TResearch

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Rising to the challenge

Teagasc's Climate Centre is spearheading innovative research to meet the biodiversity and climate challenges of tomorrow

Teagasc
Agriculture and Food Development Authority

Welcome

Climate change is undoubtedly the biggest challenge of our time. This issue of *TResearch* marks the first anniversary of the launch of Teagasc's Climate Strategy. We explore what changes have been made over this time to help the Irish agriculture sector meet its commitments to reduce greenhouse gas emissions and enhance biodiversity.

Siobhan Kavanagh and colleagues, who manage Teagasc's Signpost Programme, explain the great strides already taken on Irish farms (p6). The 120 demonstration farms that are taking part in this programme are making great progress in adopting the 12 steps to reducing greenhouse gas emissions.

Teagasc established a new virtual National Climate Centre to coordinate climate research and innovation activities. On page 14, we meet some of the researchers who are carrying out the crucial work at this centre. They tell us about their work on measuring emissions, technology adoption, biodiversity, and ultimately decreasing emissions.

In our one-to-one interview with Gary Lanigan on p24, he explains the ongoing relevance of Teagasc's MACC (Marginal Abatement Cost Curve). This is a crucial tool for policymakers to decide on what emission reduction measures to implement based on cost.

In our External Insight (p38), our colleague from the Department of Agriculture, Food and the Marine describes how continued funding support for climate research allows organisations like Teagasc to pursue this vital research.

We hope you enjoy reading about these and other articles related to our climate and environmental research in this issue.

Catriona Boyle
Editor, *TResearch* magazine, Teagasc

Gan amhras is é an t-athrú aeráide an dúshlán is mó dár linne. Leis an eagrán seo de TResearch déantar comóradh bliana a cheiliúradh de sheoladh Straitéis Aeráide Teagasc. Déanaimid plé ar na hathruithe a rinneadh sa tréimhse sin chun cuidiú le hearnáil talmhaíochta na hÉireann a cuid gealltanas a chomhlíonadh chun astaíochtaí gás ceaptha teasa a laghdú agus an bhithéagsúlacht a fheabhsú.

Míníonn Siobhan Kavanagh agus a comhghleacaithe, a bhainistíonn Clár Cuaille Eolais Teagasc, an dul chun cinn suntasach a rinneadh cheana féin ar fheirmeacha na hÉireann (lch 6). Tá dul chun cinn suntasach á dhéanamh ag na 120 feirm taispeána atá ag glacadh páirt sa chlár seo maidir leis na 12 chéim a ghlacadh i dtreo astaíochtaí gás ceaptha teasa a laghdú.

Chuir Teagasc Lárionad Náisiúnta Aeráide fíorúil nua ar bun chun taighde ar an aeráid agus gníomhaíochtaí nuála a chomhordú. Ar leathanach 14, buailimid le daoine de na taighdeoirí a bhfuil an obair ríthábhachtach á déanamh acu ag an lárionad sin. Insíonn siad dúinn faoina gcuid oibre maidir le hastaíochtaí a thomhas, teicneolaíocht a ghlacadh, bithéagsúlacht, agus ar deireadh thiar astaíochtaí a laghdú.

Inár n-agallamh duine le duine le Gary Lanigan ar lch 24, míníonn sé ábharthacht leanúnach MACC (Cuar Imeallchostais Laghdaithe) Teagasc. Is uirlis ríthábhachtach é sin don lucht ceaptha beartas chun na bearta laghdaithe astaíochtaí a chinneadh atá le cur i bhfeidhm bunaithe ar chostas.

Inár Léargas Seachtrach (lch 38), cuireann ár gcomhghleacaí ón Roinn Talmhaíochta, Bia agus Mara síos ar an dóigh a ligeann tacaíocht maoinithe leanúnach do thaighde ar an aeráid d'eagraíochtaí amhail Teagasc tabhairt faoin taighde bhunriachtanach sin.

Tá súil againn go mbainfidh tú sult as léamh faoi na nithe sin agus as ailt eile a léamh a bhaineann lenár dtaighde ar an aeráid agus ar an gcomhshaol san eagrán seo.

Catriona Boyle
Eagarthóir, iris *TResearch*, Teagasc

TResearch is an official science publication of Teagasc. It aims to disseminate the results of the organisation's research to a broad audience. The opinions expressed in the magazine are, however, those of the authors and cannot be construed as reflecting Teagasc's views. The Editor reserves the right to edit all copy submitted to the publication.

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Thanks to Karl Richards, Head of Teagasc's Climate Centre, for his editorial input to articles on climate science.

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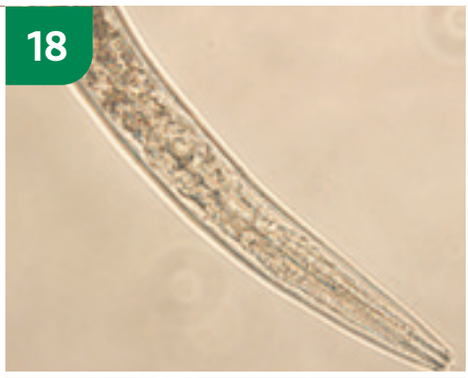


Throughout TResearch, *we include icons alongside articles where there is a clear link to the urgent actions in our Climate Action Strategy. These actions are: Reduce Nitrogen Emissions, Reduce Methane Emissions, Increase Carbon Capture, Enhance Biodiversity, Increase Diversification, Enhance Adaptation, Circular Food System, and Supporting Policy.*

Meat sensory quality scoops 'GoYoung' prize at ICoMST

Jingjing Liu scooped the 'GoYoung' award at the recent ICoMST (International Congress of Meat Science and Technology) conference in Padova, Italy, for her presentation on "Discrimination on meat sensory quality and composition of beef by using Rapid Evaporative Ionisation Mass Spectrometry".

The project (experimental work, lab analysis and data acquisition) was carried out by Jingjing when she was completing her PhD in INRA (France) in collaboration with Queen's University Belfast; and the data analysis, abstract drafting and discussion were performed by her after joining

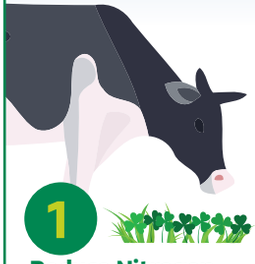
Teagasc as Research Officer working in the Enterprise Ireland-funded Meat Technology Ireland centre at Teagasc Ashtown.

Jingjing (pictured third from right) explains: "The project deals with the use of a new real-time analytical technique (REIMS) able to characterise the molecular fingerprint of a given sample. We found that this technology has the potential to discriminate among different muscle types from beef, and also shows very promising results when predicting and classifying the different samples based on their eating quality."

This innovative methodology allows for the precise characterisation of biological attributes through the analysis of molecular fingerprints in biological tissue samples.

Teagasc Climate Centre

The climate challenge requires a whole-sector co-ordinated response.
To support early and decisive action at farm level, Teagasc has accelerated its research, advisory and education activity in the following areas:



1

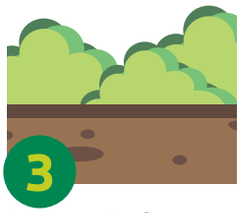
Reduce Nitrogen Emissions

Develop and implement new production systems with a lower dependence on chemical nitrogen fertilisers.

2

Reduce Methane Emissions

Develop and implement new breeding and feeding strategies to minimise the losses of methane.



3

Increase Carbon Capture

Manage land-use to capture and minimise the release of carbon so that land becomes an overall carbon sink.

4

Enhance Biodiversity

Provide nature-based solutions for areas such as climate and water.

5

Increase Diversification

Develop alternative economically viable land-uses to reduce emissions.

6

Enhance Adaptation

Develop resilience to climate change and extreme events.

7

Circular Food System

Develop food products to support new value chains and promote circular use of food resources.

8

Supporting Policy

Increase capability to inform and support policy and calculation of national inventories through coherent objective analysis of the emerging Sustainable Irish Food System.

9

Signpost Programme

Demonstrate implementation of practices to reduce emissions and increase carbon sinks.

Refreshing the EU agricultural research landscape


The RefreSCAR consortium launches the project at Teagasc Ashtown, Dublin

The EU Standing Committee on Agricultural Research, known as SCAR, was set up in 1974 and is the cornerstone of Research and Innovation cooperation in Europe in this area.

Building on this strong foundation, and as Ireland celebrates 50 years of EU membership, Teagasc is leading the EU-funded RefreSCAR project to support research coordination across Europe.

Frank O'Mara, Director of Teagasc, says: "Teagasc has long been an active contributor to European and international initiatives to coordinate and align research policies and programmes. Taking the leadership role in the RefreSCAR project further demonstrates our commitment to strengthening Europe's research and innovation system."

The project is led by Teagasc's Órlaith Ní Choncubhair, who adds: "SCAR is a fundamental part of the infrastructure of the research and innovation system in Europe. No other research area has a dedicated EU committee to support its development. We look forward to supporting SCAR to further enhance cooperation, coordination and information exchange across European countries."

The project will provide support to SCAR Working Groups through a number of mechanisms: increasing participation among countries that are not currently active; boosting the visibility of SCAR; supporting foresight activities to identify future developments in food, agriculture, fisheries, forestry and the bioeconomy; and connecting researchers, policymakers, farmers and other practitioners so that research can better contribute to policy and practice.

The RefreSCAR project launched this September, includes 18 partner organisations, and runs for four years with a budget of €4 million.

News in brief

Why Irish milk is more nutritious

Irish grass-fed milk contains more beneficial nutrients than milk from conventional indoor-feeding practices. Researchers from Teagasc and Food for Health Ireland (FHI) discovered that dairy cows who operate on an Irish grass-fed system produced milk with higher percentages of omega-3 (83% increase) and conjugated linoleic (CLA) fatty acids (141% increase), compared to cows fed medium and low proportions of grass. The research is published by Mark Timlin and FHI colleagues in the *Journal of Dairy Science*.

They also found that Irish milk contained the highest levels of unsaturated fatty acids (including mono- and polyunsaturated) and the lowest levels of saturated fatty acids.

Food for Health Ireland is a project co-funded by Enterprise Ireland and four dairy industry partners (Tirlán, Dairygold, Carbery and Kerry).

Farm sustainability report

Using data from Teagasc National Farm Survey, the latest farm sustainability report is launched for 2022. Lead author Cathal Buckley, Teagasc Rural Economy and Development Programme, says: "Measured on a whole farm or per hectare basis, it is notable that, on average, greenhouse gas emissions across dairy, cattle, sheep and tillage declined in 2022 on the back of reduced chemical nitrogen (N) fertiliser use."

The report also illustrates the continuing adoption of actions to address gaseous emissions, particularly by dairy farmers. For example, in 2022, 34% and 75% of slurry on cattle and dairy farms respectively was applied to land using Low Emissions Slurry Spreading (LESS) equipment. However, the uptake of other desirable practices, such as a transition to lower GHG emission fertilisers, remains low.

Plant diversity in grasslands

New research from the Teagasc Environment Research Centre, Johnstown Castle, shows that higher plant diversity of intensively managed multi-species swards enhances belowground soil biodiversity and health. The study, which has been published in the international scientific journal, *European Journal of Soil Biology*, by Israel Ikoyi, Guylain Grange, John Finn and Fiona Brennan, showed that as grasslands increased plant diversity, soil-dwelling nematode communities also had increased diversity and improved performance across a range of ecological soil health indices. **For more on this story, see p18.**

Reduce Nitrogen Emissions

Reduce Methane Emissions

One step at a time

The Signpost Programme dairy demonstration farmers are making progress in adopting the 12 Steps to Reducing Greenhouse Gas Emissions.

Farmers participating in Teagasc's Signpost Programme are on target to reduce their emissions through a series of actions and adjustments to their farming systems.

The Signpost Programme is designed to support and enable all farmers to farm more sustainably, and the role of the 120 demonstration farms taking part in the programme is to showcase technologies that can reduce gaseous emissions, and to provide a location for other farmers to learn. The 12 Steps to Reducing Greenhouse Gas Emissions framework is the basis of the advisory programme supporting and enabling farmers to reduce emissions. The 12 Steps translates the mitigation actions in the Marginal Abatement Cost Curve into key actions at farm level.

The baseline year for data collection for the Signpost demonstration farms was 2021, and Teagasc expects to track on-farm changes on the Signpost Farms over multiple years – at a minimum to 2025, for a five-year time series. The results referred to in this feature are for the first 24-month period and, as such, are initial indicators only of progression towards lower greenhouse gas emissions.

Progress and potential

On average, total greenhouse gas emissions for these farms was 974t CO_2-e per dairy farm. Carbon emissions Life Cycle Assessment (LCA) per kilogramme of product was 0.92kg CO_2 e/kg fat and protein corrected milk. Emissions per hectare were 10.4 t CO_2 e/ha.

Considerable progress has been made on the Signpost dairy farms to implement the 12 Steps. There is more potential to further reduce total GHG emissions on the Signpost farms by further reducing chemical nitrogen use and increasing the proportion of their chemical N applied as protected urea. The data from beef, sheep and tillage enterprises is currently being analysed and will be available over the coming weeks.

Richard and Wendy Starrett's award-winning farm in Co. Donegal is among the leading Signpost Programme farms helping to promote sustainable practices

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STEP 1

Use protected urea

Framework recommendation: Apply protected urea instead of CAN/ straight urea.
Baseline data for Signpost farms: These farmers are using protected urea as a source of more than half of their fertiliser nitrogen (N), but there is still scope to increase its usage. Availability was an issue in 2022.

