TResearch

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SHADOW WAGES
Increasing the value of labour on family farms

LEAF NO WASTE
Future-proofing food packaging and food waste

MIXED FARMING
Ensuring farming systems stay sustainable

BACK IN TIME: 20 years of agri-food industry contributions p28

Teagasc's campaign to improve the status of all waterbodies across Ireland

Water-course correction

Teagasc
Agriculture and Food Development Authority

Welcome

Protecting the quality of our water is the cornerstone of a sustainable farming system. In recognition of this, Teagasc recently launched the campaign *Better Farming for Water – 8-Actions for Change*. Building on Teagasc initiatives, such as the Agricultural Catchments Programme and the Agricultural Sustainability Support and Advisory Programme, this campaign brings together a range of stakeholders to support farmers in implementing solutions to address the water quality in their catchment. From a practical perspective, the campaign focuses on eight actions that farmers can undertake on their farms to improve water quality.

Aligning with these actions, Teagasc researchers are developing farm-scale measures to break pollutant pathways and reduce nutrient and sediment runoff into waterbodies. On p12, Karen Daly, Owen Fenton and Patrick Tuohy discuss the practical measures being undertaken by farmers to help achieve this.

We meet researcher Daire Ó hUallacháin for our one-to-one interview. His work focuses on assessing the impact of excessive sediment and nutrients on aquatic ecosystems and identifying cost-effective mitigation measures to improve water quality. Find out more on p16.

In 'A Look Ahead' on p38, Pat Dillon and Pat Murphy explain how the *Better Farming for Water* campaign will be crucial to meeting objectives under the Water Framework Directive.

They explain that clean water is a critical part of nature and human wellbeing. They say it is also a crucial resource for many economic sectors and that agriculture needs a constant supply of fresh, clean water for animals, crops and food processing.

By investing in sustainable farming practices and water management technologies, we can secure a future where agricultural productivity and water quality go side-by-side. We hope you enjoy finding out more about how we can protect this crucial resource in this issue.

Catriona Boyle
Editor, *TResearch* magazine, Teagasc

Tá cosaint ár gcáilíochta uisce ina bunchloch le córas feirmeoireachta inbhuanaithe. Mar aitheantas air sin, sheol Teagasc an feachtas Feirmeoireacht Níos Fearr don Uisce – 8 nGníomhaíocht le haghaidh Athraithe le déanaí. Ag tógáil ar thionscnaimh de chuid Teagasc, amhail an Clár um Dhobharcheantair Talmhaíochta agus an Clár Tacaíochta agus Comhairle don Inbhuanaitheacht Talmhaíochta, tugtar le chéile leis an bhfeachtas sin réimse páirtithe leasmhara chun tacú le feirmeoirí réitigh a chur chun feidhme chun aghaidh a thabhairt ar cháilíocht an uisce ina ndobharcheantar. Ó dhearcadh praiticiúil de, dírítear an feachtas ar ocht ngníomhaíocht ar féidir le feirmeoirí a dhéanamh ar a bhfeirmeacha chun cáilíocht an uisce a fheabhsú.

Ag teacht leis na gníomhaíochtaí sin, tá bearta á bhforbairt ag taighdeoirí de chuid Teagasc ar scála feirme chun bealaí truailleán a bhriseadh agus rith chun srutha cothaitheach agus dríodair isteach i ndobharlaigh a laghdú. Ar lch. 12, pléann Karen Daly, Owen Fenton agus Patrick Tuohy na bearta praiticiúla atá á ndéanamh ag feirmeoirí chun cuidiú leis sin a bhaint amach.

Bhuaileamar leis an taighdeoir Daire Ó hUallacháin dár n-agallamh aghaidh ar aghaidh. Díríonn a chuid oibre ar mheasúnú a dhéanamh ar thionchar an iomarca dríodair agus cothaitheach ar éiceachórais uisceacha – agus ar bhearta maolaithe costéifeachtacha chun feabhas a chur ar an gcáilíocht uisce a shainaithint. Faigh tuilleadh eolais ar lch. 16.

In 'A Look Ahead' ar lch. 38, míníonn Pat Dillon agus Pat Murphy conas a bheidh an feachtas Feirmeoireacht Níos Fearr don Uisce ríthábhachtach chun cuspóirí faoin gCreat-treoir Uisce a bhaint amach.

Míníonn siad go bhfuil uisce glan ina chuid ríthábhachtach den dúlra agus d'fholláine an duine. Deir siad gur acmhainn ríthábhachtach é freisin do go leor earnálacha eacnamaíocha agus go dteastaíonn soláthar leanúnach uisce úir ghlain d'ainmhithe, do bharra agus do phróiseáil bia ó thalmhaíocht.

Trí infheistíocht a dhéanamh i gcleachtais feirmeoireachta inbhuanaithe agus i dteicneolaíochtaí bainistíochta uisce, is féidir linn todhchaí ina mbeidh an táirgiúlacht talmhaíochta agus cáilíocht uisce taobh le chéile a chinntiú. Tá súil againn go mbainfidh tú sult as tuilleadh eolais a fháil faoi conas is féidir linn an acmhainn ríthábhachtach sin a chosaint 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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Main image shows Teagasc Senior Research Officer Daire Ó hUallacháin in the River Funshion, Fermoy, Co. Cork.

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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. Teagasc's four research programmes, frequently referred to by their acronyms, are: Animal and Grassland Research & Innovation (AGRIP); Crops, Environment and Land-Use (CELUP); Food (FOOD); and Rural Economy and Development (REDP).*

High-level visit exploring sustainable farming

Anne Kinsella, Qu Dongyu, Brendan Dunford and FAO Deputy Director of Cabinet, Hua Yang

A high-level visit to the West of Ireland by Qu Dongyu, Director General of the United Nations Food and Agriculture Organisation (FAO), came about as a result of an article, 'Where farming and biodiversity unite', published in last year's *TResearch* autumn issue. The article featured the BurrenLIFE project, which ran between 2005 and 2010 and developed a new model for the sustainable agricultural management of the priority habitats of the Burren region.

Qu Dongyu and his colleagues made contact with its lead author, Teagasc research economist, Anne Kinsella, to arrange a visit for a delegation to Ireland and observe sustainable farming in the Burren. The visit also took in Kelly's Oyster Farm, the University of Galway and the Cliffs of Moher.

Anne Kinsella and Qu Dongyu FAO with the *TResearch* article that led to the visit

Along with her co-author on the article, Brendan Dunford, BurrenLIFE Programme Consultant, Anne accompanied the group on their tour of the Burren, where Brendan showcased the unique landscape and gave a most informative overview of the unique flora and sustainable farming in the region. The delegation also visited Poulnabrone Dolmen and the Cliffs of Moher. Anne also engaged with a local artisan food producer in selecting a showcase of local produce from land and sea.

FAO

Better Farming for Water campaign

Teagasc aims to support and accelerate the adoption of actions on all farms to improve waterbodies to good or high ecological status.

Better Farming for Water 8-Actions for Change

8-Actions for Change:

Nutrient management

1. Reduce purchased nitrogen (N) and phosphorus (P) surplus per hectare
2. Ensure soil fertility is optimal for lime, phosphorus and potassium
3. Ensure application of fertiliser and organic manure at appropriate times and conditions

Farmyard management

4. Have sufficient slurry and soiled water storage capacity
5. Manage and minimise nutrient loss from farmyards and roadways

Land management

6. Fence off watercourses to prevent bovine access
7. Promote targeted use of mitigation actions such as riparian margins, buffer strips and sediment traps
8. Maintain over-winter green cover to reduce nutrient leaching from tillage soils

Reeling in the years


Attendees at the Oak Park open day

Finbarr O'Rourke

Visitors from far and wide visited Teagasc Oak Park recently, as 60 years of agricultural innovation were celebrated at the Teagasc Crops Research Centre and Head Office.

Described by attendees as "a journey through time", the event showcased machinery from both today and yesteryear to illustrate the advancements in mechanisation, work rates and safety that have occurred over the last six decades.

With the winter harvest commencing across the country, visitors both young and old saw first-hand how combining technology has changed; moving from an era of tractor-drawn threshers to the GPS-guided machines of today – rekindling fond memories for some and providing a snapshot of history for those of a younger vintage. Additionally, given its proximity and close ties to the sugar beet industry, the open day showcased how beet harvesting equipment has changed.

Visitors got to meet our scientists and find out about their work in potato breeding, cereal diseases, brewing and distilling, the Teagasc Signpost Programme, the Teagasc *Better Farming for Water* campaign, along with other research ongoing in the areas of cereals, apple production and forestry.

Visitors to the open day had the opportunity to take a tour of Oak Park House, visit the museum and learn about the history of the estate.

Farming for a better future

Staff at the Teagasc Soil, Environment and Land Use Research Centre, Johnstown Castle, recently welcomed visitors to their open day, focusing on 'Resilient and Sustainable Farming Systems'. The event was designed to help farmers deal with the many challenges facing the sector, such as changing weather patterns, price volatility, and policy changes, to name but a few.

Karen Daly, acting Head of the Centre, explains: "Many of the technologies and farm practice strategies on show will help farmers maintain productivity while increasing the profitability and environmental sustainability of their family farm businesses. These include multispecies and grass-white and red clover swards, grazing and silage conservation management, sustainable fertiliser technologies and organic manure management, winter and spring dairy cow management and nutrition, dairy-beef and organic beef finishing production systems, animal health, tillage soil management and farm planning."

David Wall, Enterprise Leader, Johnstown Castle, adds: "Reducing gaseous emissions, protecting water quality, enhancing biodiversity and soil health to reduce the environmental footprint of grassland and tillage production systems will be essential to maintain the competitiveness and sustainability of Irish farms and the agricultural and food sector."


Karen Daly and David Wall welcome visitors

Patrick Browne

News in brief

Calf welfare funding welcomed

Teagasc was delighted to receive €22.3 million in research funding for 21 new projects following the announcement of successful projects from the Department of Agriculture, Food and the Marine's 2023 funding call. One of these projects was WELCalf – a research project aiming to improve the health and welfare of calves born on dairy farms.

Led by Emer Kennedy, Senior Researcher in Teagasc Moorepark, the collaborative project between Teagasc, University College Dublin and the Irish Cattle Breeding Federation will focus on the health and welfare of calves that remain on their farm of origin, move to beef farms or travel to other EU member states.


Awardees with Minister Martin Heydon

DAFM

FLIARA champions women's innovations

The FLIARA Project, of which Teagasc is a partner, recently celebrated its inaugural Community of Practice event at the University of Galway, bringing together passionate individuals dedicated to supporting and accelerating women-led innovation in rural areas.

FLIARA, or Female-Led Innovation in Agriculture and Rural Areas, is a Horizon Europe project aimed at creating a European-wide rural innovation ecosystem. The project focuses on enhancing the recognition and support of women's contributions to agriculture through a robust network and a high-impact visibility campaign.

The FLIARA Project's consortium has conducted extensive case studies, identifying 200 innovative practices across ten European countries: Ireland, the Netherlands, Germany, the Czech Republic, Slovenia, Sweden, Finland, Spain, Romania and Italy. From this impressive pool, 20 FLIARA ambassadors have been chosen. During the first Community of Practice event, the initial group of six ambassadors were presented to a wider audience and stakeholders.

Reduce Methane Emissions

Circular Food System

MASTERing food chain microbiomes

The Teagasc-led, EU-funded project MASTER focused on harnessing food chain microbiomes to benefit the global agri-food industry by improving the quantity, quality, safety and sustainability of foods.

The microbiomes that exist all around and inside us hugely impact our health and wellbeing, and that of the animals, crops and environments that contribute to our food supply. The project Microbiome Applications for Sustainable food systems through Technologies and EnteRprise, or MASTER, used DNA sequencing and other technologies to identify and improve microbiome-related applications throughout the food chain.

The 29-partner MASTER team was based across 14 countries, and included research organisations, large industries and SMEs in the soil, crop, marine, animal, food and human health spaces. The €10.9 million project was coordinated by Teagasc Senior Principal Research Officer, Paul Cotter, assisted by Senior Research Officers Fiona Brennan and Sinéad Waters, Project Manager Mairéad Coakley and research teams across Teagasc programme areas Food, CELUP and AGRIP.

Fertile ground

Soil microbes play a vital role in food production by supporting crop health and maintaining our planet's ecosystems. With the transition to carbon-neutral farming, a major challenge is maintaining productivity while reducing fertiliser inputs that can have negative environmental impacts. Microbial bioinoculants, microbes that enhance plant health and growth, have been proposed as an alternative to chemical fertilisers. However, their effectiveness in grasslands was not previously well-understood, explains Fiona.

"In MASTER, we tested the efficacy of various bioinoculants in both pot and field trials on ryegrass, ryegrass with clover, and mixed-species grassland swards. We found that soil fertility significantly affected the ability of mycorrhizal bioinoculants, fungi that form mutually beneficial associations with plants, to colonise plant roots."

Although bioinoculants could persist in the soil for over a year, they generally had no significant impact on yield and nutrient uptake, bar a few exceptions, Fiona continues.

"Our research showed that, under field

"The harnessing of these research outputs has the potential to bring about transformational changes in agri-food over the coming years."

Rumen gut microbes play a pivotal role in enteric methane production

Andrew Downes

MASTER researchers created a unified approach to the analysis of food chain microbiomes

AV Star Systems

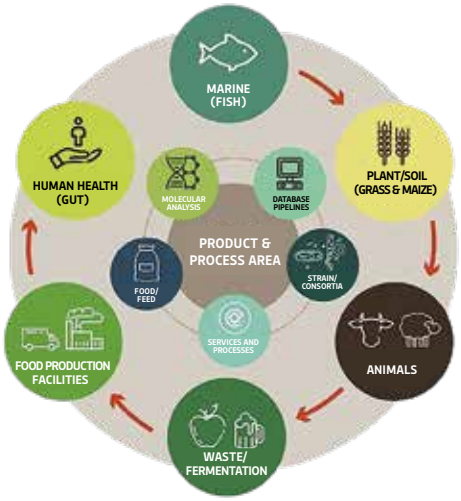
conditions, diversifying grasslands by including legumes and herbs – and thereby harnessing the indigenous microbial community – was a far more effective strategy for enhancing forage yield and nutrient uptake than using microbial inoculants. This approach proved to be a better farm-scale management strategy for sustainable agriculture, supporting both productivity and environmental health."

