potential to aid Irish pasture-based systems to be more resilient to climate change, however, flexibility in management to overcome climate challenges when managing the changing dynamics in clover content from year to year is vital to ensure the long-term success of clover. Further work is required on the agronomic factors to gain a better understanding of sward persistence, however, despite these challenges, white clover is essential for enhancing the resilience and sustainability of pasture-based systems in Ireland.

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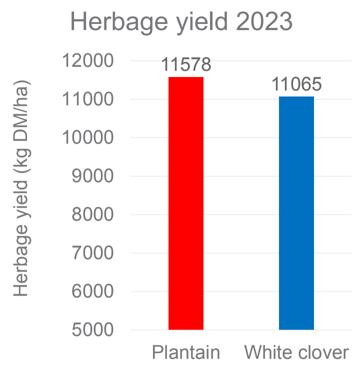
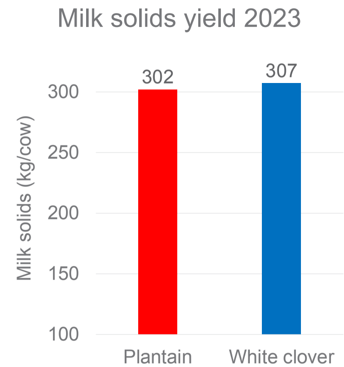
Moorepark grassland studies

Plantain grazing trial

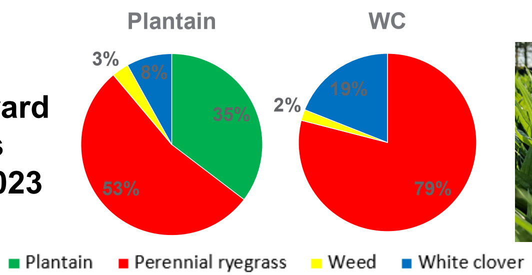
Introduction

- Plantain persisting in grazed plots >5 years
- Milk production study established 2022
  - Perennial ryegrass/white clover sward (WC)
  - Perennial ryegrass/white clover/plantain sward (PL)
- Rotationally grazed May to November 2023
- Fertilisation: 175 kg N/ha/year
- Measurements:
  - Milk yield
  - Herbage production
  - Sward species proportion
  - Herbage intake





Annual sward species content 2023



Results & Conclusion

- Sward plantain content - 35%
- Similar herbage and milk solids production
- Environmental measurements ongoing
  - Methane production (Greenfeed),
  - Nitrogen leaching (ceramic cups)
  - Nitrification inhibition

Grassland Nutrition - Plantain and Clover Impacts

Introduction

Climate Change and Water Quality
(increasing temperatures, changing patterns of precipitation and drought)

Mitigation of N and GHG emissions

Impacts
(< pasture and milk supply, > emissions)

Adaptation through sward diversification

Policy Responses

Adapted from Climate Ireland; EPA, 2023

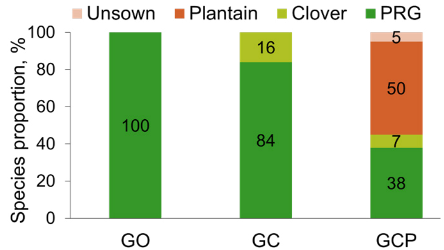
- White clover: N fixation capability essential to maintain herbage and milk production
- Plantain: potential to reduce environmental N emissions and might contribute drought tolerance

Materials and methods


Grass-Only (GO)
50 kg N/ha/cut


Grass-Clover (GC)
25 kg N/ha/cut


GC-Plantain (GCP)
25 kg N/ha/cut



Item	GO	GC	GCP
DM yield (kg DM/ha)	1260	1289	1391
DM (%)	13.6	13.7	11.8
Crude protein (%)	22.8	21.8	19.8

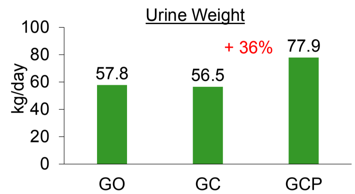
This project was funded by the Department of Agriculture, Food and the Marine's Competitive Research Funding Programme (2021R482 – 'PASTURE-NUE')

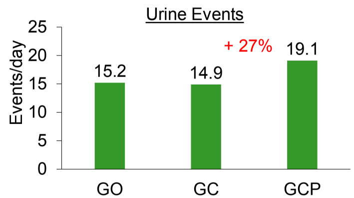
Grassland Nutrition - Plantain and Clover Impacts (continued)