STEP 2

Apply lime

Framework recommendation: Apply lime to fields identified as low pH.
Baseline data for Signpost farms: These farms were extensively soil sampled in late 2021 and early 2022, and the farmers have used the results to target lime applications, with 77 tonnes spread per farm on average (equivalent to 0.86 tonnes per hectare farmed) in 2022. It is important that an increase in the use of lime is matched by a decrease in chemical N, as that is where emissions savings occur.

STEP 3

Build or maintain soil fertility

Framework recommendation: Continue to use phosphorous (P) and potassium (K) fertilisers such as 18:6:12.
Baseline data for Signpost farms: Four out of ten soil samples had the correct soil pH, P and K. This is higher than is the case on a typical dairy farm (two in ten samples for 2022).

STEP 4

Use 100% LESS

Framework recommendation: Apply slurry in spring/early summer using Low Emission Slurry Spreading (LESS) technology.
Baseline data for Signpost farms: There has been complete adoption of LESS by this group of farmers. All dairy farmers sampled their slurry in 2022, allowing them to make informed decisions as to where and how much slurry to apply.


Improving dairy herd quality is just one of the 12 Steps toward reduced GHG emissions

STEP 5

Reduce chemical N use by 30%

Framework recommendation:
Apply lime, incorporate clover and make best use of slurry/farmyard manure.
Baseline data for Signpost farms:
These farmers have started the transition to a lower dependence of fertiliser N use, with fertiliser N usage 17% lower in 2022, and an average chemical N use of 170kg/ha. There is scope to further reduce chemical N use by incorporating clover on these farms as well as maximising the value of liming and slurry application.

STEP 6

Better grassland management

Framework recommendation:
Weekly farm walk, measure grass and extend grazing season.
Baseline data for Signpost farms:
Signpost dairy farmers have a high level of grass utilisation; the target of 12t DM grass utilised/ha was exceeded by many of them last year.

STEP 7

Improve animal health

Framework recommendation:
Create a herd health plan.
Baseline data for Signpost farms:
Many different elements contribute to herd health, including lameness, mastitis, infertility, pneumonia, fluke, etc. Milk was produced with a low somatic cell count of 124,000 cells/ml on average.

STEP 8

Improve dairy herd quality

Framework recommendation:
Use high Economic Breeding Index (EBI) bulls and increase herd EBI by >€10/year. Use sexed semen to accelerate genetic gain.
Baseline data for Signpost farms:
The target on the programme was to increase herd EBI by €10 per year, which was achieved by the Signpost dairy farms.

STEP 9

Increase milk solids/cow

Framework recommendation: Milk record, cull poor cows and aim for 305 day lactation.
Baseline data for Signpost farms: There was a high level of technical performance on the Signpost dairy farms in 2022 with an average milk solids output of 498kg per cow and feeding 1,189kg concentrates per cow. Concentrate usage was high due to the drought conditions in 2022.

STEP 10

Reduce age at first calving

Framework recommendation:
Calf heifers at 22 to 26 months.
Baseline data for Signpost farms:
The average age at first calving was 24 months on these farms.

STEP 11

Finish cattle earlier

Framework recommendation:
Use Dairy Beef Index (DBI) to produce earlier finishing cattle.
Baseline data for Signpost farms:
Dairy farmers have a significant role to play in improving the quality of the dairy male calves available for finishing. The DBI of the beef sires used by the Signpost dairy farmers was on average €71 in 2022.

STEP 12

Incorporate clover

Framework recommendation:
Incorporating 5kg/ha (2kg/ac) clover seed will replace up to 100kg/ha (80 units/ac) of chemical N/year.
Baseline data for Signpost farms:
More than eight out of ten farmers (86%) have incorporated clover into reseeds in 2022, setting them up for further reductions in chemical N use. An assessment of clover content on these farms was made in 2023. Almost 50% of area farmed was assessed as having some clover. One third had high levels of clover, with similar amounts with medium and low levels. T

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The sustainability metrics for individual farmers presented in this article are generated by the National Farm Survey (NFS) team.

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Increase Carbon Capture

Clearing the air

Carbon sequestration – the capture of carbon into soil – can be an effective tool to combat climate change. Attaining more accurate measurements of soil carbon levels requires widespread and in-depth attention to land-use practices.

Agriculture contributes significantly to greenhouse gas (GHG) emissions. Sustainable soil management to increase storage of soil organic carbon (SOC) can provide opportunities to offset these emissions. Accurately quantifying SOC levels in deeper soil layers across different soil types, land uses and management practices is essential to achieve accurate baseline measurements and monitoring.

Carbon sequestration refers to the process of capturing carbon from the atmosphere and storing it in soil over time. It involves increasing the amount of carbon in the soil compared to its previous baseline levels.

Giulia Bondi, Senior Research Officer at Teagasc's Environment Research Centre, explains: "Plants remove carbon from the atmosphere through photosynthesis, storing it in tissue such as leaves and stems. When this tissue eventually dies, the carbon is then deposited onto the soil surface. Over time this residue is decomposed by soil microorganisms which release some carbon back into the atmosphere as part of heterotrophic respiration. The leftover carbon in this cycle, not in flux, is the carbon that has been taken out from the atmosphere and fixed — or sequestered — in the soil."

Stock options

These amounts of carbon sequestered in particular soils are referred to as SOC stocks, continues Giulia. "SOC stocks are typically expressed in units of mass per unit area, such as kilograms of carbon per hectare. Existing standard methods for assessing SOC stocks are based on field and lab measurements that are costly and time consuming."

These methods include SOC concentration, measured from soil samples digested and combusted in the lab, and soil bulk density, measured in-field at depths down to 60cm and extrapolated over a given area.

Improved analysis of soil carbon levels is a key tactic in combatting greenhouse gas emissions

Teagasc

Giulia Bondi taking soil samples for measuring of carbon sequestration

As Giulia points out, carbon sequestration has the potential to be a crucial tool to engage with climate challenges, such as global warming.

"Global warming is the long-term increase in the Earth's temperature due to the accumulation of GHGs in the atmosphere, such as CO_2. Although the capacity for CO_2 to trap heat is less than that of nitrous oxide and methane, the concentration of CO_2 in the atmosphere tends to be higher."

In 2022, CO_2 emissions accounted for 60.4% of the total national GHG emissions (excluding those from the Land-Use, Land-Use Change and Forestry sector), while CH_4 (methane) and N_2O (nitrous oxide) accounted for 29% and 9.4% respectively. Thus, sequestration can help to reduce global warming by offsetting the warming affect associated with high concentrations of CO_2 in the atmosphere.

However, just as not all emissions are equal, not all soils have the same capacity to store carbon. For example, explains Giulia, "heavier soils have a better capacity to bind the carbon with fine soil particles like silt and clay, or to protect the carbon into aggregates, which are the basis of the physical structure of soil. This carbon remains protected in the soil for longer timeframes — this is what we refer to as sequestered carbon."

Each soil is different and has different carbon sequestration potential. For this reason, management practices need to be tailored to the carbon sequestration capacity of different soils.

Improving practices

Increasing SOC is a long-term process, and results may not be immediately apparent. Sustainable soil management practices benefit both agriculture and the environment by sequestering carbon and improving overall soil health. This process can be achieved through various practices based on reducing soil disturbance and improving land-use management.

- Soil fertility management: Balanced nutrient management can promote healthy soils and plant growth, leading to improved SOC sequestration dynamics.
- Cover cropping: Planting cover crops like legumes and grasses between main crop seasons is known to increase SOC, especially in the lower soil layers, by adding an organic matter input.
- Crop rotation: Rotating crops with different root structures and residue qualities helps diversify the organic matter inputs to the soil, increasing overall SOC content.
- Reduce traffic: Limiting heavy machinery traffic on soil surfaces reduces the breakdown of soil aggregates that protect SOC and prevent losses to the atmosphere.
- Build up SOC: Applying organic materials rich in carbon, such as compost, manure and crop residues (i.e. straw) to the soil provides an immediate boost to SOC levels.
- Maintain good soil structure: Minimise soil compaction, as compacted soils have reduced organic matter decomposition rates.

Improving SOC practices across Ireland is a key element of Teagasc's Signpost Programme (*see p.6*), Giulia explains.

"The Signpost Programme aims to quantify SOC stocks in depth, examine SOC landscape distribution patterns, and identify factors influencing SOC stability in agricultural systems in Ireland." A core principle of Signpost involves strategically selecting locations across various soil types, land use, and management scenarios.

"The Signpost Programme avails itself of more than 100 farms where deep soil sampling coupled with high-resolution analytical techniques, such as spectra analysis and SOC sequestration measurements, are employed to elucidate the composition and stability of SOC within the deep soil layers."

This research helps attain more accurate baselines of SOC quantification and SOC sequestration rates across various soil types, land-use scenarios and management practices. This, in turn, is essential in improving the accuracy and precision of Irish soil carbon estimates from Tier 1 to Tier 2.

Irish-specific SOC sequestration factors across the main mineral soils will be produced that can then be inputted into national inventories, continues Giulia.

"This will provide the basis for inclusion of agricultural soils into carbon trading schemes and life-cycle assessments, which will assist the sector in terms of carbon credits and a reduced carbon footprint on agricultural produce.

"Signpost will contribute to developing and implementing tailored management practices for increasing SOC stocks and robust carbon accounting frameworks for sustainable agricultural systems. This will benefit farmers, land managers, and society in effectively managing their soils." T

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Reduce Nitrogen Emissions

Reduce Methane Emissions

Teagasc's new digital sustainability platform, AgNav, aims to create a centralised solution for farm sustainability assessments.

Navigating agricultural sustainability

The Irish Government has set a target for the agriculture sector of a 25% reduction in greenhouse gas emissions by 2030 relative to 2018. As part of its Climate Action Strategy, Teagasc has set out a roadmap on how this can be achieved without impacting the competitiveness of the agri-food sector. One of the three key pillars of the Teagasc Climate Action Strategy is to develop a new digital sustainability platform to function as a central connected system for researchers, farmers and advisors involved in all aspects of farm sustainability assessment and planning.

Siobhán Jordan, Head of the Technology Transfer and Commercialisation office for Teagasc, explains: "Whilst the 25% target by 2030 offered certainty as to the destination for farmers, there are many varying options to get there, and many questions as to what the overall target means to each individual farm enterprise – each of which is unique and different.

"The Sustainability Digital Platform, now known as AgNav, is helping Irish farmers visualise the potential actions they can adopt on farms with respect to greenhouse gas emissions – helping them to decide where they can make real changes."

Streamlining data collection

Through years of collaboration, Teagasc, the Irish Cattle Breeding Federation (ICBF) and Bord Bia have integrated Teagasc life cycle assessment models into the ICBF infrastructure. This allows each organisation to calculate the greenhouse gas intensity, or carbon footprint, of Bord Bia-certified beef and dairy farms. Using this infrastructure, the collaboration has developed the AgNav platform, a digital platform accessible for farmers and advisors that presents the environmental performance of commercial farms.

"With farmer consent in place, the tool streamlines the collection of existing data and utilises that data to accurately provide the baseline figure for the farm," says Siobhán. "That means that every farmer can know the quantity of greenhouse gases emitted from their farms – a first in the world in terms of integrating peer-reviewed research models and data from a range of sources."

Farm data residing in existing databases (e.g. ICBF and Bord Bia) is collated to create a snapshot of each unique farming system. Collating existing data for individual farms streamlines the assessment process, which improves the user experience and enables more precise capture and analysis of data, allowing accurate calculation of action. For transparency, farm activity data is presented on the user interface.

> **"AgNav is helping Irish farmers decide where they can make real changes to greenhouse gas emissions."**

A three-part system

The AgNav platform is being developed through a co-design process, where a series of workshops are organised with the development team, farmers and advisors to obtain feedback on accessibility, applicability, interpretability and recommendations.

Siobhán adds: "The AgNav platform also provides the user with a live decision support tool that communicates the benefits of best practice adoption on a product, area and total enterprise basis. This tool will be used to inform the creation of a farm specific sustainability plan."

There are three key elements to the AgNav platform as outlined: Assess, Analysis and Action Planner.

Through the '**Assess**' feature, farm data is collated from the Bord Bia Quality Assurance Scheme survey to build a picture of the operations on the farm, capturing data such as fertiliser use, feed concentrates and manure management. Animal-specific data such as numbers, sales, purchases, and performance is gathered through the ICBF database which is sourced from DAFM's Animal Identification and Movement

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Teagasc's new sustainability platform, AgNav, will support farmers in improving productivity, ensuring economic viability, and setting new standards for environmental sustainability.

Pictured are representatives from Teagasc, Bord Bia and government discussing the platform at the National Ploughing Championships

system. Life-cycle assessment models developed through many years of Teagasc research use the above collated farm data to calculate greenhouse gas emissions and ammonia emissions from individual farming systems and their associated products. This is used to provide a "starting point" for a given farm.

The second element – '**Analysis**' – is a live decision support tool. It allows the user to assess the effect of different mitigation strategies at different adoption rates on their overall greenhouse gases and ammonia emissions. Mitigation strategies included in the decision support tool have been identified through Teagasc's Marginal Abatement Cost Curve to reduce the environmental burden of agricultural systems while also being economically beneficial/neutral.