Gut feeling

Rumen microbes, which reside in the gastrointestinal tract of ruminant animals such as cattle and sheep, play a pivotal role in animal production through the digestion of feed and in the production of enteric methane, a by-product of ruminants' natural digestive process. Research during MASTER involved establishing the rumen microbial composition of a large number of animals, including 1,600 cattle (mainly beef from a range of breeds) and over 150 sheep (breeds of Cheviot, Connemara, Lanark & Perth).

Research then focused on their role in improving animal production and reducing environmental impact, through the manipulation of these rumen microbiomes. MASTER identified residual methane emissions as a good trait to exploit inter-animal variation in enteric emissions, and to investigate underlying biological regulatory mechanisms related to the rumen microbiome.

Sinéad explains, "Throughout MASTER, methane, rumen microbiome and performance data was collected on a continual basis, leading to the accumulation of data from 1,600 beef cattle. Our data contributed to the development of the world's first genetic methane evaluation for the selection of beef cattle with lower methane emissions.



"Enteric methane emissions is a trait which is moderately heritable and, as such, selective breeding strategies offer promising solutions for producing animals that are less methane-intensive and more environmentally friendly. These solutions are long-lasting and cumulative."

Food for thought

During MASTER, a sampling campaign was completed at 114 food industries across Europe, with 15 of these undertaken in Ireland by Teagasc. MASTER researchers created a unified approach to the analysis of food chain microbiomes via DNA sequencing; these standardised methods are available on the project website. This approach allows the rapid and accurate analysis of all microbes present in food chain samples, including unknown or overlooked aetiological and spoilage agents. Demonstration activities were since completed for over 200 European food companies who may wish to employ this technology in the future. Its use is facilitated by the fact that one of the MASTER partners is developing, for commercial release, an associated DNA extraction kit designed for food processing industry use.

The microbiome-related data generated through this sampling campaign was deposited in a curated database and it, and the computational pipelines that can be used to analyse this data, are now freely available to be exploited by the scientific community, food producers, food processors, regulators and consumers.

MASTER researchers used DNA sequencing technologies to investigate the microbiomes of food systems and mined microbiome data relating to food chains; developed big data management tools to identify relationships between microbiomes across food chains; and generated applications which will promote sustainability and circularity. A variety of technologies, microbial strains, foods, food ingredients, feeds, procedures and computational approaches were developed in parallel, Mairéad notes.

"Over 80 research outputs have been published to date from the MASTER team, with 21 innovative outputs currently featured on the EC's Innovation Radar platform, an initiative to identify high potential innovations and innovators in EU-funded research and innovation projects. The harnessing of these research and innovative outputs has the potential to bring about transformational changes in agri-food over the coming years." T

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Teagasc

Under the shadow

Research conducted by Teagasc and the University of Galway has estimated the economic value – or shadow wage – of farm family labour on Irish dairy farms, highlighting the critical role of agricultural education in increasing its value.

Agriculture, a cornerstone of the Irish economy, is at something of a crossroads as it strives to achieve sustainability and food security goals amid emerging challenges in a changing policy environment. One such challenge is the currently constrained nature of the labour market. This is putting pressure on dairy farms because of the limited supply of, and uneven demand for, labour throughout the year due to the seasonality of production and the spring-calving system.

This challenging situation highlights the necessity of family labour in ensuring the continued viability and resilience of farms.

New research by Teagasc and the University of Galway is helping to improve understanding of the interdependence between family and hired labour supply and demand. It reveals the fundamental importance of formal agricultural education in increasing the economic value of family labour.

Meeting labour needs on family farms

Across the Irish dairy sector, the expansion in milk production since the end of the EU quota in 2015 has been facilitated by both increased labour input and the adoption of new labour-saving technologies on farms.

Additional labour requirements on family farms have been met by both family and hired labour. Challenges in sourcing labour, and the seasonal nature of labour demand, require effective labour management strategies in combining family and hired labour where needed.

This new research explores the value of farm family labour and the extent to which it can be substituted with hired labour if available through the estimation of a shadow wage for family labour.

Shadow wage and FFI

A *shadow wage* is the hypothetical or implicit wage rate that reflects the value of labour provided by individuals not formally compensated for their work. It is the economic value of unpaid labour, such as household work, family labour on farms or voluntary work in community organisations. Specifically, the concept of shadow wages arises because these unpaid types of labour do not have a market-determined wage rate. As a result, economists use shadow wages to assign an economic value to this unpaid labour, allowing for more accurate assessments of economic activity and welfare.

***Farm Family Income (FFI)* is defined as gross output less total net expenses and represents the total return to family labour, management and capital investment in the farm business.**

Calculating the shadow wage

The study by Teagasc and the University of Galway estimates the shadow wage of family labour on Irish dairy farms using data from the National Farm Survey (NFS), which operates as part of the EU Farm Accountancy Data Network (FADN).

In the NFS, in line with FADN methodology, farm family labour is technically referred to as being unpaid with the return to labour accounted for in the definition of Farm Family Income (FFI).

Emma Dillon, Senior Research Officer at Teagasc, explains: "To obtain the shadow wage measure, we use a concept from economics called a production function. This assumes that the amount of farm output – milk and calves, for instance – depends on several factors: capital – money and equipment; labour – paid and unpaid hours; land; and other miscellaneous inputs. Each of these factors contributes a certain percentage to the total value of farm output, which is referred to as the production coefficient."

The focus of the study was on investigating the unpaid labour element of production.

"To do this," Emma continues, "we determine how much each hour of unpaid family labour adds to the value of farm output. This calculated value is known as the shadow wage of labour."

The seasonal nature of labour demand on dairy farms requires effective labour management

monkeybusinessimages/istockphoto.com

Results of the study

Using data from 2019, the research suggests that the average shadow wage of farm family labour (including for the main operator) was €30.97 per hour.

It was observed that, as farm size increases, so does the shadow wage. For smaller farms (<43 cows), which represent the first quartile (the 25% smallest farms), the shadow wage is €12.17, and for larger farms (>86 cows), which represent the third quartile (the 25% largest farms), the shadow wage is €43.94.

The relatively lower shadow wage highlights the additional challenges that small farms may face in terms of financial viability given the relatively poorer return compared to larger farms.

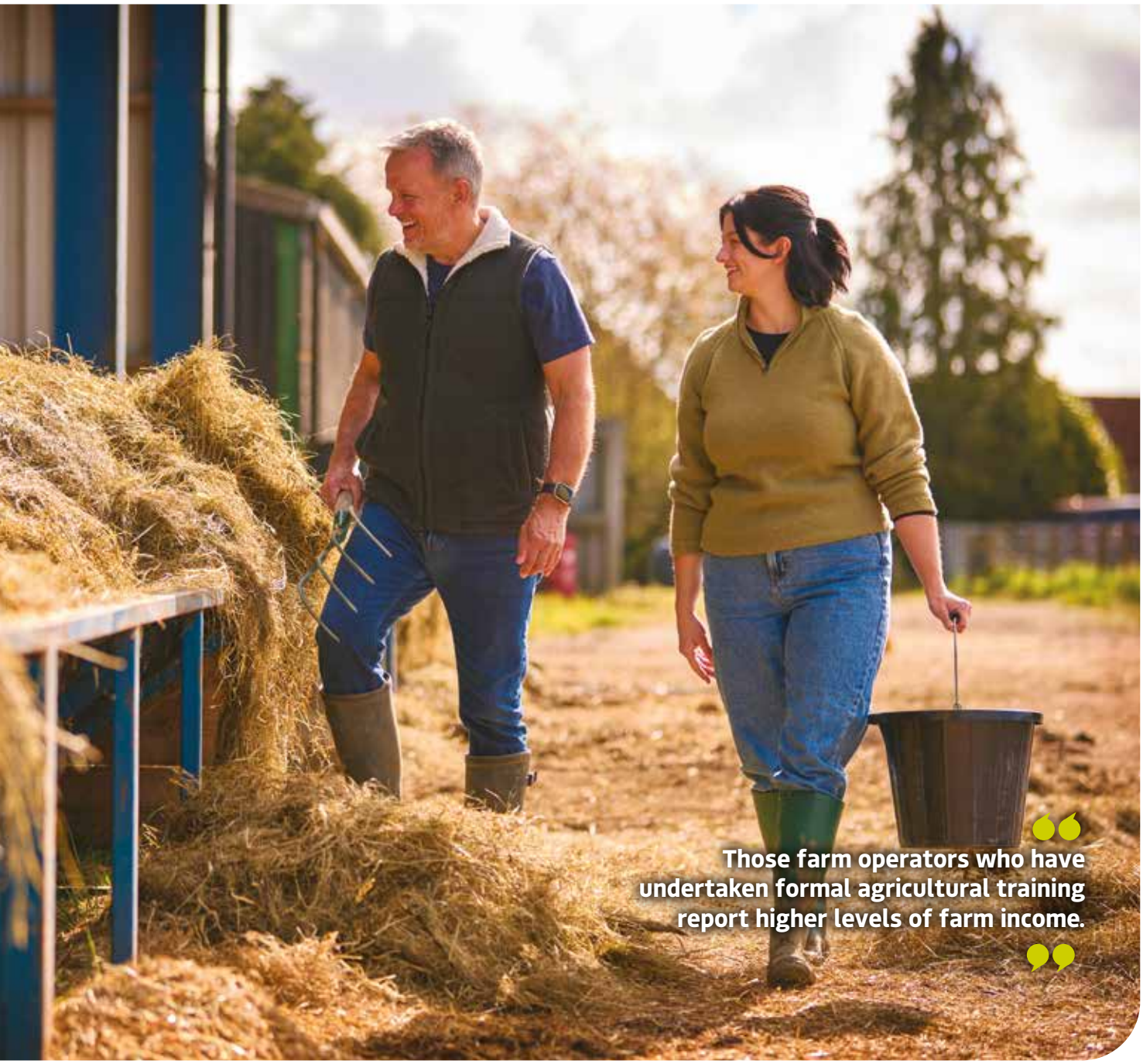
In addition, the findings indicate that agricultural education influences the value of the shadow wage. The average shadow wage of farmers with formal agricultural education is almost twice that of those without, at €34 and €19 respectively. Consequently, the return of agricultural education on shadow wages is approximately €15 per hour.

Furthermore, Figure 1 (p.10) illustrates that the returns to family labour increase as the level of agricultural education increases. Our research therefore highlights the role of the level of agricultural education in enhancing farm viability as those farm operators who have undertaken formal agricultural training report higher levels of farm income.

Increase in demand for hired labour

In recent years, there has been a significant increase in the proportion of hired labour on Irish dairy farms following the abolition of milk quotas in 2015.

Luis Garcia-Covarrubias, a Postdoctoral Research Associate at University of Galway, says: "This policy change allowed farms to expand their operations, and that resulted ▶



"Those farm operators who have undertaken formal agricultural training report higher levels of farm income."

in a heightened demand for labour beyond family resources. As dairy herd sizes grew, the reliance on hired labour increased on some farms to meet the higher operational demands.

"Our findings suggest that this shift has been due to the economic concept of shadow wages, which in turn influences the decision-making process regarding the employment of additional labour."

Specifically, as shadow wages increase, so too does the demand for hired labour, indicating that, on average, family and hired labour act as substitutes on Irish dairy farms. This substitution effect is more pronounced for casual hired labour compared to permanent hired labour.

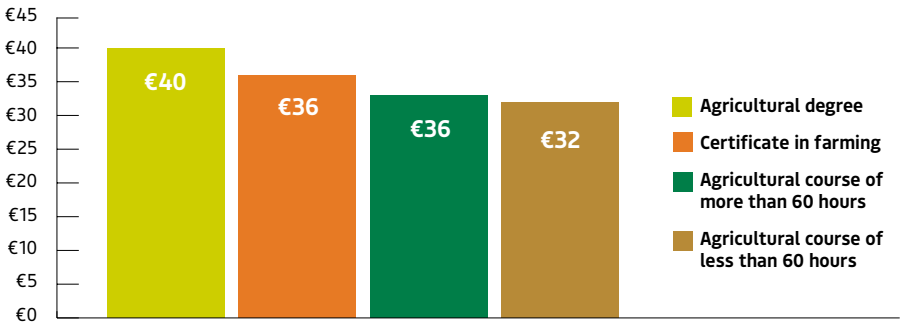
Fiona Thorne, Teagasc Principal Research Officer, says: "The substitution of family labour with hired labour allows farmers and their family members to dedicate more time to other management operations on the farm, enhancing overall farm efficiency. During vacation periods or over less intensive months, casual hired labour can take over, ensuring the continuity of farm operations without overburdening family members."

This strategic labour allocation not only optimises resource use, but also supports better work-life balance for farming families, which may lead to improved farm management and productivity.

"This insight makes intuitive sense given the demand for casual labour is highest during the peak workload period in the spring," Fiona continues. "The presence of such labour then allows the farmer to occupy a more managerial role or even perform some off-farm work if needed.

"With the substitution effect being less pronounced for more permanent labour, farmers can thus allocate tasks to those workers more similar to the ones previously performed by family labour."

Figure1. Shadow wage of family labour and agricultural education level



Note: A further 3% of farmers did not specify the formal agricultural education they had undertaken and are thus not included in these categories.

€30.97

The average shadow wage of farm family labour per hour (2019).

Impact on policy

The research findings have important implications for policymaking. Dairy farmers are navigating significant changes, being required to meet the ambitious sector targets identified in the Irish Climate Action Plan 2024 and the EU Climate Target Plan 2030.

"This research highlights the contribution of agricultural education," says Emma, "particularly in the context of the rapid technological and sustainability challenges affecting the dairy sector. Our findings support the idea that policies to increase formal agricultural education for farmers are essential for the farms' viability and the industry's future."

