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Research

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The future of the CAP – a view from the farm

SPECIAL FEATURE: EU GREEN DEAL

ASSAP IMPROVING WATER QUALITY

SEAWEED ALGAL FIBRE

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CONTENTS

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EU Green Deal for a climate-neutral Europe

The EU Green Deal is the big initiative of the recently installed EU Commission, led by Commission President Ursula Von der Leyen, which has the overall aim of making Europe a climate-neutral continent by 2050. She has described it as Europe's "man on the moon moment". It contains a set of policy initiatives, two of which are directly relevant to agriculture and food production, namely the Farm to Fork strategy and the Biodiversity strategy.

With headline targets such as cutting fertiliser use by 20 %, reducing use of antimicrobials in farmed animals by 50 %, a similar reduction in pesticide use, 10 % of agricultural area under high-diversity landscape features, 25 % of farmed land in organic production, and proposals to allow farmers to monetise carbon sequestration, a very challenging change agenda for Europe's agri-food system has been set out.

The proposals and the pace of implementation will be debated a lot, as will the allocation of targets to individual countries, which will be dependent on their particular circumstances. However, there is no doubt that the Green Deal is setting the direction of travel for European agriculture for the coming years.

European agriculture will require a paradigm shift if it is to attain this vision. Since the Green Revolution, we have used plant and animal breeding, fertilisers and pesticides to make dramatic advances in agriculture, but with an almost singular focus on production. Now, we have to add other dimensions – including climate change and biodiversity – as priorities for the agriculture systems of the future.

In this issue of *TResearch*, a number of papers expand on some of the main aspects of the Green Deal. We need a lot of new knowledge and innovation; however, we can build on our strengths and work with our stakeholders to create a future-proofed agri-food system.

Frank O'Mara
Director of Research
Teagasc

Comhaontú Glas don Eoraip le go mbeidh an Eoraip aeráidneodrach

Is é an Comhaontú Glas don Eoraip mórthionscnamh Choimisiúin an Aontais Eorpaigh a cuireadh ar bun le gairid agus a dtugann Uachtarán an Choimisiúin, Ursula Von der Leyen, ceannasaíocht air. Is é is aidhm fhoriomlán don Chomhaontú mór-roinn aeráidneodrach a dhéanamh den Eoraip faoi 2050. Is é an cur síos atá déanta aici air "deis duine a chur ar an ngealach" na hEorpa. Tá sraith de thionscnaimh bheartais ann, agus tá dhá cheann de na tionscnaimh sin a bhaineann go díreach le talmhaíocht agus táirgeadh bia, is iad sin an Straitéis 'Ón bhFeirm chuig an bhForc' agus an Straitéis Bhithéagsúlachta.

Tá clár oibre an-dúshlánach don athrú leagtha amach ann do chóras agraibhia na hEorpa, mar gheall ar phríomhspriocanna cuir i gcás: úsáid leasacháin a laghdú 20 %, úsáid ábhar frithmhiocróbach i gcás ainmhithe feirmshaothraithe a ísliú 50 %, ísliú mar an gcéanna a bhaint amach san fheidhm a bhaintear as lotnaidicídí, 10 % den limistéar talmhaíochta le bheith faoi ghnéithe tírdhreacha éagsúlachta ardleibhéil, táirgeadh orgánach ar 25 % de thalamh feirmshaothraithe, agus tograí le cead a thabhairt d'fheirmeoirí luach airgid a chur ar cheapadh carbóin. Déanfar cuid mhór díospóireachta ar na tograí agus an luas a gcuirfear i bhfeidhm iad, faoi mar a dhéanfar ar dháileadh na spriocanna do thíortha ar leith, a bheidh ag brath ar chúinsí faoi leith na dtíortha sin. Níl amhras ar bith ann, áfach, ach go bhfuil an bealach chun cinn á shocrú ag an gComhaontú Glas d'earnáil na talmhaíochta san Eoraip do na blianta atá le teacht.

Beidh athrú ó bhonn de dhíth ar thalmhaíocht na hEorpa má táthar leis an aisling seo a bhaint amach. Ó bhí an Réabhlóid Ghlas ann, tá feidhm á baint againn as pórú plandaí agus ainmhithe, leasacháin agus lotnaidicídí le dul chun cinn dochreidte a bhaint amach i gcúrsaí talmhaíochta, ach is ar tháirgeadh is mó a rabhthas ag díriú thar aon rud eile. Caithfimid tús áite a thabhairt do réimsí eile sna córais talmhaíochta san am atá le teacht, an t-athrú aeráide agus bithéagsúlacht san áireamh.

San eagrán seo de *TResearch*, déantar cuid de na príomhghnéithe sa Chomhaontú Glas a chíoradh i bpáipéir áirithe. Tá a lán eolas nua agus nuálaíochta de dhíobháil orainn; is féidir linn forbairt a dhéanamh ar ár láidreachtaí áfach agus oibriú lenár bpáirtithe leasmhara le córas agraibhia a chruthú a bheidh oiriúnaithe don am atá romhainn.

Frank O'Mara
Stiúrthóir Taighde
Teagasc

Food digestion paper top for citations

Peer-reviewed publications are a very important, accepted metric for measuring the quality, productivity and impact of research. Therefore, as one way to capture the impact of our work, Teagasc tracks citations to scientific papers authored by Teagasc researchers and published in peer-reviewed journals. An annual report is produced each year to track publications, citations and related metrics over the previous six years (known as bibliometric analysis).

The 2020 report found that the most cited Teagasc article published over the last five years (in the time period 2014 to 2019), was a paper co-ordinated by André Brodkorb, Teagasc Food Chemistry and Technology Department.

The paper can be accessed at http://dx.doi.org/10.1039/C3FO60702J. Full reference: Minekus, M., Alminger, M., Alvito, P. and Brodkorb, A. (2014). 'A standardised static *in vitro* digestion method suitable for food – an international consensus'. *Food & Function*, 5 (6): 1113-1124.

At the time of compiling this annual report (March 2020), the article had 1,171 citations, as measured in the Scopus database (a research intelligence tool tracking citations to millions of scientific articles). At the time of writing, this had risen to 1,427 as measured by Scopus. You'll find more on the topic of food digestion on page 28 in this issue.

A Teagasc article on in vitro *digestion was the most cited in the last five years.*

Researcher profile

Dominika Krol

Dominika graduated with a BSc in Environmental Science from Jagiellonian University in Poland in 2006, and received her MSc in 2008.

She has a PhD from Trinity College Dublin, and also holds a certificate in crop nutrition.

She joined Teagasc in 2013 as a Research Technician, and has worked as a Research Officer in the Environment, Soils and Land Use Department at Johnstown Castle since 2017.

Dominika's research led to the adoption of new, refined nitrous oxide emission factors from pasture, range and paddock in the national greenhouse gas (GHG) inventory, and she was also a co-author of work on emission factors from synthetic fertiliser. This research led to reducing Irish GHG emissions and identifying low-emission fertiliser formulations, which are now quoted as the main measure to reduce agricultural emissions under the National Climate Action Plan.

Dominika is involved in producing Teagasc's marginal abatement cost curve (MACC) analyses for GHG and ammonia and, with Cathal Buckley of the Rural Economy Department, has led the refinement work for the recently published new ammonia MACC.

She is currently leading a large collaborative RSF-funded project called Triple A on Abating Ammonia Emissions from Agriculture.

Together with partners from the Agri-Food and Biosciences Institute and University College Dublin, the team is researching ammonia mitigation options for Irish agriculture.

She is also leading a research project on further refinement of nitrous oxide emission factors from pasture, range and paddock, this time focusing on sheep production systems.

Dominika is supervisor to a number of PhD and MSc students, as well as postdoctoral researchers and technicians.

She regularly teaches environmental science (agricultural gaseous emissions) to visiting student groups from University College Dublin, Waterford Institute of Technology and NUI Galway, and gives presentations to visiting farmer groups, and at stakeholder events and open days.

Teagasc spin-out company – SeqBiome

SeqBiome, a spin-out from the APC Microbiome Ireland SFI Research Centre, University College Cork (UCC) and Teagasc, was launched recently. SeqBiome provides high-quality, interactive sequencing and microbiome analysis for academia and industry. It will create meaningful microbiome insights for clients across industries such as pharmaceuticals, nutrition, sport, healthcare, agriculture and other life sciences. The gut microbiome is made up of trillions of bacteria, fungi and other microbes. It plays a very important role in health by helping to control digestion and benefiting the immune system and many other aspects of health. Gerry Boyle, Teagasc Director, said: "Teagasc is delighted to see the launch of the spin-out company SeqBiome Ltd. It's a further reflection of the cutting-edge nature of the applied microbiome, DNA sequencing- and bioinformatics-related research that is carried out at Teagasc. It also exemplifies another route through which Teagasc can contribute to high-quality job creation to support the Irish economy. We wish co-founder and Chief Technology Officer Paul Cotter, who is the Head of Food Biosciences at Teagasc, his APC Microbiome Ireland colleague and CEO Marcus Claesson, and Executive Director Brad Wrigley the very best with this venture and note the important contributions of Orla O'Sullivan and Fiona Crispie of Teagasc in the establishment of SeqBiome".
Visit www.seqbiome.com for more information.

Teagasc performs well in knowledge transfer national report

The Annual Knowledge Transfer Survey, reporting on the performance of Irish research-performing organisations (RPOs) in business engagement and intellectual property (IP) commercialisation during 2019, was recently published by Knowledge Transfer Ireland (KTI). Teagasc data submitted to KTI is co-ordinated by its Technology Transfer Office (TTO), with contributions from other research departments and the finance department. This review of such activity in the State-funded research sector is a useful mechanism to compare the performance of RPOs in knowledge transfer (KT) activities, and in showing return on investment into State-supported research and innovation at a national level.
It is important to state, however, that many positive impacts of KT cannot be captured by quantitative measures alone; hence, the importance of specific case studies and success stories to give a more complete picture. This report shows that Teagasc performs very favourably, in terms of innovative activity measured through invention disclosure and patent filing numbers, but especially in terms of engagements with industry through a range of collaborative and service-based activities, and IP commercialisation measured through numbers of licences, options and assignments (LOAs) negotiated with companies, licensing revenue and spin-out companies formed. As an example, Teagasc signed 24 industry-sponsored agreements (through its TTO), consulted with 21 enterprises through Enterprise Ireland-supported Innovation vouchers, and reported 173 fee-paying services to businesses (primarily SMEs). It reported the highest consultancy services revenue among all RPOs, reflecting its mission, and 30% of total RPO licensing revenue came from Teagasc, much of which emanates from licensing of plant breeders' rights. **The KTI review and annual KT survey 2019 can be found at: www.knowledgetransferireland.com.**

Beef Eating Quality Index launched

The world's first national multi-breed genomic evaluation for sensory-based meat eating quality was launched at the Meat Technology Ireland (MTI) centre, Teagasc, Ashtown, Dublin, recently.

The goal of genetic evaluations is to identify, as accurately as possible, genetically elite animals. These animals are often chosen as parents of the next generation in the pursuit of genetic gain. Accurate genetic evaluations are predicated on large databases of performance, ancestry and DNA information. One of the main objectives of the MTI research programme was to generate such a database of informative and genetically diverse animals for meat eating quality, optimised for the generation of accurate national genomic evaluations pertinent to the Irish cattle population. Sensory data collected on over 6,000 cattle, which began in November 2016, now resides within the database, making it the largest such database globally used for genetic evaluations.

Donagh Berry, Teagasc geneticist, said at the launch that: "Ireland boasts a unique selling point of safe, nutritious and responsibly produced beef, but is under constant threat from ever-aggressive competitors. We must continually innovate, and delivering year-on-year improvement in meat eating quality will become our new point of differentiation".

John Colreavy, Director of MTI, explained that MTI is an Enterprise Ireland, industry-led initiative that builds a strategic research and innovation base in beef and sheep meat processing in Ireland. The MTI industry-led consortium is unique in the northern hemisphere and represents an opportunity that will have global impact in addressing improvements for Irish beef and sheep meat processing,

The Beef Eating Quality Index will add value to Ireland's meat industry.

such as today's Index launch. This collaboration between the world's fifth largest beef and sheep meat processors and the custodians of the world's largest animal genetics breeding database presents a unique opportunity to address fundamental issues, such as sustainable beef production, that face the industry not just in Ireland but globally.

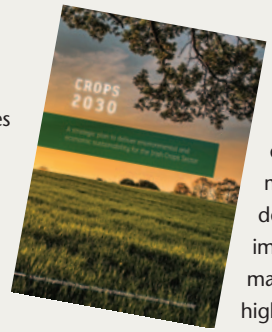
The launch of the Meat Eating Quality Index means that the meat eating quality of the Irish national herd will systematically improve through genetic improvement without sacrificing important breeding traits. This will ensure that consumers of Irish beef around the world can expect the very best dining experience.

Crops 2030

The Teagasc Tillage Stakeholder Consultative Group and Minister of State Martin Heydon, TD, launched a strategic plan for the Irish tillage sector recently. Crops 2030 assesses the current state of the sector and provides 54 tangible recommendations.

These collectively highlight how tillage farming in Ireland can make a significant contribution to meeting national greenhouse gas reduction targets, supporting the authenticity and sustainability credentials of Irish exports, and exploiting the provenance of our native grains to market a suite of Irish-produced food and drink products.