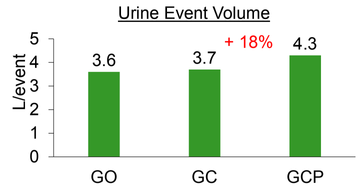
Nitrogen output and partitioning

Items	GO	GC	GCP
N intake (g/d)	714	664	613
			- 41%
N in urine (g/100 g)	0.63	0.58	0.36
N in faeces (g/100 g DM)	3.39	3.45	3.09
N in milk (g/100 g)	0.61	0.61	0.60
N output (g/d)		- 9%	- 25%
N to urine	355	323	267
N to faeces	161	158	182
N to milk	110	109	107
N unaccounted	89	78	62

- Plantain inclusion increased urine volume and reduced urinary N concentration
- This led to lower urinary N excretion
- Cows fed plantain partitioned more N towards faeces and less towards urine







Animal performance

Items	GO	GC	GCP
DMI (kg/d)	19.7	19.2	19.2
Milk yield (kg/d)	18.2	18.0	17.8
Milk fat (%)	4.60	4.58	4.23
Milk protein (%)	3.88	3.87	3.83
Milk solids (kg/d)	1.53	1.50	1.41
MUN (mg/dL)	19.5	18.1	15.4

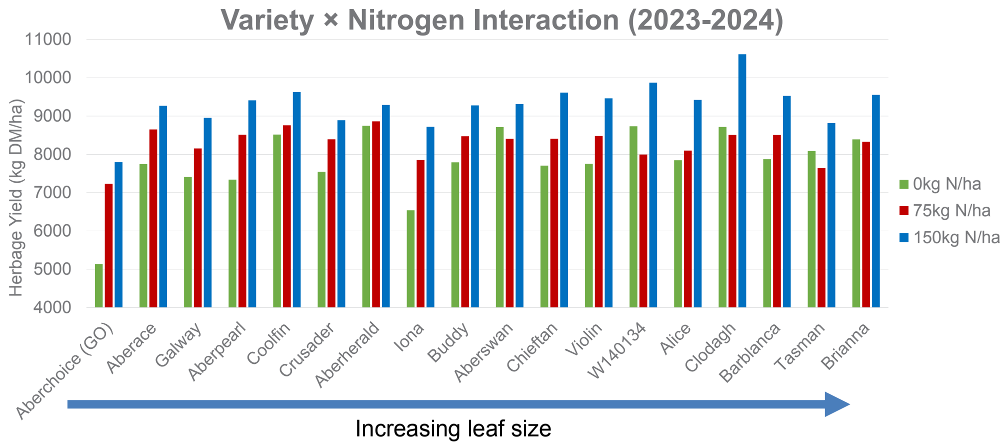
Take home messages

- Cows fed a sward containing 50% plantain had reduced N excretion when compared with a GO or GC sward
- Plantain can help reduce environmental N emissions
- More system level experimentation is required to assess the robustness of a GCP sward in an ever changing climate

White clover cultivar evaluation

Introduction

- Limited data available on white clover variety performance
- 17 white clover cultivars assessed
- Sown with AberChoice PRG
- AberChoice monoculture - control
- 3 N fertiliser rates - 0, 75, 150 kg N/ha
- Plots cut at approx. 1400 kg DM/ha
- Measurements:
  - Herbage yield
  - Sward clover content
  - Nitrogen fixation
  - Herbage quality



Results & Conclusion

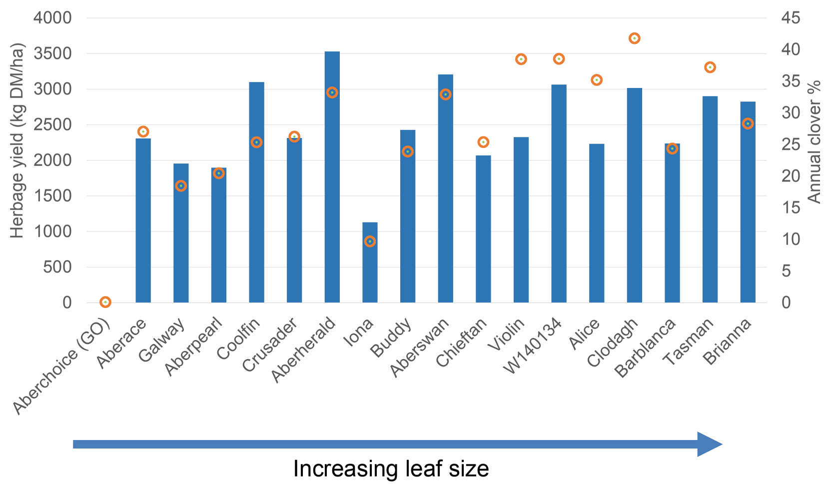
- Herbage yield differences between cultivars
- Larger leaf cultivars
  - Greatest sward clover content
  - Greatest herbage yield
- Nitrogen fixation differences apparent between varieties