In Ireland, several policy tools aim to modernise and promote the viability of the dairy sector. However, these programmes require a minimum level of formal agricultural education to qualify. For instance, the CAP Strategic Plan contains a targeted scheme for younger farmers. The scheme focuses on supporting generational renewal in agriculture through financial support. To apply to the scheme, it is a requirement for the farmer to complete a recognised agricultural education course equivalent to the Further Education and Training Awards Council Level 6. Therefore, the team recommends the continued support, through policy incentives, for agricultural education.

Similarly, an improved understanding of the supply and demand dynamics between family and hired labour can help inform more effective labour management strategies, and policies to support farmers, essential for the long-term viability of the dairy sector. Initiatives that incentivise and attract workers to employment opportunities in the agricultural sector should be supported.

In addition, smaller farms – and those not traditionally using or requiring hired labour – may need financial and logistical support to hire labour. Targeted policies to support smaller farms to hire extra labour during busy seasons, especially in the first few months of the year, would be beneficial – especially for those farms with an aging operator profile where there may be workload challenges.

This effort would help smaller farms meet peak labour demands and ensure their continued viability in the dairy industry.

The findings of this research provide a compelling direction for future research in this area, particularly in the context of supporting the long-term sustainability and intergenerational transfer of farms. T

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Ministers Malcolm Noonan (left), Pippa Hackett and Charlie McConalogue at Lough Ennel for the launch of the Farming for Water EIP

Measuring up

Locally led water stewardship is following catchment science principles and focusing on water quality with multiple benefits.

Water quality supports the variety and quality of life in Ireland. Our international reputation as a producer of sustainable food depends on an abundance of clean water. However, there are many challenges to protecting water quality. Ireland's River Basin Management Plan provides the roadmap to achieve this. Approximately half of our estimated 4,810 waterbodies don't meet required objectives, and the agriculture sector exerts significant pressure on national waterbodies. Potential solutions require an understanding of the sector and its issues, and the development of measures that are fit for purpose.

Farming for Water (EIP) is a €60 million European Innovation Partnership project, running until the end of 2027. It aims to support farmers in placing "the right measures in the right place" by taking a targeted approach to managing risk to water quality from their farms. It is guided by the learnings of Teagasc's Agricultural Sustainability Support and Advisory Programme. Key among these learnings is the need to provide financial support for farmers to implement recommended measures.

Words by: Fran Igoe, Regional Coordinator at the Local Authority Waters Programme
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The project follows catchment science principles but puts farmers at the forefront of co-design and implementation of measures. Taking a multi-benefit approach, it focuses on water quality alongside biodiversity and climate issues. The project is a partnership led by the Local Authority Waters Programme, Teagasc and Dairy Industry Ireland and was established in response to the sixth competitive call by the Department of Agriculture, Food, and the Marine for proposals under the EIP initiative.

This call specifically focused on reducing losses of phosphorus, nitrogen, sediment and pesticides to water from agricultural lands. To do so, principles of integrated catchment science are followed, promoting the adoption of innovative best practice in nutrient management, the application of nature-based natural water retention measures and other suitable measures at farm level.

Farmer-first philosophy

The project aims to involve up to 15,000 farmers across Ireland; entry to the scheme will be prioritised to areas identified under the River Basin Management Plan as 'Priority Areas for Action'. There are over 40 measures applicable, addressing risk from phosphorous, sediment and pesticides. Nitrogen surplus use is addressed, providing support to farmers to increase their nitrogen use efficiency and reduce loss to water.

A key philosophy is to examine issues from a farmer's perspective, applying catchment science and practical advisory knowledge to develop solutions that work for a particular farm. The development of a rainwater management plan will assist in working out where best to place the measures. Crucially, nature-based approaches will also help make farms more climate-resilient.

The project's vision is to support and facilitate the application of locally-led water stewardship, following catchment science principles and focusing on water quality, climate and biodiversity. This will be done through championing project actions, integrating project learnings into sustainability initiatives and ensuring that the work programme is supported at every stage in the delivery process.

A Farming for Water EIP research hub has also been established, to facilitate the participation of research institutes across Ireland, to address research questions and to support project validation. T

Supporting Policy

Slowing down to get ahead

In-drain measure to slow the flow of water in surface open drains in farm landscapes

With agriculture putting a strain on water quality, Teagasc researchers are developing farm-scale measures to break pollutant pathways and reduce nutrient and sediment runoff into waterbodies.

Agriculture is putting significant pressure on water quality. The challenge is to connect national trends to local improvement efforts, particularly at farm level. Researchers at Teagasc have been working on water quality measures that could prevent nutrient and sediment from areas around farms infiltrating streams and rivers.

Water that flows across or drains through the farm landscape can carry nutrients, sediment and pesticides, causing problems when they enter local rivers, streams and groundwater bodies. When this occurs multiple times, the potential effect is a decline in water quality or, at best, no signs of improvement.

The campaign *Better Farming for Water - 8 Actions for Change* is a multi-actor initiative bringing research, advisory and policy professionals together with farmers to improve water quality and identify the measures and actions needed at local level. The campaign's actions (see p.13) can be adopted at farm-scale to deliver improvements at waterbody scale.

Some of the simple but effective measures being developed by Teagasc include slowing the flow of water and breaking the pathway between sources of pollutants and delivery points to the stream, explains Principal Research Officer Karen Daly.

"This concept works well on features such as farm roadways and surface drainage ditches, which often act as networks or arteries around the farm that move sediment and water to small streams and rivers."

Slowing the flow

Many farms are built on a complex network of in-field pipe or mole drains connecting with a surface open-ditch network, sometimes connected to a farmyard and discharging directly to surface waters or a drainage outlet.

Road camber installed on farm roadway breaks the pathway and diverts runoff into neighbouring fields

"Traditionally," says Karen, "in-field drains and surface open ditches were seen as a fully connected system installed to quickly remove excess water off the farm. To protect water quality, we need to understand the corridors for water movement on the farm that might bring pollutants with it."

Teagasc

> **To protect water quality, we need to understand the corridors for water movement on the farm that might bring pollutants with it.**

Open drainage ditches occur more frequently in low-lying areas prone to waterlogging as a result of low permeability soils or where the water table is shallow. Surface drainage ditches typically occur as boundary ditches between fields on the farm connected at an outflow and which carry water directly to a stream or river. Drainage ditches can quickly move excess water away from agricultural land, roads and yards and potentially transport sediment and nutrients.

This type of drain poses the greatest risk for transporting nutrients, says Karen. "In some cases, these can also drain across the farm boundary through neighbouring land. These 'connected' ditches aim to prevent waterlogging. However, if we can avoid contaminants such as nutrients and pesticides from entering these ditches, water quality in the receiving streams will be protected."

The actions for these features include in-ditch, pathway-control measures to mitigate nutrient loss by breaking the pathway between the farm and the waterbody. In general, these measures aim to slow the flow of water so that the nutrient and sediment being carried by the water is dropped, and to allow nitrogen and phosphorus to be attenuated. These include sediment traps, such as a small dam feature installed within the surface open drain, and sediment ponds to allow water to pond and settle out sediment and attenuate nutrients. It's important that installed measures are maintained and cleaned out, otherwise they risk nutrients such as phosphorus accumulating in the sediment settling in the pond.

Breaking the pathway

There is little research in Ireland on the composition, pathways and impacts of roadway runoff entering waterbodies. Solutions to halt roadway runoff entering streams are also part of the research at Teagasc.

The dominant nutrient losses are from fresh animal deposits, but another source stems from nutrients stored in the roadway materials themselves. During the closed period when animals are housed, high concentrations of nutrients can be washed out of roadway materials during rainfall all year round, and runoff from farm roadways can negatively impact water quality.

To help reduce the soiling of runoff waters, key intervention points on farmyards have been identified, including a 100-metre radius around the farmyard; underpasses and waiting areas associated with underpasses; and water troughs along roadways, roadway junctions or anywhere that impedes animal movement. Connectivity with water can occur directly – runoff into drains, rivers, lakes, etc. – or indirectly, for example on farmyards. Targeted mitigation aims to break the connectivity between the nutrient source on the roadway and waters. Examples include cambering roads towards fields, diversion bars or berms to direct runoff away from open waters, and moving entry points to paddocks away from the water course to reduce sediment or nutrient entering.

In conclusion, our research shows that by adopting measures such as slowing water flow and disrupting pollutant pathways, farms can significantly reduce nutrient and sediment runoff – and the collective effort at local level can enhance water quality on a broader scale.

If every farm takes one or two actions from the *Better Farming for Water* campaign, including slowing the flow and breaking the pathway, we can move the dial at national level and get ahead of our water quality targets. T

A sediment pond intercepting nutrients and sediment in the farm landscape

Better Farming for Water campaign

8-Actions for Change

1. **Reduce purchased nitrogen and phosphorus surplus per hectare.**
2. **Ensure soil fertility is optimal for lime, phosphorus and potassium.**
3. **Ensure application of fertiliser and organic manure at appropriate times and conditions.**
4. **Have sufficient slurry and soiled water storage capacity.**
5. **Manage and minimise nutrient loss from farmyards and roadways.**
6. **Fence off watercourses to prevent bovine access.**
7. **Promote targeted use of mitigation actions such as riparian margins, buffer strips and sediment traps to mitigate nutrient and sediment loss to water.**
8. **Maintain over-winter green cover to reduce nutrient leaching from tillage soils.**

FUNDING

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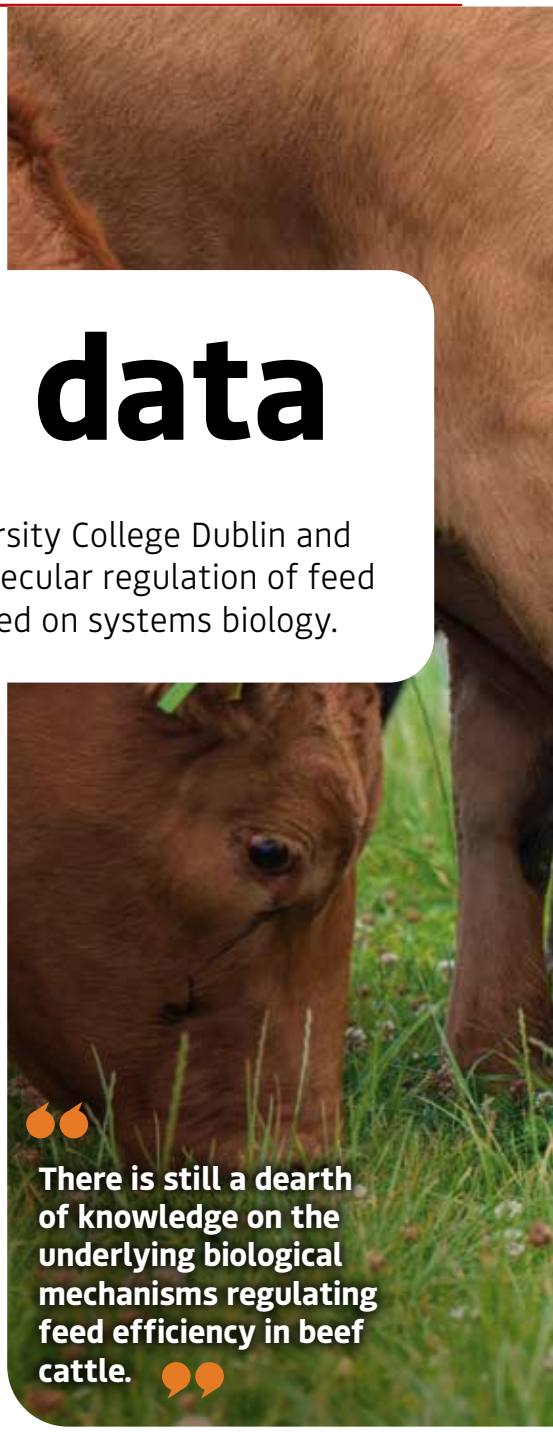
Reduce Methane Emissions



Steady diet of data

Feed-Omics, a collaborative project between Teagasc, University College Dublin and CSIRO in Australia, aims to provide new insights into the molecular regulation of feed efficiency in beef cattle, using state-of-the-art analyses based on systems biology.

There is increasing pressure on the global agri-food industry to reduce its environmental footprint, while simultaneously meeting the growing demand for animal protein. Feed accounts for up to 75% of the variable costs in beef cattle production systems; consequently, feed provision is a major determinant of overall profitability and economic sustainability of the enterprise.

There is considerable inter-animal variation for feed efficiency, as defined by residual feed intake (RFI). Feed-efficient cattle are more economical to produce as these animals inherently consume less feed than is expected based on their predicted dietary requirements for maintenance and growth. Additionally, feed-efficient cattle will also contribute to the environmental sustainability of beef production, as these animals typically produce less methane.

Trait complexity

Kate Keogh, a Research Leaders Fellow at Teagasc Grange, explains that identifying and subsequently breeding feed-efficient cattle using genomic selection technology provides an approach through which feed input costs and the environmental footprint of beef production may be reduced.

"However, despite much international research efforts in recent decades, there is still a dearth of knowledge on the underlying biological mechanisms regulating feed efficiency in beef cattle. This is undoubtedly due to the complexity of the trait and the heterogenous nature, in terms of animals and diets employed, of many published studies."

For example, differences in animal breed, developmental stage and diet, which ultimately confound interpretation of results, have led to inconsistency between experiments.

Moreover, Kate adds: "The potential for a genotype × environment interaction, manifested as the inconsistent ranking of animals for feed efficiency and growth-related traits across contrasting diet types, is an additional concern. This is particularly apparent for grass-based beef production systems, such as that practised in Ireland and in many temperate regions throughout the world."

The Feed-Omics project, in collaboration with CSIRO in Brisbane, Australia, and The Insight Centre at UCD, aims to bridge this gap. By harnessing data from a number of recent large experiments conducted in Teagasc, it uses advanced systems biology and machine learning analyses to examine the interaction between the effects of genotype (breed) and environment (diet composition) on feed efficiency phenotype.

Gene co-expression

This study used data from the Department of Agriculture, Food and the Marine-funded IDENTIFEED project, which examined the repeatability of feed efficiency in beef cattle.