The report identifies areas where native cereals can be further developed to help substitute imported ingredients currently used in the food, drink and animal feed sectors. There are substantial opportunities to increase native grain uses in cereal-based foods and oat products. There are also opportunities in cold pressed oils and potato products, which can contribute to healthier diets and help tackle obesity. The drinks industry is increasing exports year on year, and there is further potential to increase grain supply to this



industry to offset imports and hence support the legitimacy of labelled products.

The level of animal feed imports has increased dramatically from two million tonnes in 2008 to over four million tonnes in 2018, with much of the additional demand driven by the expansion of the dairy sector. Ireland imports animal feed ingredients from over 60 countries, many of which have production systems associated with high GHG emissions and negative impacts on biodiversity. Substitution of many of these imported ingredients represents a significant opportunity for the Irish crops sector, with potential to produce both energy and protein crops for the feed market.

Through this publication the Stakeholder Group hopes to make a major contribution to the development of Irish agriculture over the next decade, said John Spink, Head of the Crops, Environment and Land Use Programme in Teagasc.

See the full report at:
https://www.teagasc.ie/publications/2020/crops-2030.php.

Farmers are highly vulnerable to Covid-19

Preventing the horrific mortality and ill health consequences of Covid-19 infection poses a huge and ongoing challenge in Ireland, including among the farming community, over the coming months. A study by a research and knowledge transfer team from Teagasc and the National Centre for Men's Health, Institute of Technology Carlow, indicates that the farming population is highly vulnerable to Covid-19 due mainly to its older age profile and poor health status.

The study, entitled 'Essential and Vulnerable: Implications of Covid-19 in Ireland', was published recently in the *Journal of Agromedicine*. Lead author David Meredith, Teagasc Rural Economy and Development Programme, said that there are greater numbers of older people in the rural and farming population and, generally, they are in poorer health, which makes these communities vulnerable to Covid-19 infection. Continuing to adhere to the public health guidelines associated with handwashing, wearing masks and limiting close contacts is critical to keeping these communities safe.

David added: "Many farmers have limited personal contacts outside the farm due to the nature of their work, but they still face infection risks associated with vital activities such as trading via the sale of produce, or obtaining farm supplies. They should continue to take the necessary Covid-19 precautions. In light of the recent increase in Covid-19 cases within households across the country, these precautions should be followed by all members of the household when returning from school, shopping, work or social activities".

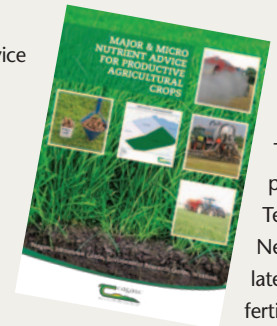
Doctoral scholar in farmers' health, Diana van Doorn, at Teagasc/IT Carlow, stated that medical conditions associated with more severe symptoms of Covid-19 include lung disease of asthma, diabetes, cardiovascular disease, and the co-occurrence of these diseases with obesity and smoking. She said that Irish farmers' health research found that 31% of farmers used medication to control risk factors for cardiovascular disease, which they used as prescribed in 95% of cases, which is a positive finding. However, since the Covid-19 emergency there is a marked reduction generally in persons attending medical services, when these services remain fully open, which could lead to adverse health consequences in the future.

Farmers must take all necessary precautions to protect against Covid-19.

Teagasc Green Book

Promoting good soil fertility and nutrient management advice for increased farm productivity, profitability and environmental sustainability is a cornerstone of Teagasc's activities.

The Teagasc *Green Book of Major and Micro Nutrient Advice for Productive Agricultural Crops* has been revised this year and provides up-to-date, cutting-edge information for farmers, advisors, agronomists and the wider agricultural industry, backed by the latest research and science.



Teagasc Director Gerry Boyle said: "Making better use of soil nutrients is good for farm productivity and good for the environment. This brings together the latest research and science available to guide farmers, advisors and agronomists on how to maintain their production through more efficient use of nutrients, while at the same time protecting and enhancing the environment".

A major responsibility of the research staff at Johnstown Castle has been the publication of leaflets, booklets and manuals giving nutrient and trace element advice for grassland and crops. This began in the 1940s and was the scientific basis for soil analysis (Coulter, 2000). Since then, further updates were published by Coulter in 2004 (2nd edition), by Coulter and Lalor in 2008 (3rd edition), and by Wall and Plunkett in 2016 (4th edition). This version has now been enhanced and expanded to produce the current volume (5th edition), published by Teagasc's David Wall and Mark Plunkett in 2020.

New sections, and information and updates based on the latest scientific findings, have been added to the grassland fertiliser advice section including nitrogen advice for grass–white clover swards.

Many of the chapters have been reorganised to make them easier to consult, and the advice and tables have been redesigned to be compliant with the latest European and Irish legislation.

The book is available at: https://www.teagasc.ie/publications/2020/major--micro-nutrient-advice-for-productive-agricultural-crops.php.

On the path to biodiversity recovery

The EU Biodiversity Strategy for 2030 has proposed a number of challenging targets that will inform policy, practice and research for the coming decades, including a number that are relevant to agriculture.

The EU Biodiversity Strategy for 2030 has set ambitious targets that will require transformative change if they are to be achieved. In an unprecedented move, the Biodiversity Strategy was announced in tandem with the EU Farm to Fork Strategy, signalling the co-dependency of the two strategies in supporting human health, economic recovery and food security. Recognising the current global threat to biodiversity, the EU has committed to the Convention on Biological Diversity's aim to "ensure that by 2050 all of the world's ecosystems are restored, resilient, and adequately protected". In the meantime, the EU "aims to ensure that Europe's biodiversity will be on the path to recovery by 2030".

Strategic actions

The first strategic action of the EU Biodiversity Strategy aims to widen the network of protected areas and establish "a coherent network of protected areas". The aim is that at least 30 % of the land (an increase of 4 %) and 30 % of the sea (an increase of 19 %) will be protected and connected through ecological corridors as part of a European-wide network. It remains to be seen how this EU-level target will translate into targets for individual member states.

The second strategic action explicitly recognises that significant restoration actions will be required to reverse decades of biodiversity loss. This restoration will include, for example: strengthening the EU legal framework for nature restoration; bringing nature back to agricultural land; addressing land take and restoring soil ecosystems; increasing the quantity of forests and improving their health and resilience; restoring freshwater ecosystems; reducing pollution; and, addressing invasive alien species.

> At least 30 % of EU land area will be protected and connected through ecological corridors, and at least 10 % of agricultural area under high-diversity landscape features.

Key commitments

There are key commitments associated with the above restoration themes, and the following have the strongest

interaction with land use and agricultural practices:

1. Legally binding EU nature restoration targets to be proposed in 2021, subject to an impact assessment. By 2030, significant areas of degraded and carbon-rich ecosystems to be restored, habitats and species to show no deterioration in conservation trends and status, and at least 30 % to reach favourable conservation status or at least show a positive trend.
2. The decline in pollinators to be reversed.
3. The risk and use of chemical pesticides to be reduced by 50 % and the use of more hazardous pesticides by 50 %.
4. At least 10 % of agricultural area to be under high-diversity landscape features.
5. At least 25 % of agricultural land to be under organic farming management, and the uptake of agro-ecological practices significantly increased.
6. Three billion new trees to be planted in the EU, in full respect of ecological principles.
7. Significant progress to be made in the remediation of contaminated soil sites.
8. At least 25,000 km of free-flowing rivers to be restored.
9. A 50 % reduction in the number of Red List species threatened by invasive alien species.
10. Losses of nutrients from fertilisers to be reduced by 50 %, resulting in the reduction of the use of fertilisers by at least 20 %.

The inclusion of habitats currently considered 'ineligible' under existing Cross Compliance (e.g., ponds, scrub, wetlands) will likely be a strong discussion point.

Impact on agriculture

Clearly, alignment with these key commitments can be expected to have significant impacts on the management practices of agricultural systems, for example through reduced use of pesticides and fertilisers. As mentioned above, the Farm to Fork Strategy contains and supports several of the same commitments, and can be expected to strongly influence Common Agricultural Policy (CAP) reform and choices about direct payments and rural development actions, especially the objectives and design of eco-schemes, agri-environment schemes and results-based payments. The aim for 10 % of agricultural area to be high-diversity landscape features will incorporate, e.g., buffer strips (**Figure 1**), rotational or non-rotational fallow land, hedges, non-productive trees, terrace walls, and ponds. The inclusion of habitats currently considered 'ineligible' under existing Cross Compliance (e.g., ponds, scrub, wetlands) will likely be a strong discussion point. The target of three billion new trees represents a major intervention in land use, and the Commission will develop guidelines on biodiversity-friendly afforestation and reforestation, and closer-to-nature forestry practices (in parallel with the new EU Forest Strategy).

FIGURE 1: The aim is for 10 % of agricultural area to be high-diversity landscape features, e.g., buffer strips.

Transformative

The third strategic action aims to "enable transformative change". This proposes new and improved governance frameworks that facilitate a system with effective indicators, progress assessment and corrective actions. This aims to significantly increase the implementation and enforcement of EU environmental legislation. In an innovative approach, the Commission envisages improved use of both public and private investments to financially incentivise nature-based solutions for biodiversity conservation and climate action. The fourth strategic action supports "an ambitious global biodiversity agenda" to improve international governance for the protection and restoration of biodiversity.

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Pest control

Reducing pesticide use on farms, as required by the European Commission, is a significant challenge, which can only be met through more diverse crop rotations and a greater focus on integrated pest management (IPM) strategies.

As part of the recently published Farm to Fork Strategy, the European Commission has committed to take action to reduce by 50 % the use and risk of chemical pesticides by 2030. Frequently used in a generic sense, pesticide is an over-arching term that, as defined by EU legislation, encompasses fungicides, herbicides, bactericides, insecticides, plant growth regulators, molluscicides, and other plant protection products (PPPs).

The most recent usage surveys completed by the Department of Agriculture, Food and the Marine calculate that 1,058,461 kg of active substance* were applied to arable crops in 2016 (DAFM, 2016) with an estimated 516,189 kg applied to grassland and fodder crops in 2017 (DAFM, 2016). In the case of arable systems and the 120 active substances used, this represented a 7.2 % decrease on 2012 figures, while for grassland and fodder this was a 13 % decrease (for 82 active substances) relative to the previous survey in 2013. On grassland systems herbicide usage dominates, representing ~96 % of the total weight of pesticides used. In contrast, 31 % of pesticides used on arable systems were herbicides, with fungicides taking up 46 %, followed by growth regulators (18 %) and insecticides (2 %).

Due to a deficit of both durable resistance within existing varieties and robust integrated pest management (IPM) strategies, farmers have become reliant on pesticides to control pests, pathogens, and weeds within their crops in order to maintain profitability. However, no farmer wants to spray; it takes time and money, and users must be registered and fully trained to minimise potential risks to health and safety, and the environment. In the case of pesticide-intensive crops such as potatoes, where up to 12 sprays per season are typically required to offset the potential losses of late blight disease, annual expenditure on potato disease control is typically ~€5 million to offset disease within the national crop.

An over-reliance on pesticide use presents further challenges with regard to the ability of a pest to overcome a pesticide's mode of action. Irrespective of whether the host is a plant/animal, the more the same chemical is used the greater the chance the target pest will negate the efficacy of the active substance.

Depending on the biology of the targeted pest this can have a dramatic effect. For example, in the case of septoria blotch disease (STB) of wheat, septoria strains now exist in Ireland with resistance to strobilurin and SDHI fungicide classes, as well as tolerance to several azole chemistries. Combined with the loss of chlorothalonil fungicide in 2020 due to legislative constraints, there are now a diminishing number of effective pesticides available to control STB in wheat, therefore undermining the future sustainability of an important crop in tillage rotations.

Drivers for change

The drive within the EU to limit pesticide use did not begin with the publication of Farm to Fork. For over 20 years, various legislative directives and regulations have focused on heightened water quality requirements to limit pesticide levels in drinking water, redesign of pesticide approval procedures to a hazard-based versus the previous risk-based assessment, and promoting the sustainable use of pesticides across member states via a greater reliance on IPM practices. In its simplest form IPM is the use of multiple approaches/agents, be they physical, biological, chemical or cultural, to diminish pest damage, while maintaining the economic sustainability of the cropping system. At a practical level, IPM does not preclude the use of PPPs, but rather triggers their use only as a last resort. Hence, the decision to spray is made only once all other options have proven ineffective.

In 2019, Teagasc partnered with 38 EU academic and public entities in a new European Research Alliance to develop novel research and experimentation strategies to achieve the goal of reducing pesticide usage across the EU.

Next steps

Based on current crop management systems, a blanket reduction of 50 % in PPP usage will significantly increase economic risk for farmers, making the cultivation of several crops impractical, and thereby further increasing Ireland's dependency on imported substitutes. However, the key to mitigating any risk is diversification. With IPM a cornerstone of the Farm to Fork strategy, diversification will mean expanded and more diverse rotations, with additional break crops between cereals in addition to adopting alternative cultivation techniques, to give more opportunities within the rotation to minimise pest damage. Expanding arable margins to promote beneficial organisms and minimise grassweed populations will be important, as will increased vigilance on behalf of the grower to survey their crops and identify pest incidence at an early stage. To inform decision making, enhanced disease surveillance will be key. At a basic level, this simply starts with the farmer devoting more time to walking crops. In time, assistance from the use of in-field biosensors, image-based plant disease detection, and landscape surveillance networks linked with rapid diagnostic platforms will add additional depth to surveillance strategies.

