TEAGASC

Research

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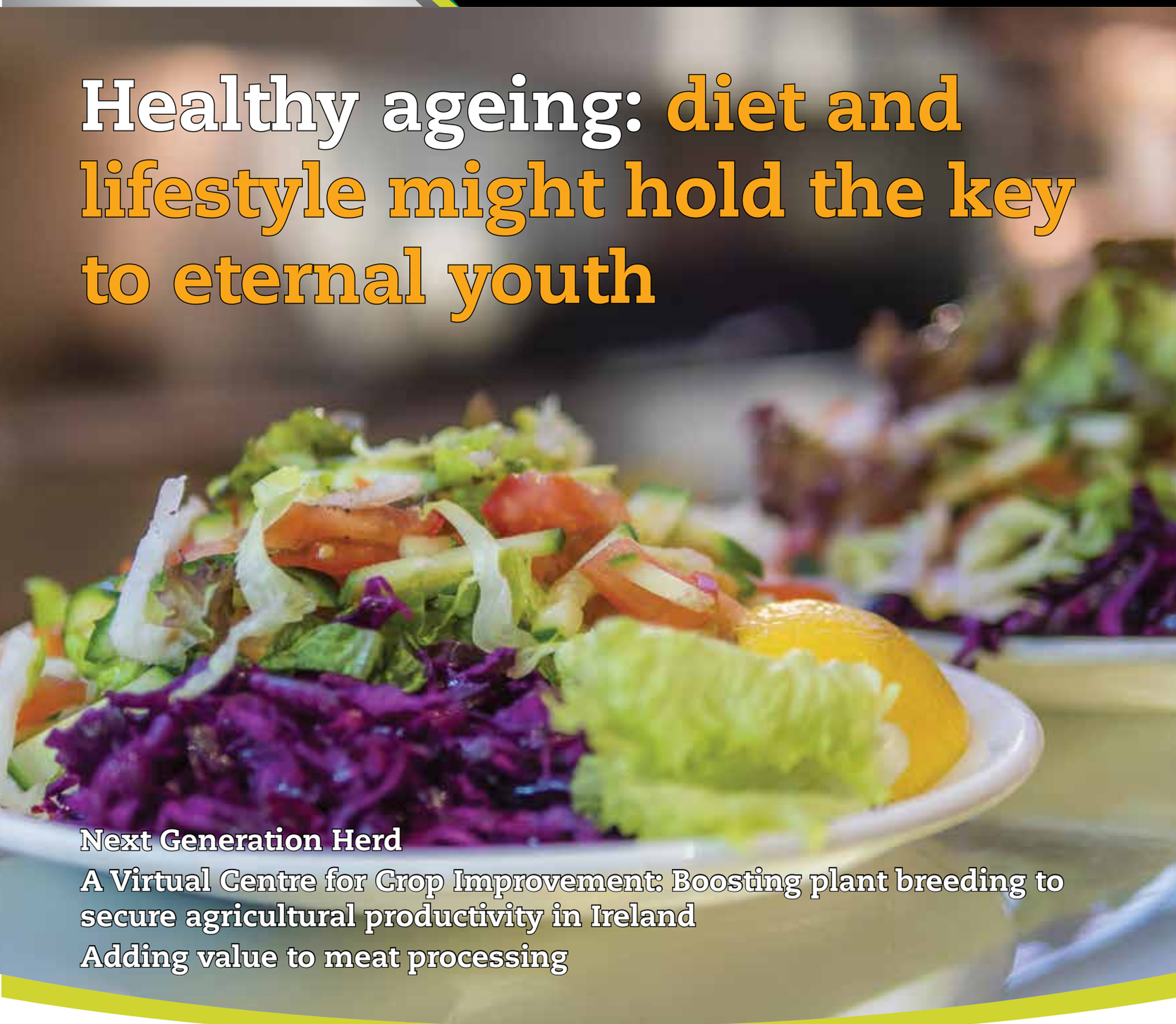

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teagasc

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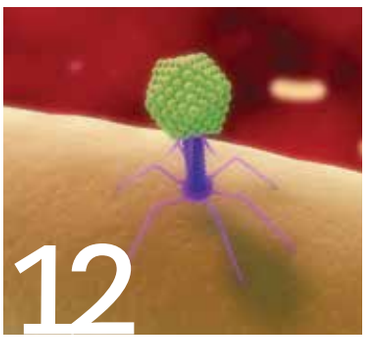

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Agriculture and Food Development Authority

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

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Teagasc Research Impact in 2014

This issue of *TResearch* contains a supplement on 'Teagasc Research Impact Highlights in 2014', which highlights the impacts achieved, in 2014, from research conducted in Teagasc. It follows a similar publication last year.