Kate explains further: "Gene co-expression network analyses were applied to transcriptomic datasets from contrasting breeds of beef cattle, Charolais and Holstein-Friesian steers. These were designated, within breed, as either feed-efficient (Low-RFI; consumed less feed than expected) or feed-inefficient (High-RFI; consumed more feed than expected), following separate contrasting dietary phases (zero-grazed grass and high-concentrate ration)."

Gene co-expression network analysis is based on determining the interaction between genes, such that a change in the expression of one gene may be propagated through interactions and affect the expression of other genes.

Such analyses may also provide more in-depth information on the underlying complex molecular regulation of the trait, which may not be detectable through traditional analyses, says Kate.

> **There is still a dearth of knowledge on the underlying biological mechanisms regulating feed efficiency in beef cattle.**

"To-date, our analyses have identified biological processes – such as lipid metabolism and immune system function – that are contributing to feed efficiency in beef cattle, irrespective of breed or prevailing diet type. Additionally, our study highlights a potential central role for the *NR1H3* gene in regulating feed efficiency of beef cattle, irrespective of the breed or diet offered. Indeed, the *NR1H3* gene encodes a protein secreted into the plasma from the liver tissue, providing the possibility for this gene to be explored as a robust biomarker for feed efficiency in beef cattle."

Rumen microbiome

The community of microorganisms, or microbiome, residing in the rumen

Andrew Downes

dictates the feed degradation capacity and subsequent nutrient supply to the ruminant animal, and is thus a potential contributor to inter-animal variation in feed efficiency. However, the relationship between rumen microbiota and feed efficiency phenotype is not well understood, Kate concludes.

"We aimed to decipher this relationship by applying systems network analysis to rumen microbiome data from selected animals in the IDENTIFEED project. This analysis revealed the *Pyramidobacter* bacterial genus as the most commonly represented microbe associated with feed efficiency across the contrasting breeds and diets examined; however, no single microbe was related to feed efficiency across all breeds and diets evaluated."

Ongoing work in this project will further test and validate the results generated thus far for their potential use as biomarkers for the genomic selection of feed efficient beef cattle. T

FUNDING

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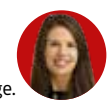

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Teagasc's Better Farming for Water campaign aims to support the agri-food sector to improve water quality across Ireland's catchments. To learn more, *TResearch* spoke to a researcher on the campaign, Daire Ó hUallacháin.

Mapping a course

Photography: Fergal O'Gorman

Daire Ó hUallacháin is a Principal Research Officer in the CELUP programme at Teagasc Johnstown Castle. His background is in zoology, following which he progressed to a PhD in farm ecology, and a stint in consultancy, before joining Teagasc. Today, his key research focus areas are around biodiversity and water quality.

Can you explain the background of this campaign?

Water quality is a key topic since water is a vital natural resource. Under the Water Framework Directive, Ireland has ambitious and challenging targets for safeguarding water quality. Chief among these is the goal for all waterbodies to reach 'good' status by 2027. Approximately half the waterbodies in Ireland are achieving good status at present.

We have seen encouraging improvements in water quality in some catchments. However, this is offset by other catchments deteriorating – hence, overall water quality across Ireland has not improved in recent years. Water quality in Ireland is impacted by multiple sectors; agriculture, as the country's dominant land-use, has a key role to play in improving water quality. Against this backdrop, Teagasc has launched the campaign *Better Farming for Water - 8-Actions for Change*.

How has this topic evolved over the years?

There has been significant progress; a huge development in the understanding of water quality processes, in the mapping of waterbodies and risk – by Teagasc and the Environmental Protection Agency (EPA), among others – as well as developments in mitigation techniques.

Along with these changes on the research side, we've seen land-use and agricultural actors gain an increasingly enhanced understanding of water quality factors. We're seeing much greater interest in protecting local water quality, especially from farmers – a crucial audience – but also from the public more widely.

So, this public awareness is a key element behind the campaign.

What are the challenges surrounding this topic?

There are multiple factors at play here, both anthropogenic and environmental. Achieving water quality objectives is a slow process and requires the engagement of multiple different stakeholders. A major challenge in achieving good water quality is the lag time; it takes a while for the environment to respond to mitigation measures. Another notable challenge is the trade-offs between mitigation measures – we need to develop measures that are as beneficial for water quality as they are for issues like biodiversity and carbon.

One example would be how we manage riparian margins; these are buffer zones running adjacent to rivers or streams where little to no agricultural activity takes place. Correctly managed, these can be effective in reducing surface water runoff or pollutants from entering waterbodies.

On top of that, you're dealing with environmental variables such as changing climactic conditions – so you're attempting mitigation measures against a shifting backdrop. However, the activities we're now implementing are based around a long-term approach.

On the outreach side, there's the ongoing task of ensuring impactful knowledge transfer and communication with relevant stakeholders and audiences. Knowledge transfer and building awareness are key pillars in *Better Farming for Water*.

What impacts is this topic having?

Overall water quality in Ireland is seeing no significant improvement, according to data from the EPA, which monitors catchments on an annual basis. The biggest stressors we see are nutrient and sediment losses to watercourses – primarily, nitrogen (N) in better drained catchments, and phosphorus (P) and sediment in more poorly drained catchments.

Sediment is a more physical stressor, degrading aquatic habitats and impacting life in the watercourse. Nutrients N and P can impact aquatic habitats by promoting excessive plant growth.

On a positive note, some catchments are improving. Improvements have been seen following integrated activity from Teagasc's Agricultural Sustainability Support and Advisory Programme (ASSAP). Elsewhere however, we're still seeing excessive loss of nutrients and sediment to waterways from multiple sources.

Up close and personal

What's your favourite animal? Asking an ecologist what their favourite animal is, is like asking them to pick a favourite child! That said: farmland birds, such as the skylark or yellowhammer, or birds of prey.

If you hadn't ended up in research, what other job would you have wanted to give a go? Either 2nd or 3rd level education.

What are you most proud of professionally? It's encouraging that water quality research has been used to inform policy and practice.

Analysing aquatic ecology is an important tool in assessing water quality, explains researcher Daire Ó hUallacháin

In terms of policy development, this campaign aims to support water quality policy objectives. We need to see greater resources directed towards water quality improvement, as well as integration of policy directives. Engagement with policy and wider stakeholders is an important element of the campaign, as seen in its key pillars.

What research have you been doing in this field?

I've been undertaking environmental research for nearly 20 years, but more recently I've focused on assessing the impact of excessive sediment on aquatic ecosystems – both sediment in isolation and sediment with phosphorous and nitrogen – and how this affects stream ecology. I have also been assessing the effectiveness of mitigation measures for water quality, and wider ecosystem services.

Much of what I do is about assessing and developing tools for the right measure in the right place, being cognisant of synergies and trade-offs. One example, our new AgriBirds project. This looks at green cover on winter stubbles with an aim to reduce nitrogen leaching during winter months; but if you were to remove winter stubbles to improve water quality, this could have negative impacts for farmland birds. So, it's a very complex policy environment, with multiple policy objectives, and we need to keep this in mind when identifying synergies and trade-offs.

What has the industry response been?

There's now heightened awareness and eagerness across the agri-food industry to tackle water quality challenges. We know we need a multi-actor approach and greater stakeholder engagement; more resources are being directed at this, whether at catchment scale, or with advisors at ASSAP level. We've seen a very positive response, which is encouraging. It reflects a desire for action, both at policy level and at ground level from landowners.

What comes next?

We need to identify and assess cost-effective measures to reduce N, P and sediment. Research is needed to identify synergies and trade-offs for environmental and production services. Further research is needed to integrate learnings from bio-physical research with socioeconomic research and production research, i.e. a multi-actor approach, to enhance the performance and adoption of measures. T

Greening and growing

Research at the Horticulture Development Department in Ashtown has implemented a commercial vertical hydroponic system for growing leafy greens.

Vertical hydroponic farming is an innovative agricultural concept for food production. With the world's population growing and rapidly urbanising, and expected to reach nearly 10 billion by 2050, vertical hydroponic production has a potential role to play in delivering food year-round, particularly in large population centres and colder climates.

Some of the reported benefits include greater yields in a shorter growing period, water and nutrient efficiency, maximising space efficiency, and production in a range of buildings – from warehouse-type buildings to glasshouse facilities. Due to the controlled nature of resources like light and nutrients to the crop, a homogenous crop can be achieved with consistent and predictable yields.

The term 'hydroponics' is a catch-all term that refers to a myriad of production systems that typically involve the delivery of water (irrigation) and water with added nutrients (fertigation) to a growing medium instead of soil. Aeroponics, deep water culture, nutrient film technique and wick systems are examples of some of these systems.

Reservoir knowledge

The research facilities at Teagasc Ashtown are based on the deep water culture system, where a separate reservoir is used to hold the nutrient and water solution. This system also contains an air pump which serves to

Iain White, Maxwell Photography

Research Officers Michael Gaffney and Zoia Awan are investigating hydroponic growth systems at Teagasc Food Research Centre, Ashtown

oxygenate the water, preventing the roots from drowning.

Lael Walsh, Principal Investigator at Teagasc, explains: "The oxygen-nutrient-rich water is constantly circulated through a closed circulatory chamber where the roots of plants are suspended in solution. Seeds are germinated separately in a growing media – such as coir, peat, paper, etc. Then, at the second true leaf stage, they are equally spaced across a four-tier shelving system and receive a light regime with high-performance LED grow lights for typically 16-20 hours a day, depending on the envisaged production cycle.

Ventilation is important to keep air circulating, preventing moisture forming on the crop, which can lead to the development of fungal diseases."

> **It's important to assess if [different production systems] may be agronomically and economically feasible.**

Setting the dose

This research is made possible through the *Leaf No Waste* project (SFI Future Innovator Prize 2022) awarded to TU Dublin and Teagasc. Some of the research trials conducted under the Leaf No Waste project have focused on cultivating sweet basil (*Ocimum basilicum*) with the purpose of understanding the effect of silicon-based biostimulant supplementation on hydroponically grown basil.

Zoia Awan, Research Officer at Teagasc, explains: "Although basil is well studied in more traditional hydroponic systems, the use of silicon biostimulant supplementation in hydroponically grown basil, and its benefits to plant production and crop shelf life post-harvest, are not well understood."

One of the initial major challenges has been optimising the levels and forms of silicon required for positive plant growth. At the correct silicon dose there are notable, positive changes to plant physiology particularly increases in yield, shoot and root length.

Lael adds: "Our work on silicon doses was a really important, fundamental part of the research that we had to get right, particularly because many silicon products available on the market are optimised for soil production."

In some instances, when optimising the concentrations for this type of production system, at higher silicon application rates we did observe reduced plant growth and excessive deposition on crop roots."

Market value

In addition to the research on basil, other leafy greens have been grown in the system at Teagasc, including chard, different types of lettuce, kale, fennel and pak choi. These have been used for demonstration purposes at public events like Bord Bia Bloom and for education purposes, explains Principal Research Officer, Michael Gaffney.

"As part of our research and knowledge transfer function, it has been important for us to demonstrate different production systems and assess if they may be agronomically and economically feasible within the context of the Irish market," says Michael.

The *Leaf No Waste* project evaluates silicon supplementation in a range of horticulture crops, production systems and tests different application methods. It also investigates product performance post-harvest in a range of packaging solutions. Finally, it evaluates the environmental impacts of production and packaging interventions using life cycle assessment. T

FUNDING

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Circular Food System

Diversification

Over the past three years Teagasc has made significant strides by partnering with various organisations to nurture entrepreneurial skills for the future leaders of the agri-food sector.

Entrepreneurial excellence

In an era where innovation drives economic growth and sustainability, nurturing entrepreneurship skills has become a critical priority for governments, research centres and industry leaders. The Irish government's *Impact 2030 Research and Innovation* strategy emphasises the cultivation of entrepreneurial talent to ensure a dynamic and resilient economy. Alongside that, Mission 4 of The *Food Vision 2030* strategy for Ireland highlights the need for an 'Innovative, Competitive and Resilient Agri-Food Sector, Driven by Technology and Talent'.

Siobhán Jordan, Teagasc's Head of Technology Transfer and Commercialisation notes that entrepreneurship fosters innovation, creates jobs and drives competitiveness:

"By equipping our students and researchers with entrepreneurial skills, they can in turn deliver creativity and innovation to address local and global challenges. These skills are wider than launching and scaling businesses; they offer an appreciation of how leading research can deliver real world impact."

Catalysing Connections

A cornerstone of Teagasc's commitment to entrepreneurship is the *Catalysing Connections* programme: a pilot pre-accelerator programme designed to foster novel idea generation, innovation and entrepreneurship in early-career researchers. In 2023, multidisciplinary teams of postgraduate students from the Teagasc Walsh Scholarships Programme came together for a series of workshops where the participants could explore and grow their leadership and innovation skills outside of their day-to-day research.

The *Catalysing Connections* model draws from best practice approaches to entrepreneurship training, adapted specifically for the agri-food sector. It employs a collaborative workshop format that provides experiential learning that allows postgrads to apply theoretical concepts to real-world scenarios, Siobhán explains.

"Interdisciplinary teams of researchers are assembled, preparing students for the diverse nature of both industry and academia, combined with mentorship and networking from entrepreneurs and industry professionals. Finally, we emphasise the potential to achieve societal impact through entrepreneurial or commercialisation research in tackling key sustainability goals."

The outcomes have led to a greater appreciation of how research outputs translate into practical solutions and viable businesses. Inspired by the learnings, a team of Walsh Scholars based in Ashtown submitted an application to the 2024 National Student Entrepreneur Awards run by Enterprise Ireland, showcasing their novel protein snack product.

> **The *Food Works* programme has helped more than 100 high-potential start-ups transform their ideas into successful businesses.**

Although ultimately not shortlisted to the final 10, they made it to the penultimate stage of the competition, having created an exciting video pitch and a comprehensive business plan building on key learnings from the programme.

Fennell Photography

Programmes like *Food Works* support entrepreneurs to innovate, scale and grow their companies, leading to significant global development opportunities

Food Works

One of the most impactful sessions at *Catalysing Connections* was the opportunity to learn from role models who have developed new businesses, including Ainé Farrelly from Co. Meath-based URBÓ Milk. Ainé's connections to Teagasc are many and varied, including recently graduating from the *Food Works* programme.