Future developments of AgNav will help farmers assess purchasing decisions such as the reduction in fertiliser use or the replacement of straight urea and calcium ammonium nitrate fertiliser with protected urea.

Following the identification of the most appropriate actions for their farm, a farmer and/or the advisor will use the '**Action Planner**' to create a sustainability plan for the farm, which can include targets and timelines for implementation/completion of specific measures. This plan will act as a guide for farmer/advisor engagement and demonstrate each farmer's commitment to delivering on the action plan.

Expanding the scope

The initial pilot phase of the AgNav platform is currently available for beef and dairy farms that are Bord Bia quality assured and have signed up for the new Teagasc Signpost Advisory Programme. However, explains Research Officer Jonathan Herron, "the scope of AgNav will expand to accommodate all cattle systems as well as other enterprises in Ireland's agricultural sector, such as sheep, tillage, pigs, forestry and poultry. Future phases of AgNav will also cater for all farmers regardless of their affiliation to AgNav partners".

While the initial phase of the AgNav platform focuses on greenhouse gas and ammonia emissions, future phases will include other environmental indicators such as biodiversity, water quality and carbon storage. Where possible, AgNav will establish data flows with relevant databases to improve assessment quality (i.e. verified data) and user experience.

"Once the pilot phase has been completed, the ambition is that AgNav – which is free to use – will expand to all farmers, including those availing of private advisory services," Siobhán says. "The aim is that, through industry-wide collaboration and data integration, AgNav will become the predominant method of conducting sustainability assessments of farming systems in Ireland." T

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Sensor sensibility

Use of smart technology on dairy farms allows more precise management decisions for tasks such as grass allocation, milk yield monitoring and slurry application.

In modern dairy farm systems, data may be considered a valuable asset that can aid farmers in making critical management decisions. However, data must be easily collected, accurate, and analysed and interpreted correctly. Dairy farms in Ireland are currently challenged with sustainability concerns associated with the environment, herd management and animal welfare, alongside farm family quality of life issues, while also consistently aiming to increase profitability. Digital technology presents a strategy that could contribute a significant role in meeting these challenges, particularly with the availability of real-time data from smart technologies.

Establishing a framework

Ploutos is a European Union-funded sustainable innovation project; it is one of 11 such projects in place across EU countries including Greece, Spain, Italy and France.

Smart sensor networks can provide rural farms with crucial real-time data for metrics such as milk levels and grass growth

Bernadette O'Brien, a Principal Research Officer for Teagasc, explains: "The overarching aim of the Ploutos project is to enhance the sustainability of the agri-food chain by establishing a sustainable framework powered by a combination of behaviour innovation, collaborative business model innovation and data-driven technology services."

Within the Ploutos project, one pilot programme aims to establish and test a Smart Farming Strategy on rural farms, while also demonstrating its benefit in the wider agri-food community on the Dingle Peninsula. The Dingle Innovation Hub is leading this pilot programme with contributions from Teagasc and Net Feasa, a sensor technology company based in Dingle.

Integrating technology

The vision is to integrate smart technology into pasture-based systems focusing initially on dairy production, says Bernadette.

"Initially, six dairy farmers were enrolled as 'Ambassador' farmers in the pilot programme. A long-range wide area network system was initially used to allow sensor communication. Sensor technologies were chosen based on the importance of their respective and combined data for decision-making on farms and cost effectiveness.

"Firstly, farmers were encouraged to focus on grass measurement and use the grassland management tool PastureBase Ireland (PBI). Then, a network of sensor technologies was installed on the farms, including sensors to measure milk height and slurry height in their respective storage tanks (for conversion to volume) and soil moisture."

A weather station was also installed that measured wind speed, temperature and rainfall. Following significant interest in the project, there was an additional rollout of sensors to farms on the Dingle Peninsula, bringing the total number of farms to 28. A new platform was installed to facilitate communication from this larger number of sensors.

Gathering the data

In addition to measuring levels of slurry, milk and soil moisture, the project also seeks to gather data on grass growth.

"For grass measurement and grass growth prediction," says Bernadette, "the farmers were asked to undertake weekly farm walks to record their grass covers and upload their data to the PBI database. Some farmers initially used the visual estimation method for grass measuring, but increasingly transferred to using a manual rising plate meter."

Farm-specific grass growth predictions were made available on a weekly basis to those farmers that provided regular grass measures; weather data was also used in this model. A predicted grass growth rate helped to estimate grass availability in the following week, allowing more precise planning for grass allocation to animals.

The low-cost milk sensor measures the height of milk in the bulk tank on an hourly basis; this height data was then converted to volume using relationship data (milk height and associated volume as measured by the purchasing co-op at milk collection), developed over time for each bulk tank. Thus, information on daily and weekly milk yield per cow was available to the farmer, explains Bernadette.

> **"The capture and use of real time can improve the accuracy of day-to-day decision-making on farms."**

Automated slurry sensors can provide key data for more informed decisions on when to apply slurry

"This milk production data could then be examined in conjunction with the grass data from PBI and the weather data. Together, these may be used to judge appropriate grass allocation or alternative nutritional options."

Similarly, the slurry sensor measures the height of the slurry stored in the slurry tank, with the height reading updated every six hours. A calculation is available to convert the sensor height measurements to volume and percentage of available remaining tank capacity. As Bernadette explains, this information, together with slurry tank fill rate, soil moisture and rainfall data assists farmers in making more informed decisions about when to apply slurry within the National Guidelines. "The value of slurry has increased in recent times due to the rising cost of chemical fertiliser; access to the slurry data in conjunction with farm mapping helps farmers to use less fertiliser and apply slurry more effectively to achieve optimal growth."

Further, the soil moisture probe measures moisture in the soil on an hourly basis using hertz as the unit of measurement. The hertz reading is then converted to percentage soil moisture. The soil moisture data may be used in conjunction with the weather data in deciding on an appropriate timeframe for fertiliser application.

Access and monitor

The data from the different sensors is cleaned, analysed and presented on an app called EvenKeel. This app was developed to allow the farmer to access and monitor the data collected. The information collected by the sensors is displayed in text and graphical form. The farmer may view the data results and trends over hourly, daily, weekly and monthly timeframes.

Data-driven farming strategies show great potential, provided that proper measures are taken, says Bernadette, explaining that there are three key lessons to take away from this pilot programme. "Firstly, the technologies must be relevant, appropriate and cost-effective; the data must be farmer user-friendly; and sensors must be regularly checked and serviced."

Smart sensor technology on-farm can provide evidence-based information on the farming system; this can be particularly important in, for example, describing positive environmental attributes of the farm. The capture and use of real time data — rather than just historical data — is also important and can have a positive impact on efficiencies and improve the accuracy of day-to-day decision-making. T

FUNDING

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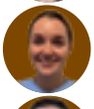


Elodie Ruelle
Senior Research Officer, Teagasc Moorepark.

Taking centre stage

Researchers at Teagasc's Climate Centre are driving some of the organisation's most urgent work to meet challenges around climate change and biodiversity (L-R: Paul Smith, Simon Leach, Rachael Murphy and Lorraine Balaine)

Teagasc's Climate Centre takes an interdisciplinary approach, bringing together staff from across the organisation to work on some of the biggest climate and biodiversity challenges facing us. Research Officers Lorraine Balaine (REDP), Rachael Murphy (CELUP) and Paul Smith (AGRIP) and Technologist Simon Leach (CELUP) tell us more about the crucial research happening within the centre.

Photography: Karl McDonough

Can you explain your role within the Teagasc Climate Centre?

Lorraine: As an agri-environmental economist, my work focuses on understanding and informing farmers' technology adoption decisions, with a specific focus on GHG mitigation. Using Teagasc NFS data helps identify farm-level solutions that can reconcile the three sustainability dimensions (economic, environmental and social) towards achieving carbon reduction targets. I work in multi-disciplinary teams within and outside of Teagasc proposing policy recommendations for enhanced agricultural sustainability.

Rachael: I am a Research Officer working on measuring carbon emissions, working on the National Agricultural Soil Carbon Observatory (NASCO) data. NASCO is a Climate Centre infrastructure consisting of 28 flux towers that measure GHGs such as carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) on different land-uses, soil types and managements.

Paul: I'm a Research Officer based in Teagasc Grange, focused on improving the sustainability of beef cattle production. Within the Climate Centre, my main aim is to develop strategies for reducing the finishing age of Irish beef cattle, to decrease the quantity of GHG emissions emitted over an animal's lifetime.

Simon: My main role in the climate centre is contributing to the design, implementation and management of a new biodiversity survey within the National Farm Survey (NFS) and the Small Farm Survey (SFS). I work with colleagues in both the Environment Research Centre in Johnstown Castle and REDP in Athenry. I also provide biodiversity support to research staff with a focus on the use of Geographic Information and associated software systems (GIS).

What are your specific priorities and objectives within the Climate Centre?

Simon: There is currently no regular, systematic, repeatable and statistically representative monitoring of farmland biodiversity in the wider countryside. Implementing a biodiversity indicator within the NFS aims to address this gap. The main objectives are to create an indicator of habitat quantity (as a proxy for biodiversity) and deliver a field survey to assess variation in the quality of these habitat features in our farmland landscapes.

Paul: Presently, the average finishing age of prime beef cattle on commercial Irish farms is 25.6 months, substantially older than at research level and on top-performing commercial farms. Finishing age is influenced by animal growth rates; increasing overall lifetime live weight gain of the national beef herd is a central priority to achieve the 2030 ambition to reduce average finishing age to 22-23 months.

Lorraine: We need to increase farmer buy-in to encourage the widespread uptake of identified mitigation measures; reaching our climate targets depends on it. This requires a deeper understanding of constraints to adoption from a farmer perspective so that more support systems are developed to accompany farmers in the sustainability transition. We also need to ensure the continued economic and technical feasibility of implementing proposed solutions at the farm level and foster adaptation to future challenges.

Rachael: A key priority within the Climate Centre is to publish Irish-specific soil carbon sequestration and emission factors by 2027. An objective of my research programme is to utilise the NASCO carbon flux data to generate Irish-specific - or Tier 2 - emission factors for soil carbon emissions from agricultural soils.

How does your research achieve these objectives?

Rachael: We will measure high-frequency CO_2 and non-CO_2 GHGs over large spatial domains (up to 1 km_2) from different agricultural managements (dairy, beef, sheep, arable, multi-species swards and rye-grass clover swards) and soil types (mineral, peat and organo-mineral), as well as ▶

collecting management data. Both flux and management data will be incorporated into a process-based model to provide Tier 2 and Tier 3 (modelled) emission factors.

Lorraine: My research explores farmers' profiles, decisions and sustainability performance to help propose tailored solutions for different production systems. I use and produce quantitative, economic and environmental metrics that can be easily communicated to farmers, advisors, industry stakeholders and policymakers. I also write perspective and methodological articles that reflect upon agri-environmental policy, multi-disciplinary research needs and the future of production systems within and outside of Ireland.

Simon: We will produce a habitat quantity index employing nationally available spatial datasets, the periodic update of which will offer opportunities to assess change over time. We plan to complement this metric with a targeted, repeatable field survey of habitat quality. Delivering these biodiversity outputs for all farms within the NFS/SFS will facilitate the combined analysis of habitat data with other environmental, financial and socio-economic variables collected within the nationally representative framework of the NFS.

Paul: A key focus of this research programme is to identify and quantify the main factors negatively influencing the lifetime live weight gain and subsequent finishing age of cattle on commercial beef farms. The acquisition of this data will play a key role in developing both policy and farm level interventions focused on reducing the national finishing age.

What are the key techniques and tools you use to achieve this work?

Lorraine: I apply advanced econometric methods to large datasets such as the Teagasc NFS. Econometrics is the application of statistical methods to economic theory, which can help us understand the allocation of farm and farmers' resources. With the help of others in the Climate Centre, I plan to combine these methods with qualitative work and in-depth case study analysis of farm environmental performance. This will help better inform technology adoption decisions that are adapted to specific farming conditions, as well as the development of successful agri-environmental policies.

The team brings together a breadth of interdisciplinary knowledge, under the guidance of Head of Climate Centre Karl Richards (far right)

Paul: A dual-focused approach will be undertaken to develop an understanding of the factors influencing the finishing age of Irish beef cattle. Initially, there will be a focus on the collation and amalgamation of live weight data to determine the key stages across the production cycle whereby growth targets are not being achieved nationally. Following this, there will be a more comprehensive focus on obtaining data from commercial beef farms to investigate the effects of nutrition, animal health and on-farm environment on finishing age.

38.4%

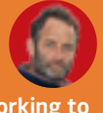
In 2022, the agricultural sector was directly responsible for 38.4% of national GHG emissions.

Rachael: The NASCO flux tower network represents the densest network of flux towers globally, making Ireland a global leader in monitoring GHG emissions from agricultural soils. Some of the NASCO sites are co-located with additional GHG-measuring infrastructure such as greenfeeds for measuring enteric CH_4, and static and automated chambers for measuring soil emissions of CO_2, N_2O and CH_4.

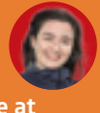
Simon: We use a range of geospatial tools and techniques, spatial data sources and associated remote sensing technologies in biodiversity-related research. The National

What are you proudest of as a member of the Climate Centre? Is there an achievement you would like to highlight?

Lorraine: I think it's a privilege to be part of this group and to participate in something that truly matters for the future of our society.