Choosing the most appropriate variety is central to effective IPM, but that is based on the assumption that material with durable resistance is available. When it is, the impact is significant, as we have seen with the use of genes conferring late blight resistance in potatoes. Combined with weather modelling and disease surveillance we demonstrated how genetic resistance to late blight in potatoes can reduce the environmental impact by >80 % and reduce sprays from 12 to two per season (Kessel *et al.*, 2018) clearly demonstrating that improved crop genetics can actually exceed the required 50 % mandated cut in PPP use as per Farm to Fork.

In 2019, Teagasc partnered with 38 EU academic and public entities in a new European Research Alliance to develop research and experimentation strategies to achieve the goal of reducing pesticide usage across the EU. The Alliance is currently designing a programme of research focused on testing, piloting and demonstrating systemic innovations in support of the Farm to Fork Strategy. While the integration of multiple tools, technologies and practices can deliver crop management systems with the potential to achieve a 50 % cut in pesticide usage, it is important to note that this is on the assumption that in time the positive impact novel technologies can play in achieving this ambitious goal is fully realised.

*Active substances are the essential ingredients in a pesticide that enable the product to do its job. The pesticide is the final product placed on the market. Apart from active substances, a pesticide usually contains other ingredients to increase its efficacy and better protect the plant on which it is applied. For more information, see https://ec.europa.eu/assets/sante/food/plants/pesticides/lop/index.html.

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Multi-year grassland bio-based fertiliser trial, Johnstown Castle, Co. Wexford.

Reducing nutrient losses and fertiliser use

TEAGASC researchers have spent many years looking at alternative nutrient sources to reduce chemical fertiliser demand on farms.

In the EU Farm to Fork Strategy for a fair, healthy and environmentally friendly food system, one of the key targets is to act to reduce nutrient losses by at least 50 %, while ensuring that there is no deterioration in soil fertility. This is likely to affect the quantity and type of nutrient inputs farmers use to produce grass and crops, and the European Commission has indicated that a reduction in fertiliser use of at least 20 % by 2030 will be needed to achieve these targets across the EU. Under Farm to Fork, the Commission aims to develop, in conjunction with member states, an integrated nutrient management action plan to address nutrient pollution at source and increase the sustainability of the livestock sector. They will also want member states to promote the application of precise fertilisation techniques and sustainable agricultural practices, notably in nutrient hotspot areas of intensive livestock farming, and to recycle organic wastes into renewable fertilisers.

Research support for agri-industry and farmers

Achieving these targets for reducing nutrient losses and fertiliser use on farms may present challenges for conventional methods of farming. However, in Ireland, the Teagasc, Crops, Environment and Land-use Programme at Johnstown Castle has been conducting research and innovation in the area of soils and nutrient efficiency for many decades. This research knowledge and the technologies developed are available to support farmers through the transition period and to guide new technology transfer in the area of smart, sustainable and climate-friendly agricultural production systems. For example, the Nutrient Management Planning Online (NMP Online) decision support tool harnesses the latest research to enable farm advisors and agronomists to tailor fertiliser and organic manure advice to individual fields on farms. NMP Online recognises spatial and temporal variability in nutrient demand and risks for nutrient losses.

> Farmers have the potential to displace a portion of their conventional mineral fertiliser usage with new bio-based and recycled fertilisers, and to build soil health.

Soil fertility limiting N efficiency on grassland farms

A recent study across dairy farms in Ireland highlights suboptimal soil fertility as a limitation to herbage production, leading to unbalanced nutrient uptake and grass nutrition. Across the 446 grassland fields

studied, the general nutrient limitation followed the order phosphorus (P) > potassium (K) ≥ nitrogen (N) from most limiting to least limiting (Nikoloski *et al.*, 2019). The mean N use efficiency for P Index 1 soils of 50 % was significantly lower than the mean N use efficiency for P Index 3 soils at 59 %. Similarly, this study found that the mean N use efficiency for K Index 1 soils of 44 % was significantly lower than both K Index 3 and 4 at 57 % and 60 %, respectively. Across the fields nutrient supply was limiting grass growth through suboptimal background soil fertility levels and/or unbalanced fertiliser and nutrient applications. In general, these findings indicate that grassland swards are often undersupplied with some nutrients, while being adequately or oversupplied with others, depending on the levels of grass production achieved. Overall, the supply of N across these fields was often least limiting; however, given the pH, P and K limitations detected, the fertiliser and organic manure N sources were less efficiently used by the grassland than they could have been.

Sustainable alternative nutrient sources

The EU Farm to Fork Strategy highlights that the "circular bio-based economy is still a largely untapped potential for farmers", for example, "to produce bio-based fertilisers". Farmers have the potential to displace a portion of their conventional mineral fertiliser usage with new bio-based and recycled fertilisers, and to build soil health. Consequently, providing agronomic advice for these fertilisers requires urgent attention as significant knowledge gaps exist surrounding nutrient release, field performance and the economics of these new bio-based fertilisers. These knowledge gaps need to be filled before these new fertilisers can be employed as strategies to meet the ambitions of a 20 % reduction in fertiliser use and to reach "at least 25 % of the EU's agricultural land under organic farming by 2030".

New research on bio-based fertiliser sources

The importance of crop quality as well as yield and economics has resulted in arable farmers becoming leaders in tailoring nutrient rates and timing to precisely meet crop requirements and in actively managing their soil resource. Mineral fertilisers have proven to be a convenient and consistent source of nutrients for many years. However, there is a growing interest in the potential long-term soil health benefits of including other sources of nutrients such as organic or recycling-derived fertilisers. These fertilisers often deliver other nutrients to soil in addition to N, P and K, along with carbon. As part of the EU H2020-funded Nutri2Cycle project, a multi-year research and demonstration study in collaboration with Teagasc tillage specialists and advisors has been established. In this research the agronomic performance, practicality, economics and soil health effects of using organic nutrients recaptured via processing are currently being evaluated and demonstrated to farmers (**Figure 1**).

Performance of organic manures and recycled residues to date

In 2019, silage maize, which has a high nutrient demand, was grown. Fertiliser programmes incorporating poultry manure, broiler

FIGURE 1: The Nutri2Cycle on-farm arable site where fertiliser programmes incorporating organic and recycled nutrient sources are being applied for each rotational crop (spring wheat 2020).

manure, cattle slurry, and two types of dairy processing sludge were applied and compared to a nutrient programme using mineral fertiliser only. These initial results indicate that the manure- and sludge-based nutrient sources performed similarly to mineral fertiliser and all treatments produced maize yields of c. 25 t/ha dry matter. Using these bio-based fertilisers, significant cost savings of 23-37 % on mineral fertiliser were achieved without compromising yield. Soil health effects and the benefits of recurring applications of organic manures will be measured and demonstrated over the coming years of this experiment.

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Antimicrobial use and resistance in ruminants

Research to monitor and quantify antimicrobial use and resistance in ruminants will be essential to meet EU reduction targets.

Antimicrobials are one of the main advances in medicine and are a key tool used to fight infectious diseases in humans and animals. However, their misuse has resulted in an increase in antimicrobial resistance (AMR), which has been recognised by the World Health Organization as one of the biggest challenges for both human and animal health. In the last 20 years, human infections with multi-resistant bacteria, for which no antimicrobial treatment is effective, have increased worldwide, and the development of new antimicrobials has been unsuccessful. In this context, a drastic reduction in antimicrobial use (AMU) in both humans and animals is the only approach to reduce AMR.

Publicly available figures on AMU have become best practice both in human and veterinary medicine. On the animal side, most EU countries have data on total antimicrobial sales, with breakdowns by pharmaceutical form and antimicrobial type. However, only countries like Sweden, Denmark and the Netherlands have been recording AMU at species level (e.g., pig, chicken, dairy) for a long time and have achieved significant AMU reductions. The availability of AMU figures at species level is key to monitoring reductions, and will become an EU requirement and an important commercial barrier in the near future. Thus, many countries are now starting data collection systems to have databases for the different species and production systems (**Figure 1**).

Data collection in Ireland

The pig and poultry sectors are the main users of antimicrobials because of in-feed use to prevent disease. Chicken farmers have done an exceptional job in reducing AMU and now they are producing with low or no antimicrobials in many cases. This is the case in Ireland, where chicken production is probably one of the lowest users. The Irish pig sector also reacted early with the first national database on AMU in 2019. The first AMU data collection in pigs was done by Teagasc/UCD (AMURAP DAFM ref: 15S676) in 2016, as part of the first iNAP (Irish National Action Plan on AMR), and included one-third of the Irish pig herd. This data showed that the pig industry is responsible for most of the in-feed use of antimicrobials as premix, accounting for 30-35 % of total antimicrobial sales. However, it also showed that the pig industry was not responsible for the use of those antimicrobials classified as oral remedies. Altogether, pigs and poultry are responsible for around 40-45 % of the AMU in animals in Ireland including injectables, premix and oral remedies. The question now, is: who is responsible for the rest?

Intramammary use is probably an easy one to guess, as it is only used in dairy cattle. However, it accounts for less than 3 % of total sales (**Figure 2**). Then there is a significant portion of the oral (38 %) and injectable (28 %) remedies to be assigned. Small animals and horses are important users of injectables, although they probably do not account for the whole amount. The rest of injectables and the oral remedies are expected to be used mainly for cattle and sheep. It is especially important for public health and commercial reasons to know where these antimicrobials are being used (i.e., dairy, beef, sheep) and what the main causes of use are (e.g., mastitis, lameness, respiratory infections).

Critically important antimicrobials

Other than the total amount of AMU, it is important to consider the use of critically important antimicrobials (CIAs). These are antimicrobials that are used in both humans and animals but that are of special importance to treat human infections as a last resort. In other words, if bacteria develop resistance to these antimicrobials, we will have no treatment left for these bacteria and any infection

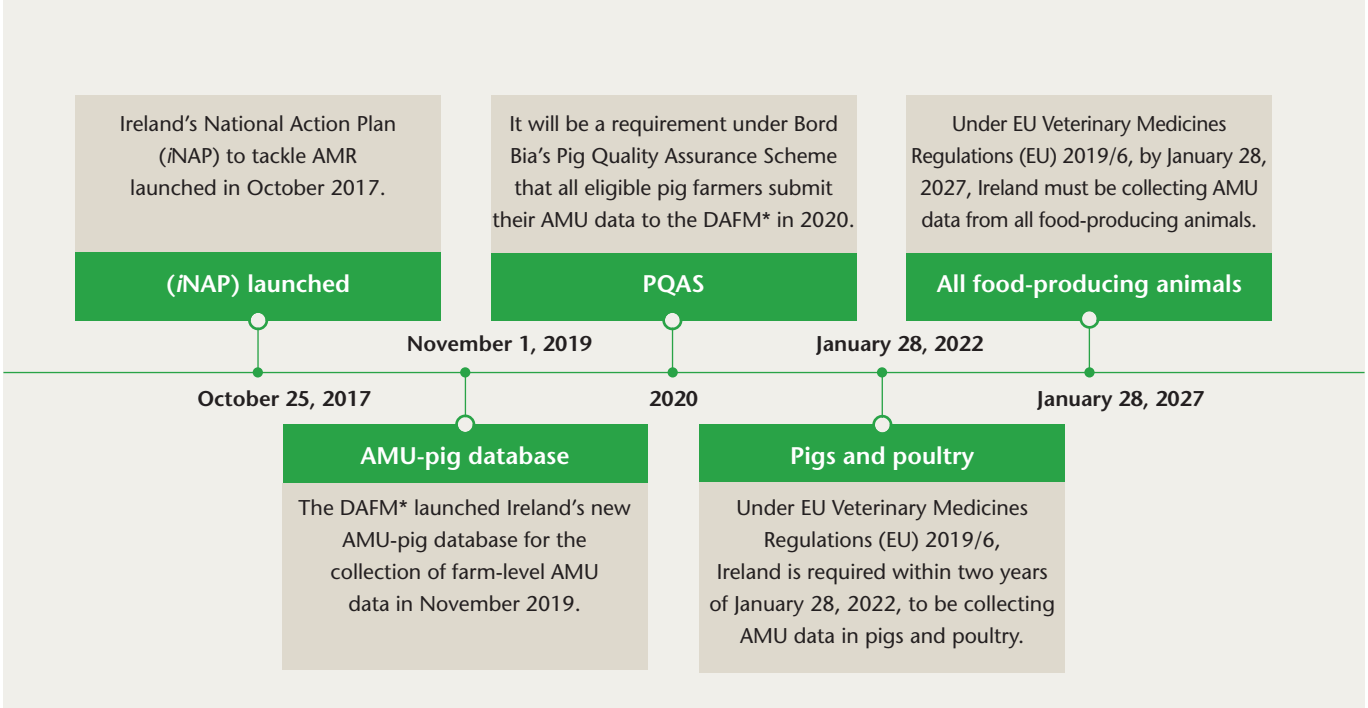

*FIGURE 1: Timeline of the main actions taken in Ireland to promote prudent use of antimicrobials. *Department of Agriculture, Food and the Marine.*

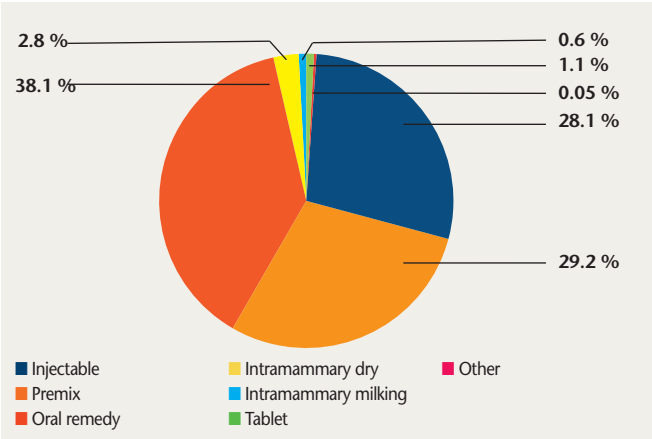

FIGURE 2: Pharmaceutical form breakdown of veterinary antibiotics sold in 2018 in Ireland.

could be fatal. Thus, they should be used as little as possible in animals. The use of these CIAs is low in pigs and poultry in Ireland. In the case of ruminants, some antimicrobials of importance for humans are still in use, such as cephalosporins for mastitis treatment and fluoroquinolones for respiratory infections in calves. However, new EU regulations will place restrictions on the use of CIAs in animals, to ensure that they are only used when no alternative treatment is available, to preserve them for use in human medicine. Under the Farm to Fork Strategy, a key component of the European Green Deal, the European Commission (EC) has committed to taking action to reduce overall EU sales of antimicrobials for farmed animals and in aquaculture by 50 % by 2030. Monitoring AMU at species level will be important for Ireland, to account for the antimicrobials sold and allow for the main areas of use to be identified. Once we are aware of how the antimicrobials are being used, targeted reduction strategies can be put in place to ensure that Ireland is on track with the EC to reduce antimicrobial sales and the threat of AMR.