Since 2012, the *Food Works* partnership between Teagasc, Bord Bia and Enterprise Ireland has achieved remarkable success in nurturing entrepreneurship and innovation, adds Siobhán: "Through expert mentorship, market insights, R&D resources and financial support, the programme has helped more than 100 high-potential start-ups transform their ideas into successful businesses."

Teagasc's involvement in *Food Works* has provided participants with access to cutting-edge research and development resources – particularly from the Ashtown Food Research Centre and The National Prepared Consumer Food Centre. The latter was established by the Department of Agriculture, Food and the Marine in consultation with Teagasc, Food Drink Ireland's Prepared Consumer Food company members, Enterprise Ireland and Bord Bia, to support research, development and innovation in the Prepared Consumer Food sector.

Leveraging expertise

The extensive technical expertise from Teagasc researchers has enabled the *Food Works* start-ups to leverage scientific expertise in areas such as food technology, nutrition and sustainability. By integrating R&D into their business strategies, *Food Works* participants have been able to develop innovative products that meet consumer demands and adhere to industry standards and regulations.

As *Food Works* continues to evolve, it will undoubtedly play a vital role in shaping the future of Ireland's food industry, driving economic growth and enhancing the country's reputation as a hub for food innovation.

"As Teagasc continues to champion entrepreneurship in the agri-food sector, the focus remains on fostering many partnerships that support innovation and enterprise," concludes Siobhán.

"By nurturing the next generation of entrepreneurs, Teagasc is contributing to a vibrant and resilient economy, capable of addressing the complex challenges of the future." T

Food Works - success stories

Several companies that have participated in the *Food Works* programme have gone on to achieve significant success. These include:

Strong Roots

Strong Roots, a company specialising in plant-based frozen foods, has experienced rapid growth and international expansion since participating in *Food Works*. The programme provided the company with critical support in refining its business model, understanding market trends and developing a robust go-to-market strategy. Today, Strong Roots products are available in major retailers across the UK, Ireland and the US, and the company continues to innovate in the plant-based food sector.

Nobó

Nobó, known for its dairy-free ice cream, leveraged the resources and mentorship provided by *Food Works* to scale its business and enter new markets. The programme helped Nobó with product development, branding and market positioning, enabling the company to build a strong presence in the growing dairy-free market. Founders Brian and Rachel Nolan commented: "*Food Works* was an incredible launch pad for our brand, giving us the support and expertise to help us find solutions and stay true to our vision and passion."

Fiid

Fiid, a company that produces plant-based ready meals, has also benefited from the *Food Works* programme. The *Food Works* programme was undoubtedly transformative for both the business and the lead entrepreneur Shane Ryan. It gave him the resources, expertise and freedom to think bigger and more creatively about the problem he was trying to solve for his customers, resulting in a whole new approach.

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As plant-based diets gain traction, Ireland is shifting its focus to high-quality plant proteins, notably faba beans. With production increasing, these beans promise soil enrichment, sustainable farming and advanced meat alternatives.

Full of beans

In response to global concerns about food security and climate change, there has been a significant shift towards plant-based diets. The expected consequences of this dietary transition include improved environmental footprint and heightened resilience within the agri-food sector.

Ireland, renowned for its high-quality beef products, is also capable of delivering high-quality plant proteins.

A faba-ulous crop option

The country has witnessed a sharp increase in beans and peas production, rising by almost 24% from 2022 to 2023, as reported by the Central Statistics Office.

Faba beans, in particular, have a high growth potential in Ireland due to the suitable agro-climatic conditions. It's a combinable crop (crops cut using a combine harvester) and well-suited in Irish rotations as a break crop for cereals (to break the cycle of pests and weeds). Their exceptional nitrogen fixation capacity naturally enriches the soil with inorganic nitrogen compounds – for example, they boost soil fertility naturally, reducing the reliance on synthetic fertilisers.

Animesh Singh Sengar, a Walsh Scholar from the Food Industry Development Department at Teagasc Ashtown, is working on the Teagasc-funded Shift+Enter project that aligns with the deliverables of the Department of Agriculture, Food and the Marine-funded U-Protein (Unlocking Protein Resource Opportunities To Evolve Ireland's Nutrition). Animesh's project recognises the potential of Irish faba bean varieties to transform the plant protein market.

"Our focus is to identify and characterise faba bean varieties that will best grow in spring and winter seasons of Ireland," he explains.

Shivani Pathania, Senior Research Officer on the project, adds: "The project is fostering strong interdisciplinary collaborations by establishing feedback loops between the processing and crop research teams at Teagasc Oak Park."

Moreover, a scalable structure-forming technique, i.e. high-moisture extrusion of Irish pulse protein, is currently being assessed to develop a cross-linked and elongated meat-like fibrous network.

Analysing bean character

Four spring varieties (Tiffany, Lynx, Fanfare and Cartouche) and four winter varieties (Vespa, Irena, Tundra and Augusta) of faba

Shredded high-moisture meat alternatives with seasonings

Teagasc

Animesh Singh Sengar from Teasgasc Ashtown sets up the screw profile of pilot-scale extruder

Israel Ikoyi

beans have been assessed for their agronomic behaviour and yield.

The bean flours were systematically characterised, feeding into a comprehensive database that takes into account their nutritional profile, functional properties and thermal suitability for processing. The project also explores the isolation and characterisation of proteins for the development of high-moisture meat alternatives.

The high protein content of faba bean flours was evident from their 28-33% protein concentration, with winter varieties exhibiting higher protein content than spring varieties. Osborne fractionation – a technique to produce protein – of flours showed the highest recovery of water soluble proteins, eliminating the need to use chemical solvents and enabling the product to have a green label. Irena, a winter variety, had the highest protein recovery, followed by the spring variety Cartouche.

"All the faba bean flours are rich in lysine amino acid, which has potential to lower cholesterol levels," says Animesh. "Their functional properties are comparable to the other commercially popular legume flours. Our findings reveal that Irish faba bean flours could serve as a viable source of alternative proteins."

81,300 tonnes

Beans and peas production in 2023 – up from 65,700 tonnes in 2002.

Plant protein to support meat's future

Meat alternatives in the diet could increase the plant-based food intake.

Meat alternatives are in-demand products that require constant research through exploring new ingredients and the integration of technologies.

The National Prepared Consumer Food Centre, Teagasc Ashtown, houses laboratory and pilot-scale extrusion facilities producing high-moisture meat alternatives (HMMA), and are using versatile and scalable twin-screw extrusion technology to structure Irish plant proteins into meat alternatives.

The project evaluates the possibility of developing hybrid meat products by combining indigenous Irish meat with meat alternatives. The extruder, equipped with a long cooling die, ensures the restructured protein dough cools down before being discharged from the machine. Understanding and controlling structure formation require consideration of machine parameter settings, machine configuration and ingredient properties.

Plans are in place to develop HMMA using air-classified Irish plant protein concentrates, which will enhance the fibre content in HMMA in order to meet dietary needs. These developed HMMA are further processed and seasoned to create end-products such as patties and shredded meat alternatives.

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Joint research by Teagasc and Queen's University Belfast suggests that consumers displaying characteristics including a high level of moral responsibility are more likely to buy high-welfare assured pork.

This little piggy went to market

Recent studies indicate that consumers are becoming more conscious of how their food is produced and concerned for the welfare of farm animals. More specifically, conventional pig farming has come under scrutiny in recent years due to its intensive nature. Pork and bacon products are a staple part of many Irish people's diets – consider the full Irish breakfast! However, when purchasing rashers, sausages and black pudding, do consumers consider how these products are produced, and the welfare of the pigs they are made from? Many countries have established higher welfare assurance schemes that communicate the welfare standards on pig farms using product labelling to enable consumers to make informed purchases. Whilst quality assurance labelling exists in Ireland, there is currently no pork product labelling scheme dedicated to higher welfare standards.

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Consumers with a high intention to buy higher-welfare pork more commonly ranked high welfare as the most important characteristic and cheapness as the least important.

Positive characteristics of higher welfare Irish pork could be included on product packaging to appeal to consumers' perception of quality

Influencing factors

By better understanding what influences consumers' purchasing decisions, we can identify whether the current market meets the wants of consumers or if there is space for introducing new categories of pork products, explains Teagasc Walsh Scholar Molly Harrison.

"We carried out an online survey to determine if consumers considered pig welfare to be important when purchasing pork, and what factors may influence their decision to purchase high-welfare pork products. The survey was completed by a representative panel of over 800 consumers from Ireland and the UK who regularly purchased pork products."

As there is a successful and well-established higher-welfare pig assurance scheme in the UK, UK pig meat consumers were included in the survey for comparison, and as a potential future export market. The results from both countries were found to be similar and therefore analysed together.

Using the survey results, the study's authors were able to categorise consumers as being more or less likely to buy high-welfare assured pork, and explore which influences were most salient in determining their purchase intentions (Figure 1).

Assessing intentions

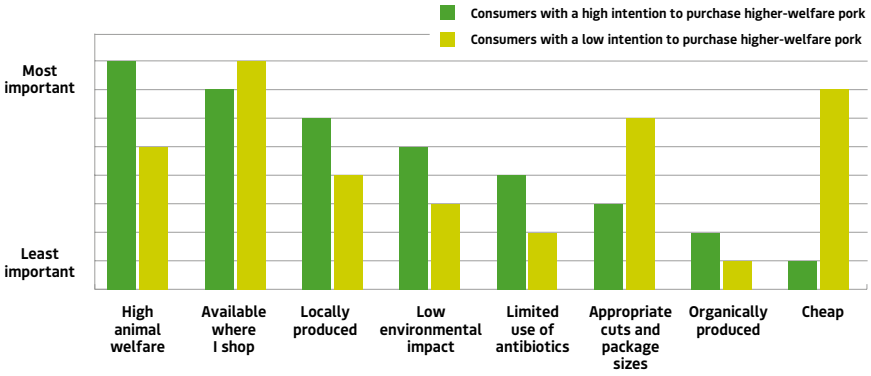
Consumers with a high intention to buy higher-welfare pork were more likely to have a stronger sense of moral responsibility as a consumer with regards to the pork products they buy, and also to associate the characteristic 'higher welfare' with other positive qualities such as the product being tastier and healthier, Molly explains.

"These consumers also considered pig welfare and local production to be of greater importance compared to consumers who had a lower intention to buy welfare-labelled pork products. In addition, they were also more likely to be influenced by the opinions of family and friends regarding what meat they should buy, and were less likely to think that higher-welfare products were out of their budget."

Overall, 48% of Irish and UK consumers considered it to be 'important' or 'very important' to produce pork in a pig-friendly way. When asking consumers to rank eight pork product characteristics from most to least important, some interesting differences were observed between the average ranks, based on the mean scores of consumers with low and high intention to buy high-welfare assured pork (Figure 2).

Molly explains further: "Consumers with a high intention to buy higher-welfare pork more commonly ranked high welfare as the most important characteristic and cheapness as the least important. Whereas for consumers with a low intention, availability where they shop and cheapness were ranked more commonly as the most important characteristics."

Figure 2: Compares the mean ranks of eight pork product characteristics in Irish and UK consumers with low and high intention to buy high-welfare pork products.



Quality perception

The similarity of results between UK and Irish consumers indicates that the same welfare-assurance products could perform equally well in both markets. Importantly, the survey identified the most influential factors that warrant consideration in marketing higher welfare pork products to enhance the potential for successful introduction in Ireland.

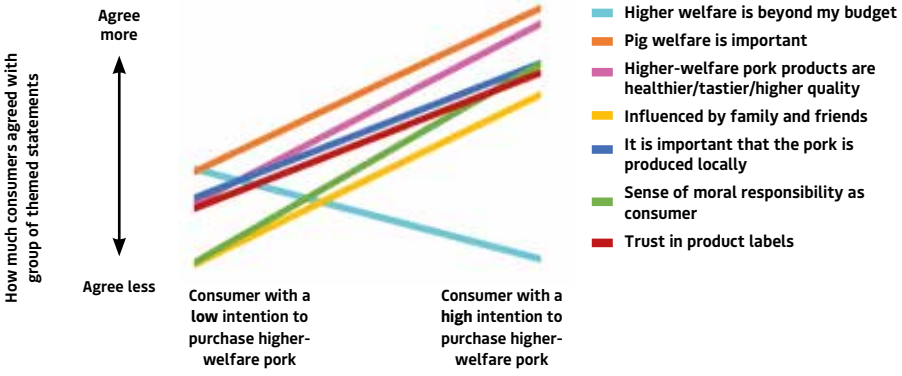
"The positive characteristics of higher-welfare Irish pork could be included on product packaging, and in advertising, to appeal to consumers' perception of quality and making a morally informed purchase," Molly concludes.

"Campaigns to increase awareness of the higher-welfare label could increase social influence and encourage pig welfare to be considered as important when selecting pork products." T

FUNDING

This project was funded by Teagasc's Walsh Scholarship Programme.

Figure 1. Factors that influence consumers with a high intention to purchase higher-welfare pork products compared to consumers with a low intention.



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Circular Food System

Diversification

At Teagasc Ashtown's Food Research Centre, Research Officers Lael Walsh and Shivani Pathania are at the forefront of fighting food waste and future-proofing food packaging with their *Leaf No Waste* project.

Lael Walsh (left) and Shivani Pathania inspect basil crops grown at the Food Research Centre at Teagasc Ashtown

Pack to the future

Photography: Iain White, Maxwell Photography

For protecting resources and food security, it's important to come up with viable methods for fighting food waste. To tackle this pressing issue, the *Leaf No Waste* project at Teagasc Ashtown is investigating interventions at multiple steps along the food production chain. To learn more, *TResearch* spoke to the project's team leaders, Lael Walsh and Shivani Pathania.

Can you explain the history of your team within Teagasc?

Lael: The team came together in 2020 when we worked on the seed and concept phases of the Science Foundation Ireland food challenge. We were competing against five other teams for the prize of €2 million. This was the first time any of us were involved in challenge funding. The timelines were short; six to nine months to deliver results and it was during Covid so it was indeed a challenge. For the prize proposal, we expanded the work to grow different crops to test different packaging interventions, so we grew the team to include other researchers in Teagasc.