Our strategy is to conduct excellent research that provides a solid basis for achieving science-based impact. The examples shown here, of actual impact at industry level, demonstrate that this strategy works. Having an impact is critically important to Teagasc, and highlighting the impact we have is necessary to demonstrate to the taxpayer and stakeholders, who fund our research, that it is a good investment. These are just examples and are not an exhaustive account of the impact of Teagasc, which is achieved by the combination of our research, advisory and education activities. We strive to ensure our research will have impact, so it is pleasing to have such a set of significant impacts to highlight again for 2014. I would like to acknowledge the huge contribution of Teagasc specialists and advisors, both in terms of direct input into some of the research underpinning these impacts, and in transferring this knowledge to farmers and food companies to allow the impact to be achieved. I would also like to acknowledge the many collaborators we have in universities and institutes of technology, other external bodies, farmers and agri-food companies that were involved in many of the research projects leading to these impacts, and were instrumental in the successful achievement reported. We greatly value those contributions that are highlighted in the individual reports.

The Department of Agriculture, Food and the Marine is the major funder of Teagasc research through provision of grant-in-aid and through its competitive funding programmes, FIRM, Research Stimulus Fund, and CoFoRD. Other funding comes from EU research and innovation programmes, Science Foundation Ireland, Enterprise Ireland, the Environmental Protection Agency, farmers and agri-food companies. This funding is gratefully acknowledged.

Dr Frank O'Mara
Director of Research, Teagasc

Tionchar Thaighde Teagasc in 2014

Tá forlíonadh san eagrán seo de *TResearch* ar "Buaicphointí Tionchar Taighde Teagasc in 2014", ina bhfuil cur síos ar na buaicphointí taighde a rinneadh i dTeagasc in 2014. Foilsíodh saothar den chineál céanna anuraidh. Is é an straitéis atá againn ná taighde den scoth a dhéanamh a sholáthraíonn bonn daingean chun go mbeidh tionchar bunaithe ar an eolaíocht againn. Is léir ó na samplaí a thaispeántar anseo an tionchar iarbhír atá againn ar leibhéal an tionscail agus go bhfuil ag éirí leis an straitéis seo. Tá sé thar a bheith tábhachtach do Theagasc go mbeadh tionchar againn agus leagaimid béim ar an tionchar sin lena léiriú don cháiníocóir agus do pháirtithe leasmhara a mhaoiníonn ár gcuid taighde gur infheistíocht fhiúntach í. Níl anseo ach samplaí agus ní cuntas uileghabhálach atá ann ar thionchar Teagasc a cuireadh i gcrích trí theaglaim dár ngníomhaíochtaí taighde, agus dár ngníomhaíochtaí comhairleacha agus oideachais. Déanfaimid ár ndícheall a chinntiú go mbeidh tionchar ag ár dtaighde, agus ar an ábhar sin is deas an rud é go bhfuil a leithéid d'iarmhairtí suntasacha againn chun aird a tharraingt orthu arís i gcomhthéacs na bliana 2014. Ba mhaith liom aitheantas a thabhairt don obair ollmhór atá déanta ag speisialtóirí agus ag comhairleoirí Teagasc, ó thaobh ionchur díreach i gcuid den taighde a ba bhun leis na tionchair sin, agus in aistriú an eolais sin chuig feirmeoirí agus chuideachtaí bia chun go bhféadfaí an tionchar a bhaint amach. Ba mhaith liom freisin aitheantas a thabhairt do na daoine go léir a bhíonn ag comhoibriú linn in Ollscoileanna agus in Institiúidí Teicneolaíochta, agus i gcomhlachtaí seachtracha eile, d'fheirmeoirí agus do chuideachtaí agraibhia a bhí páirteach i gcuid mhaith de na tionscadail taighde ónar tháinig na tionchair sin, agus a raibh páirt acu i mbaint amach na dtorthaí rathúla. Tá ardmheas againn an obair atá aibhsithe sna tuarascálacha faoi leith.