Simon: It's great to be part of a collaborative, multi-disciplinary group, working to develop innovative solutions to address climate and biodiversity challenges.



Rachael: I am proud to be a part of an institution that can instigate real change at national level regarding how we address climate change within agriculture.

Paul: It is a privilege to be a member of a multi-disciplinary group focused on increasing the sustainability of Irish agriculture.

Land Cover Map, released by Tailte Éireann in March 2023, represents a step change in the level of digital mapping captured nationally for the agricultural landscape in Ireland. We plan to make extensive use of this innovative and novel resource, while also investigating the degree to which this and other digital data products can meet wider objectives around biodiversity monitoring.

Can you explain why your work is important in the context of meeting climate and biodiversity challenges?

Simon: We are in a widely acknowledged biodiversity crisis, failing to achieve a series of targets over the last 10-20 years. If we are to halt and reverse biodiversity loss, it is important that we have mechanisms and methodologies in place to effectively monitor biodiversity and measure the impact of the investments that are made and the actions that are implemented to meet these challenges.

Lorraine: We need to better unite more science, policy and the farming community. It is only by working together that we can tackle the climate and biodiversity challenges ahead of us. Farmers play a key role in our food systems; thus, my research is centred around their views and behaviours, with the objective of facilitating progress in building climate-resilient and sustainable production systems.

> **We need to better unite more science, policy and the farming community. It is only by working together that we can tackle the climate and biodiversity challenges ahead of us.**

Rachael: Ireland has an emission reduction target of 51% by 2030, of which approximately 5% can be attributed to the inclusion of carbon sinks from Land Use, Land-Use Change and Forestry (known as LULUCF). By measuring CO_2 fluxes from Irish agricultural soils, we can better determine the carbon sequestration potential of different land-uses managed for agriculture and utilise these systems to help achieve our emission reduction target.

Paul: Reducing the finishing age of prime beef cattle has been identified as a top GHG mitigation priority for the agricultural sector. Reducing the finishing age of beef cattle also has an economic advantage by reducing daily costs associated with animal production. Therefore, the ongoing work on reducing finishing age has the potential to both increase the economic sustainability of beef cattle production and deliver GHG mitigation savings of 0.57-0.82 MT CO_2eq for the sector.

Are there any trends coming up that will affect your work? How are you anticipating this?

Paul: Since 2018, the average finishing age of steers, bulls and heifers has decreased by 34, 10 and 12 days respectively, with minimal negative effects to average carcass weight. The upcoming inclusion of "finishing age" as a trait in the national cattle breeding indices has the potential to further advance the annual decline in finishing age.

Rachael: We aim to expand the applications of the NASCO flux data by working with Terrain-AI, an SFI and Microsoft-funded project led by Maynooth University, on using the flux towers as ground truths - actual on-ground locations relative to GPS coordinates - for earth observations of gross primary productivity (GPP). We also aim to use the flux data to constrain model outputs of CO_2 under different managements and climate scenarios.

Simon: GIS and related spatial data technologies are developing rapidly. We aim to make best use of new technical developments and advances where possible. We will look closely at field data collection technologies over the next 12-24 months as our field survey campaign will generate a large volume of information and will also be important to build in the ability to repeat the surveys in the future to assess change. Mobile GIS applications and tools will likely play a key role in managing these processes.

Lorraine: Methods in the field of machine learning are improving exponentially. With the current trend of collecting and accessing more and more data on farms, I believe that the use of these powerful methods is the future in my field. There is a very steep learning curve to use them and unlock their potential, but I am hoping to start catching up within the next two to three years.

What are the Climate Centre's values? What are the principles you work to that you think make your team successful?

Rachael: The Climate Centre values interdisciplinary research, knowledge transfer and high-quality data outputs that can enable policymakers to make science-based decisions on agriculture's role in mitigating climate change.

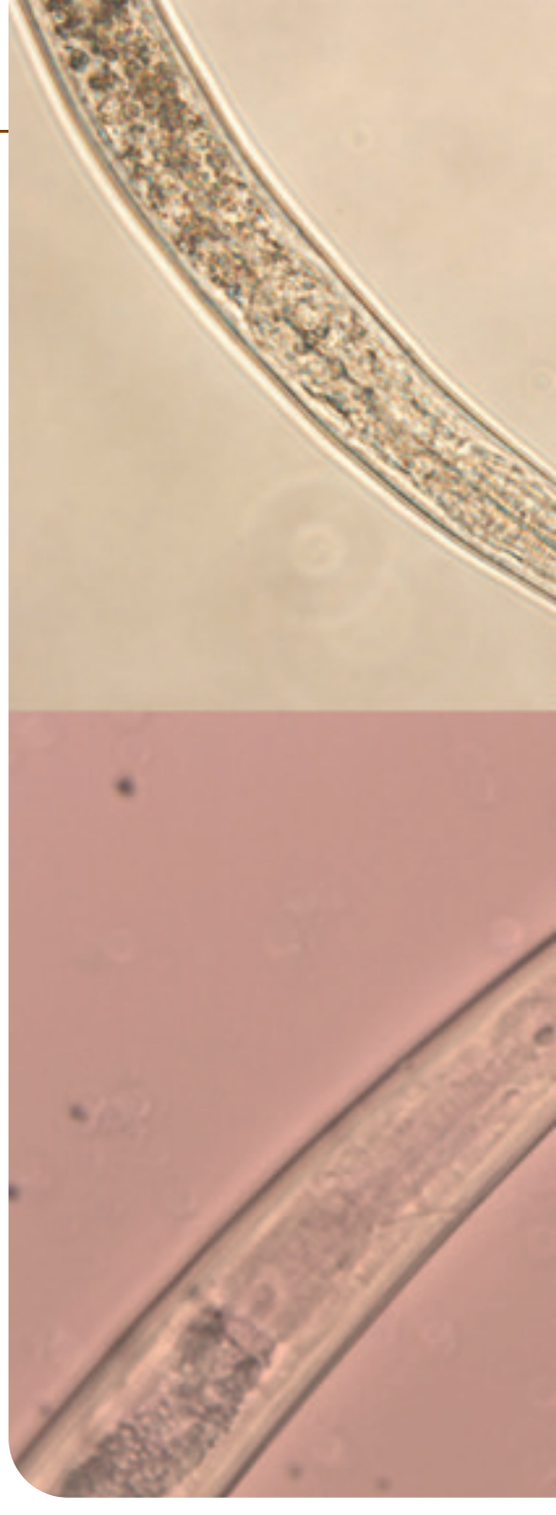
Lorraine: The Climate Centre gathers a group of people who are motivated and committed to the transition towards more sustainable agricultural production. Space to share ideas and voice concerns has made the experience very enjoyable for me so far. The Centre is still relatively new, but we are building close links that will support Teagasc in its missions going forward.

Enhance biodiversity

Adaptation

As part of international efforts to safeguard soil health and biodiversity, Teagasc researchers have been assessing practical farm-scale measures to enhance soil biodiversity in intensively managed grasslands.

A worm welcome



New research from the Teagasc Environment Research Centre at Johnstown Castle shows that higher plant diversity of intensively managed multi-species swards enhances belowground biodiversity and soil health

The study, which has been published in the international scientific journal, *European Journal of Soil Biology*, showed that as grasslands increased plant diversity up to six species of grasses, clovers and herbs, soil-dwelling nematode communities also had increased diversity and improved performance across several indices that reflect the ecological health of soil.

Fiona Brennan, Teagasc Senior Research Officer and one of the study's lead authors, explains that soils harbour an incredible diversity of life.

"In fact, soil is the most biodiverse habitat on the planet, with recent estimates indicating that it is home to 59% of biodiversity. This biodiversity underpins our food production systems and is vital for the delivery of a range of essential ecosystem services. The more we learn about this reservoir of biodiversity the more we understand its incredible importance for addressing the major societal challenges of our times."

The central role played by soil biota in nutrient transformations, climate regulation and plant health place them at the heart of global challenges around food security, biodiversity loss and climate change. As international efforts to safeguard our soils intensify, it is critically important that the scientific evidence is available to underpin policy and practical management advice. At EU level these efforts include the recent development of an EU soils strategy, the establishment of an EU Mission on Soil Health and Food, and the publication of a proposed EU soil health law, which would provide the first legal protection to soil at EU level.

The benefits of diversity

Research carried out at Teagasc Johnstown Castle has recently assessed the impact of plant diversity on belowground diversity using soil nematodes as indicators of soil health and ecosystem functioning, explains Fiona.

"Nematodes — tiny round worms that are widely distributed and highly abundant in soils — play important roles in the health of soil systems, especially for nutrient and carbon cycling. They are sensitive to changes in the environment and can give an indication of multiple aspects of the soil food web."

> **"Diversifying plant communities can create more habitats in soil, which in turn supports more diverse soil biological communities."**

Several nematode-based soil quality indices are available that relate to soil function, making them especially attractive as a soil biodiversity indicator. The research found that multi-species grasslands with six species had a positive effect on the soil nematode community and nematode soil quality indices. Compared to monocultures of forage plants, multi-species grasslands had a higher abundance of predatory nematodes, which can be beneficial for the biocontrol for plant pests. Conversely, there was a lower abundance of herbivorous nematodes in multi-species grasslands, the presence of which can negatively affect plant performance. This is

Israel Ikoyi

Bacterial feeding nematode (top) and plant parasitic nematode (bottom) from grassland soil. Nematodes are often used as indicators of soil health and ecosystem functioning

Teagasc

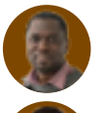
More diverse multi-species grassland swards showed a higher diversity of soil nematodes

of practical relevance for farmers seeking to enhance soil biodiversity and for policy aimed at farming for biodiversity benefits.

The life within soil is strongly impacted by how soil is managed. Plant-soil interactions are incredibly important for the maintenance of belowground soil biodiversity, and incorporating diversity in plant communities may represent a simple and practical way of enhancing soil biodiversity at farm level. As Fiona explains: "Diversifying plant communities can create more habitats in soil, which in turn supports more diverse soil biological communities. There has been renewed focus on the incorporation of legumes into intensive grassland-livestock systems, either as grass-clover or as grass-clover-herb multispecies mixtures."

She adds that multiple benefits associated with plant diversity in multispecies swards have been documented. "These include higher yields with lower nitrogen application, high weed suppression, lower nitrous oxide emissions intensity, enhanced soil fertility, enhanced drought resilience and improved livestock performance. This latest research reveals additional positive effects of multi-species swards on belowground soil biodiversity." T

CONTRIBUTORS



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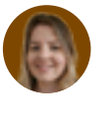

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Adaptation

Supporting Policy

Snout of character

The Research Leaders 2025 project PIGSMELL is investigating how pigs communicate using their senses and how their positive interactions can ultimately support social stability and improve their health.

“Excessive aggression, usually caused by constant regrouping practices and a lack of space, is shown to cause injuries and stress for pigs.”

Domesticated animals are gregarious in nature, so social environment has a substantial impact on their welfare. Most farm animals are group-housed, and negative social interactions are partly due to the constraints of housing environments and management practices, which can then lead to welfare problems.

A plethora of literature has focused on minimising the consequences of negative social interactions, says Jen-Yun Chou, a Marie Skłodowska-Curie Postdoctoral Fellow and part of Research Leaders 2025.

“In pigs, for example, excessive aggression is usually caused by constant regrouping practices and the lack of sufficient space to display avoidance behaviour,” suggests Jen-Yun. “This is shown to cause injuries and stress for pigs and reduce their performance. In contrast, we have limited knowledge of what constitutes positive social interactions for pigs.”

Project PIGSMELL is focused on maintaining social stability, which could be key to improving pigs’ health, welfare and performance.

Part of the Research Leaders 2025 programme, Project PIGSMELL brings together researchers from Teagasc, Research Institute in Semiochemistry and Applied Ethology (France) and the University of Veterinary Medicine Vienna (Austria).

Nosing behaviour: how pigs communicate

Pigs communicate through visual, vocal and olfactory (sense of smell) sensory cues. Compared to vocalisation, olfaction in pigs is a less understood sensory modality, even though it is their main tool to interact with their environment and conspecifics. Pigs’ olfactory ability outperforms that of numerous other animal species, including dogs. Nosing – the use of the snout in direct or close contact with a subject – is a complex behaviour that needs to be dissected in order to better understand how pigs communicate socially. This is the main focus of this project.

Different metrics, same conclusions?

A range of social metrics are used to analyse pigs’ social grouping. Research on dominance hierarchy in pigs started in the 1970s and remains the main conceptual framework to understand pigs’ social structure.

A clear dominance relationship may be vital to a healthy group as it prevents aggression and increases consolation behaviour, and thus reduces stress; however, little is known about the establishment and stability of hierarchical ranks and the

FooTToo/istockphoto.com

Interaction through sense of smell is the main way in which pigs interact with their environment, including social interaction between pigs

effect of rank position on an individual pig's welfare.

More recently, Social Network Analysis (SNA) has emerged as a new conceptual toolkit applied in farm animal studies. It describes an animal's position in relation to the rest of the group.

"Using contact patterns between pairs within a group of animals, a set of computational metrics calculates the strengths and directions of social interactions," explains Jen-Yun. "This produces a dynamic and relational picture of social structure.

"In addition, the concept of social preference is even less understood. Pigs show preferences for specific individuals, but husbandry practices, such as cross-fostering of piglets and regrouping, reduces the display of preferences. How this may influence their positive social interactions remains unknown."