Shivani: The initial team consisted of Lael and me, expanding the team as we progressed to the prize phase. Lael leads the horticultural team, which includes Orla O'Halloran, Zoia Awan, Daniela Costa, Éamonn Walsh and Anthony Gargan. I lead the packaging team, which comprises Tigist Shonte and Mehraj Fatema Mulla.

What are your core priorities and objectives?

Lael: The *Leaf No Waste* project has six main tasks, four of which are led by Teagasc.

1. The inclusion of silicon biostimulants in the production of vegetables, fruit and mushrooms.
2. To assess approved food contact materials and novel packaging materials, and their efficacy in extending the shelf life of horticultural produce.
3. Conducting post-harvest testing of packaged produce to generate scenario analyses, benchmarking silicon dosage and packaging transition.
4. Assessing plant responses to silicon uptake, focusing on physiological changes and disease incidence.
5. Assessing environmental impact using life cycle assessment of interventions in growing and packaging.
6. Examining the commercialisation potential of this research.

Can you talk about how your research achieves these objectives? How do you present your findings?

Lael: Food waste is an issue for stakeholders across the supply chain, and customers have been demanding changes to packaging and the removal of single use plastics. This research shows how interventions at production and packaging stages can extend the shelf life of fresh foods. Our research is showing that electrolyte leakage and respiration is reduced, and membrane stability holds for longer with our biostimulant interventions during growth and at post-harvest, along with packaging interventions.

Shivani: We present our findings to the scientific community through literature reviews, original research articles and conferences. For the public, we showcase our work at events like Bord Bia Bloom, ESB Science Blast, and during Science Week. Stakeholders, including industry partners, receive regular updates through meetings, reports and presentations.

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

Shivani: We have explored different packaging formats such as trays, hinged-lid containers, punnets and bags, and use recyclable polymers, such as recycled polyethylene terephthalate. Additionally, we investigate bio-based polymers, including polylactic acid (PLA), cellulose and paper. We have assessed packaging designs like thermoforming, tray sealing and horizontal film form and seal to create tailored solutions for each crop.

One particularly innovative technique we use is the thermoformed package for mushrooms, which uses 100% recyclable material. This method significantly improves

Meet the team

The full team behind *Leaf No Waste* brings together key interdisciplinary knowledge on both horticulture and food industry development.

Anthony Gargan, Research Masters Student, UCD/ Horticulture Development Department:
"I'm Investigating the effects of biostimulant application on strawberry and spinach physiology and drought response."

Daniela Costa, Post-doctoral Researcher, Horticulture Development Department:
"I am investigating the effects of biostimulant application in strawberry production and disease."

Éamonn Walsh, Postdoctoral Researcher, Horticulture Development Department:
"I'm conducting life cycle assessments on mushroom and strawberry production to evaluate the sustainability of novel plant treatments and food packaging solutions."

Mehraj Fatema Mulla, Research Officer, Food Industry Development Department:
"I am currently conducting research on the shelf life of strawberries and basil to assess the application of innovative food packaging solutions, specifically modified atmosphere packaging and plant treatments."

Orla O'Halloran, Research Officer, Horticulture Development Department:
"I am investigating the effect of biostimulant application in horticultural crops, focusing on mushroom production."

Tigist Shonte, Postdoctoral Researcher, Food Industry Development Department:
"I work on the development of novel packaging systems for horticultural crops and extraction of novel bio-polymers for packaging material development."

Zoia Awan, Research Officer, Horticulture Development Department:
"My research is investigating the effect of biostimulant application in horticultural crops, focusing on hydroponic and glasshouse production of leafy greens and herbs."

mushroom quality and shelf life compared to the traditional tray wrapped in cling film. Our packaging design for strawberries extends the shelf life from 14 to 26 days for the Malling Centenary variety. Additionally, for basil, our packaging solution extends the shelf life from 5 to 10 days. These advancements highlight the effectiveness of our tailored packaging solutions in enhancing the preservation and quality of various crops.

What is the importance of this work in the context of Irish farming and agriculture?

Lael: White button mushrooms are a significant economic driver in Ireland's horticulture sector, contributing €130 million annually. Improving their post-harvest longevity addresses challenges posed by their high moisture content and rapid metabolism, ensuring better marketability and reduced waste in both domestic and export markets.

For soft fruits like strawberries, optimising packaging materials can significantly enhance shelf life, as demonstrated by our new packaging system extending it up to 26 days. This extension not only increases profitability for growers and suppliers by allowing them to command higher prices during off-season periods, but also facilitates exports to lucrative UK and European markets.

Finally, extending the shelf life of basil from 5 to 10 days results in significantly less food waste and increased value. We are also extracting novel biopolymers and bioactives from rhubarb stems and nettle plant, for potential anti-microbial food packaging applications.

Are there any trends coming up that will affect your work?

Lael: Production systems are under pressure to reduce fertiliser and pesticide input and to lower the environmental impact of food production. This project responds to this in several ways: we are assessing the extent to which silicon biostimulants reduce the need for pesticide application; we are also generating Life Cycle Assessment data for horticulture crops modelling Irish production systems for the first time. This information doesn't exist currently and will hopefully help the sector understand and report on environmental emissions.

Shivani: Around one-third of global food production is lost or wasted, highlighting the urgency of tackling food waste. Additionally, food waste in landfills contributes significantly to emissions from the agri-food system. This project aligns with the EPA Food Waste Charter and supports the European Plastic Strategy 2030 by promoting sustainable and resilient food systems. *Leaf No Waste* aims to enhance crop health and develop eco-friendly packaging solutions to extend shelf life and reduce plastic use in fresh produce packaging. We are identifying non-food sources of biopolymers for food packaging applications reducing reliance on food crop-derived biopolymers like PLA.

How would you sum up your team's key achievements and value?

Shivani: Our team's ability to integrate knowledge and expertise from multiple disciplines – from agriculture and environmental science to packaging technology and sustainability – is a significant achievement. This not only enhances our understanding of the issues at hand, but also allows us to develop holistic solutions that consider the entire lifecycle of food production and consumption. *Leaf No Waste* is one of the key projects addressing food waste in Teagasc. As a signatory of the EPA-led Food Waste charter, Teagasc is committed to helping primary producers address food loss and waste.

Looking back at two decades of contributions from the Animal & Grassland Research and Innovation Programme at Teagasc, driving positive developments across the agri-food industry.

Celebrating AGRIP

Teagasc's Animal & Grassland Research and Innovation Programme (AGRIP) strives to make an impact to the agri-food sector by bringing together several streams of work at different disciplinary, strategic and temporal scales.

In November 2023, as part of its peer review process, AGRIP chose to highlight 12 particularly impactful case studies from the past two decades, providing insight into how AGRIP research and knowledge transfer over time has contributed to worthwhile outcomes for farmers, industry partners and policymakers. The case studies also point towards AGRIP's potential for greater future impact through its ever-evolving network of industry relationships.

Each case study contributed to change along some or all of three identified impact pathways: technology development & adoption; capacity-building; and policy influencing. This suggests that the programme is not only developing and transferring gap-filling research and technologies, but also contributing to the mechanisms that make this knowledge accessible and usable by end users. These pathways, outlined in Teagasc's Statement of Strategy, 'Teagasc Together', depict an overarching model of how Teagasc contributes to developmental impact in the agri-food sector.

Andrew Downes

Teagasc's Animal & Grassland Research Innovation Programme provides valuable research and knowledge transfer for farmers and policymakers alike

Increasing tech uptake on dairy calf-to-beef farms

Established in 2015, the Teagasc Green Acres Demonstration Farm Programme operated for two phases of three years each and consisted of 10 to 12 demonstration farms that implemented best practice in their dairy calf-to-beef enterprises, supported by an intensive advisory service provided to them by Teagasc. Additional support and advice came from six commercial companies that provided funding for the programme. The primary output from the programme was the production of a significant amount of knowledge transfer material. This was used by Teagasc advisors, specialists and researchers and industry partners with over 10,000 farmers who have a significant dairy calf-to-beef enterprise on their farm, to confirm how the uptake of technologies on their farms would support their sustainable dairy calf-to-beef system.

Pathways: Technology development & adoption, capacity-building
Teagasc Researcher: Pearse Kelly

Sex-Sorted Semen Research and Implementation Programme

Over the last decade, several research projects conducted by Teagasc Moorepark – in collaboration with the Irish Cattle Breeding Federation, University College Dublin, Sexing Technologies, and Irish artificial insemination companies – elucidated the optimal strategies for using sexed semen. Sexing Technologies established a laboratory at Moorepark in September 2021 and a second lab at the National Cattle Breeding Centre in Naas in November 2022, providing a sex-sorting service for all artificial insemination companies operating in Ireland.

Through co-ordinated research and extension activities led by the Teagasc Animal and Bioscience Research Department, Teagasc Dairy KT, and Teagasc Dairy advisors, dairy farmers are now using an increasing amount of sexed semen to generate their replacement heifers. As usage increases in the years ahead, this will diminish the number of lower beef merit male dairy calves, improve the quality of beef calves derived from the dairy herd, and improve the environmental footprint of beef production by reducing age at slaughter.

Pathways: Technology development & adoption, capacity-building
Teagasc Researcher: Stephen Butler

Donal O'Leary

Roll out of the €uro-Star indexes for sheep

Introduced in 2009 by Sheep Ireland, the national €uro-Star genetic indexes have been crucial in enabling farmers to make more informed breeding and selection decisions – ensuring desirable genetics combinations for their flock. Since its inception, Teagasc researchers and Knowledge Transfer have played a pivotal role in developing and refining the national sheep breeding programme.

Although initially focused on one breeding goal – the Sheep Value Index – further breeding goals and indices (terminal and replacement) were launched in 2014, following consultation with industry, including input from Teagasc geneticists who were involved in their inception and development. The €uro-star indices aim to identify low-cost, easy-care animals with good maternal characteristics, that also produce high-quality lambs that reach slaughter at an early age. Research shows there is a difference of €18 per ewe between flocks of high versus low genetic merit for maternal traits. In addition, greenhouse gas emissions intensity was 7% lower for flocks of high genetic merit.

Pathways: Technology adoption, capacity-building, policy influencing
Teagasc Researchers: Noirin McHugh, Phillip Creighton and Fiona McGovern

Developing the AgNav Digital Platform

AgNav is a farmer-centric digital sustainability platform which presents farmers and advisors with farm-specific greenhouse gas (GHG) values, a decision support tool, and an action planner. It is currently being used with farmers through the Teagasc Signpost Programme which is targeting 50,000 participants before 2030.

AgNav is a collaboration between Teagasc, Bord Bia, and ICBF and emerged from a longer standing partnership between the three organisations and other stakeholders as part of the national farm carbon audit programme and the Teagasc research programme.

Pathways: Technology development & adoption, capacity-building
Teagasc Researchers: Jonathan Herron, Donal O'Brien and Paul Crosson

PastureBase Ireland

PastureBase Ireland (PBI), developed with extensive industry collaboration, was launched in January 2013 with the objectives of optimising pasture utilisation across all ruminant sectors, improving farm productivity, promoting sustainable grazing practices, and supporting evidence-based decision-making in Irish agriculture. The database is a central reservoir for commercial and research grassland measurements that can be accessed by famers, advisors and co-op representatives. PBI has grown its user base substantially and supports its users through an offline app and fulltime helpdesk.

Supporting the use of PBI and promoting sustainable grassland excellence are the Pasture Profit Index, developed in 2015, which provides an economic value for different perennial ryegrass varieties, and the 2017 Grass 10 Campaign with partners Grassland Agro, AIB, FBD, Department of Agriculture Food and the Marine and the *Irish Farmers Journal*.

Pathways: Technology adoption, capacity-building, policy influencing
Teagasc Researchers: Michael O'Donovan, Tomas Tubritt and Ciaran Hearne

Mitigation of chlorine-associated residues in the Irish dairy chain

In 2007, concerns emerged regarding levels of trichloromethane in Irish butter. Teagasc researchers identified the sources of these residues, developed testing methods, and worked with industry stakeholders to implement mitigation strategies. This led to a substantial decrease in chlorine-associated residue levels in milk and dairy products over time, allowing Irish dairy processors to meet stringent regulatory and customer requirements.

Key actors included the milk producers, milk processors and milk quality personnel, Teagasc advisors, Ornua, Department of Agriculture, Food and the Marine (DAFM), Food Safety Authority of Ireland (FSAI), water suppliers (UE/NFGWS), Milk Quality Ireland, infant milk formula manufacturers and chlorine-free detergent supply companies.

Pathways: Technology adoption, capacity-building, policy influencing

Teagasc Researchers: Bernadette O'Brien and David Gleeson

Elena Medoks/istockphoto.com

Delivering gains in cattle

Breeding is a proven technology that has demonstrably delivered sustainable, cumulative and permanent gains in performance with no required change to day-to-day farm management. Sustainable genetic gain is based on an effective database of information from a wide range of genetically divergent animals representative of the national population. Ireland boasts one of the best animal databases globally, held by the Irish Cattle Breeding Federation and Sheep Ireland.

Through collaboration with industry, Teagasc's main role is to develop the direction of breeding for future production systems and to subsequently evaluate the outputs through controlled experiments and population studies, as well as identifying genetically elite animals. The outputs are tools to help make better breeding decisions, both by the breeding industry and the farmer end users. The impact on the sector has been quantified at €3.48bn over the past 22 years, as well as lessening the environmental footprint of production.

Pathways: Technology adoption, capacity-building, policy influencing

Teagasc Researchers: Donagh Berry, Alan Twomey, Noirin McHugh, David Kelly and Maeve Williams

Enhancing uptake of key dairy farm management technologies

From 2015 to 2021, AGRIP assisted in the delivery of the Teagasc-Dairygold joint programme operating in the Southern region, and the Teagasc-Lakeland joint programme, operating in the Midlands-North region. The Dairygold joint programme delivered monthly content to 1,000 milk suppliers across 65 Teagasc dairy discussion groups. The Lakeland Dairies joint programme delivered 25-30 regional technical workshops annually, directly contacting 600-800 suppliers.