Is í an Roinn Talmhaíochta, Bia agus Mara is mó a thugann maoiniú do thaighde Teagasc trí dheontais i gcabhair a sholáthar agus trína cláir mhaoinithe iomaíocha, An Beart um Thaighde Institiúideach Bia (FIRM), an Ciste um Spreagadh Taighde, agus CoFoRD (an Chomhairle Náisiúnta um Thaighde agus Forbairt Foraoise). Faighimid maoiniú eile ó chláir thaighde agus nuálaíochta an AE, Fondúireacht Eolaíochta Éireann, Fiontraíocht Éireann, an Ghníomhaireacht um Chaomhnú Comhshaoil, feirmeoirí agus cuideachtaí agraibhia. Aithnímid go buíoch an maoiniú sin.

An Dr Frank O'Mara
Stiúrthóir Taighde, Teagasc

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Dr John Finnan

Dr John Finnan originally came to Oak Park in 1990 where he completed a PhD with TCD and two post-doc contracts on a variety of projects exploring the effects of elevated ozone and elevated carbon dioxide on wheat and potatoes, as well as on bicropping cereals and white clover. After spending a few years with the Environmental Protection Agency, John returned to Oak Park where he now works as a researcher in the Crops Research Department. Upon his return, John worked primarily on bioenergy projects. Oak Park has had a long history of research on bioenergy, which started in the early 1970s. However, the resurgence in interest in bioenergy during the mid-2000s left many unanswered questions and, John says, the bioenergy research programme expanded rapidly to encompass a very broad and diverse range of research subjects, including: the agronomy and harvesting of energy crops; biomass drying and storage; biomass combustion and emissions; and life-cycle assessment. As a result, John says the role of a researcher became increasingly varied, becoming a juggling act between field work, lab work, desk work, student supervision, talks, meetings and queries.

Data from the bioenergy programme has been extensively published in peer-reviewed literature and John has represented Ireland on the International Energy Agency's working group on biomass combustion and co-firing.

Until recently, John's work has been entirely focused on bioenergy and, more specifically, on energy crops. Previous projects included: cereal grains and crop residues as feedstocks for combustion; the role of energy crops in effluent disposal, energy supply and soil remediation; feasibility of production and combustion of pellets from straw and energy crops; evaluating Irish grassland as a source for bioenergy: environmental impacts and long-term sustainability; and producing biomass for energy, future low-emission biomass production systems. More recently, John has started to work on the agronomy of oats. This new programme will focus on improving yield and quality in oats while trying to reduce lodging and mycotoxin accumulation.

Packie Commins Rural Research Award NUIG

Erin Coll, MA in Rural Sustainability, NUI Galway, was awarded the Professor Packie Commins Rural Research Award, sponsored by Teagasc.
Pictured (from left) are: Dr Edward Herring, Dean, College of Arts, Social Sciences, and Celtic Studies; Máirín Uí Chomáin, wife of the late Professor Patrick Commin; Erin Coll, award recipient; Dr Áine Macken Walsh, Teagasc; Dr Maura Farrell, Director of the MA in Rural Sustainability; and NUI Galway President, Dr James Browne.

Behaviour and age leading to farm death rise

A combination of farmer behaviours and the ageing profile of the farm population are leading to the rising trend in farm deaths, a long-term geo-demographic study has found. Jointly conducted by Teagasc and the Health and Safety Authority, the overall aim of the research is to uncover trends that will be of assistance in cutting the farm death toll. It examined farm workplace death patterns since 1993 in relation to population, geography, primary causes of fatalities and the timing of deaths.

While the average number of deaths was 18 per year, between 1993 and 2013, in four of the last five years farm deaths have been substantially higher than this average. In 2014, there were 30 deaths, and in three of the remaining years the number of deaths was greater than 20 per annum.

The study's lead researcher, Dr David Meredith of Teagasc's Rural Economy Development Programme said: "While age is not a primary cause of fatalities it does help explain some of the trends that have become more prominent in recent years. Fatalities among the population of farmers under 45 years of age since 2009 are below the long-run average. In stark contrast to this, deaths among farmers between 45 and 64 years of age are 57% above the long-run average for this group. This is the equivalent of three extra deaths per year in this age group. This trend is thought to be associated with an increase in the number of farmers in this age group resulting from large numbers returning to farming following the collapse of the construction sector."