eagasc
Agriculture and Food Development Authority

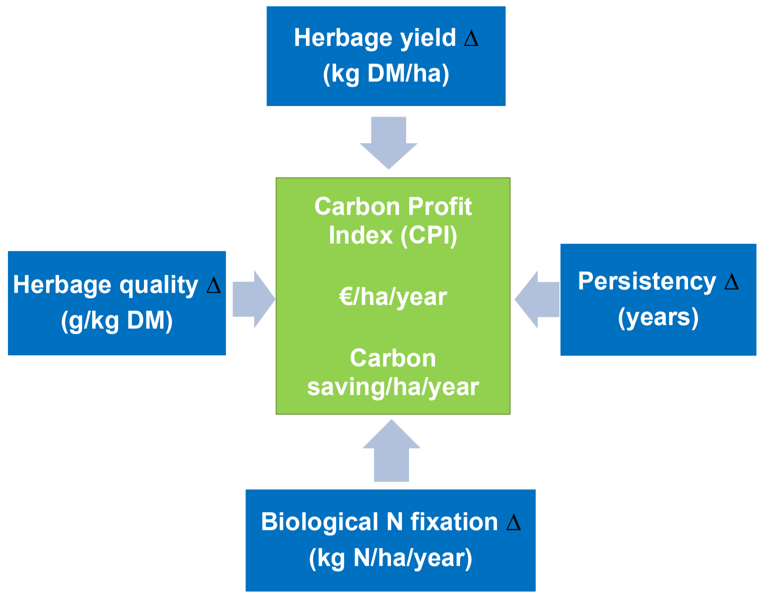
Economic index for white clover

An Roinn Talmhaíochta, Bia agus Mara
Department of Agriculture, Food and the Marine

Yield increase compared to AberChoice monoculture & clover % at 0N (2023)



- Agronomic differences between cultivars
- Rank cultivars using an Economic Index
- Carbon savings/ha

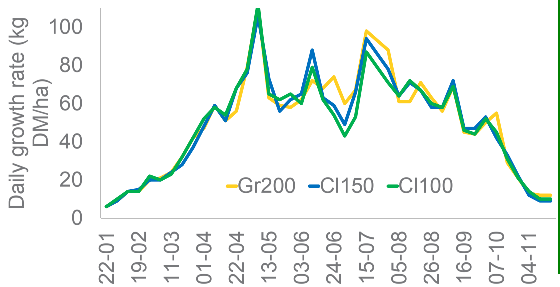


Moorepark grass-clover trial

Experimental details

	Grass 200	Grass-clover 150	Grass-clover 100
Whole farm SR (LU/ha)	2.4	2.4	2.4
Milking platform SR (LU/ha)	3.1	3.1	3.1
Conc.(kg/cow)	Common	Common	Common
Target pre-graze HM (kg DM/ha)	1300-1500	1300-1500	1300-1500

Daily growth rate - 2023

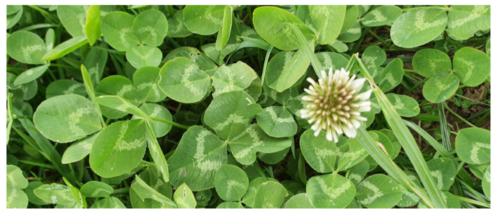


Herbage & milk production 2023

	Grass 200	Grass Clover 150	Grass Clover 100
Grass grown graz. platform (t DM/ha)	14.2	14.2	14.0
Clover content (%)	-	19.0	19.1
Milk yield production (kg/cow)	5,671	5,992	6,081
Milk solids yield (kg/cow)	492	528	538
Fat (%)	5.00	5.10	5.16
Protein (%)	3.62	3.67	3.63
Conc. fed (kg/cow)	575	582	572
Silage fed during lact. (kg DM/cow)	416	416	416

Nitrogen balance

	Grass 200	Grass-clover 150	Grass-clover 100
Total N inputs (kg N/ha)	241	192	140
Total N outputs (kg N/ha)	95	100	101
N use efficiency (%) – farm gate	39	52	72
N surplus (kg)	146	92	39