There was a high degree of commonality in technical objectives across the joint programmes: financial sustainability of growth in milk supply; increased uptake of milk recording; breeding for higher Economic Breeding Index; improved soil fertility and grassland; and building awareness of environmental sustainability obligations. On-farm changes across all these dimensions took place with farmer suppliers. The continuity of such programmes is important for driving the longer-term impact of extension programmes.

Pathways: Technology development & adoption, capacity-building

Teagasc Researchers: Joe Patton, Stuart Childs and James Dunne

Improving sustainability of Irish dairy and dairy-beef production

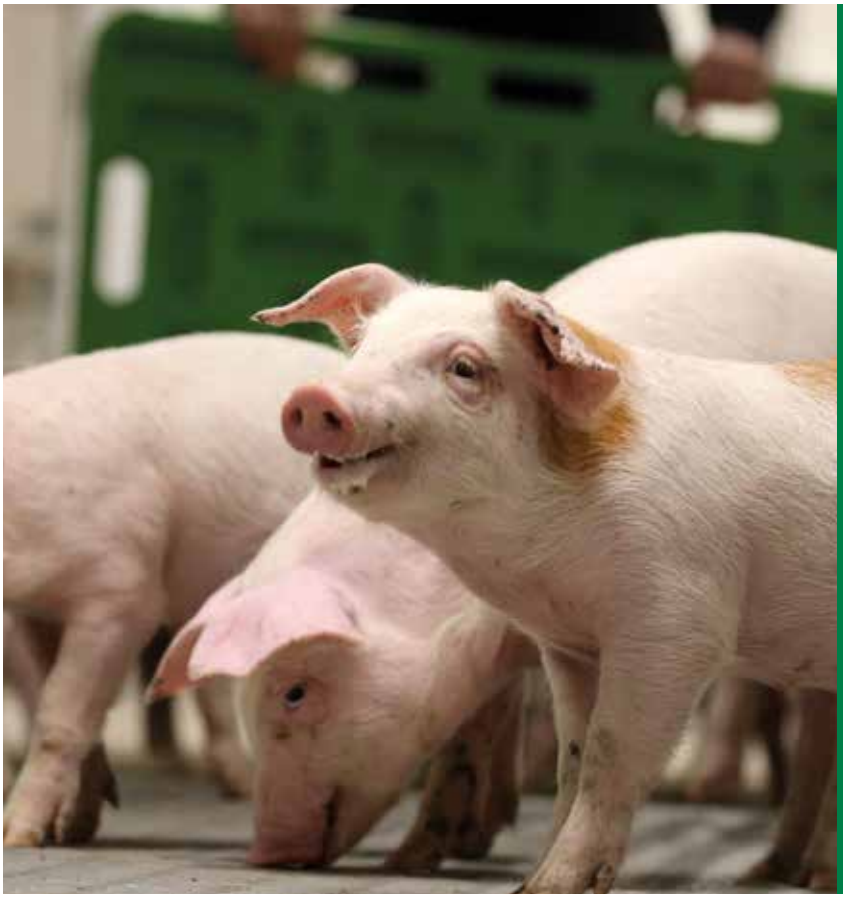
Teagasc's dairy-beef research programme has made significant contributions to the development, promotion and implementation of production blueprints that enhance productivity, profitability and environmental efficiency. The programme's focus on high welfare, grass-based systems, early age at slaughter and carbon efficiency has furthered the social acceptance of Irish dairy and beef production, aligning with societal expectations and environmental sustainability goals. Teagasc research and Knowledge Transfer is providing policymakers and other key stakeholders with the necessary evidence to support further dairy-beef integration.

To build sectoral capacity, Teagasc and other organisations have developed training and outreach programs (DairyBeef 500 Campaign) and resources to educate farmers on the benefits of dairy-beef production. This has increased awareness and understanding of dairy-beef's potential and provided farmers with the necessary knowledge and skills to adopt the technologies..

Pathways: Technology development & adoption, capacity-building, policy influencing

Teagasc Researchers: Nicky Byrne, Alan Dillon and Alan Twomey

Teagasc



Teagasc

Lowering antimicrobial use in pigs

Antimicrobial resistance is ranked as one of 10 most important global health issues by the World Health Organization. Historically, pig systems are the main users of antibiotics at an international and national level, due mainly to the use of antimicrobials in feed, often as a preventive measure. After almost 10 years of collaboration between the Department of Agriculture, Food and the Marine, Teagasc and other stakeholders, due to significant improvements in husbandry, the level of antimicrobial use in the pig sector has decreased by 46%.

Although welcome, the associated challenge for the sector is to ensure, through the prudent use of antimicrobials, that there are no unnecessary health and welfare issues on pig farms. The research, tools and advice to support this are being generated by Teagasc's research and Knowledge Transfer together with key collaborators DAFM, Animal Health Ireland, Pig HealthCheck programme, UCD Veterinary School, Bord Bia and the Irish Farmers Association.

Pathways: Technology adoption, capacity-building, policy influencing
Teagasc Researchers: Edgar Garcia Manzanilla and Ciaran Carroll

Influencing policy and clover uptake

TAMER YILMAZ/istockphoto.com

Since the implementation of the clover research programme in 2010, Teagasc researchers, knowledge transfer specialists and advisors have played a key role in providing peer-reviewed scientific data, developing management strategies, and demonstrating technologies to give confidence to the industry that clover can replace chemical N fertiliser at farm level, and increase the sustainability of Irish agriculture.

Although uptake at farm level was initially slow, white clover seed sales increased by 177% between 2013 and 2022, with red clover sales increasing by 538% over the same period.

Pathways: Technology adoption, capacity-building, policy influencing
Teagasc Researchers: Brian McCarthy and Michael Egan

Expanding the Irish dairy sector

Prior to and following the abolition of milk quota, Teagasc research identified, evaluated and demonstrated technologies that would allow farmers to expand milk production while maintaining or reducing cost of production. Teagasc research and modelling fed into the Department of Agriculture, Food and the Marine's *FoodHarvest 2020* recommendations for expansion of the dairy sector.

The Teagasc Dairy Expansion Service was established in 2015 to help farmers plan their dairy farm expansion decisions in the wake of the milk quota abolition. The service was also available to new entrants to dairy farming. The service had three main components: a business planning service, which offered physical and financial planning for the clients; a collaborative farming service to support new collaborative farming structures; and a discussion group programme for new entrants to dairying. The service also provided an annual training course for non-Teagasc farm advisors, bankers and accountants on financial KPIs for dairy systems.

Pathways: Capacity-building, policy influencing
Teagasc Researchers: Padraig French and Joe Patton

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Circular Food System

Supporting Policy

Mixed farming systems: towards sustainability

Integrated crop and livestock farming systems have the potential to provide a sustainable alternative to reduce greenhouse gas emissions and maintain family farm income.

Global agriculture is set to tackle economic, environmental and social challenges in order to maintain sustainable food production. Income pressures related to rising input costs, farm management labour requirements and the continuously changing regulatory landscape are among the factors that elevate stress among farm families and reduce their wellbeing.

Consequently, farmers and society must find a balance between sustainability aims. In this context, quantifying the synergies and trade-offs between environmental goals, such as reducing agriculture's carbon footprint and maintaining farmers' livelihood, is vital in guiding policy-making and designing adjustment pathways for enhanced sustainability.

European Union authorities have compiled a new climate strategy through the EU Green Deal, which has set ambitious greenhouse gas (GHG) emission reduction targets in all economic sectors of -55%

Andrew Downes

Table 1. Agricultural share of emissions in Europe and Ireland including 2030 and 2050 targets (DAFM, 2023; EPRS - Green Deal, 2021; EU Climate Target Plan, 2020).

Emissions in Agriculture	Europe	Ireland
2023 figures	10%[1]	37.8%
2030 targets[1]	-55% (all sectors)[2]	-25% (agriculture)[3]
2050 targets[4]	-100%	-100%

[1] Approximately, European Commission, Climate Action, 2023. [2] Emission reduction targets for all economic sectors including agriculture, compared to 1990 emission levels. [3] Total agricultural emissions reduction target compared to 2018 emission levels. [4] Net zero carbon dioxide equivalent.

by 2030 and climate neutral by 2050 (see Table 1). In Ireland, the agricultural sector contributes over one-third of national GHG emissions, with ruminant production systems being a key emission driver.

As a result, decarbonisation in the Irish agricultural sector is an important step going forward, with adaptation of farming systems being the sensible strategy ensuring national emission targets are met.

Redeveloping systems

A new Common Agricultural Policy (CAP) Strategic Plan is being implemented by the Irish government to support the production of nutritious and sustainable food while protecting family farm incomes and supporting climate change ambitions.

In this context, the redevelopment of mixed farming systems that integrate crop and livestock enterprises may improve sustainability, exploiting opportunities aligned to Ireland's CAP Strategic Plan.

Tasos Chatzichristou, a Walsh Scholar at Teagasc Moorepark, explains: "Locally grown feed and organic fertiliser in the form of manure provide a sustainable pathway to shorten supply chains, promote nutrient recycling and minimise input requirements, ultimately promoting farm integration and circularity. Circularity is an array of ecological practices, new technologies, economic models and social services that foster resource reuse, thereby reducing environmental pressures from agricultural production and income risks by exploiting economies of scope – the production of complimentary products."

Although mixed systems provide a promising avenue for boosting sustainability, they face barriers such as increased requirements in capital, knowledge, infrastructure and management techniques. For operational and financial reasons, production systems on farms in Ireland have become increasingly specialised in recent decades.

Increasingly specialised

Farm mechanisation and the favourable agricultural policy environment transformed farm structures from the historically prevalent mixed crop and livestock model, to product-oriented and specialised, Tasos continues.

"Accordingly, the majority of farms focus on the production of a primary output – milk, for example – taking advantage of economies of scale to achieve lower average costs with higher productivity. Specialisation is capital-intensive, focusing on linear production processes to maximise output efficiency. Linear production refers to the extraction of raw materials from resource rich countries, processing in industrial countries, and shipping to income rich countries, where they are used, discarded and replaced."

As a result, there is a chance that certain intensive specialised systems might fall short on environmental sustainability targets, due to neglecting material recycling and input minimisation.

Consequently, research is needed to understand the impacts of mixed farms in comparison to specialised systems across various sustainability dimensions, and to provide tangible evidence to farmers and policy-makers on their relative strengths and limitations.

Re-Live, a European project funded by Era-Net, promotes the collaboration between research and educational organisations across Europe – such as universities, research institutes and private partners – and is set to tackle questions related to the environmental, economic and societal impact of mixed crop and livestock systems. The Re-Live project aims to answer questions about sustainable food production, introducing a gold standard methodology that will support farmers with management decisions to lower their farm carbon footprint and maintain profitability.

The research programme intertwines work packages that span from on-field research to systems modelling, Tasos explains.

"In that regard, our ongoing research conducted in Teagasc Moorepark, collaborating with University College Dublin, aims to provide a decision support tool for evaluating the economic and environmental performance of farms across Ireland, and test the impact of mixed farm scenarios and land use interventions on environmental, economic and social dimensions."

Setting a standard

In particular, this provides insight into the impacts of different soil interventions, cultivation practices, manure management, residue utilisation and nutrient upcycling. In broad terms, it is a tool that encompasses and quantifies a series of sustainability concepts implemented by the latest European and Irish Agricultural Policy.

"As modern agriculture faces multifaceted challenges, including greenhouse gas mitigation and economic sustainability, mixed livestock and cropping systems are resurfacing as a potential solution to bridge the gap between linear and circular farming systems," concludes Tasos.

However, research is still needed to identify the impacts of mixed systems on sustainable food production and it is imperative that initiatives should align with a restructured CAP. As a result, farm integration might be a missing piece to the agricultural sustainability puzzle. T

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Diversification

Circular Food System

Leading the way with LCA

Research at the Horticulture Development Department in Ashtown is examining the environmental impact of fruit and vegetables grown with biostimulant inputs and packaged with different packaging forms.

Businesses and farms in the food and agriculture sector, all along the value chain, are searching for tools to help them understand the impact of their product on the environment. Producers recognise the importance of reducing environmental emissions and creating a more sustainable food system, but also identifying the critical impact areas where these reductions can be made. Simultaneously, there is pressure in the policy environment to address these issues. But how do we go about achieving this change?

"More and more farms are looking to assure their sustainability going into the future and are exploring different options to assess their current state and progress," explains Éamonn Walsh, a postdoctoral researcher at Teagasc Ashtown.

"A base assessment of environmental impact is important as a first step in understanding where to make changes to improve the sustainability of a food product. Life Cycle Assessment – LCA – is a tool which can be used to assess the environmental impact of a specific product's life cycle. It can be restricted to particular parts of a life cycle – just the farm for example – or it can extend to the whole life cycle, including pre-production, processing, packaging, transport, storage and retail."

A range of impacts

LCA is an iterative process of data collection and emissions calculations. At the start, the scope of the LCA is set by determining the boundaries of what will or will not be included in the calculations. Based on that boundary, data is collected directly from stakeholders or from existing databases, such as Ecoinvent, Agri-footprint or Agribalyse. Many databases are behind a paywall, but some are free to access, for example, Agribalyse and Environmental Footprint from the EU. These collected values are then used with emission factors for specific substances, CO_2 for example, to calculate environmental emissions. LCA practitioners can use free (openLCA) or paid (SimaPro) software programs to calculate emissions.

"LCA can model the environmental impact in a range of categories, providing insight into not just greenhouse gas emissions, but other notable impacts like eutrophication, terrestrial and marine acidification, human toxicity, and resource and water scarcity," Éamonn continues.

"The range of impact categories broadens the focus beyond greenhouse gas emissions, which, while important for climate change, do not provide a rounded assessment of environmental impact."

Screen greens

LCA is now frequently utilised in the agriculture and food industries. In the *Leaf No Waste* project, funded through the Future Innovator Prize Programme from Science Foundation Ireland, LCA is being used to identify emissions hotspots and assess sustainable interventions in important Irish-grown horticulture crops such as mushrooms, strawberries and leafy greens.