Further reading

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EU organic logo.

Organic ambition

The EU wants more organic farming and has set a big target to grow the sector.

Overview of EU plans for the organic sector

A target of 25 % land area under organic management by 2030 has been set by the EU under the new Farm to Fork Strategy. This target is very ambitious and gives a clear indication of the important role organic farming will play in moving towards a "fair, healthy and environmentally friendly food system" as envisaged under the Strategy. The Commission says that it wants to focus on the sustainable economic development of the organic sector and on increasing consumer demand for organic food.

Organic targets for Ireland and Europe

Individual targets for member states have yet to be decided. The target of 25 % organically managed land is an average for the EU as a whole, and all countries will have to contribute. It is envisaged that member state Common Agricultural Policy (CAP) strategic plans will set appropriate, country-specific targets, based on the current status and scope for organic market development (**Table 1**).

The average organic land area in the EU is 7.5 % (2018). Organic land area in Ireland remains proportionally small at just over 2 %, but has seen a 50 % increase in size since 2014 (**Figure 1**).

What is organic farming?

Organic farming is an overall system of farm management and food production that combines best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high welfare standards, and a production method in line with the preference of certain consumers for products produced using natural substances and processes.

Why organics?

There are several reasons why organic farming is supported:

Legal backing

The organic farming system is enshrined in law from farm to fork and has the trust of the consumer. All EU operators farm to a strict set of EU standards and are inspected regularly.

Sustainable low-input farming

We know from the research that, in general, organic farming has a more benign effect on the environment compared to conventional farming. No artificial nitrogen or agro-chemicals are permitted, and we need to reduce levels of both in the future according to the EU. Organic production leads to increased biodiversity due to plant species diversity, crop rotations and lower input use.

Additional animal welfare considerations

Animal welfare and health has become more relevant in farming, and is considered of paramount importance in organic farming. On organic farms, animals are given more space if housed and are allowed to express their normal behaviour.

Increasing demand for organic food

The global demand for organic food is worth €100 billion and this is forecast to rise. The EU market has doubled over the last 10 years and is worth almost €40 billion. According to Bord Bia, organic retail sales amount to €250 million, which is about 1 %

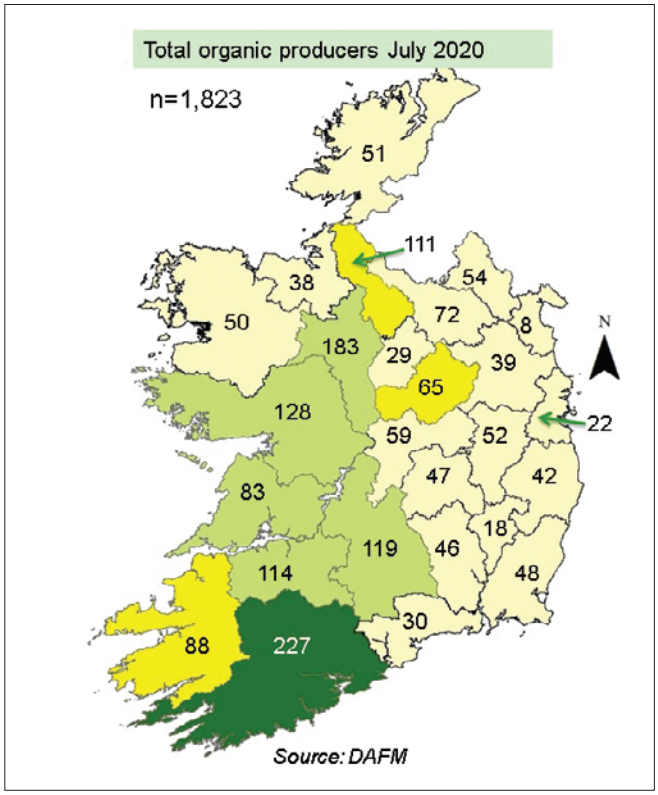
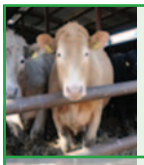


FIGURE 1: Total organic producers to July 2020. Top six counties: Cork – 227; Roscommon – 183; Galway – 128; Tipperary – 119; Limerick – 114; and, Leitrim – 111.

Table 1: Organic enterprises in Ireland (latest figures 2019).

	**CATTLE** ~1,400 farmers; ~18,500 suckler cows
	**SHEEP** ~600 farmers; ~65,000 ewes
	**TILLAGE** ~160 farmers farming ~2,500 ha (mainly oats)
	**HORTICULTURE** ~300 farmers produce vegetables on ~520 ha
	**DAIRY:** 62 farmers milking 5,000 cows

Source: Department of Agriculture, Food and the Marine.

of total food sales. The EU wants to invest in growing the demand for organic food further.

Farmer lifestyle choice

Younger farmers especially are looking at their farms with 'new eyes', free from the stigma that their parents may have associated with organics. Some may have spent time abroad and learned about organic farming then. Some see it as a way of cutting back on inputs and labour while still returning a good income.

Increasing rural viability

Organics can be a profitable option with the potential to boost investment in the local economy and create jobs. This can be the case for all types of organic enterprises. In particular, small horticulture enterprises, many of which employ local people, can have a very positive economic effect on the locality.

Where are the market opportunities?

In Ireland, markets exist for the majority of organic products. In particular, demand exists for tillage, horticulture and dairy products, much of which have to be imported. Large companies including Glenisk (organic milk), Flahavans (organic porridge oats), Good Herdsmen and Slaney Meats (organic beef), and Irish Country Meats (organic lamb) are involved in the organic business and buy product from farmers. Contracts may also be available from some processors. Many organic farmers also avail of short supply chains and like to sell directly through farmers' markets, box schemes and farm shops.

It is envisaged that market opportunities for organic produce will continue to grow and will be aided by the EU's plan to invest in promoting the benefits of organic production and food as part of the overall Farm to Fork Strategy.

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Good respiratory health improves profitability of Irish pig farms

TEAGASC research used data from the Irish national sow herd to quantify the impact of common pathogens on financial viability.

Background

Pathogens such as porcine reproductive and respiratory syndrome virus (PRRSv), swine influenza virus (SIV) and *Mycoplasma hyopneumoniae* (*M. hyo*) are common in intensive pig production systems worldwide. These pathogens are part of what is known as the porcine respiratory complex, and are responsible for the diseases commonly known as blue ear, swine flu and enzootic pneumonia, respectively. Although the presence of the pathogen does not necessarily mean the development of the disease, herds with endemic disease always suffer effects on profitability that are not well understood and might not be evident to producers.

There are few reports regarding these financial losses and most of them come from the USA. Differences in production systems, costs of production, revenue streams and other assumptions incorporated into North American studies mean that the results are not easily comparable to European pig production systems. Moreover, the majority of existing reports used data from experts and/or from the scientific literature for their financial estimations, which might not reflect current market conditions. In this study we used farm data representing 30 % of the Irish national sow herd to quantify the financial impact of positive herd status for PRRSv, SIV and *M. hyo*.

Bio-economic analysis

We incorporated the effect of PRRSv, SIV and *M. hyo* on key performance indicators into the Teagasc Pig Production Model (Calderón Díaz *et al.*, 2019), a bio-economic simulation model for farrow-to-finish pig farms. We simulated the performance of an average Irish sow farm with either negative or positive status for each of the respiratory pathogens for an entire year.

The number of pigs in each production stage was calculated each week within the model based on the mortality rates for different production stages. All pigs were slaughtered once they reached 110.8 kg bodyweight. Time to reach target slaughter weight varied depending on disease status. For all scenarios, farms that had negative disease status provided the baseline data for comparison of results with farms with positive disease status.

The differences between studies may be, in part, due to the different production systems and different modelling approaches, as we used actual farm data.

Financial implications of respiratory pathogens

Feed costs during the wean-to-finisher period account for almost 60 % of the total cost of production on a pig farm. Feed costs per

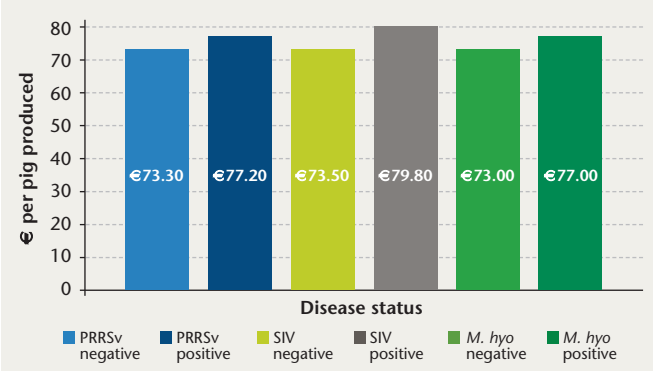

FIGURE 1: Feed costs (€ per pig produced) on farms with either negative or positive status for PRRSv, SIV and M. hyo.

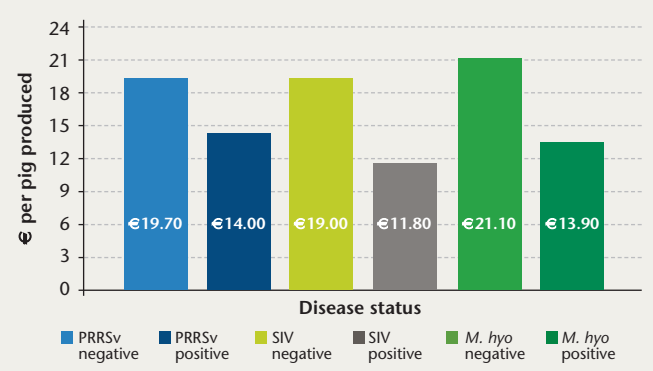

FIGURE 2: Net profit (€ per pig produced) on farms with either negative or positive status for PRRSv, SIV and M. hyo.

pig were 5.3 %, 8.6 % and 5.5 % greater in PRRSv-, SIV- and *M. hyo*-positive farms, respectively, compared with negative farms (**Figure 1**). This was due to lower average daily gain in farms with positive disease status, and thus, pigs required more time to reach target slaughter weight. Dead animal disposal was also greater in farms with positive disease status, reflecting greater mortality rates in the different production stages. Greater mortality rates also translated into less income: PRRSv-, SIV- and *M. hyo*-positive farms sold 3.8 %, 1.4 % and 5.3 % fewer pigs per year, respectively, than farms with negative disease status.

Greater variable costs and smaller sales reduced net profit in farms with positive disease status (**Figure 2**). The financial losses observed in this study for PRRSv, SIV and *M. hyo* are greater than those reported in US production systems. The differences between studies may be, in part, due to the different production systems and different modelling approaches, as we used actual farm data. This demonstrates the importance of using a bio-economic model that is capable of simulating the particular Irish pig production system and market conditions. Finally, contrary to reports from the USA, greater financial losses were associated with positive disease status for *M. hyo* than for PRRSv in Irish pig farms. This was mainly attributed to a greater reduction in income in *M. hyo*-positive farms compared with PRRSv-positive farms in Ireland. Alternatively, it is possible that the North American PRRSv genotype causes more severe respiratory disease in pigs compared with the European PRRSv genotype.

Benefits to the pig industry

Our results provide information regarding the adverse effects of the presence of respiratory pathogens on farm profitability, and highlight the importance of disease prevention on Irish pig farms. Disease prevention strategies should include improved biosecurity practices (e.g., reduced stocking density, better ventilation) to avoid introducing respiratory pathogens into the herd and controlling their effects once they have been introduced.

Furthermore, our results should encourage farmers to implement disease eradication programmes to minimise the adverse economic effects of infection with respiratory pathogens, especially when prices are low.

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The project was funded by the Department of Agriculture, Food and the Marine under the Research Stimulus Fund (grant no. 14/S/832). Maria Rodrigues da Costa (Teagasc), Jarkko Niemi (LUKE), Ilias Kyriazakis (Newcastle University) and Rose M. Fitzgerald (CIT) are also collaborators on this project.

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Photograph taken during Nicola Fetherstone's visit to Blackdale Stud, Riverton, New Zealand, as part of the Walsh Scholar International Training Programme 2019.

Can the Irish sheep industry benefit from New Zealand genetics?

TEAGASC research investigated the possible benefits of using elite maternal genetics in the Irish sheep industry.