Fatal farm accident data also indicates a strong behavioural dimension to farm workplace deaths, particularly those associated with tractors and machinery, livestock and falls, particularly from heights. "The data indicate that accidents become increasingly lethal with increasing age. This highlights the importance of forming habits of safe behaviours at an early age and maintaining these habits as age increases."

Teagasc National Health and Safety Officer, Mr John McNamara, who collaborated in the study, stated that its findings are in line with international trends, which indicate that safety behaviour is a factor in 90% of accidents and that farm death rates increase with increasing age, particularly from 45 years of age onwards.

Smart Futures

Smart Futures is a Government-industry programme promoting science, technology, engineering and maths (STEM) careers to second-level students in Ireland. It is managed by Science Foundation Ireland (SFI) Discover, the education and outreach programme of SFI, in partnership with Engineers Ireland-STEPS.
Twenty-one Teagasc researchers attended one of two Smart Futures training workshops that took place at Teagasc locations earlier this year. These researchers will give talks at schools across Ireland, providing details about careers in research.
Schools interested in having a Teagasc researcher give a talk should contact Donna McCabe at Smart Futures (donna.mccabe@sfi.ie). Researchers interested in receiving Smart Futures training and giving talks in schools should contact Catriona Boyle (catriona.boyle@teagasc.ie).

Donna McCabe, SFI, delivering a Smart Futures workshop at Teagasc, Ashtown.

Tyndall and Teagasc to develop world-first for dairy industry

Tyndall National Institute, Cork, and Teagasc are delighted to announce the launch of the Spore Analysis Critical Control Point (SACCP) partnership. Funded by the Department of Agriculture, Food and the Marine's Food Institution Research Measure (FIRM), which has committed €625,000 to the project. It is the a first-of-its-kind project that will develop a portable biosensor to detect spore-forming, harmful bacteria of environmental origins that may enter the dairy supply chain and exceed the ever-tightening microbiological specifications for high-end products such as infant milk formula. Developed in Ireland, this new system will revolutionise quality monitoring processes within the dairy industry at a global level, benefiting businesses and consumers.
Ireland produces approximately 15% of the world's infant milk formula and the removal of milk quotas makes this global marketplace even more competitive.
The SACCP will look to create a biosensor that will allow on-site, in-line and real-time testing of milk to ensure that spore-forming bacteria, which can survive pasteurisation, do not reach harmful levels.
Current spore detection processes are cumbersome and can take days of analysis in laboratories before establishing a definitive result. By comparison, the biosensor under development will be portable and can produce results in just minutes.
Commenting on the announcement, Dr Karen Twomey of Tyndall said: "This biosensor has the potential to become an essential component of the dairy manufacturing process all over the world. Early detection is key and the biosensor will enable producers to take preventative measures at earlier stages, thus, preventing unnecessary product degradation.
"This technology is also incredibly flexible and can be modified to detect a range of other bodies, enabling it to be used across other areas of the food industry and other sectors such as environment, security and medical to name but a few. This is currently the only research of its kind taking place so we have a real opportunity to create an important tool that will not only benefit businesses but also consumers all over the world."
Project coordinator Dr Phil Kelly of Teagasc said: "We are particularly pleased to be collaborating with Tyndall on the SACCP project. There is an urgency in dairy food manufacturing for the creation of a biosensor that will give a rapid indication of the presence of spore-forming bacteria, and enable early intervention process control strategies to be implemented. The Teagasc microbiological and technological tasks running in tandem throughout the project will provide a platform for early prototype testing and biosensor calibration."

Pictured are Dr Phil Kelly of Teagasc and Dr Karen Twomey of Tyndall

Teagasc and Irish Aid sign MoU

Teagasc and Irish Aid signed a Memorandum of Understanding (MoU) in February 2015, which provides for collaboration to enhance Ireland's contribution, through agricultural research, training and extension, to developing countries. The agreement supports Ireland's objectives of reducing hunger and under-nutrition in African countries.
Irish Aid is the Government's programme for overseas development. The One World, One Future policy, published in May 2013, sets out Ireland's policy for international development and prioritises the reduction of hunger and the promotion of sustainable growth to tackle food insecurity. Support for improving the productivity of smallholder agriculture to combat hunger is a central priority of the Irish Aid programme.
Speaking at Teagasc's Animal and Grassland Research and Innovation Centre, in Fermoy, Professor Gerry Boyle, Director of Teagasc, said: "As the national body responsible for agricultural research and knowledge transfer in Ireland, Teagasc has a responsibility to support the national effort aimed at strengthening agricultural development and reducing hunger and under-nutrition in under-developed countries. This objective is best pursued by aligning and coordinating our efforts and resources with those of the Irish Aid programme. This is a major step in ensuring that Teagasc's knowledge, expertise and commitment to international agricultural development can have a more focused impact on addressing the challenge of food security in developing countries."