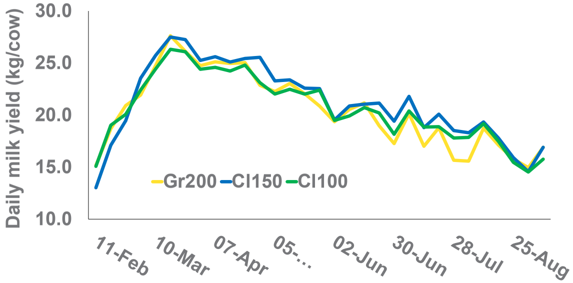


Moorepark grass-clover trial
(continued)

2024 update

	Grass 200	Grass Clover 150	Grass Clover 100
Grass grown (tonnes)			
Milk yield (kg/cow)			
Milk solids (kg/cow)			
Conc. fed (kg/cow)			

2024 Milk yield



Take home message

- Reduced artificial N fertiliser
  - Up to 100 kg N/ha
  - Similar herbage production - 14 t DM/ha
- Increased animal production
  - + 350 kg milk yield/cow
  - + 30 kg MS/cow
- 80 kg N/ha reduction in farm gate N surplus
- +€480/ha net profit

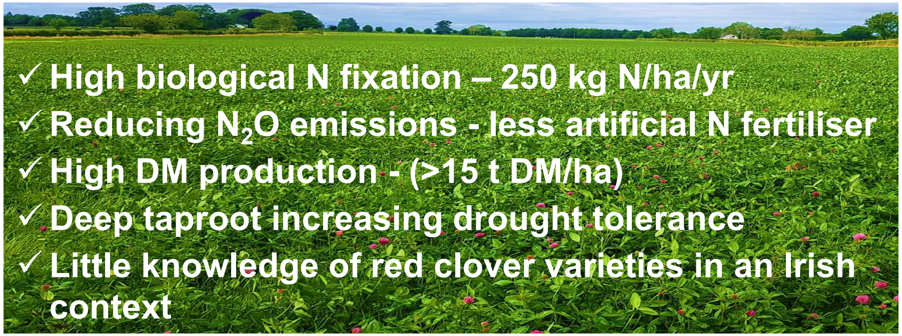
=

Future plan?

- Climate adaptation of systems experiment
- Precision nitrogen treatment
  - MoSt model
  - Paddock clover content
- Ceramic cup measurements
  - September 2024 onwards
  - Nitrate leaching
  - Water quality
- Challenges
  - Climate challenges
  - Adapting to changing grazing conditions

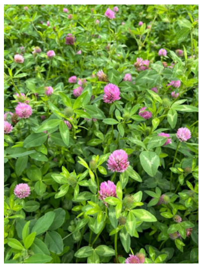
Red clover evaluation trials

Role of Red clover silage swards in climate adaptation



Establishment

- Sown May 2022
- 8 red clover varieties sown at 4 kg/ac
- 5 kg/ac Gracehill & 5 kg/ac Atonconqueror



Evaluation protocol

- 3 N rates - 0, 75 & 150 kg N/ha

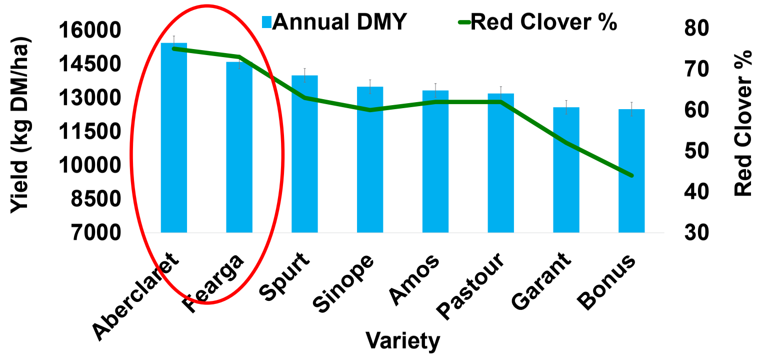
	Cut 1 (kg N/ha)	Cut 2 (kg N/ha)	Cut 3 (kg N/ha)
0 kg N/ha	0	0	0
75 kg N/ha	33	25	14
150 kg N/ha	66	50	27

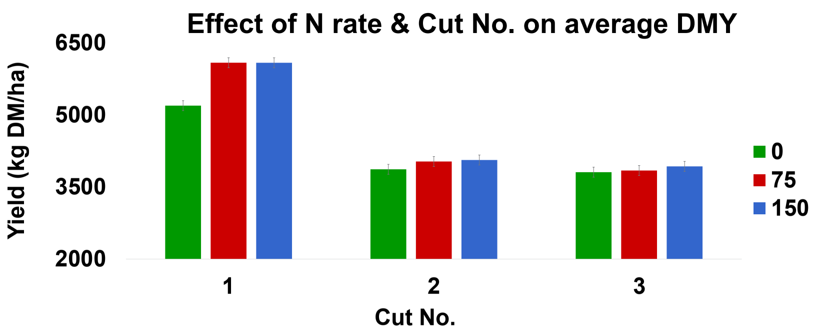
- All plots;
  - 350 kg K/ha/year
  - 35 kg P/ha/year
  - 3 silage cuts
  - 6 cm cutting height
  - 2 years data
    - 2023 & 2024