The transfer of germplasm between countries occurs frequently across the beef and dairy industries. However, such practices are limited in sheep, with the exception of animals traded between a small number of countries such as Ireland, the United Kingdom and France, with animals tending to be traded based on their physical attributes rather than their genetic potential. Recent research findings from the INZAC flock in Teagasc Athenry have highlighted the potential genetic and economic benefits that can be achieved within the Irish sheep industry through the use of genetically elite maternal genetics sourced from either Irish or New Zealand flocks. The use of foreign genetics has been shown as a suitable method to accelerate genetic gain achievable within the domestic industry in both the beef and dairy industries. Given the potential benefit of incorporating elite maternal genetics into the Irish sheep industry, the most appropriate source of these genetics, coupled with the methods of disseminating them, must be investigated. Therefore, the objective of this research was to assess, using a gene flow model, whether the Irish sheep industry would benefit from the use of elite maternal genetics, sourced from either Irish or New Zealand flocks, and if so, how best to incorporate those genetics into the industry in order to maximise genetic gain.

Gene flow models

A gene flow model can be used to identify optimal breeding strategies that maximise the economic and genetic benefits, while allowing for the gradual improvement in the rate of genetic gain to be achieved over time. Previously, gene flow models have been used across the sheep, beef and dairy industries to quantify the impact of performance recording, genomic selection, genetic evaluations, or the use of foreign genetics on genetic improvement.

For this study, data used to generate the gene flow model was retrieved from the Sheep Ireland Replacement and the New Zealand Maternal Worth Indexes, as well as data generated from the INZAC research flock in Teagasc Athenry. The model predicted the genetic improvement, in economic merit, for future generations of commercial sheep as a consequence of the

widespread implementation of alternative breeding strategies. Various subpopulations were used within the model to demonstrate the current structure of the Irish sheep population. They included: conservative breeders who select animals based on physical attributes rather than genetics; progressive breeders who are actively performance recording and select animals based on genetics; foreign breeders who supply superior foreign genetics directly to commercial farmers; and, commercial farmers who are the end users of the domestic and/or foreign genetics.

In this study, three contrasting scenarios were investigated. A Base scenario was firstly modelled, which predicted future performance of the Irish sheep industry assuming no change to current breeding strategies. A Progressive Irish scenario modelled the impact of the shift of market share away from conservative breeders towards progressive breeders who use domestic maternal genetics. Finally, a New Zealand scenario investigated the impact of the direct use of elite New Zealand maternal genetics, whereby New Zealand rams were imported every five years.

For each scenario the economic and genetic benefits to the Irish sheep industry were calculated over a 20-year time frame. For the three modelled scenarios, the greatest economic and genetic gains were achieved by the Progressive Irish scenario, which had the potential to increase economic gains four fold over the base scenario (**Figure 1**). When a strategy including the widespread implementation of imported New Zealand genetics within the Irish sheep industry was investigated, the annualised cumulative benefit was almost three times greater than the Base scenario after the same time frame, but was less than that generated by the Progressive Irish scenario. Lambs born as a result of the implementation of the New Zealand import scenario benefit from an initial boost due to the superiority of the foreign genetics over domestic genetics. However, the long-term impacts of the New Zealand scenario are hampered by the foreign population having a low long-term genetic trend, and therefore benefits plateau faster than the Progressive Irish scenario.

Implications

Results from this research demonstrate that it is possible to substantially increase the genetic and economic benefits to the Irish sheep industry over time, without the use of foreign genetics, but through the strategic use of progressive domestic genetics. Essential to the success of this breeding strategy is a shift in the market share away from conservative breeders towards progressive breeders, therefore requiring Irish sheep breeders to become more engaged with the national breeding programme and select high genetic merit animals to become parents of the next generation. However, the use of foreign genetics, such as New Zealand genetics, may play a key role in triggering this shift. The gene flow model developed as part of this study now provides a roadmap for a future breeding strategy of the Irish sheep industry, and acts as a template for other scenarios or even industries to quantify their genetic and economic benefits as a result of foreign genetics, regardless of country or species.

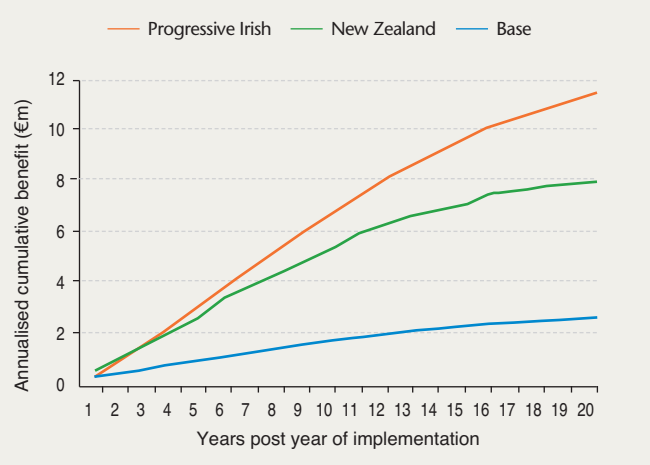

FIGURE 1: Annualised cumulative benefit (expressed in € millions) from year 1 to 20 post implementation of the Base, Progressive Irish and New Zealand scenarios.

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Deciding who makes the cut

A decision support tool co-developed by TEAGASC will aid farmers in choosing beef females for retention or culling.

Decision support tools founded on estimates of animal genetic merit have almost exclusively focused on identifying superior candidate parents to breed the next generation of more profitable progeny. One exception is the dairy Cow's Own Worth (COW) tool (*TResearch*, Spring 2018), which ranks dairy cows as candidates for culling. The framework for a decision support tool to identify which beef females (both heifers and cows) are likely to be most profitable for the remainder of their lifetime has now been developed by Teagasc in collaboration with the Irish Cattle Breeding Federation and AbacusBio, New Zealand; the new tool is called the Beef Female's Profit Potential (BFPP). Voluntary culling decisions are notoriously multifactorial, leading to the demand for the BFPP to aid producers in making more informed, data-driven decisions when choosing beef females suitable for retention and culling.

Beef Female's Profit Potential

The BFPP tool consists of four key modules, which, when combined, culminate in the predicted profit potential for each beef female, depicted as a single Euro value. These four key modules are: 1) the female's profit potential as a heifer, provided she has not yet calved; 2) the potential profit from her current parity, provided she has calved at least once; 3) the predicted profit potential from her expected remaining future parities; and, 4) the value of the beef female if she were to be retained within the herd and not voluntarily culled. The index is underpinned by information on a total of 17 different animal traits, providing the user with a comprehensive BFPP value for each beef female; nonetheless, the framework is sufficiently flexible to cater for any newly developed animal feature should it become available. While genetic evaluations only consider the merit of an animal that is directly transmitted to its progeny, the actual future performance of any given female is a manifestation of both her genes that are directly transmitted and how these genes interact, as well as non-genetic effects such as the age of the cow, the environment she performs in, and both her actual and expected calving dates.

> The gene variants that are transmitted from a parent to its offspring cannot be known *a priori*; however, predictions can be made.

Therefore, all of these factors are included in the estimation of the BFPP. Moreover, the performance of the beef female's progeny is also included in the BFPP, as this too will dictate her future profit potential, since some of her progeny will be directly processed for human consumption, while others may eventually graduate into the mature beef herd as cows. The gene variants that are transmitted from a parent to its offspring cannot be known *a priori*; however, predictions can be made. Similarly, by using mathematical approaches to combine cow-level features with historical population-level data, it is possible to estimate the expected remaining lifetime of a given female.

Table 1: Least squares means performance of beef cows when ranked on their Beef Female's Profit Potential value and the performance of their progeny for carcass traits (i.e., weight, conformation and fat); standard error in parenthesis.

		Beef female stratum			
	Trait	Best 25 %	50-75 %	25-50 %	Worst 25 %
Cow traits	Survival[1]	1.63[a]	1.49[a]	1.33[a]	1.00[b]
	Calving interval (days)	377.21 (0.55)[a]	372.38 (0.54)[b]	371.19 (0.53)[b]	368.88 (0.57)[c]
Progeny traits	Carcass weight (kg)	398.46 (0.85)[a]	398.48 (0.82)[a]	396.61 (0.80)[ab]	394.29 (0.83)[b]
	Carcass conformation (1 to 15 scale)[2]	7.19 (0.02)[a]	7.14 (0.02)[ab]	7.07 (0.02)[b]	6.94 (0.02)[c]
	Carcass fat (1 to 15 scale)[3]	7.94 (0.02)[a]	7.99 (0.02)[ab]	8.04 (0.02)[b]	8.04 (0.02)[b]

Different superscripts within row indicate significance difference P < 0.05:
[1]Odds of surviving to the next lactation relative to the worst stratum;
[2]Carcass conformation ranges from 1 (poor) to 15 (excellent); and,
[3]Carcass fat ranges from 1 (very low fat) to 15 (very high fat).

BFPP validation

The BFPP tool was validated on a population of 21,102 Irish beef females and their progeny based on their calvings in the year 2017. Each female was stratified into one of four groups based on her within-herd BFPP value. The beef females in the best 25 % stratum had a 1.6 times greater probability of surviving to next lactation relative to the beef females in the worst 25 % stratum, despite having a longer calving interval (i.e., only available on cows that survived – **Table 1**). The difference in performance between the beef females in the best 25 % stratum relative to the worst stratum was estimated to be worth an additional €32 profit per calving. This additional profit was a result of not only the beef female's own survival and calving interval performance, but also the performance of her processed progeny. The harvested progeny of the best 25 % BFPP females were, on average, heavier, with better conformed carcasses and less fat cover relative to the progeny of the worst 25 % BFPP females (**Table 1**).

A huge advantage of the BFPP index is that it includes a heifer module, which, in turn, facilitates the decision-making process when deciding which heifers have a greater lifetime profit potential and thus should be retained for breeding. Ranking the BFPP of both heifers and cows together identifies the point at which the next most profitable candidate heifer replacement is no better than the next least profitable cow; at this point, culling any more cows does not make economic sense. The BFPP was developed to be used complementary to the national breeding indexes. Therefore, once the decision has been made as to which animals will be voluntarily culled from the herd, the producer can progress to using the national Replacement Index to identify superior females for breeding replacements and the national Terminal Index to breed superior finishers.

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ASSAP improving water quality

The recently published Agricultural Sustainability Support and Advisory Programme (ASSAP) Interim Report #1 identifies collaboration with farmers and industry, and provision of farm-specific plans, as key to improving water quality in Ireland.

The EU Water Framework Directive (WFD) requires Ireland to have all waters at "good status" by 2027, with the recently published Environmental Protection Agency (EPA) water quality report for 2013-2018 showing that Ireland has 53 % of our surface waters at the required EU status. There has been a declining trend in water quality during that period.

The WFD also requires Ireland to prepare and implement a national River Basin Management Plan (RBMP). The current RBMP, published in 2018, adopted a more collaborative and engagement-based approach with stakeholders. It also implemented a more focused approach to improving water quality by identifying 190 Priority Areas for Action (PAAs), with the emphasis on establishing an evidence-based approach to pressure identification provided by Local Authorities Waters Programme (LAWPRO) scientists. Farmer-focused advice and farm-specific plans designed to help implement the 'right measure in the right place' are provided by Teagasc (20 advisors) and the dairy processing co-ops (10 advisors).

ASSAP industry-wide collaboration

The principle of collaboration in the RBMP is fundamental to the establishment and implementation of the Agricultural Sustainability Support and Advisory Programme (ASSAP). Funding is provided by the Department of Housing, Planning and Local Government, the Department of Agriculture, Food and the Marine (DAFM) and the dairy processing co-ops. The LAWPRO provides the catchment science teams, and Teagasc and the dairy processing co-ops provide the advisory services for the programme.

However, a key element to ensuring farmer participation with the programme involved engagement with the farming organisations and their participation in the ASSAP co-ordination structures, resulting in strong support for the ASSAP at national and local level. This industry-wide collaboration is crucial for the ASSAP to aid in achieving the collective goal of "good status" for Ireland's waters, and will help to strengthen agriculture by reinforcing our green image as food producers and underpinning the future development of sustainable Irish agriculture.

Farm assessments – issues identified, mitigation actions and farm plans

The ASSAP provides farmers in PAAs with a free and confidential advisory service. The purpose of the farm visit is to identify any potential practices or behaviours that may be having an impact on water quality. The advisors assess the farms under three categories: farmyard management; nutrient management; and, land management. Farmer engagement with the programme has been very positive, with 96 % of farmers availing of an advisor visit.

At the end of the farm visit the advisor and farmer will agree on how best to focus improvements or mitigation actions, if any are required, on the farm. The practical advice will be designed to put the right measure in the right place and prevent nutrients, sediment and pesticides from entering water. A written farm-specific plan detailing advice and actions will be provided to the farmer and a timeframe for completion agreed. Advisors will revisit farms where necessary to aid with the implementation of mitigation actions.

To date, diffuse phosphorus (P; 32 %), diffuse nitrogen (N; 16 %) and sediment (27 %) losses account for 75 % of the pressures

Table 1: Recommended mitigation actions for the five most frequent issues arising on farms.