New research project commences on novel food products for elderly consumers

Chronic malnutrition is widespread in the Irish elderly population, however it is preventable. A new collaborative research project entitled NUTRIMAL, coordinated by UCD, in collaboration with Teagasc and the HSE, has just commenced to develop novel nutritional food products for older consumers, specifically targeting malnutrition and its effects on loss of muscle mass and physical function.

This research is funded by the Department of Agriculture, Food and the Marine under the FIRM programme with the aim of stimulating product innovation for older consumers beyond oral nutritional supplements, whereby the products are targeted to the unmet needs of this rapidly expanding segment of the population. In addition, the efficacy of novel food products will also be demonstrated. NUTRIMAL is also working with several food ingredient companies with a view to developing new food products to combat malnutrition.

Any organisation with an interest in healthy ageing and prevention of malnutrition in older consumers is welcome to participate/contribute to this research project. You can contact the research team to discuss opportunities by contacting Sinéad McCarthy (sinead.mccarthy@teagasc.ie), Helen Roche (helen.roche@ucd.ie) or Brendan Egan (brendan.egan@ucd.ie).

European Food Safety Authority appointment

Dr Declan Bolton, Principal Research Officer in the Food Safety Department, has been reappointed to the European Food Safety Authority (EFSA) Biohazard Panel to serve a second three-year term. EFSA was set up in January 2002 as an independent agency to improve EU food safety, ensure a high level of consumer protection and restore and maintain confidence in the European food supply. The current remit covers: food and feed safety; nutrition; animal health and welfare; plant protection; and plant health. The EFSA Biohazard Panel undertakes risk assessment in food and feed safety and provides scientific advice on existing and emerging food safety issues. This advice, published in the *EFSA Journal*, underpins the European food safety system and provides the scientific basis for EC food safety policy and legislation. It also informs the activities of national authorities in individual member states. Dr Bolton will commence his new appointment in July this year.

FameLab

Ruaíri Roberstson came second in the FameLab finals, which took place at the Science Gallery at Trinity College recently. Ruaíri graduated from UCD with a BSc in Human Nutrition. Currently, he is a third-year PhD student in nutrition and microbiology at UCC.

Ruaíri's passion for food and nutrition has brought him to all corners of the world to carry out research, from Boston to Melbourne to Madagascar. His current PhD research examines bioactive ingredients from seaweeds and their potential as foods to fight diet-related disease.

Pictured at FameLab (from left) are: Back row – Ruaíri Robertson, who placed second in the competition; Niall Smith; compere Jonathan McCrea; and judge Jenny Hill. Front row: Gillian Murphy, who placed third in the competition; Lisa Murphy, who won FameLab Ireland with her talk on how selfies are linked with our genes – facial symmetry; and judge Claire O'Connell.

Report launched on investment needs

A report entitled *A Review of the Financial Status of Irish Farms and Future Investment Requirements* has been published by Teagasc. The research was conducted by Teagasc economists, in collaboration with Michael McKeon, Pig Development Department, Teagasc, and Dr Doris Laepple from UCD. It was launched by Minister for Agriculture, Food and the Marine, Simon Coveney TD, and part-sponsored by Bank of Ireland. The research examined the financial status of Irish farms and the investment required at the farm level in Ireland to reach the *Food Harvest 2020* targets. Speaking at the launch of the report, Dr Fiona Thorne, Rural Economy and Development Programme, Teagasc said: "Irish farms in general have a sound financial structure with debt to asset levels quite low by international standards."

Pictured at the launch of the new Teagasc/Bank of Ireland research on the financial status of Irish farms are: Dr Fiona Thorne, economist with Teagasc; Minister for Agriculture, Food and the Marine, Simon Coveney, TD; and Mark Cunningham, Director, Bank of Ireland Business Banking.