Presently, LCA is being used to build a scenario for each crop as it is currently produced and packaged. With the basic scenario generated, the use of novel treatments and packaging can be built on top of this. For example, an LCA has recently been published assessing how a change in shelf life through the use of a silicon biostimulant during production,

Lael Walsh and Éamonn Walsh are part of the team examining how Life Cycle Assessments can provide a more nuanced view of horticultural impacts

> **An LCA can tease out the balance of inputs and outputs in a specific scenario to determine how the use of a new technology may increase or decrease emissions.**

together with a novel packaging film, affects the environmental impact of spinach.

This spinach LCA showed that an assessment of shelf life is not as straightforward as it seems, explains the study's author, Research Officer Lael Walsh.

"One could easily assume that a longer shelf life would always be more sustainable or that a compostable film is usually preferrable. However, the energy use from refrigeration during this extended shelf life must also be taken account of, as well as the changes to the amount of waste food being generated during this storage. An LCA can tease out the balance of inputs and outputs in a specific scenario to determine how the use of a new technology may increase or decrease emissions."

Finding hotspots

What kind of a benefit could a business or farmer expect from an LCA? An LCA identifies the emissions hotspots in the production of an agricultural product, allowing for initial judgement of what process elements require most focus. Furthermore, an LCA can help identify whether emissions hotspots are in parts of the life cycle under direct control of the business. For example, if an emission hotspot is a product input used in cultivation there is a possibility to change that.

Aiduan Borrion, Professor at University College London and advisor to the project, explains: "Any business or farm looking to undertake this process will have to create an inventory of data containing values for all the inputs and outputs associated with a specific agricultural product. Most of this data can be straightforwardly collected, but it does require some effort on behalf of the business to make sure it is an accurate representation of the real-life farm or site."

In the horticulture sector, this includes data on inputs like growing media, fertilisers, transport, electricity, heat generation, gaseous emissions and waste recycling.

Context clues

One of the main challenges in undertaking an LCA is the interpretation of the results. The results cannot be understood in isolation, but must be assessed in the context of the methodology. This is especially true when comparing values from other studies, as methodology can have a significant impact on the results, explains Lael.

"A prime example of this is the system boundary of the study. Some studies will set the boundary from the cradle to farm-gate, whereas others will set the boundary later in the life cycle, e.g. the cradle to retail-stage, which includes emissions post production such as transport, packaging and cold-storage."

Other methodological choices, like the allocation of emissions between different but connected production systems, should be done following the ISO standards to maintain consistency. Finally, many assumptions will have been used in the LCA, which should be clearly stated. Despite these caveats, an LCA generates results that can act as a useful guide for decision-makers in the horticulture sector. T

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Sustainable, compostable packing solutions for fresh produce

Technology

- Teagasc, through a Science Foundation Ireland (SFI)-funded collaborative project with Technological University Dublin (TUD), is developing novel compostable packaging solutions based on sustainable raw materials including stinging nettles and rhubarb
- These solutions include cellulose trays and paper bags for packaging fresh produce from stinging nettles, and absorbent pads for fruit and vegetables from rhubarb cellulose and mucilage

Value propositions

- Use of existing weeds and underused plants as sources of novel biopolymers, including mucilage and cellulose fibres
- Reduced non-recyclable polymer use in food packaging, contributing to reduced food waste, bio-circularity and increased food safety

Development stage

- Stinging nettle: compostable pulp tray and paper bag prototypes in development at pilot scale; compostability testing completed
- Rhubarb: green dual extraction process developed; optimisation in progress of active absorbent pad solutions for fruit and vegetable packaging to achieve longer shelf life

Opportunity to engage

- Of relevance to fruit, vegetable and mushroom producers and packaging solution providers
- We welcome business engagement to discuss potential collaborations for further technology development and for market validation purposes

Research funding

SFI Food Waste Challenge: LEAF NO WASTE, led by Technological University Dublin

Teagasc PI: Shivani Pathania, Teagasc Food Research Centre, Ashtown

For further information or opportunity to discuss, contact Miriam Walsh miriam.walsh@teagasc.ie or engage@teagasc.ie (Reference: LEAF NO WASTE opportunity)

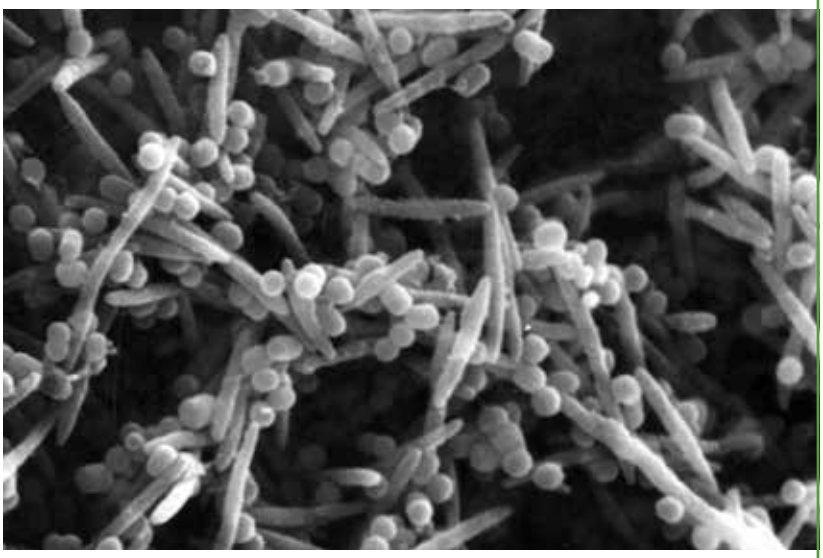
Nisin G: a novel anti-*Fusobacterium nucleatum* therapeutic

CHALLENGE

- *Fusobacterium nucleatum* is an important human pathogen with a number of associated pathologies in the gastrointestinal (GI) tract, including colorectal cancer (CRC)
- This bacterium can induce pro-inflammatory and oncogenic activities and is identified as a risk factor for disease progression
- *F. nucleatum* infections can be clinically treated with a combination of antibiotics, but this approach often disturbs gut microbiota
- As a result of this, and increasing reports of antibiotic resistance in gut pathogens, there is a need for therapeutic alternatives

OPPORTUNITY

- The antimicrobial solution described here could be a natural, effective alternative to antibiotic therapy
- This gut isolate produces a novel variant of the bacteriocin nisin, nisin G, which can potentially target the pathogen without disrupting the gut microbial balance
- The gut isolate itself, *Streptococcus salivarius*, is distinctive as most other nisin producers come from dairy strains of lactococci
- The inventors have demonstrated anti-*Fusobacterium* activity in a simulated colon model and shown that the current invention has demonstrated a relatively narrow spectrum of inhibitory activity inhibiting *Fusobacterium spp*
- Nisin G may also indicate a potential application for this bacteriocin to control pathogen growth in the vaginal microbiome



- The novelty of this solution is in the production of this antimicrobial from an organism that could potentially be used as an oral probiotic

APPLICATIONS

Companies are invited to discuss this technology with a view to further development in the following areas:

- Probiotic potential/functional food development
- Biotherapeutic for the prevention of CRC or other cancers
- Pathogen control in the vaginal microbiome

DEVELOPMENT

- The current Technology Readiness Level of the technology is TRL 4 (validated in the laboratory)
- An international PCT application has been filed by MTU and Teagasc (PCT/EP2022/087124)

MTU and Teagasc are seeking commercial partners to further develop and commercialise the strain for applications in functional foods, biotherapeutics and women's vaginal health

For more information please contact:
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Baylor College of Medicine

Mullingar-based Teagasc ASSAP advisor David Webster and farmer Shane Pearson examine Dysart stream at Clontineen, county Westmeath

Easing the pressure

The *Better Farming for Water* campaign will be crucial to meeting objectives under the Water Framework Directive, explain Teagasc's Director of Research, Pat Dillon, and Head of Environment Knowledge Transfer, Pat Murphy.

Clean water is a critical part of nature and human wellbeing. It is also a crucial resource for many economic sectors; agriculture needs a constant supply of fresh, clean water for animals, crops and food processing. Although water quality in Ireland compares favourably to the EU average, the challenge remains: meeting the objectives under the Water Framework Directive, whereby all waterbodies achieve good status by 2027.

The latest EPA Water Quality report, covering the period 2016–2021, found that 54% of our surface water had satisfactory (≥ good) ecological status. Overall water quality has not improved in recent years; the proportion of waterbodies improving in status has been exactly matched by that of those declining in status. The main causes of poor water quality are run-off of nutrients, sediment and pesticides from agricultural lands and farmyards; discharges of poorly treated sewage from urban wastewater treatment plants, domestic treatment systems and storm water overflows; hydromorphology; and run-off nutrients and sediment from forestry operations.

The Nitrate Directive, in place since 1991, aims to protect surface water from pollution by agriculture sources and promote good farming practices. The current Nitrate Action Programme, covering the period up to 31 December 2025, contains specific measures to protect surface waters from nutrient pollution arising from agriculture. Ireland has availed of a derogation from the maximum limit of 170 kg/ha of livestock manure nitrogen as provided in the Nitrate Directive. Maintaining Ireland's nitrates derogation will require improvements in water quality.

In 2024, the Minister for Agriculture, Food and the Marine, Charlie McConalogue TD, requested Teagasc to lead a multi-actor water quality advisory campaign. The aim is to deliver clear, simple and positive messaging to enhance understanding – on farms and across the agri-food industry – of agriculture's pressure on water quality and the need for improvement.

In response, Teagasc has developed the *Better Farming for Water* campaign, the objective of which is to reduce nutrient, sediment, pesticides and pathogen loss to all waterbodies. The campaign has identified *8-Actions for Change* that farmers can make on-farm to improve water quality. These actions cover three critical management areas (nutrient, farmyard and land management) and apply to all farmers (dairy, dry stock and tillage).

The campaign will be delivered at farm, catchment and regional scale, and will be part of a wider whole-government approach to improve water quality. T

***Better Farming for Water - 8-Actions for Change* will build on the progress made through existing water quality programmes such ASSAP, Farming for Water EIP, Waters of LIFE and Blue Dot Catchments. The campaign will be delivered by way of six pillars:**

1. **Stakeholder engagement through a multi-actor approach (farmers, farming organisations, government departments, meat and milk processors, environmental regulators, media and local communities)**
2. **Building awareness by acquisition and utilisation of water quality data**
3. **Upskilling farmers, advisors, and industry professionals**
4. **An impactful knowledge transfer programme**
5. **Supporting research programme**
6. **A strong communications plan**

Mark Moore

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.

Protecting our native trees

Event: Teagasc Forestry Open Day, at Teagasc, Oak Park, Carlow
Date: 4 July 2024

Protecting our native tree species is important for preserving biodiversity, maintaining ecosystem services, and ensuring the resilience of our forests in the face of climate change. Nearly 300 forest owners, foresters, and industry stakeholders attended the recent Forestry Open Day, where Teagasc Forestry Research Officer and event co-organiser Dheeraj Rathore emphasised the importance of tree improvement and breeding initiatives. He outlined priorities, including the development of tree species adapted to Irish climatic conditions, and highlighted ongoing projects aimed at enhancing resilience against pests and pathogens in broadleaf species such as ash, alder, and elm. "These efforts are crucial to sustain future productivity, maintain genetic diversity, and ensure ecosystem stability, thereby enhancing tree resilience in response to climate change," says Dheeraj.

Dheeraj encouraged attendees to report healthy ash trees to aid in identifying resilient specimens and safeguarding these species for future generations. Dheeraj explains: "By joining the *AshforFuture* Research Project, you play a crucial part in safeguarding our beloved ash trees! Your involvement helps protect genetic diversity, accelerates selection for resilient trees, and contributes to building a comprehensive database for easier identification and conservation efforts." Scan the QR code for more information on how to contribute and save our ash trees.

Dheeraj Rathore presenting at the Forestry Open Day

Tony Keane

Culturing engagement with fermented foods stakeholders

Event: Living Labs stakeholder event hosted by the DOMINO project
Date: 16 July 2024

Fermented foods have the potential to meet consumer expectations for healthier and more sustainable foods, but there is a need to demonstrate their health impacts scientifically. DOMINO is a Horizon Europe-funded Research Innovation Action, which is investigating the health impacts of consuming fermented foods, as well as developing novel plant-based fermented foods which address the changing societal demands for healthier and more sustainable nourishment.

Living Labs are defined as "settings for experimentation and testing of solutions to sustainability challenges in collaboration with various actors". As part of DOMINO, a Living Lab event was hosted in Teagasc Ashtown by Sinéad McCarthy and John Kenny to engage with relevant fermented food stakeholders (including researchers, producers, SMEs, policy makers and regulators). In breakout sessions, attendees discussed the opportunities and challenges in product development, future impact and sustainability across the food system.

Sinéad McCarthy addresses the Living Lab audience

Teagasc

Sinéad explains: "This stakeholder engagement enables the researchers to identify the knowledge gaps in the sector, where the project can support fermented food producers through research and access to new technologies, while also enhancing the relevance of outputs from the DOMINO project."

John adds: "The Living Labs are being conducted in five other DOMINO partner organisations across Europe and the results used to ensure co-creation across the research project with insights for both the domestic and export markets."

Don't miss out on Teagasc's upcoming events! Join us at Ashtown on October 10 for *Biocircularity in Action Summit – Opportunities within Sustainable and Circular Food Systems*. Our *Climate Adaptation Conference* takes place in Moorepark on October 15. The Dairy Calf-to-Beef International Conference will take place at Clayton Whites Hotel, Wexford on October 16 & 17. Visit Teagasc.ie for more information.

The Irish frog

Field biodiversity is often unsuspected, especially when the diversity of habitats can support a large diversity of species. Amphibians are indicators of the ecosystem's health. They are very sensitive to pesticide and other environmental perturbation. Over the last few years, they have massively declined. However, they are very important for ecosystems. They mainly feed on insects and serve as food for many species of higher trophic levels.

Photo and description by:
Virgile Ballandras
Teagasc project:
Walsh Scholarship