1: Phosphorus loss through overland flow	%	2: Preparation and implementation of nutrient management plan	%
Management of critical source areas (CSAs)	35	Application of nutrients at correct rate	51
Riparian buffers	28	Informing and educating farmers	39
In-field grass buffers	15	Avoiding application at high-risk times and locations	6
Other	22	Other	4
3: Drinking points and stream fencing	**%**	**4: Buffers**	**%**
Preventing livestock access to waters	75	Adhering to buffer zones	76
Informing and educating farmers	20	Riparian buffers	8
Other	5	Avoiding application at high-risk times and locations	6
		Other	10
5: Organic manure timing, location and method	**%**		
Avoiding application at high-risk times and locations	67		
Informing and educating farmers	16		
Adopting latest application techniques	9		
Other	8		

identified in PAAs by the LAWPRO as affecting watercourses/streams, with point sources, toxicity/pesticides and ammonium making up the remainder.

The issues identified at farm level as contributing to the nutrient or sediment losses to waters correspond with the pressures identified, with diffuse P and sediment losses and nutrient management practices being identified by advisors as potential risks to water quality from farming activity.

The ASSAP provides farmers in PAAs with a free and confidential advisory service. The purpose of the farm visit is to identify any potential practices or behaviours that may be having an impact on water quality.

Diffuse P and sediment losses occur most frequently on 'heavy' soils that get saturated easily; this leads to water flowing overland, bringing with it plant-available P and sediment. This can get washed into drains and streams, especially where these are not protected by riparian/buffer margins, which help to reduce these diffuse losses. Cattle access to streams also contributes to the levels of P and sediment in streams. Mitigation actions for reducing P and sediment losses are detailed in **Table 1**.

Diffuse N losses tend to occur on sandy, free-draining soils, with N not taken up by the growing crop potentially being leached into groundwater in times of heavy rainfall. Using a nutrient management plan (NMP) for N (and P) applications, and applying the correct nutrient rates during appropriate weather conditions and times of the year in suitable locations on the farm, can improve nutrient use efficiency and minimise losses to waters. Mitigation actions for reducing N losses are also detailed in **Table 1**.

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Seaweed algal fibre – a novel source of dietary fibre

TEAGASC researchers are collaborating with industry to obtain high-quality dietary fibre from Irish seaweed using a sustainable, biorefinery approach.

What is dietary fibre?

The beneficial role of dietary fibre in human nutrition is well documented. Dietary fibre is usually defined as the edible part of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine, with complete or partial fermentation in the large intestine. The term 'dietary fibre' was first coined by Hipsley in 1953 to describe the non-digestible components of plants that make up the plant cell wall and include cellulose, hemicellulose and lignin. Later it was realised that a number of health benefits are associated with the consumption of dietary fibres, e.g., reduction in atherosclerosis, and in heart and gastrointestinal diseases. The definition of dietary fibre was expanded to include other non-digestible polysaccharides.

Dietary fibres are generally classified as soluble (SDFs) and insoluble (IDFs). SDFs are widely used as food additives (thickeners, stabilisers, emulsifiers and gelling agents). These are quickly and extensively degraded and fermented in the large intestine, whereas IDFs are often degraded slowly, and partially degraded DFs are fermented. Research studies have shown a consistent association between IDFs and protection against cancer, compared to SDFs. Various sources of dietary fibre including oats, barley, rye, wheat bran and sugar beet have gained European Commission health and nutritional claim status (Commission Regulation 432/2012) (**Table 1**). Generally, it is recommended that the consumption of 25-38 g of dietary fibre per day, depending on calorie intake, will have health benefits (https://ec.europa.eu/jrc/en/health-knowledge-gateway/promotion-prevention/nutrition/fibre).

A number of health benefits are associated with the consumption of dietary fibres, e.g., reduction in atherosclerosis, and in heart and gastrointestinal diseases.

Algal fibre

Fucus vesiculosus or bladder wrack is a brown seaweed commonly found in west coastal areas of Ireland, and also in temperate or cold waters of the Atlantic and Pacific Oceans. *Fucus* is well known for several health benefit compounds, namely phlorotannins, fucoidans, laminarin, alginates, dietary fibre, essential minerals and vitamins, which are linked to a range of biological functions including antioxidant, anti-inflammatory, anti-tumour, anti-obesity, anti-coagulant, anti-diabetes and others. Algal fibre obtained from *Fucus* is also an excellent source of dietary fibre, and has been reported to impart similar improvements in human gastrointestinal health and other benefits to those obtained from dietary fibres in terrestrial plants.

Table 1: Authorised health benefits of various sources of functional fibre (EC 432/2012).

Fibre source	Claimed benefits
Oat fibre	Increase in faecal bulk; reduction of postprandial glycaemic responses
Barley fibre	Increase in faecal bulk, reduction of postprandial glycaemic responses
Rye fibre	Changes in bowel function
Sugarbeet fibre	Increase in faecal bulk
Wheat fibre	Increase in faecal bulk; reduction of postprandial glycaemic responses; reduction in intestinal transit time
Algal fibre*	Laxation; gut health, blood lipid lowering; attenuates blood glucose

**Algal fibre obtained from* Fucus vesiculosis; *claims reported are based on research studies.*

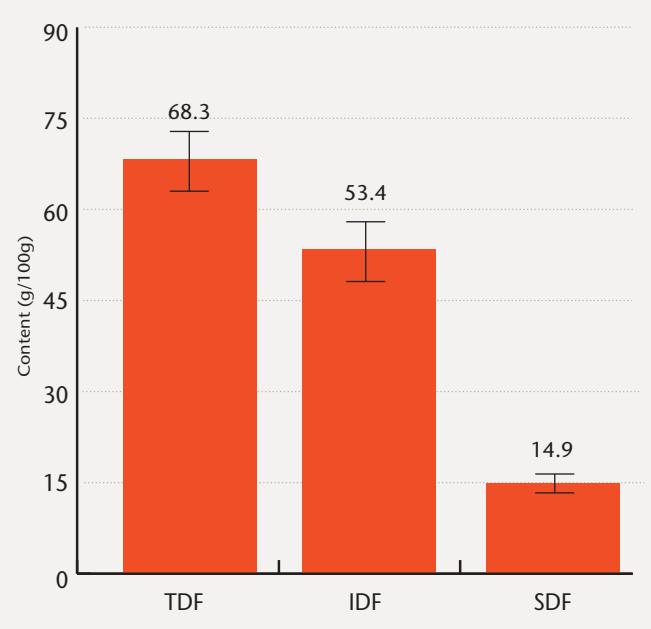

FIGURE 1: Total dietary fibre (TDF), insoluble dietary fibre (IDF) and soluble dietary fibre (SDF) obtained from Fucus vesiculosus *(data expressed as g per 100 g of dry weight).*

Teagasc researchers, in collaboration with Nutramara Ltd (Co. Kerry), under the SFI-funded BiOrbic – Bioeconomy Research Centre, have developed a green process to obtain high-quality algal fibre from Irish *Fucus*.

The proximate composition of algal fibre obtained is shown in **Figure 1**.

Generally, it is recommended that the consumption of 25-38 g of dietary fibre per day, depending on calorie intake, will have health benefits.

The algal fibre is obtained from the *Fucus* via a biorefinery approach, which retains key biomolecules including fucoidans, mannitol, laminarin, alginates and dietary fibre, without the use of chemicals. The biorefinery approach for Irish-grown seaweeds is a step towards a sustainable and zero waste concept for the seaweed industry, adding value to Irish marine bioresources.

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Fast and slow food – a matter for digestion

Researchers at TEAGASC Moorepark are leading the way in studies of *in vitro* digestion models.

When we eat food, a vast number of chemical, biochemical and biological processes are initiated. Some of these are well understood, whereas others are a complicated interplay of chemical reactions and physiological responses within the body. The first steps in the digestion of food involve the oral (mouth), gastric (stomach) and intestinal phases, where the food disintegrates into its nutrients in a form that can be absorbed by the body. To understand the physiological response to specific foods, it is necessary to follow these complex digestive processes within the human digestive tract in more detail. However, *in vivo* human intervention trials to correlate diet with the health of different demographic groups can be difficult to undertake, unsuitable, expensive, or may be unjustifiable on ethical grounds. For these reasons, *in vitro* models have been developed to simulate the digestion of food in the laboratory.

In vitro digestion models

Teagasc researchers at the Moorepark Food Research Centre have been to the forefront in developing and internationally standardising digestion models. These lab-based models, called *in vitro* models, can be simple static 'one-pot' methods such as the INFOGEST method,[1,2] or more sophisticated semi-dynamic methods.[3] Some of the more recently developed methods can also recreate the diverse physiological conditions of specific population groups such as infants, adults, older adults and those with compromised digestive systems. *In vitro* digestion studies assess changes in the structure of food during gastrointestinal (GI) transit, as well as the bioavailability of digested food.

Proteins fall into two categories – fast and slow – based on their amino acid absorption.

Slow and fast digestion

Carbohydrates are commonly classified as slow and fast molecules because their structure can affect the rate of absorption as well as the metabolic and hormonal response to a meal, as measured by the well-established glycaemic index. Equally, proteins fall into two categories – fast and slow – based on their amino acid absorption.

For instance, caseins from milk and most plant proteins such as those from soy, pea, nuts or seeds are known as slow proteins, whereas whey proteins are typically referred to as fast proteins. Key factors in determining the rate of protein digestion are their structure during gastric digestion and the rate of gastric emptying, i.e., how fast the food can transfer from the stomach into the small intestine.

The importance of gastric digestion studies

Controlling the gastric digestion using different food structures can be a tool for delivering specific rates of nutrients to the digestive tract. Food tailored to the specific digestive requirements of particular population groups can be of great benefit, e.g., faster nutrient digestion will benefit athletes for a quick recovery after exercise. On the other hand, slowing gastric

emptying could help to enhance the effect of satiety, i.e., the feeling of 'fullness' after eating, and thus delay the onset of hunger in healthy and overweight people, but also in those with diabetes, by reducing or delaying the peaks of glycaemia or lipaemia. Controlling gastric emptying can also improve digestive complications such as gastric reflux and aspiration pneumonia in infants and older adults.

The components of food and how they are processed in particular can have a profound effect on how they are digested.

Moorepark's role in the development of our understanding of gastric digestion

The components of food and how they are processed in particular can have a profound effect on how they are digested. For example, the heating of milk can eliminate dangerous pathogenic organisms and preserve it for weeks or even months. Brodkorb and co-workers have used *in vitro* digestion to show that ultra high temperature (UHT) processing milk leads to softer curd formation in the stomach in comparison to that of raw and pasteurised milk.[4]

This implies that low-heat milk is digested more slowly than high-heat milk, a result that was confirmed by some preliminary testing on humans using wireless endoscopy. The differences in the gastric behaviour were named 'gastric re-structuring', as this better describes how food with identical nutrients and ingredients can be digested differently.

Corrigan and Brodkorb[5] recently observed that milk protein products intended for infant formula can be digested differently depending on the prior processing. Pre-digestion, or hydrolysis, of the milk proteins provided a head start in the gastric digestion when compared to the non-hydrolysed, intact protein products. A lower observable protein coagulation or curd formation was found in the gastric phase of casein-dominant formulas, which could lead to an earlier onset of gastric emptying in infants. This could help with the design of infant formula, lowering gastrointestinal transit times. This might help ease problems associated with their digestion, particularly for infants where breastfeeding was not an option.

Continuous improvements in digestion models

Currently there is a lack of reliable physiological data on the digestion mechanism of infants. Moorepark researchers are currently leading an observational human study, InfantDigest, in collaboration with Trinity College Dublin, Children's Health Ireland Hospital Crumlin, University College Cork and Cork University Maternity Hospital, funded under an Enterprise Ireland Innovative Partnership Programme with industry partners. The collection of this *in vivo* information will help to prepare more accurate and robust *in vitro* methods to simulate the immature digestion of pre- and full-term infants.

Industry impact

Teagasc researchers perform *in vitro* and *in vivo* digestion studies for the manufacturers of foods, food ingredients, supplements and infant formula, both on a collaborative project and straight client contract basis. The findings of these projects can help start-ups, small, medium and multinational companies to better position their products in the marketplace and help substantiate claims regarding the digestive behaviour of food or food ingredients.

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Supporting safer and healthier farmers

TEAGASC is collaborating on research and practical initiatives to improve the health and safety of farmers, including a programme aimed at addressing farmers' cardiovascular health.

The health and safety of farmers is an issue of major national and international importance. Worldwide, farming accounts for a disproportionate number of occupational accidents (Sheehan *et al.*, 2020), and farm fatalities (Meredith, 2012). In addition to being a risky occupation it is also a relatively unhealthy one. Previous research undertaken with farmers establishes that they have a higher risk of chronic illnesses (van Doorn *et al.*, 2018) and, associated with this, of dying at an earlier age (Smyth *et al.*, 2013), than their counterparts working in other occupations. The consequences for farmers impact not only on their quality of life, but also on the viability of farm enterprises (Whelan *et al.*, 2009). These findings underpin the need to adopt a holistic view on occupational health and safety in farming built around an integrated response.

Teagasc has developed such a response through a series of research and extension initiatives that bring together key influencers of behavioural change to collaborate in research leading to practical interventions or initiatives that enhance safety or health. This article summarises this approach and the associated projects before drawing on the Farmers Have Hearts – Cardiovascular Health Programme (FHH-CHP) to provide an example of the framework in action.