BT Young Scientist

The winners of the Teagasc BT Young Scientist Award, pictured here with Professor Gerry Boyle, Director of Teagasc are Shane Seery and Sean Pettit, Moate Community School Co Westmeath. They were awarded for their project: Not "mush-room" for turf anymore! It was entered in the Chemical, Physical and Mathematical Sciences - Intermediate category group. This year, Teagasc's stand at the BT Young Scientist and Technology Exhibition had a special focus on soils, in recognition of the designation by the UN of 2015 as the International Year of Soils.

Jobs dividend from end of milk quotas highlighted at Dairy Conference

The impact of dairy farming on the recovery of the rural economy was highlighted at a conference held to mark the elimination of the EU milk quota system. The event, organised by Teagasc and the Irish Co-operatives Organisation Society, took place at the City West Hotel, Dublin. Held on April 1, it coincided with the lifting of milk quotas and marked the launch of a new book that charts the history of the dairy sector in Ireland under quota. It also estimates the jobs dividend that the policy change will bring for Ireland.

An estimated 15,000 additional jobs could be created over the next five years as a result of quotas ending, including additional people employed on farms to milk Ireland's increasing dairy cow population. Agri-input suppliers will see an upturn in their business as they service the needs of the expanding sector; while the milk collection business will need to expand considerably to cope with the targeted 50% increase in milk production, this will provide employment in the transport sector. Furthermore, manufacturing and distribution jobs will also be created, while construction jobs have already been created with several projects aimed at catering for the additional milk production already well advanced. Allied to this will be the jobs created in upgrading the roadway and building infrastructure on expanding dairy farms and the installation of dairy equipment such as milking machines and bulk tank refrigerators.

According to Teagasc economist Trevor Donnellan, for every additional job created in the dairy and allied sectors, a further job will be created in the wider economy.

Teagasc Director, Professor Gerry Boyle said: "The removal of quotas is highly significant as it provides farmers with the freedom to choose whether or not to produce milk, or produce more milk through expanding their production. However, he warned that expansion is not for all milk producers.

"Some existing producers do not necessarily want to produce more milk, while for others producing more milk is not a good option. In my view, we must clearly advise farmers that it is a case of 'better before bigger', efficiency before expansion, or 'skill before scale'."

Two publications produced by Teagasc were circulated at the conference:

The end of the Quota Era: A History of the Dairy Sector and its Future Prospects. Edited by Trevor Donnellan, Thia Hennessy and Fiona Thorne

Teagasc e-Profit Monitor Analysis Dairy Farms 2014. Edited by George Ramsbottom and the Teagasc Specialist Services.

New Agricultural Economics and Policy course

Teagasc and NUIG have launched a new Agricultural Economics and Policy course, offered as part of the Natural Resource Economics and Policy Masters. Delivered by NUIG staff and Teagasc economists Dr Thia Hennessy, Dr Kevin Hanrahan and Trevor Donnellan of the Rural Economy and Development Programme, the course is designed to develop the skills of economics graduates for employment in the agri-food sector. Course director Dr Stephen Hynes of NUIG said: "Given that agriculture and food is a key element in the Irish economy, and natural resource management is vital for the continued development of the sector, it is important that we have students coming through with the tools to analyse the impact of policy on the sector. The participation of the Teagasc economists in the delivery of the course is a great opportunity for the students to see how agricultural economic theories and models can be applied in a practical way to answer real-world agricultural policy questions."

Eritrea dairy and potato programmes

A senior delegation led by Irish NGO Vita and including Teagasc and Gorta/SHA traveled to Eritrea at the weekend to build on the partnership between these agencies and the Eritrean government. They will be evaluating the impact of a model dairy programme and a model potato programme set up last year.

The group will visit the dairy and potato farmers to evaluate the pilot programmes, which were set up in partnership with the Eritrean Ministry of Agriculture. The pioneering dairy pilot has 20 model farmers, and early results are already showing a doubling of the milk yield.

The potato pilot programme, which has 25 model farmers, has evolved out of the Irish Potato Coalition. This was set up by the agencies above as well as the Irish Potato Federation and Irish Potato Marketing (IPM). It is a research led programme that supports farmers as they develop every aspect of the production and value chain – from establishing co-ops to improving seed stock, market research, pest and disease control.

EC-funded CommBeBiz to support effective application of research

Teagasc is one of four partners from the UK, Ireland and Belgium that have won their bid to provide tailored and expert support to EC-funded bioeconomy research projects. This will enable more effective and speedier transfer of knowledge to the marketplace and to policy-makers.