Red clover evaluation trials (continued)

Results

- Year by variety effect on DM yield & clover content
  - DM yield reduced Yr 1 to 2 on all varieties
  - Aberclaret, Fearga & Pastour had similar clover content Yr 1 & 2, all other varieties lower in Yr 2
- N fertiliser increased 1st cut yield + 894 kg DM/ha
  - No difference in subsequent cuts





Conclusion

- Persistency of red clover varieties appears to vary
  - Need long term assessment – 3 years +
  - Variety selection is key
- N fertiliser required to increase yield in first cut

Initiatives on climate adaptation on Moorepark farm

Farm Management Improvements

- 80% grassland area with clover
- 100% protected urea
- Low emission slurry storage and application
- Herd genetics – EBI of €236 vs. €181 average
- Low concentrate feeding rate

Farm energy

- Green energy - solar panels on milking parlour
- Energy efficiency - variable speed pumps

Carbon removals

>5km hedgerow planted

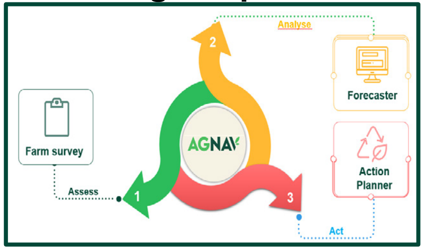
2.9 ha Native Woodlands

Visit www.agnav.ie

AGNAV Digital Sustainability Platform

How does AgNav work?

The AgNav process



Moorepark farm 2023	
Farm GHG emissions	1,692 kt CO_2eq
Carbon footprint	0.88 kg CO_2eq/kg FPCM
Nitrogen balance	153 kg N/ha
Ammonia	34 kg NH_3/ha

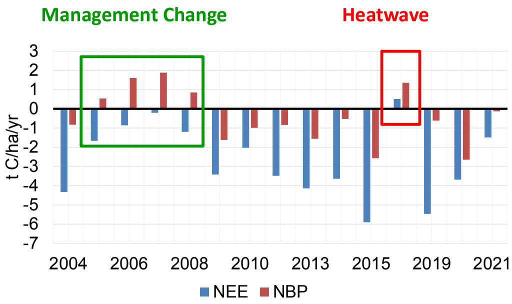
Field scale carbon balance - grassland & arable

Introduction

- The C balance or net biome productivity (NBP) = Net Ecosystem Exchange (NEE) + C imports – C exports
- National Inventory Report reports a net C sequestration rate of 0.1 t C/ha/yr or 0.38 t CO_2/ha/yr for managed mineral soils
- Irish measured data suggests a higher mean C sequestration rate of 0.64 t C/ha/yr or 2.34 t CO_2/ha/yr

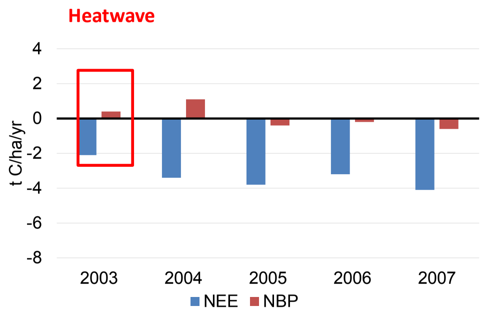
Results from long-term monitoring

Grassland – Johnstown Castle



- The net C balance ranged from a **source of 1.87 t C/ha/yr to a sink of 2.65 t C/ha/yr** driven mainly by land management decisions and extreme climatic events

Cropland – Oakpark



- The C balance ranged from a net **sink of C at a rate of 0.6 t C/ha/yr to a net source of C at a rate of 1.1 t C/ha/yr** during the 2003 heatwave

Funding

- Department of Agriculture, Food and the Marine (DAFM), Terrain-AI, Vistamilk, Dairy Levy.

Take home message

Managed mineral soils are sequestering more C than reported in the National GHG Inventory

Notes

Contact details

Teagasc,
Animal & Grassland Research and Innovation Centre,
Moorepark,
Fermoy,
Co. Cork

Tel : 353 (0)25 42458

www.teagasc.ie

Agriculture and Food Development Authority