Collaborating for impact

The decision to be safer or to adopt a healthier lifestyle is not made in a vacuum. In order to influence and sustain behavioural change that impacts on occupational health or safety it is necessary to understand how individuals interact with their work environment. Exploring how personal, social and professional relationships shape these interactions, we can learn much about an individual's capacity and willingness to change. Teagasc has developed this approach over the past 15 years and the current programme is anchored around the Department of Agriculture, Food and the Marine (DAFM)-funded Behaviours for Safer Farming, a project involving studies of the physical and social contexts of farmers, their attitudes and behaviours, the role of institutional frameworks, and the development of pilot interventions that seek to enhance machinery and livestock safety. Other projects include studies of the potential of discussion groups to influence farmer safety behaviours, developing advisory support tools targeting farmer health and well-being issues, and developing healthy lifestyle support programmes that work for farmers. The latter are funded through Teagasc Walsh Scholarships involving partnerships with several academic institutions in Ireland. In each instance, practitioners, regulators or industry stakeholders, including the Health and Safety Authority, Glanbia Ireland (GI), the Irish Heart Foundation (IHF), and the Health Service Executive (HSE) are financially supporting or contributing resources, and are active partners.

The FHH-CHP

Figure 1 provides an example of how this framework is implemented within the FHH-CHP. The FHH-CHP is a large-scale health behaviour change programme that involves 868 dairy and cattle farmers. Cardiovascular disease (CVD) is the leading cause of death in Ireland, and is more prevalent among farmers than in other occupational groups (van Doorn *et al.*, 2018). The programme consists of a physical health check and survey at Week 0, three different health support options, which farmers can self-select, and a follow-up health check at Week 52. This study brings together a Teagasc Walsh Scholarship involving the National Centre for Men's Health – IT Carlow and UCD School of Agriculture and Health Sciences, and is supported by the IHF, HSE and GI. The IHF planned, supervised and implemented the health checks, the HSE funded the health coach intervention and partly funded the health checks, and GI supported the recruitment of the dairy farmers and provided additional research funding.

The results of the Week 0 health checks and Week 0 surveys are presented in **Figure 2**. Overall, 74% of farmers have four or more risk factors for CVD, which increases their chance of having a stroke or heart attack threefold compared to those with fewer risk factors. The findings emphasise the importance of supporting farmers to adopt and sustain health behaviour changes and improve their cardiovascular health. The detailed results of the health checks (**Figure 2**) highlight the need for programmes that support farmers to improve their diet, increase their levels of physical activity and enhance their well-being.

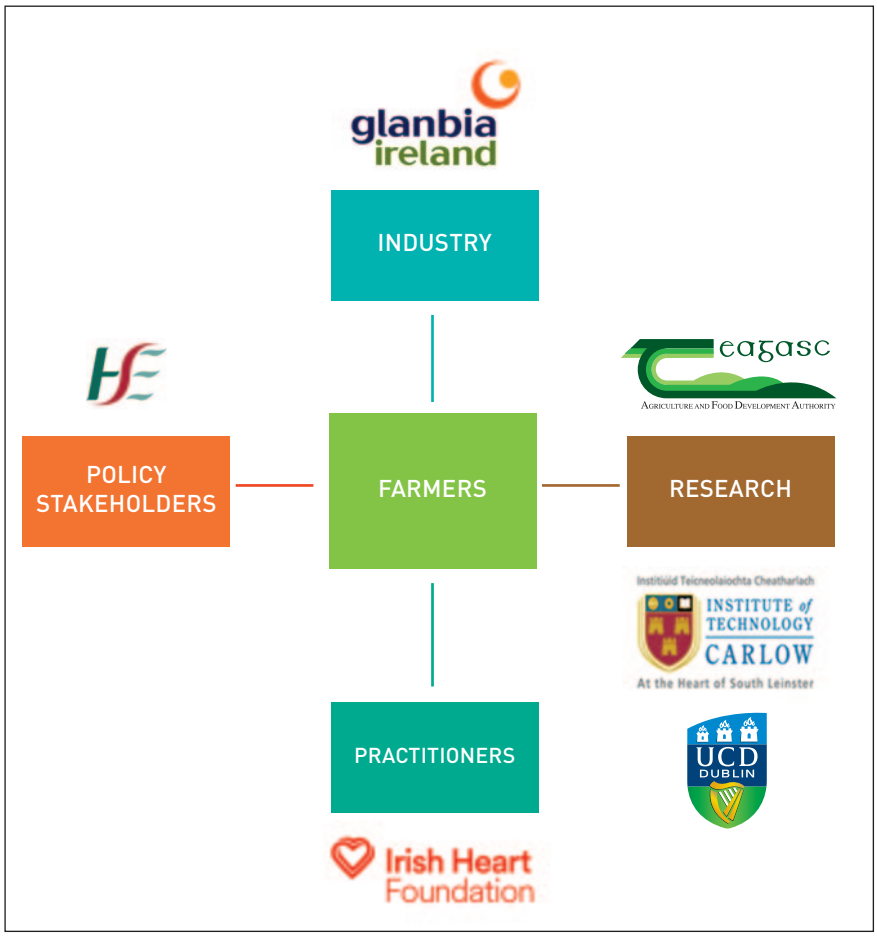

FIGURE 1: The FHH-CHP transdisciplinary structure.

9%	SMOKE
72%	DAILY SALTY/SUGARY SNACKS
22%	DEEP FRIED FOOD ≥3X PER WEEK
49%	MEAT/POULTRY ≥2X A DAY
15%	DAILY FIZZY DRINKS
46%	HIGH CHOLESTEROL ≥5.0 MMOL/L
40%	HIGH BLOOD PRESSURE ≥140-90 MMHG
33%	PHYSICALLY INACTIVE
80%	WAIST CIRCUMFERENCE ≥94 CM
23%	BLOOD GLUCOSE ≥7.0 MMOL/L
31%	HARMFUL DRINKING PATTERN
35%	WELL-BEING 'POOR' OR 'BELOW AVERAGE'

FIGURE 2: Prevalence of risk factors among farmers.

Conclusions

Changing human behaviour with respect to health and safety is challenging in most contexts. It is even more so in farming where farmers are self-employed and work alone.

As a consequence, the culture of health and safety that underpins beliefs, values and behaviours varies from individual to individual, and consequently from farm to farm. Teagasc, in partnership with academic partners, and policy and industry stakeholders, takes a leading role in promoting a transdisciplinary approach to the design, implementation and testing of initiatives supporting farmers to adopt healthier and safer behaviours.

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The future of the CAP – a view from the farm

A TEAGASC study has gathered farmers views' on reform of the Common Agricultural Policy, in particular the link between direct payments and environmental conditionality.

In June 2018, the European Commission outlined proposals for reform of the Common Agricultural Policy (CAP) beyond 2020. The proposals aim to make the CAP more responsive to major challenges such as climate change and generational renewal, while simultaneously supporting farmers in achieving a sustainable and competitive agricultural sector. Previous reforms of the CAP have strengthened the link between the receipt of direct payments and environmental objectives. On the back of the recently published EU Farm to Fork and Biodiversity strategies, this link is set to grow in importance given the grand environmental challenges facing society. It is acknowledged that farmers can play a key role in tackling climate change, as well as maintaining and improving water quality and biodiversity. Given the likely shift in CAP resources towards greater environmental conditionality, this research explores farmer opinion on the link between direct payments and environmental conditionality, as well as their views on where resources should be targeted under the next CAP.

Methodology

Data for this study was collected through the Teagasc National Farm Survey (NFS). This is part of the EU Farm Accountancy Data Network (FADN). The data employed in this analysis relates to 2018 and the final dataset included for the analysis consisted of 740 farms weighted to be representative of 74,507 farms nationally.

In the first instance, farmers were asked their opinion on the linkage between environmental conditionality (as encapsulated through good agricultural practice and cross-compliance standards) and direct payments under the CAP. This relationship had been previously investigated in a 2010 survey of NFS farmers. In both the 2010 and 2018 surveys, farmers were asked if they agreed or disagreed with the principle that "Farmers should only be eligible to receive CAP basic payments scheme monies (single farm payment scheme in 2010) if they meet good agricultural practice and cross compliance standards". They were asked to answer on a five-point Likert-type scale, where 1 was strongly disagree and 5 was strongly agree.

Secondly, in the 2018 NFS, farmers were informed that the future of the CAP is currently under review and that policymakers may choose to prioritise certain areas as the CAP budget may come under pressure. Farmers were again presented with a five-point Likert-type scale and asked to score a series of potential future options for CAP funding prioritisation, such as recoupling/flattening of direct payments, generational renewal, tackling climate change, improving water quality, and promoting biodiversity.

Results

Principle of conditionality – In all, 449 farmers within the NFS were asked the identical question (as set out above) in the 2010 and 2018 NFS surveys regarding the link between CAP payments and environmental conditionality (as encapsulated through good agricultural practice and cross-compliance standards). Support for such a link increased across this cohort of farmers over the period between the two surveys. On a scale of 1 (strongly disagree) to 5 (strongly agree), the mean agreement score increased from 3.9 in 2010 to 4.1 in 2018. It was found that farmers with higher levels of agricultural education and off-farm employment indicated a significantly stronger level of agreement with the conditionality link, as did farmers who were members of discussion groups. Agreement was also stronger among farmers drawing down higher levels of direct payments under pillar 1 and pillar 2 of the CAP.

Future CAP prioritisation – Again on a scale of 1 (strongly disagree) to 5 (strongly agree), mean agreement score results indicated that generational renewal was the highest ranked priority among farmers in the next CAP, with a mean score of 4.05. Next in descending order of importance were improved water quality outcomes (3.98), improved biodiversity outcomes (3.52), and reduction in greenhouse gases from agriculture (3.43). Convergence (flattening) of payments among farmers (2.97) and recoupling of payments to livestock or crops (2.71) were the lowest ranked options by farmers in the survey, as outlined in **Figure 1**.

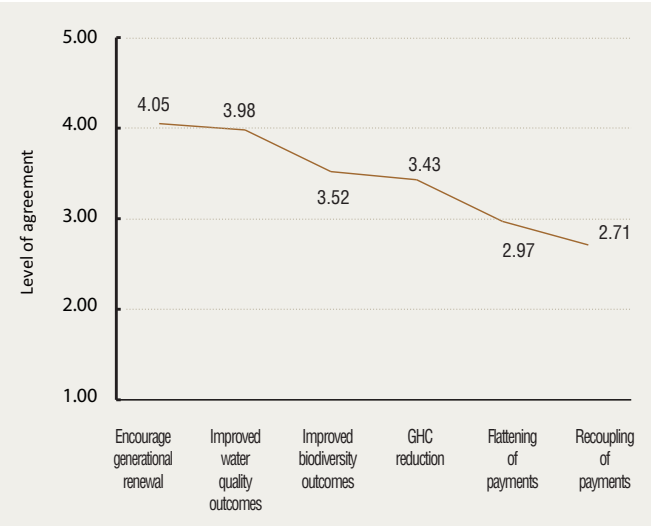

FIGURE 1: Mean agreement score by farmers for different CAP measure prioritisation (N = 740).

Of the three main environmental priorities explored in the survey, improved water quality outcomes was the highest ranked issue among farmers by some distance, followed by improved biodiversity outcomes and, finally, greenhouse gas emissions reduction.

Conclusion

Results indicate that there is a strong level of support among farmers for the principle of linking CAP payments to environmental conditionality (as encapsulated through good agricultural practice and cross-compliance standards). The acceptance of this conditionality principle has increased among farmers who were surveyed in both the 2010 and 2018 NFS surveys.

A range of future options for CAP funding prioritisation were presented to farmers and the issue that scored highest was the need to prioritise generational renewal. Ireland has one of the lowest shares of farmers under 40 years of age in the EU (less than 10 %; European Commission, 2016). Of the three main environmental priorities explored in the survey, improved water quality outcomes was the highest ranked issue among farmers by some distance, followed by improved biodiversity outcomes and, finally, greenhouse gas emissions reduction. Farmers may have favoured initiatives in the area of water quality as these tend to be associated with local activity and improvements can be seen locally. Similarly, enhanced biodiversity may be recognised as having a local and immediate benefit, whereas the benefits of addressing climate change might be perceived as more long term and not location specific. Across the entire sample, flattening/convergence of payments received a mixed response as there are likely to be winners and losers in terms of payments. Finally, recoupling of direct payments was the lowest ranked option by farmers in the sample.

Reference

European Commission. (2016). 'Proportion of farm managers aged under 40, 2016 %'. Available from: https://ec.europa.eu/eurostat/documents/4187653/8516146/Young+farmers /a27e105d-cfc2-4bff-9080-7dd62e5c0a6e?t=1531727855268.