The new project CommBeBiz – Bridging Bioeconomy Research to Business is funded by the European Commission under the call for developing an innovative, sustainable and inclusive bioeconomy.

Rhonda Smith, Coordinator of CommBeBiz, Director of partner Minerva Communciations UK, says: "CommBeBiz will provide the opportunity to EC-funded bioeconomy projects to access the expertise and contacts that will inspire research projects to create not only new business ideas, products and services, but also new ways of thinking, and action to address societal challenges such as the ageing population and climate change."

Through the creation of the CommBeBiz network and five specialist Bioeconomy clusters (food, agriculture, fisheries, forestry, and biotechnology), the project will facilitate the exchange of ideas and transfer of knowledge and expertise between researchers, start-ups, SMEs, accelerator programmes, investors, policy makers, social entrepreneurs and media.

Declan Troy, Director of the Technology Transfer Office in Teagasc says: "Involvement with CommBeBiz will complement the work of the Technology Transfer Office within Teagasc and build on the industry-focused Gateways events we have held in recent years."

CommBeBiz is a three-year project running from March 2015.

AFBI peer review

The Teagasc Director of Research recently chaired a peer review of the Sustainable Livestock Systems programme of the Agri-Food and Bioscience Institute, Northern Ireland. Members of the Peer review panel are: Professor Bob Bansback; Dr Caroline Rymer; Professor Nigel Scollan; Dr Frank O'Mara (Chair of Panel); Tony O'Neill; Professor Helen Miller; and Wesley Aston.

Dr Mark Fenelon appointed Head of Food Research

Dr Mark Fenelon appointed Head of Food Research

Teagasc has appointed Dr Mark Fenelon as Head of Food Research. Dr Fenelon will have responsibility for providing overall leadership for the Teagasc Food Research programme.

Dr Fenelon graduated with a degree in food science and technology from UCC. He completed a PhD in UCC in 2000 and went on to complete a Diploma in Processing and Chemical Engineering in UCC in 2007.

He worked for Wyeth Nutritionals as a food scientist in liquid and powdered infant formula from 2000 to 2004. He joined Teagasc in 2005 as a senior research officer in Moorepark, before being promoted to principal research officer and Head of the Food Chemistry and Technology Department in Teagasc. Since joining Teagasc he has formed a number of large collaborative projects with the Irish dairy and infant formula sector.

Dr Pat Dillon reappointed as Head of the Animal and Grassland Research and Innovation programme

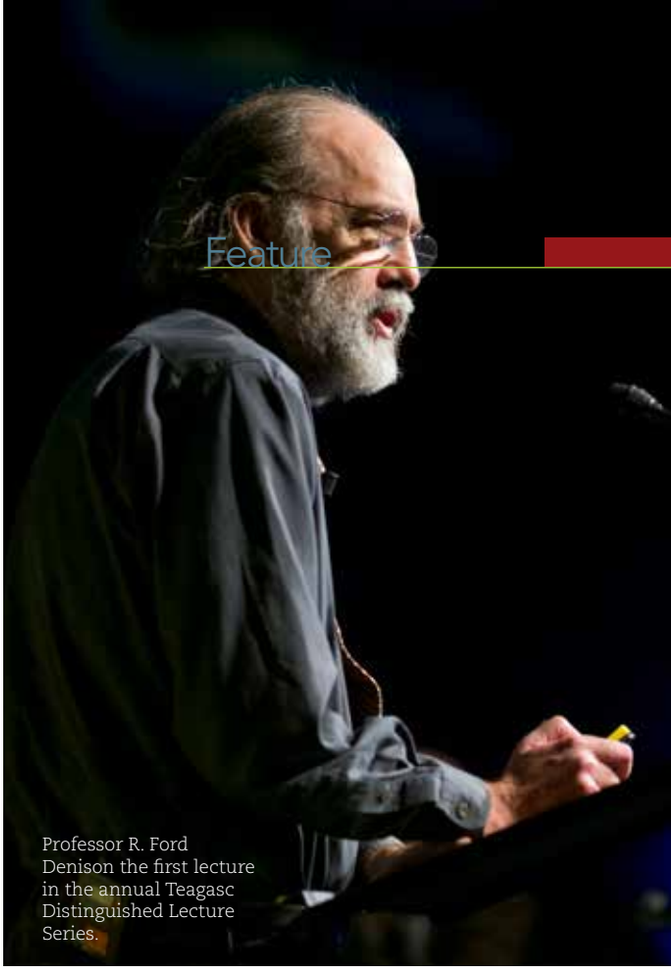
Pat Dillon reappointed Head of Teagasc Animal and Grassland programme