Project PIGSMELL therefore explores pigs' social activities using these different metrics, namely social hierarchy, social network and social preference.

Promoting social stability

Pigs use olfactory information to communicate, but the role of pheromones in pig communication is not well understood. A synthetic analogue of the Pig Appeasing Pheromone (PAP), a pheromone naturally secreted from the mammary glands of lactating sows, mimics this maternal pheromone.

Studies have shown that this type of pheromonal compound can reduce weaning stress in piglets and aggression in older pigs, but its efficacy in promoting stability in social groups and positive social interactions is unknown. This project uses PAP as an external aid to provide stability upon regrouping and reintroduction.

"Our aim," Jen-Yun concludes, "is to investigate whether, in the long run, this intervention can be applied in commercial settings to improve social stability and consequently improve pig welfare and performance." T

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Innovation gets a head START

By supporting researchers in entrepreneurship, commercialisation and technology transfer, Engage@Teagasc helps foster innovation, sustainability and economic growth. Here, we look at three new research projects getting a financial boost from Teagasc's START Fund scheme.

Innovations developed at Teagasc can play a key role in fostering sustainability and driving economic growth, by encouraging regional investments and creation of jobs within the agri-food and related sector. Since 2021, Teagasc has been investing in the acceleration of translational research and technologies towards commercialisation through its annual START Fund awards.

The awards aim to complement Enterprise Ireland commercialisation funding, while nurturing entrepreneurship and increasing commercialisation activity within Teagasc. Funding the strengthening of Intellectual Property (IP) and gaining insights into potential markets and customers helps build commercial pathways for establishing a spin-out company or engaging with potential licensees.

The Engage@Teagasc team, which supports researchers in technology transfer, commercialisation and entrepreneurship, recently announced the three latest START Fund 2023 recipients. The selections followed an external review and each project was funded up to €15,000 over a three-to-six-month period. These three projects join seven other early-stage innovations that have been supported through the START Fund since its launch, effectively bridging the gap between research and commercialisation.

Milkybiotics – Boosting adherence of probiotics

Rita Hickey, Food Research Centre, Moorepark

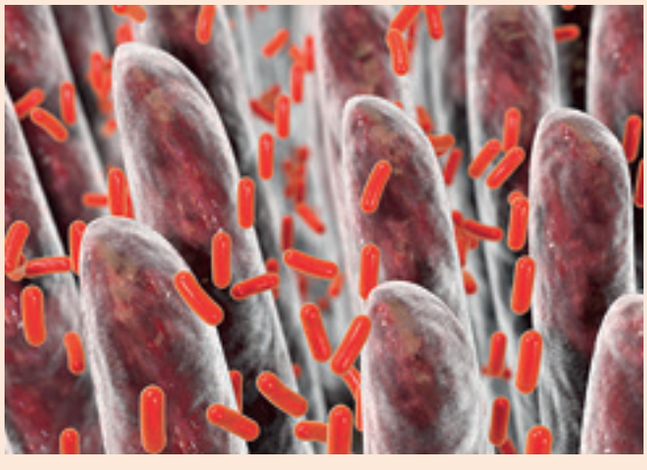
There are concerns among scientists that probiotic supplements are unable to establish themselves in the gut and fail to exert a lasting effect on the resident community, potentially limiting their effectiveness. Although some studies have shown that the digestive tracts of infants can be colonised by probiotics, the intestinal persistence times of probiotic strains in children and adults are generally much shorter, lasting only a few days.

The Milkybiotics technology developed by Rita Hickey's team at Teagasc has proven to significantly increase the attachment of probiotic bacteria in the gut through use of immunoglobulin G from milk sources to modulate the intestinal cell surface. They have since developed a potential Milkybiotics ingredient, based on dairy side streams available at industrial scale, which is being evaluated in a clinical trial. The aim is to boost probiotic establishment for an overweight cohort.

"From IP and market analysis, there doesn't appear to be commercial products that aid or increase the attachment of probiotic bacteria to intestinal cells," says Rita. "Further development of this technology could address a valuable global market gap and potentially revolutionise the gut health product sector."

Where will the funding go?

The START Fund is supporting market feedback through extensive customer discovery interviews, to provide evidence of market need, with a view to identifying niche markets for an initial product. Information gained will support the next steps on the pathway to commercial impact, including spin-out potential, building on Rita's extensive engagement with industry through collaborative research.



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SOLAS – Soil Spectral Libraries

Karen Daly, Environment Research Centre, Johnstown Castle

Karen Daly leads a Teagasc group focusing on developing agri-tech innovation to improve the sustainability of the agri-food sector in Ireland, spanning topics in soil health, water quality, sensing and spectroscopy.

Soil testing for multiple properties carried out by commercial laboratories across Ireland and the UK is essential for environmental, quality and regulatory purposes. Such analyses, however, use labour- and time-intensive wet lab techniques, involve hazardous chemicals, and are expensive and slow.

Using their knowledge of soil science and spectroscopy, Karen's team has established the soil-sensing laboratory to lead the transition in green chemistry by replacing chemical extraction with non-destructive methods for multi-parameter soil analysis using mid-infrared spectral libraries.

"Spectroscopy allows users to 'visualise' soil," explains Karen, "and the Teagasc spectral models can predict multiple parameters from a single scan – and at a fraction of the costs of current methods."

Building on research funded by Geological Survey Ireland, the SOLAS unique analysis methodologies have the potential to provide cost and time savings without loss of accuracy for soil analysis. This provides an effective mechanism for technology adoption at a national scale in future soil monitoring as provided for in the draft EU Soil Monitoring Law (EC, 2023).

Where will the funding go?

The Teagasc START Fund is being used to scope out routes to market for the technology either via a spin-out company that can out-compete existing soil labs, or licensing of the model and national spectral libraries to existing commercial soil testing companies.

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ALPACA Bio – Novel antimicrobial peptides

Paul Cotter, Food Research Centre, Moorepark (and Miguel Fernandez de Ullivarri, University College Cork)

Paul Cotter from Teagasc's Food Research Centre is a world-renowned leader in microbiome research, focusing on food chain microbiomes, especially fermented foods, and their health impacts. Paul and Miguel Fernandez de Ullivarri, University College Cork senior post-doctoral researcher at APC Microbiome, have developed novel anti-infective therapies, including antimicrobial peptides as safe therapeutics to fight antimicrobial resistance and diverse infectious diseases such as vaginal candidiasis (VVC).

VVC comprises a group of infections affecting 75% of women worldwide at least once in their lifetime.

"The current standard treatment – anti-fungal agents – is associated with antimicrobial resistance and other undesirable side effects," says Paul. "The ALPACA Bio innovation we have developed involves natural antimicrobial peptides capable of providing new high potency therapies to treat VVC and potentially other infectious diseases, effectively and safely."

Where will the funding go?

With the ambition to create a spin-out company, ALPACA Bio, to commercialise these therapies, the START Fund is proving invaluable for such spin-out considerations. Firstly, it's funding therapeutic validation of the efficacy and safety of the platform technology, and secondly it's establishing commercial feasibility validation by funding market research and customer discovery activities. T

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Head of the Curve

Teagasc's Marginal Abatement Cost Curve seeks to inform and steer agricultural policy toward hitting targets on emissions mitigation. Here, one of its chief architects, Gary Lanigan, gives us a breakdown.

Photography: Karl McDonough

Originally a plant physiologist by training, Principal Research Officer Gary Lanigan eventually found himself heading up Teagasc Johnstown Castle's research on greenhouse gas emissions, and latterly focused on carbon sequestration. The field has become increasingly vital in recent years, and Teagasc has in turn provided key scientific guidance to agriculture policy and policymakers. The main tool for this is Teagasc's Marginal Abatement Cost Curve, or MACC. Gary spoke to *TResearch* to explain its relevance.

How did the marginal abatement cost curve (MACC) first come about?

In 2012, the Department of Agriculture, Food and the Marine wanted to know the capacity of the agriculture sector to reduce greenhouse gas (GHG) emissions, and to identify the most cost-effective measures to do so. Marginal Abatement Cost Curves had been in use since the 1990s to look at measures that would decrease emissions to air and water and, indeed, had been used by the Irish Government to look at ways to decrease national GHG emissions across all sectors. So, we decided that it was an appropriate way to quantify the mitigation capacity of Irish agriculture.

What is the MACC?

Basically, the MACC is a tool to allow policymakers and decision-makers to be able to rank emission reduction measures based on cost. Measures are simply ranked from most cost-saving to most costly. So, policymakers can see what a given measure will cost and how much it will potentially mitigate, emissions-wise.

The MACC is presented in bar chart form and provides two elements of information. The vertical axis shows the cost of a given measure, with cost-beneficial and cost-prohibitive measures appearing below and above the x-axis respectively. The abatement potential of each measure, meanwhile, is given on the horizontal axis. Of note is that the magnitude of abatement is indicated by the width of the bar – i.e. the width is more important than the height on this chart.

What is the MACC used for?

The previous MACC formed the basis for what became agricultural policies going forward— Ag Climatise, for example. Over the past few weeks, we've been talking to government departments about how they might translate MACC into policy. All we say is "this is how much you need to mitigate or uptake" – it's up to the departments to decide how to take it up. We provide scientific guidance to policy, but we're not policy advisors.

How has this area of climate mitigation research developed over the years?

Climate research has exploded. When I started out at Teagasc in 2007, I was perhaps the only permanent researcher in the organisation whose whole focus was on GHGs. Now, there are over 15 permanent researchers in the field, alongside a plethora of PhDs and postdocs.

So, now I can concentrate on one specific aspect of climate research, which is soil emissions. I'm looking at carbon sequestration, but also some nitrous oxide and ammonia emissions research. By training I'm a plant physiologist; as I happened to use a lot of cropland sites in my research, I fell into working on agriculture, rather than actually "doing" agriculture.

What research have you been doing in this field?

Carbon sequestration is my main focus now: looking at how much carbon is taken up by plants and sequestered into soil. This is quite difficult to measure, as you're looking at a very small input going into a very large background. The analogy I would use is to imagine a swimming pool being filled by a dripping tap, and the only way to measure how much water is coming in is by measuring the height of the water!

If we can take carbon out of the atmosphere and lock it into soil, that's good insofar as its being removed from the atmosphere. So ideally, you'd want to maximise how much carbon gets locked into mineral soils and minimise how much gets lost out of peat soils and back into the atmosphere.

In a mineral soil there is about 100-500 tonnes of carbon per hectare, while in peat soil it's 1,000-5,000 tonnes. The high carbon levels in peat are due to the fact that they are waterlogged and mostly acidic. This reduces decomposition to a huge degree, which is why 'bog bodies' and 'bog butter' have been found in almost perfect condition.

Broadly, I'm leading the overall carbon research area in the new Teagasc Climate Centre, and that research includes our soil carbon monitoring and the eddy covariance towers we have spread around the country. Eddy covariance is a method ▶

Ireland has the world's highest density of Eddy Covariance towers, making it a global leader in monitoring GHG emissions

for measuring gas transport between surface and atmosphere, so it's widely used for quantifying rates of CO_2 emission and sequestration.

What are the challenges surrounding the reduction of agricultural greenhouse gases?

The main challenge is that we have a pretty hard target to reach, so we need a fair bit of policy to get us there. Also, there can be resistance to some measures, especially land measures such as forestry uptake or managing peat soils. So our main challenge is knowledge transfer to farmers and land-owners: our Knowledge Transfer Office and Signpost farms will hopefully help with uptake; high and quick uptake being the key message from the MACC.

Another issue within uptake is that we want farmers to largely stop using ammonium nitrate and switch to protected urea; this has led to a degree of disquiet in the fertiliser industry, as this is a less profitable product for manufacturers. However, my colleagues are working with the industry to develop and test new products.

So, in terms of a 'top three' challenges, one would be the need for policy guidance; two, a greater need for knowledge transfer; and three, the need to engage industry.

What impacts is this research having?

The MACC tends to be quite impactful, precisely because it forms a scientific foundation for agricultural policy on greenhouse gases and ammonia. As noted, Ag Climatise was a response to the previous MACC, so we're likely to see a version two of that in response to both the new MACC, and attempts to meet 2030 targets.

Every sector has a response to meet its own targets. I think something that speaks in favour of the agricultural sector is that we've put proper numbers on it. We've got a tangible, clear path mapped out.

What I would say, though, is that we now need to get into the implementation stage. We're past the point of writing reports. This is where the Knowledge Transfer Office and Signpost Programme will come in and assist, but this absolutely also requires departmental guidance on policy, so policy supplementing the knowledge transfer.

What has the industry response been?

In terms of process: industry is committed, engaged and pretty much on board with the measures mapped out in the MACC. Other aspects of industry have been slightly more difficult – but in general we're quite encouraged by the response so far, especially from processors. When we talk to the industry, they're very concerned with reducing the footprint of their products, which is a marketing issue as much as anything else. However, this lines up with abatement measures – and in any case, these companies all have to reduce their supply-chain emissions.

What are your plans for this research?

Now that we've finished the MACC, we are looking at land-use out to 2050, the year by when we're meant to be climate neutral. We're modelling out how much forestry we'll need and how much emissions reduction can be gleaned from grasslands and peatlands, for example.