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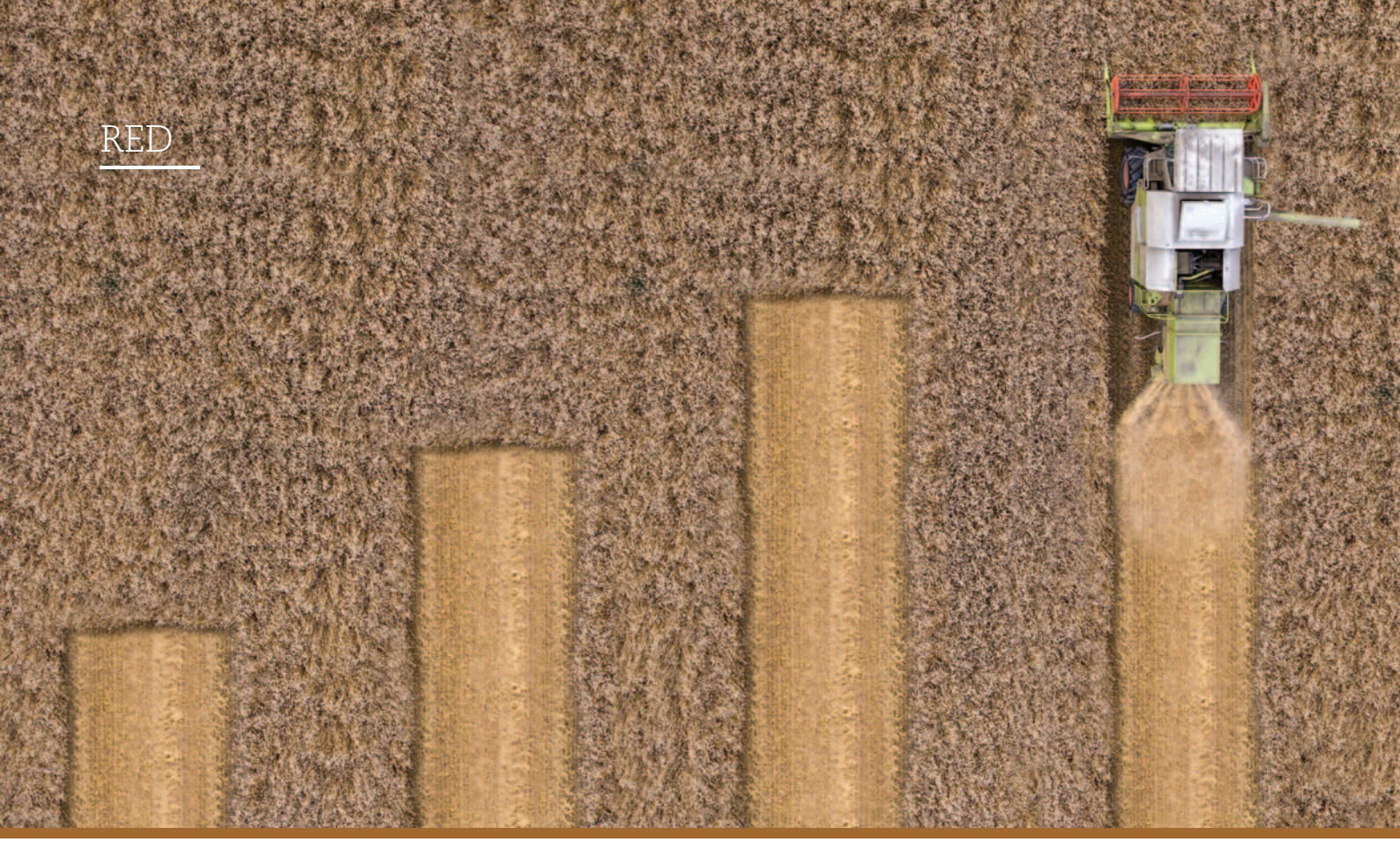

Analysing farm income distribution in Ireland

The Teagasc National Farm Survey shows how farm income distribution is changing.

Using Teagasc National Farm Survey (NFS) data, this research highlights recent trends in farm income inequality. This random survey is nationally representative and enables the detailed analysis of the financial situation on commercial family farms in Ireland. The Teagasc NFS is part of the Farm Accountancy Data Network (FADN) of the EU and has been conducted by Teagasc since 1972. Under the Farm to Fork strategy, the FADN will transition to a Farm Sustainability Data Network (FSDN).

Farm income inequality trends

Twenty years ago, Mary Keeney published an important article in the *Journal of Agricultural Economics* on farm income distribution in Ireland. Using a decomposition approach, Keeney identified a significant decline in farm income inequality between 1992 and 1996, and attributed this decline to the introduction of direct payments. Subsequent studies, including Hynes and O'Donoghue (2004) and O'Neill (2014), indicated that the decline in farm income inequality observed in the early 1990s did not sustain in the following years.

The Gini coefficient is used to calculate farm income inequality. The Gini is a standard measure of income inequality and ranges in value from zero to one. A value of zero would indicate complete equality of farm incomes. A Gini coefficient with a value of one would indicate a scenario whereby one single farm accounts for all farm income. As expected, the Gini coefficient tends to lie somewhere between these two scenarios.

Figure 1 shows the evolution of farm income inequality since 2010. There does not appear to be a clear trend over time, with short-term fluctuations in farm income inequality being evident. The inequality of total family farm income appears volatile, ranging from approximately 0.57 in 2011 and 2012 to 0.67 in 2018. These levels of income inequality are above those observed by Keeney for the mid 1990s. It is interesting to note that 2018 coincides with particularly high income inequality and a summer drought with varying impacts on incomes across farms. This merits further consideration, as the capacity of farmers to adapt to climate change could influence income distribution in the future. It is also notable that the collapse in milk prices during 2016 coincides with a reduction in income inequality. A decline in income inequality does not always have positive origins.

The Teagasc Rural Economy and Development Programme will undertake further analysis to understand the factors influencing farm income distribution in Ireland.

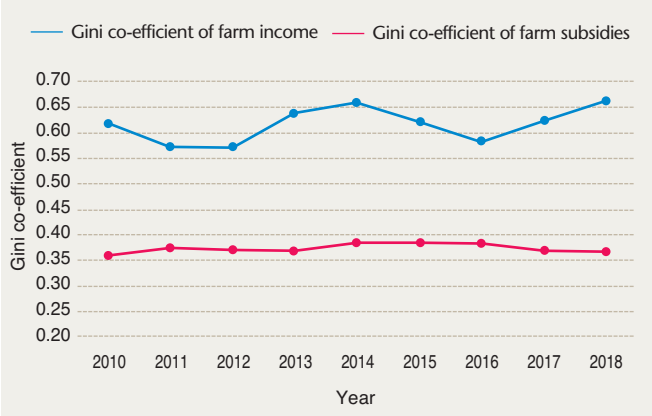

FIGURE 1: Gini co-efficient of family farm income and farm subsidies 2010-2018. Source: Author's calculations using Teagasc National Farm Survey data.

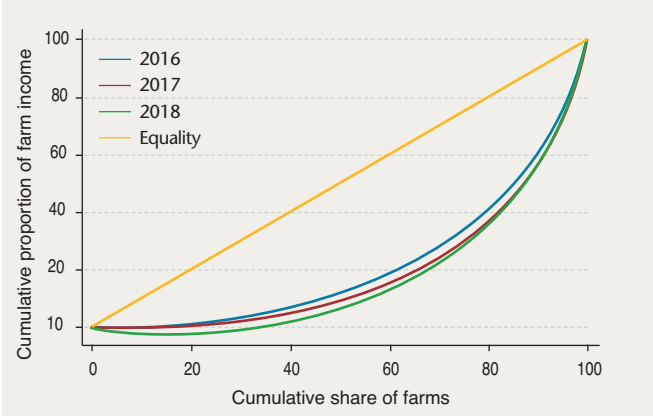

FIGURE 2: Lorenz curve of farm income distribution 2016 to 2018. Source: Author's calculations using Teagasc National Farm Survey data.

The distribution of farm subsidies has shown less volatility through time. The Gini coefficient of farm subsidies has ranged from 0.36 in 2010 to 0.39 in 2015. Interestingly, the inequality of farm subsidies declined progressively from 2015 to 2018, which may be associated with the redistribution of direct payments and subsequent increases in the value of environmental payments.

Figure 2 provides a more detailed picture of the distribution using a Lorenz curve approach. In this diagram, the 45-degree line represents a situation of complete equality in farm incomes. **Figure 2** shows three Lorenz curves for three recent years, i.e., 2016, 2017 and 2018. The closer the proximity of the Lorenz curve to the 45-degree line, the lower the income inequality. The 2018 Lorenz curve is consistently furthest from the 45-degree line for the whole distribution. This visually illustrates that income inequality was higher in 2018 than in 2016 or 2017.

Interestingly, the inequality of farm subsidies declined progressively from 2015 to 2018, which may be associated with the redistribution of direct payments and subsequent increases in the value of environmental payments.

Focusing on the 2017 (red) Lorenz curve, **Figure 2** shows that the top 20 % of farm income distribution earned or received the majority of all farm income, with a slightly lower proportion in 2016 and a greater proportion in 2018. In all three years, the bottom 40 % of farm income distribution earned or received less than 10 % of all farm income. Farm income inequality is therefore high.

However, the analysis excluded non-farming income, which could influence overall inequality in farm household income. The Teagasc Rural Economy and Development Programme will be undertaking further analysis to understand the factors influencing the shape of farm income distribution in Ireland. Further research will seek to identify the possible distributional impacts of any proposed reforms to the Common Agricultural Policy as these proposals emerge.

Acknowledgements

The contribution of the farmers participating in the Teagasc National Farm Survey and the Teagasc farm recording staff who carry out the survey.

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Hynes, S. and O'Donoghue, C. (2004). 'Farm income mobility and inequality in Ireland 1994-2001 (Working Paper No. 78)'. Department of Economics, National University of Ireland, Galway.

Keeney, M. (2000). 'The distributional impact of direct payments on Irish farm incomes'. *Journal of Agricultural Economics*, 51 (2): 252-265.

O'Neill, S. (2014). 'Three essays on the impact of the Common Agricultural Policy on Irish farms (Doctoral dissertation)'. NUI Galway.

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Animal & Grassland Research and Innovation Programme | Crops, Environment and Land Use Programme | Teagasc Head Office | Food Programme | Rural Economy & Development Programme

NOVEMBER

November 4 (9.30am-10.30am) *Online*

Teagasc Research Insights Webinar: (Bio)Activity: Food Ingredients and Our Health and Fitness

A special episode of Teagasc's Research Insight Seminar series will run as part of the Festival of Farming and Food – SFI Science Week at Teagasc (see below). Bioactives are the active ingredients in food that fuel our active lives. Join Teagasc researchers on this webinar to find out the latest research on the bioactive components in food, novel sources of food bioactives, and the effect of food on our fitness – from a run in the park to the Six Nations.

Contact: jane.kavanagh@teagasc.ie

https://www.teagasc.ie/about/research--innovation/teagasc-research-insights-webinars/

November 5 (11.00am-12.30pm) *Online*

Walsh Scholars – The Next Generation

The Walsh Scholarships Programme is another year older and we are celebrating with 'Walsh Scholars: The Next Generation', a public showcase of Teagasc's leading postgraduate agri-food research. This inaugural showcase, hosted by RTÉ's Sharon Ní Bheoláin, is an online webinar, free and open to all.

Immerse yourself in the fascinating studies of some of the next generation of food and farming leaders. Meet the Walsh Scholar Alum Award Winner 2020 and find out what being a graduate of the Programme has meant to them.

Explore Teagasc's proud history of graduate training and development, and learn how the prestigious Programme contributes to shaping innovations in agriculture and food research, education and advisory.

Contact: erin.orourke@teagasc.ie

https://www.teagasc.ie/corporate-events/walsh-scholars-the-next-generation/

November 8-15 (11.00am-11.45am daily) *Online*

The Festival of Farming and Food – SFI Science Week at Teagasc

Join Teagasc for a series of exciting virtual events and activities for Science Week.

The core theme is 'Choosing our Future', focusing on how science can improve our lives in the future and in the present.

This will explore how science can help us to make positive choices that will impact the environment, our health, and our quality of life. Join our events on Zoom and get a chance to put your questions to our scientists in our live Q&As.

Sustaining Plant Diversity into the Future: The beautiful National Botanic Gardens in Dublin is not just for recreation. It is a hub for the conservation of threatened plants, research on safeguarding plants and the education of future gardeners. Staff from the gardens and the Teagasc college will highlight some remarkable plants and initiatives for a plant-filled future. RTÉ's Damien O'Reilly brings us on this virtual tour.

Soil Health is our Wealth: Soils are diverse and multifunctional living ecosystems, underpinning most of our food and fibre production, but also other critical natural services for society, including the recycling of nutrients, atmospheric CO_2 sequestration and water regulation. As soils are a limited resource, protecting soil health from degradation is critical for human well-being. Join us to hear about soils and their impact on society. RTÉ's Damien O'Reilly hosts.

Sustainable Farming: Farm to Fork: This event focuses on how we can grow dairy farming sustainably as well as understand how new technologies are being incorporated into food science. Find out about grass measuring, milking and food processing, and the VistaMilk SFI research centre. RTÉ's Damien O'Reilly hosts.

A Taste of the Future: Plants, mushrooms, insects, algae, big data – all are features on the journey of food from the farm to your plate. Then your senses get involved and your choices can affect health and sustainability. Our story highlights Teagasc research that's changing the direction of that food journey, and gives you a Taste of the Future! Science presenter Jonathan McCrea hosts.

Back to the Future: Food fermentation is one of the oldest food preservation methods going back hundreds of years. The Festival of Farming and Food live is taking food fermentation into the future, with next-generation DNA sequencing, food microscopy, virtual reality, robotics and even 3D printing. Science presenter Jonathan McCrea hosts.

Contact: catriona.boyle@teagasc.ie

https://www.teagasc.ie/scienceweek

November 13 (3.30pm-5.00pm); November 20 (3.30pm-5.00pm); December 4 (3.30pm-5.pm). *Online*

A Better Whey of Life – The 9th International Whey Conference (IWC2020)

The IWC is a unique forum, which brings together the whey business and scientific community from around the world for an interactive dialogue on the most relevant aspects of whey production, processing and applications.

Contact: lvitali@euromilk.org

https://www.iwc2020virtual.com/

For more details on Teagasc's full range of webinars, see https://www.teagasc.ie/news--events/daily/webinars/

For a full list of Teagasc food industry training events, see https://www.teagasc.ie/food/research-and-innovation/research-areas/food-industry-development/.
For presentations from previous Teagasc events, see www.teagasc.ie/publications