Afforestation is a key area now; you're no longer allowed to afforest peat soils, so there's competition with dairy, tillage and beef for land access. However, as this has a knock-on effect on other land-uses, it requires lots of iteration and reiteration of modelling; currently, we're weighing up about 13 different scenarios. The current MACC figure is 8,000 hectares of afforestation per annum; ideally, we'll be at that rate by 2030, and sustain it between 2030 and 2040, so we'd reach 80,000 hectares of afforestation over a ten-year period. Afforestation makes a huge rate of difference per annum, so the quicker the better! T

Up close and personal

What's your favourite animal?
That'll be the cat, Hermione! She's the only one of our three cats left, probably because all she does is eat and lounge around all day. She's a bit overweight and isn't very agile but she rules the roost at home!

If you hadn't ended up in research, what other job would you have wanted to give a go?
That's a tough one... When I was going to college, I had a choice between Science in UCD and Fine Art at the National College of Art and Design. I chose UCD last minute but I still keep the painting and sculpting going. My real passion though has always been astronomy. Unfortunately, while my maths was OK it was never at the level required to make a career of it. Still, I'm happiest staring up at the stars with my telescope. It gives you a sense of perspective!

What are you most proud of professionally?
Seeing a lot of my former students doing so well. Many of them have permanent positions in research and academia, both in Teagasc and further afield and that's easily the most pleasing thing. I'm very proud of all of them!

Circular Food System

Grass half full

Grass and other plant biomass may represent an innovative new protein source for use in food and beverages.

With the world's population expected to increase from eight billion in 2023 to ten billion by 2050, the demand for protein for human consumption is rising. Accordingly, there is a need to look towards alternative protein enterprises to improve the competitiveness of agri-ecological systems through the diversification of protein resources. This is a topical area of research and development to improve food security, sustainability and variety within the diet. Technological innovation in plant proteins can add value; however, research efforts are primarily concentrated on mainstream crops.

Extraction from ryegrass

A new trend focuses on extracting proteins from low-value plant biomass, explains Sara Pérez-Villa, a PhD student at Teagasc Moorepark's Food Research Centre.

"These types of plant biomass include forages such as clover or alfalfa and other green leaves, such as the side streams from other crops like quinoa, wasabi or tomato," says Sara.

"Green leaves contain high levels of the enzyme RuBisCO, which is involved in plant photosynthesis and is a protein source with good nutritional properties."

However, they also contain high levels of cellulose, hemicellulose and lignin, which are indigestible to humans; therefore, they require an extraction process to obtain a digestible food protein-based ingredient.

Using laboratory methods, the research team at Moorepark separated the soluble and digestible protein RuBisCO from lignocellulose (dry plant biomass). The importance of proteins in food systems relies on their nutritional value and food-structuring properties, Sara explains.

"The study focused on the extraction of RuBisCO from perennial ryegrass (PRG) by two different approaches, thus tailoring the extraction yield and the functionality of the resulting protein in solution," she says.

Regardless of the extraction procedure used, protein streams had a balanced amino acid profile, meeting FAO 2011 recommendations, meaning they could become an alternative source of protein for food applications with good nutritional value.

Green light for green leaves?

The research team found that it was possible to increase solubility or extraction yield depending on the method used. The extract containing less residual chloroplast material had greater solubility, up to 40% more, and superior emulsifying properties at non-acidic pH. The interfacial properties of the extracted grass protein were influenced by its isoelectric charge (pI) and also pH of the emulsion system. For instance, at pH 7, higher than the protein's isoelectric point, the protein extract in which the chloroplast material was removed had similar emulsification properties to animal-based proteins.

The relative accessibility of plant biomass, and its potential for adaptability, is a promising sign for this research, concludes Sara.

"What the study has shown is that protein extracts from green leaves, such as the perennial ryegrass used in this case, consisting mainly of RuBisCO, have potential application for use in formulations intended for human consumption." T

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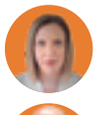

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Increase Carbon Capture

Spreading the good nutrients

Use of nitrogen-based fertilisers contributes heavily to greenhouse gas emissions. Research is underway at Teagasc Johnstown Castle to quantify the effect of alternative fertiliser formulations on nitrous oxide emissions.

Research at Johnstown Castle seeks to quantify the effect of fertiliser type on nitrous oxide emissions

Teagasc

Ireland's Climate Action Plan 2023 set out a roadmap for taking decisive action to achieve a 51% reduction in greenhouse gas emissions by 2030 across its entire economy. The agriculture sector's share of this reduction is 25%. The application of nitrogen fertiliser accounts for the largest source of anthropogenic nitrous oxide (N_2O) emissions, with the emissions dependent on what fertiliser formulation is applied.

Katie Scully, Postdoctoral Researcher at Teagasc Johnstown Castle, explains that different fertiliser types are currently measured according to different standards.

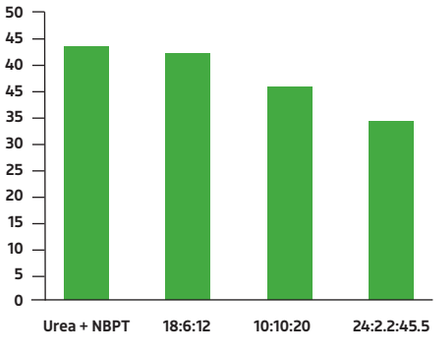
"Ireland currently uses country-specific Tier 2 emission factors for straight nitrogen fertiliser. However, for compound fertilisers we use the Intergovernmental Panel on Climate Change default emission factor for N_2O from soils. High N_2O emissions tend to be associated with nitrate-containing fertilisers such as calcium ammonium nitrate compared to urea, particularly in wet temperate grassland soils, due to the immediate availability of the nitrate substrate for denitrification."

Previous research has developed country-specific emission factors for three types of straight nitrogen fertiliser on the Irish market: calcium ammonium nitrate (CAN), urea and protected urea. Half of the nitrogen fertiliser in Ireland is spread as compound fertilisers, which contain a blend of nitrogen with other nutrients such as potassium (K), phosphorous (P) and sulphur (S). These fertilisers have different ratios of nitrate to ammonium, owing to their formulation. A preliminary field trial in 2020 showed that compound fertilisers with lower ratios of nitrate to ammonium could reduce N_2O emissions by 40%, when compared to CAN.

A new research project is underway to quantify the effects of compound fertiliser types on N_2O emissions. As Katie explains: "This will allow us to identify low-emission compound fertiliser formulations and produce national emission factors that can be included in the national inventory.

"This collaborative study between the Agri-Food & Biosciences Institute and Teagasc will take place over two years at permanent pasture sites. Sites located at Johnstown Castle will allow for measurements of well-drained soil; by contrast, sites at Hillsborough allow measuring of poorly drained soil."

Average % reduction compared to Calcium Ammonium Nitrate (CAN)



Relative % N_2O reductions of urea + NBPT fertiliser and a range of common compound fertiliser compared to CAN.

Nitrous oxide emissions are being measured from nine fertiliser treatments applied at 200kg N ha^{-1} in five equal splits, to simulate a typical grazed grassland.

Katie explains: "Nitrous oxide emissions are being measured using the National Soil Greenhouse Gas Test Platform funded by Science Foundation Ireland. This experiment's high-frequency monitoring method with low-labour intensity will generate high-resolution measurement of N_2O emissions to robustly account for events, such as rainfall, that drive high emissions." This type of high-resolution data helps paint a clearer picture of real emissions levels in Ireland, creating a better baseline for choosing fertiliser formulations. T

FUNDING

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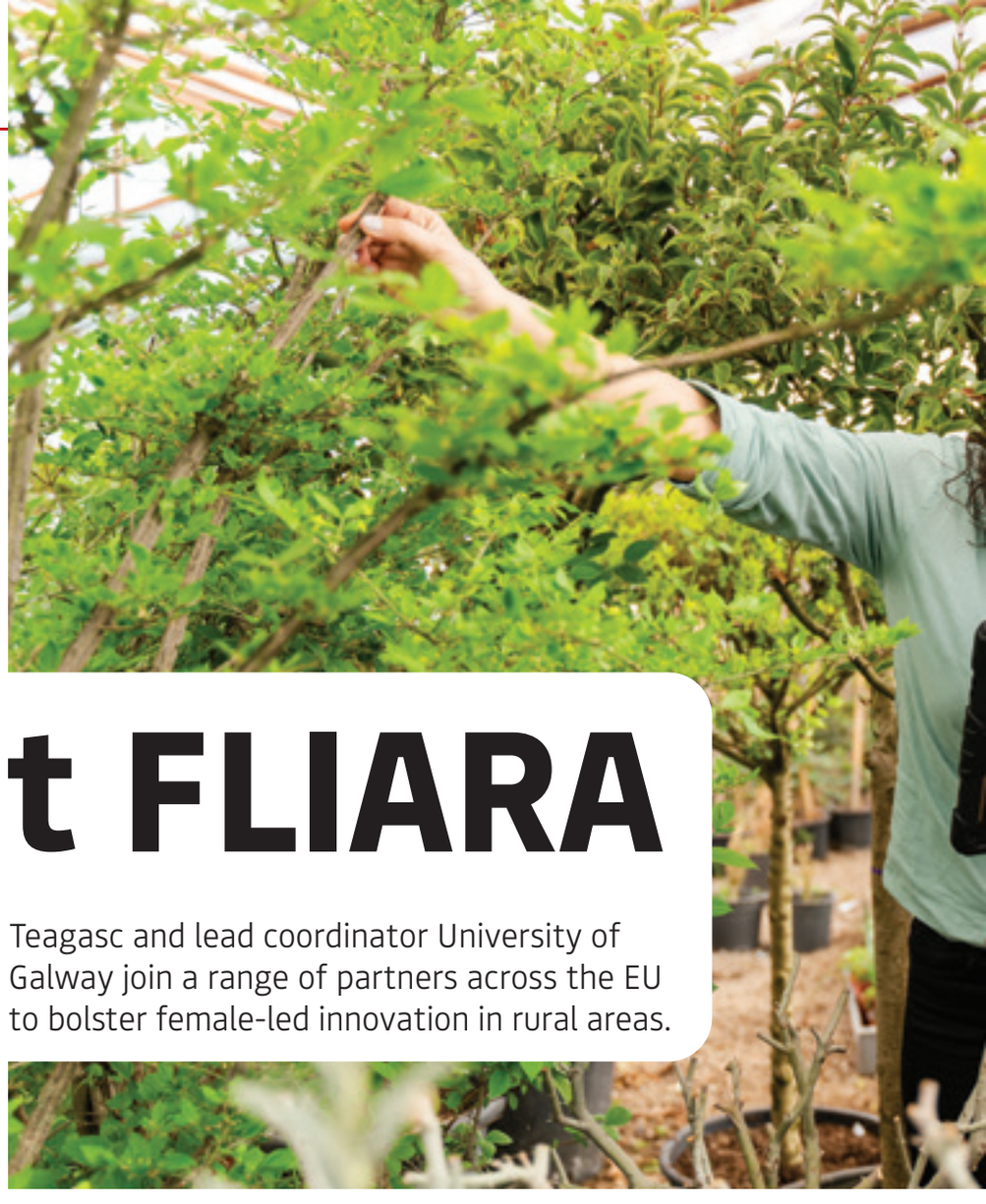

Project FLIARA

Teagasc and lead coordinator University of Galway join a range of partners across the EU to bolster female-led innovation in rural areas.

In 2021, the European Commission introduced the Long-Term Vision for Rural Areas, highlighting the various challenges and concerns faced by rural communities. These challenges encompass demographic issues, lower GDP per capita and limited access to essential services like water, electricity and broadband.

Moreover, contemporary trends such as climate change, gender inequalities, and the impact of the Covid-19 pandemic have introduced new complexities to rural Europe. However, amid these challenges, rural areas also present opportunities for building resilience, inclusivity and sustainability, particularly through digital and ecological transitions.

To address the challenges and seize the potential opportunities in European rural regions, it is imperative to promote rural innovation and ensure the active participation of all individuals and communities. Historically, the role of rural women in employment opportunities, enterprise and innovation has been marginalised and often suppressed within a patriarchal context. Against this backdrop, the Horizon Europe project FLIARA was founded.

Anne Kinsella, Senior Research Officer at Teagasc, explains: "FLIARA, which stands for 'Female-Led Innovation in Agriculture and Rural Areas,' offers a groundbreaking methodology aimed at enhancing our understanding, awareness and recognition of the crucial role played by women in shaping a more sustainable rural future. Additionally, it seeks to develop more effective policy and governance frameworks capable of supporting and enhancing the capacity of rural women to contribute significantly to this transformative process."

The FLIARA project aims to create a pan-European ecosystem that champions and supports women-led innovations in farming and rural areas. This comprehensive project is inclusive of rural women from diverse backgrounds, spanning age, class, culture, race and ethnicity, who are either already leading or aspiring to engage in innovative practices within rural and farming contexts.

At its core, Anne explains, the FLIARA Project seeks to ensure that women are integrated into a more effective innovation ecosystem. "This highlights their achievements, provides inspiration and knowledge, fosters valuable networks with key innovation stakeholders, increases their visibility in national and international decision-making arenas, enhances their capacities and skills, and empowers them to lead or embark on innovative practices in farming and rural areas."

The interdisciplinary work of FLIARA is being driven by a wide range of academics and researchers

Teagasc, Phynart Studio/iStockphoto.com

The role of women in agriculture and rural areas has often been marginalised – the FLIARA project seeks to rectify this imbalance and highlight female entrepreneurship

A systematic, organised approach

The FLIARA project has a number of key goals intended to spur innovation and change among women working in agriculture and rural areas. Among these goals: improving understanding of women-led innovations already occurring in agriculture and rural areas; imagining the role of women in future sustainable farming and rural development; analysing specific women-led innovations, examining their needs and challenges; identifying ways to increase other rural and farm women's capacity to engage in innovations; and establishing a Community of Practice network to facilitate multi-actor exchanges and knowledge sharing.

> **"The FLIARA Project aims to create a pan-European ecosystem that champions and supports women-led innovations in farming and rural areas."**

The FLIARA project is structured into six distinct work packages, each with specific objectives and tasks. These work packages ensure a systematic and organised approach to achieving the project's overarching goals. To date, the project has developed a solid conceptual framework for the project, conducting literature reviews and assessing existing knowledge. It also includes benchmarking policy and legal frameworks for gender equality.

A novel and exciting element of the FLIARA project is completing a Foresight and Trend Analysis, which envisions sustainable farming and rural futures across Europe, identifying necessary sustainability innovations and assessing the potential role of women in these innovations.

The bulk of the FLIARA work will delve into the pathways and challenges faced by women in farming and rural innovation, through a series of case studies carried out across the ten partner countries, explains Maura Farrell, associate professor of Geography at University of Galway.

"This will identify thematic case studies under four sustainability dimensions and conduct interviews with 200 innovative women. To disseminate all foresight trends and the case study results, the FLIARA project will establish four Community of Practice networks. It will also allow FLIARA to identify 20 Innovation Ambassadors to disseminate their work across the EU.

"To ensure change and progress for women-led Innovations across the EU, the FLIARA project will design more effective policy and governance frameworks, taking insights from the project into account. It engages stakeholders in participatory scenario development to adapt policies for future changes."

Depth and diversity

The FLIARA consortium is a diverse and multi-actor group of organisations with expertise in various aspects of agriculture, rural development and gender equality. It includes universities, European networks, a national agricultural agency, a community organisation, and an SME from 15 partners across ten EU countries. Within an Irish context, the University of Galway is the lead coordinator, assisted by Teagasc and Longford Women's Link, a key SME working on the project.

The FLIARA project is poised to make significant strides in empowering women in agriculture and rural areas across Europe. With its comprehensive approach, multi-actor engagement and systematic methodology, FLIARA aims to challenge gender norms, foster innovation, and create a more inclusive and sustainable future for rural communities. As the project progresses, it will contribute valuable insights, policy recommendations and a platform for knowledge sharing, ultimately paving the way for women-led innovations to become the norm rather than the exception in farming and rural development. T

FUNDING

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Adaptation

Grain the advantage

Innovations in plant variety testing in Europe are laying the foundation for more sustainable agriculture.

Breeding better crop varieties is an essential component in the development of sustainable agricultural production systems. Plant breeding has a demonstrated track record of success in driving agricultural productivity and profitability. However, increased agricultural productivity needs to be balanced against sustainability challenges.

Plant breeding develops innovative new products (varieties), and needs an intellectual property framework that fuels continued progress by enabling seed companies to profit from their sale.

Distinctive strains

"New varieties are protected by a grant of plant breeders rights (PBR), similar to a patent, granting exclusivity to the breeder or their licensees for a period of 25-30 years, after which seed of the variety may be produced by anyone," explains Senior Research Officer Dan Milbourne.

"To acquire PBR, new varieties undergo a testing process that establishes that they are sufficiently different to all other previously registered varieties of the same species, and have stable and consistent features."

This process is called distinctness, uniformity and stability (DUS) testing. In the EU, breeders can submit their variety to any of a number of recognised examination offices (EOs), where they will be placed in multi-year comparative trials with all existing varieties and other new entrants. Depending on the species, numerous morphological and developmental characteristics are measured in the new candidates, continues Dan.

"Essentially, the new variety must be measurably different in at least one way to all other varieties (distinctness) and must exhibit all measured characters consistently across the planted variety (uniformity) every time it is sown (stability). Once these conditions are met, the new variety is given a grant of PBR and placed on the EU Common Catalogue of Plant Varieties."

Advances in plant variety testing can help breed better resilience traits to preserve crop yields

"Improvement to variety testing will help underpin the development of a more sustainable agricultural system."

Teagasc

Value propositions

DUS benefits the breeder, and creates the impetus for novel variety development, but doesn't generally address performance. To ensure this, plant varieties undergo a second process called value for cultivation and use (VCU) testing. In the EU, VCU testing is carried out on a country-by-country basis; new varieties are subjected again to multi-year comparative trials to test whether they offer value in the specific environment and production system of that country.

Dan explains: "VCU evaluates varieties on the basis of characteristics such as yield, disease resistance and quality, and new varieties must represent advances in some or all of these characteristics. Successful completion of VCU trials allows a variety to be placed on the National List, which is a prerequisite for the sale of seed of that variety in the country."

INVITE the comparison

Official variety testing acts as the 'gatekeeper', directing the types of varieties that can reach the marketplace. Teagasc is part of an EU Horizon Research and Innovation project called INVITE (Innovations in Plant Variety Testing in Europe). The project started in 2019, involves 29 partner organisations from 13 countries and works on ten major species that represent crop categories for which there is significant use and breeding activity in the EU.

The goal, explains Dan, is to "foster the introduction of new varieties with high resilience to biotic and abiotic stresses, high adaptation to sustainable management practices and high resource use efficiency by advancing the state of both DUS and VCU testing."

To achieve this, continues Dan, "INVITE is identifying bioindicators associated with plant resource use efficiency, sustainability and resilience. Further, the project is developing new phenotyping and genotyping tools to measure these bioindicators, and developing statistical tools to predict variety performance under a range of environments and crop management practices".

The tools and methods will be made available for examination offices and post-registration organisations to improve efficiency and accuracy of DUS and variety performance testing. The aim is to better integrate sustainability criteria in these processes and to act as a driver for the development of sustainable varieties.

Spaced perennial ryegrass plants under evaluation

Split the difference

Within INVITE, Teagasc is responsible for tasks in two crop species important to Ireland: wheat and perennial ryegrass (PRG). For PRG, Teagasc is addressing an emerging problem in the scale of trials associated with DUS testing, explains Dan.

"New PRG varieties have to be tested against all of the varieties already on the common catalogue. DUS for PRG is based on about 20 individual morphological and developmental characteristics that have to be scored on 60 individual plants for each of the hundreds of established and candidate varieties. Managing and phenotyping these extensive trials is increasingly difficult because of the size of the trials and number of detailed measurements to be taken."

One potential solution is to identify subsets of established varieties in the common catalogue that would be suitable for comparison with new candidate varieties, reducing the total number of varieties that need to be planted in each round of testing. Teagasc and collaborators at the James Hutton Institute (Scotland) and INRAE (France) have combined DUS data from over a decade of trials with tens of thousands of genetic markers to begin the development of such approaches. They are also developing robust, cost-effective genotyping assays for routine use by EOs.

Developing resilience

Teagasc is also involved in developing resilience bioindicators for use in VCU testing, through work being led by Ewen Mullins, Head of Crop Science at Teagasc. *Septoria tritici* blotch (STB) is caused by the fungal pathogen *Zymoseptoria tritici*, and is the most prevalent disease for wheat production in Western Europe. Currently, there is no wheat variety available with durable resistance to STB, meaning farmers rely heavily on the use of fungicide to preserve yield.

"Prior to the appearance of visual STB symptoms," Ewen explains, "there is a symptomless latent period of up to 30 days, during which STB advances unchecked through the host plant, followed by rapid spore production."

Previous work at Teagasc showed that a longer latent phase is a desirable trait to define quantitative and durable resistance of wheat against STB. In INVITE, Teagasc is developing molecular diagnostics tools to measure this phenomenon by tracking STB build-up in the latent phase. This could be used in both breeding and in VCU testing to identify STB-resistant varieties.

Other highlights in INVITE include development of the use of genetic markers to directly identify genes conferring disease resistance traits; advances in drone and ground-based image analysis using hyperspectral and visible wavelengths to improve data capture of traits in large-scale trials; development of statistical methods allowing testing networks across Europe to share data more readily; and the development of variety-choosing tools for growers, based on economic and sustainability criteria.

Dan concludes: "Improvements to variety testing driven by the participation of research organisations, breeders and variety testers in INVITE will help underpin the development of the next generation of varieties for a more sustainable European agricultural system." T

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Reduce Methane Emissions

The Johnstown Castle dairy herd was established in 2003 to provide a base for winter-milk research within Teagasc.

Future-proofing winter-milk systems

Readily available, high-quality pasture during a long grazing season makes the Irish dairy industry highly seasonable. During the winter period, most spring-calving cows are non-lactating. As a result, winter-milk is a vital subsector in the dairy industry to achieve a consistent daily supply of quality fresh milk to our domestic market. In 2021/22, there were approximately 1,286 registered liquid milk producers that supplied just over 8% of national production (915 million litres). A further 600-800 producers are estimated to produce winter-milk under various non-registered price incentive schemes.

Due to the nature of winter-milk production from conserved forages, sustainability challenges such as reducing dependency on imported protein sources and reducing greenhouse gas emissions are particularly pertinent to these producers. Teagasc researchers have been performing experiments with the Johnstown Castle winter-milk herd to investigate strategies for improving the sustainability of winter-milk systems.

Investigating strategies

At the Johnstown Castle farm, a large emphasis is placed on maximising the proportion of high-quality grazed pasture in the cows' diet. Current grassland management tools provide a strong framework for winter-milk producers to achieve this, subject to some slight adjustments. During the autumn period, pre-grazing yield should be maintained below 1,800kg dry matter (DM)/ha, as the freshly calved cow can struggle on heavy autumn covers. Furthermore, a closing average farm cover of 650kg DM/ha should be targeted to allow a higher opening farm cover in early spring.

Strict breeding management rules (e.g. ten-week breeding period and no recycling of cows between breeding seasons) ensure that the herd has an optimal calving pattern for maintaining high feed efficiency, reducing annual feed costs and minimising the amount of surplus milk sold during November to February.

Experimental diets

During the winter-feeding period, there is an increased demand for high-protein feed ingredients due to the nature of conserved feeds. Currently, there is a major deficit in these ingredients, with the EU agricultural sector importing around 71% of its requirements. Home-grown or EU-grown protein sources (e.g. field beans and rapeseed) could provide economic and environmental benefits to European farmers, as well as food security to Europe as a whole.

Johnstown Castle winter-milk herd in numbers:

90 high-EBI Holstein Friesians

370-day calving interval

6-week calving rate of **78%**

Over the last four years, the herd has averaged:

7,450kg of milk, consisting of **3.66%** protein, **4.52%** fat, and **616kg** of milk solids.

1,602kg of concentrate is supplemented per year.

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Johnstown Castle winter-milk herd receiving their indoor experimental diets

PhD scholar Neil Maher presenting experimental results to the Teagasc Moorepark Walsh Scholar discussion group

With this in mind, researchers performed an experiment to compare a standard winter-milk diet of grass silage, maize silage and concentrate containing imported protein sources with a diet of grass silage and concentrates containing native cereals and protein sources (i.e. barley and field beans). Initial life cycle assessment modelling suggests a lower carbon intensity per hectare and per kg of milk when cows consumed the home-grown treatment. However, reduced animal performance was observed (-20kg of milk solids/cow/lactation) when compared with cows fed the standard treatment.

As there were several dynamic factors among the treatments (i.e concentrate ingredients, concentrate feeding level, maize silage inclusion), it was difficult to ascertain the cause of the reduced milk production performance.

In a follow-up experiment, researchers compared home-grown concentrate protein ingredients (i.e. field beans and rapeseed meal) with imported concentrate protein ingredients (i.e. soybean meal and maize distillers). The experimental concentrates were formulated to be similar in terms of crude protein and energy concentration.

Like the previous experiment, cows consuming the home-grown concentrate protein ingredients reduced milk production performance (-15kg of milk solids per cows across the 14-week experimental period) when compared with cows fed the imported concentrate protein ingredients. This was likely due to inadequate metabolisable protein/amino acid supply.

The experiments investigated the full replacement of imported ingredients, whereas currently in the industry, lower inclusion levels of home-grown protein sources occur in tandem with imported soybean inclusion, resulting in satisfactory animal performance. Furthermore, experiments from University College Dublin have demonstrated that when lower feeding rates and lower inclusion levels are offered to grazing dairy cows, there is no effect on milk production by the inclusion of home-grown protein sources.

Reducing methane production

Enteric methane is responsible for 62.5% of Irish agricultural emissions; thus, the reduction of methane will play a critical role in achieving agriculture's GHG reduction target of 25% by 2030. There are currently several mitigation solutions available such as animal genetics, pasture quality and methane-reducing feed additives.

At the Johnstown Castle farm, the researchers investigated a feed additive containing an ingredient (3-NOP) which potentially inhibits methane formation in the rumen. The feed additive was added to the diet feeder with the other dietary ingredients each morning and fed to the corresponding treatment group.

Cows fed the feed additive treatment produced less methane (330g/day) when compared to cows fed the control diet not containing the feed additive (447g/day) – a 26% reduction. In addition, cows fed the feed additive treatment produced slightly higher milk solids yield (2.50kg/day) when compared to cows fed the control diet (2.45kg/day), a 2% increase.

Although home-grown protein sources can reduce the carbon intensity and increase the protein self-sufficiency of Irish winter-milk systems, reduced animal performance was observed. Future experiments will investigate strategies to alleviate this reduced animal performance, such as rumen-protected amino acid supplementation.

Finally, the methane-reducing feed additive that was fed to Irish winter-milk cows is promising; however, an array of mitigation technologies will be required to ensure that agriculture can meet its climate targets while also being mindful of economic and social sustainability. T

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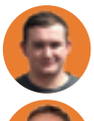

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Measure for measure

An important focus for methane mitigation efforts is to develop strategies to accurately measure and reduce methane emissions in grazing dairy, beef and sheep, explain AGRIC Principal Research Officer Sinead Waters, Walsh Scholar Emily Roskam, and Research Officer Ben Lahart.

The agricultural industry is facing a major challenge, with a legally binding 25% reduction of agricultural greenhouse gases (GHGs) required by 2030. Methane, one of the most potent GHGs, is derived from feed digestion in the stomach of livestock and from manure storage. As of 2021, methane accounts for ~68% of agricultural GHG emissions.

Teagasc's research programme on methane emissions is focused on:

- developing and refining country-specific emission factors
- mitigation strategies associated with reducing the age of finishing, feed quality,
- genetics and feed additives manure treatment and additives.

Through collaborative efforts between Teagasc, ICBF, DAFM, VistaMilk and MTI, GreenFeed technology and Portable Accumulation Chambers have been deployed to study bovines (dairy cows and beef cattle) and sheep, respectively. This has enabled widespread quantification of methane emissions, which is being used to refine the national inventories. Through this work, a seasonal nature to methane output from grazing dairy cows has been demonstrated, with the lowest methane output observed in the spring period. This has equated to ~9% less methane being lost as a proportion of gross energy intake, compared to the value used in the national inventory.

Data-driven indexing

Breeding programmes offer long-lasting and cumulative solutions for producing more efficient ruminants. Research has demonstrated that high genetic merit dairy cows selected for the Economic Breeding Index produce more milk solids, without an associated increase in methane output and reduced overall methane intensity (methane per unit of milk solids). Direct selection for low methane-emitting animals is also possible within breeding indexes.

Through the EU MASTER and DAFM-funded GREENBREED projects in collaboration with ICBF, methane and performance data were collected, creating a final dataset of 1,600 beef cattle. Animals were ranked as low, medium or high emitters. Beef cattle ranked as 'low' produced 30% less methane but maintained the same level of animal performance (feed intake, growth rate, carcass output) as their 'high'-emitting counterparts. Data obtained has contributed to the development of the world's first genetic methane evaluations for beef cattle published by the ICBF, which will need to be validated in future studies in grazing systems.

Research is also ongoing regarding differing grazing management practices and the incorporation of different plant species, such as clover in grazing swards on methane emissions. Sheep given perennial ryegrass swards including clover (white or red), rank lower for methane output. Regarding feed additives, a series of indoor beef studies have been conducted with promising results (% methane reduction) obtained from feeding linseed oil (-18%), rapeseed oil (-9%) and a seaweed extract (-7%) in a twice-daily feeding regimen.

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Reducing methane emissions

Bovaer, a feed supplement, was assessed through a total mixed ration, resulting in beef cattle emitting 30% less methane. Supplementation of Bovaer to dairy cattle within indoor settings has demonstrated similar results (-26%).

However, at pasture, a transient effect was demonstrated, resulting in a ~-6% reduction in methane. The most promising additive to date in beef cattle is the supplementation of calcium peroxide, in a pellet (resistant to pressure and temperature), offered twice a day, yielding a reduction of 28% with no effects on feed intake or animal productivity.

Ruminants at pasture at Teagasc Grange are able to have their methane measured through the GreenFeed system

A number of promising manure additives have been identified that reduce both methane and ammonia losses from manure storage and housing. These additives can reduce emissions by over 70% and increase the biogas yield potential of manure used as a feedstock of anaerobic digestion. Manure management technologies require further investigation to identify solutions that are practical on-farm for reducing emissions.

Future work will focus on generating methane production data from ruminants of all ages and across a range of dietary regimes to help validate breeding values for dairy, beef and sheep, as well as further refining the national GHG inventories for methane.

As further research is required to develop long lasting and sustainable feed additives for beef and dairy grazing systems, a major focus is the reformulation of promising feed additives into slow release formats that can be incorporated into once-daily concentrate supplementation or a rumen bolus for long-lasting mitigation effects during grazing. T

Getting to know

Vijaya Bhaskar

Vijaya Bhaskar is Teagasc's first integrated weed management Research Officer, based in Oak Park. Here, he explains the challenges of his role.

Hi Vijaya! Could you tell us a bit about yourself?

I'm originally from India, but I have now spent a good portion of my life in Europe, where I completed my post-grad education and post-doc assignments. Now, I live in Ireland, working as a Research Officer in integrated weed management (IWM).

IWM combines cultural control strategies, such as crop rotation, stale seedbed techniques, time of sowing and other management approaches to reduce weed pressure and avoid excessive use of herbicides.

When did you first become interested in scientific research?

Despite a non-farming background, I quickly gravitated towards agricultural science, where my curiosity in improved methods of food production was awakened. During my two master's degrees, I became interested in research and analysis, and how I could contribute to this area.

What led you to Teagasc?

I initially joined Teagasc as a contract Research Officer as part of the EIP-funded Enable Conservation Tillage grass-weed research and extension project. Following that, I had a brief period in another funded project, before becoming an integrated weed scientist as part of the Crop Science team in Oak Park.

Over the last 40 years, we have relied heavily on herbicide weed control strategies. However, loss of herbicides, due to tighter regulations, and increased herbicide resistance, has now created a production sustainability challenge. This is a great challenge that I am really excited to take on! I hope to quickly build up scientific research to contribute to sustainable agricultural production.

What does your current research focus on?

My focus is on herbicide resistance evolution in critical grass and broad-leaved weeds and implications for weed control, as well as the development of IWM suitable for our climate and cropping systems. I also work with different production and crop establishment systems.

What are your interests outside of work?

I love chess and have played at a state level. Now, I play with my wife and daughter. As a family, we are also passionate about food, especially experimenting with Michelin recipes.

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Continued support and funding from DAFM allows organisations like Teagasc to perform crucial work in the fields of agri-climate and environmental research

Funding a better future

The Agricultural and Land-Use sector is facing an unprecedented challenge to reduce greenhouse emissions and increase carbon removal activities to meet national and international climate targets. The Department of Agriculture, Food and the Marine's investment in research and development is key in meeting these challenges.

The Department of Agriculture, Food and the Marine (DAFM) is the third biggest department for government expenditure on R&D in Ireland, with agriculture, food and forestry accounting for almost 11% of the total public research support. DAFM's support is focused on public good research and, through the *Programme for Government*, is mandated to invest in research in the agri-food, forest and bio-based sectors, prioritising areas such as climate and the bioeconomy.

As a sectoral research funder, complementary to the activities of other public research funders, we have close collaboration with key agencies such as Science Foundation Ireland, the Environmental Protection Agency, the Sustainable Energy Authority of Ireland and the Health Research Board. Such collaboration is vital to ensure overall alignment of our respective roles. DAFM's own investment in research has totalled over €244 million since 2010. With the challenge of addressing agriculture's impact on climate change, more recently in the last six years, DAFM has allocated €30 million funding for research on climate, greenhouse gas emission mitigation, adaptation, inventory and climate-related co-benefit research.

Increased focus on climate and environment research

Most recently, in the Department's 2021 Thematic Research Call, almost €16 million was awarded to 14 projects in the area of climate and environment. This allocation represented 53% of the overall awards from the 2021 call, thus showing the current relevance and importance that DAFM places on research in the agri-climate and environmental research areas.

The Department is investing significantly in research to reduce greenhouse gas emissions, refine the national inventory and improve carbon sequestration from agriculture. For example, work from DAFM-funded projects such as 'GreenBreed' and 'MethAbate' have shown strong potential for a pipeline of scientific advancements that can contribute to methane emission reduction.

Similarly, a key research focus of DAFM has been improving nitrogen-use efficiency in pastures and developing reduced nitrogen input grassland systems, especially with the improved design of multispecies swards, to reduce nitrous oxide emissions. Notably, the DAFM-funded project SMARTSWARD, led by UCD, has demonstrated that cattle on multi-species swards can have significantly reduced fertiliser inputs into the pasture system, but also that the cattle can be finished to slaughter weight 34 days earlier than those on perennial ryegrass swards. Further research funded by DAFM through the Teagasc-led project Multi4More is further investigating the emissions profile of multispecies swards; with both these projects feeding into key measures of the recent Teagasc Marginal Abatement Cost Curve (MACC) that includes to reduce to reduce finishing age at slaughter and reduce nitrogen fertiliser inputs.

As well as building on investments in existing research areas, there has been a focused movement towards increasing investments in research on land-use management, water table management and soil organic carbon to improve carbon sequestration, reduce land emissions to the atmosphere and to feed into national inventory refinements, building on the Department's National Agricultural Soil Carbon Observatory investment.

Words by: John Harrison, Programme Manager Environment and Climate Research, Department of Agriculture, Food and the Marine.
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Events: my take-home message

Teagasc's researchers attend many events throughout the year, sharing the findings from their research with national and international audiences. Here, we capture the take-home messages – key pieces of information that our researchers want people to remember – from recent events.

Data-driven GHG inventories

Event: EAAE Congress, Rennes, France
Date: 29 August to 1 September 2023

The agricultural sector in the Republic of Ireland (ROI) accounts for 37.5% of total greenhouse gas (GHG) emissions and 99.4% of total ammonia (NH_3) emissions. National inventory-based estimations of GHG and NH_3 emissions are a function of activity data multiplied by an associated emission factor. The emissions factors used rely on scientific experiments to provide estimates of emissions from animals, chemical fertilisers or manure management practice at different levels of granularity.

Cathal Buckley, a Senior Research Officer in Teagasc's Agricultural Economics and Farm Survey Department, explains: "In the ROI we tend to rely on aggregate-level activity data for national inventory accounting purposes. However, this doesn't exist in relation to important farm-level activity data that can influence GHG and NH_3 emissions. For example, how animal manure is stored, the method of storage, the duration animals are housed versus grazing outdoors and when and how slurry manure is applied can all have a significant impact on GHG and NH_3 emissions."

Cathal was speaking at the European Association of Agricultural Economists 2023 conference recently about how Teagasc is using Teagasc National Farm Survey (NFS) data to obtain better calculation of actual emissions that have been used to inform the national inventories.

Cathal says: "Until recent times, a farm survey dating back to 2003 for manure management activity data was used for activity data in this area. This research uses Teagasc NFS data to generate updated manure management activity data for modelling national GHG and NH_3 inventories and explores the changes in emissions associated with its use. Results indicated NH_3 emissions are between 7 to 18% lower (between 2017-2121) by using the updated activity data, results are less conclusive for GHG emissions."

Cathal Buckley's poster on the use of the National Farm Survey for calculating GHG emissions received great interest

GIANT LEAPS in reshaping nutrition

Event: EU GIANT LEAPS meeting, Barcelona, Spain
Date: 6 to 8 September 2023

The footprint of our food system can shrink as consumers move from animal-based proteins to alternative food proteins— what experts call the dietary shift. The EU-funded project GIANT LEAPS aims to support and accelerate this dietary shift by generating tangible scientific information on palatable, safe, sustainable and nutritious alternative protein sources.

One year done, three more to go! GIANT LEAPS is now fully operational and the first project review took place in Barcelona, Spain, recently.

Teagasc researchers André Brodkorb and Linda Giblin are leading the largest work package, *Digestion and Health*, with an international team of researchers, post doctorates and PhD students from seven countries across four continents. To date, 20 ingredients from eight protein sources were tested: microalgae, rapeseed, oats, fava beans, lentils, chickpeas, crickets and microbial proteins.

Ever Hernandez Olivas, a post-doctorate scientist based in the Teagasc Food Research Centre, Moorepark, who also attended, explains: "We simulated the gastro-intestinal digestion of proteins in the laboratory. The digestibility can vary greatly from protein to protein. Animal-derived proteins are of high quality and generally highly digestible, i.e. over 95% of the consumed protein is absorbed and utilised by the human body."

Ever elaborates: "Some of the tested protein have a digestibility as low as 60% and may also be deficient in some essential amino acids, which would make it a poor quality protein source."

Teagasc researchers, along with their GIANT LEAPS collaborators, aim to improve the quality of these proteins and compile the information as a nutritional passport for each protein source.

Attendees at the GIANT LEAPS meeting in Spain

Don't miss out on Teagasc's upcoming events! Visit our website to see what we have planned: www.teagasc.ie

Transforming green to gold: the alchemy of Irish cheese

In Ireland, cows generally graze upon ryegrass monocultures. Multispecies swards offer benefits by increasing biodiversity and reducing costly chemical inputs through natural nitrogen fixation. This research investigates the nutritional and techno-functional consequences within cheese when applying multispecies grazing. Potential differences in cheese made from multispecies systems need to be better understood in terms of dairy processing and potential health impacts.

Photo and description by:
Richard Page
Teagasc project:
FutureMilk 2025 – Understanding the impact of next generation dairy breeding strategies and multispecies pasture diets on the nutri-functional quality of Irish milk.