Teagasc has reappointed Dr Pat Dillon as Head of the Animal and Grassland Research and Innovation programme for a second five-year term. Priorities for the next five years will be: increasing the competitiveness and profitability of livestock production systems through enhanced productivity; sustainable intensification of our livestock production systems; developing resilient system of production that reduce the impact of price volatility on farm incomes; improving the quality of meat and milk to meet the requirements of more demanding customers; and contributing to land mobility through assisting more collaborative farming arrangements.

Dr Dillon graduated from UCD with a BAgr. Sc. in 1986 followed by a MSc. in UCC and he went on to complete his PhD in Grassland Science in the National University of Ireland. He joined the research staff at Moorepark in 1990, became Head of the Moorepark centre in 2004 and has been the Head of the Teagasc Animal and Grassland Research and Innovation programme since 2009.

Darwinian agriculture: evolutionary trade-offs as opportunities

Dr Ewen Mullins summarises the first in Teagasc's Annual Distinguished Lecture Series on Darwinian Agriculture and outlines how it relates to crop breeding programmes.



Professor R. Ford Denison the first lecture in the annual Teagasc Distinguished Lecture Series.

Dr Ewen Mullins,
Teagasc Crops, Environment and Land Use Programme, Oak Park, Carlow
Correspondence: ewen.mullins@teagasc.ie

As human populations grow and resources are depleted, agriculture will need to use land, water and other resources more efficiently without sacrificing long-term sustainability. This is a mantra that is often repeated in both the scientific literature and popular press and has been the focus of much discussion in regard to how best the objective can be achieved. Of significance, this topic provided the basic context to the first lecture in the annual Teagasc Distinguished Lecture Series, which was delivered by Professor R. Ford Denison in the Mansion House on March 23. Author of *Darwinian Agriculture*, he presented an entirely new approach to addressing the global challenge of feeding more mouths with less resources by drawing on the principles of evolution and natural selection. Showing how both biotechnology and traditional plant breeding can capitalise on this approach, to identify promising routes for crop genetic improvement, Professor Denison identified clear examples of how individual crop species have evolved in natural ecosystems to coexist with microorganisms in symbiotic relationships. While mutually beneficial, these relationships are by no means charitable, as both plant and microbe accept the necessary 'trade-off' of coexisting with each other in order to ensure the completion of their individual life cycles. Professor Denison argues that when such trade-offs exist as a result of evolutionary pressure, it leads to an improvement in individual competitiveness. As such, irrespective of whether the focus is on genetic improvement of individual crop species or the enhancement of agri-ecosystem management, identifying trade-offs that constrained past evolution can often lead to new solutions to agricultural problems.

Deciphering natural ecosystems, as Professor Denison explained, will undoubtedly provide novel insights into how to tackle the major challenges that lie ahead; for, undoubtedly, the human race cannot replicate the deliverables of tens of thousands of years of evolution. Yet, while we clearly need to pay more heed to the outputs of evolution, the question must be asked: will evolution be able to adapt quickly enough in response to the environmental (and indeed legislative) challenges that today's farmers face? For example, in the EU's drive to reduce and/or eliminate specific classes of fungicides, farmers are faced with the prospect of trying to depress disease incidence with a lower number of plant protection products in their arsenal. Teagasc research shows that this will likely lead to the emergence of more disease-causing strains with resistance to the remaining class of chemicals in use. As a result, the farmer's task becomes even more difficult in the absence of novel sources of genetic resistance that could be integrated into breeding programmes. While evolution has successfully delivered plant species resistant to disease, the challenge remains to conform this material to the necessities of today's consumer and/or the demands of food production systems.

So, what can be done? Firstly, it is important to delineate between what is the driver of a natural ecosystem (i.e., sustainability) versus that of an agricultural ecosystem, which is food production. As a result, maintaining the latter while learning from the lessons of the former is key. Ignoring evolutionary trade-offs would be a mistake for any current or future crop breeding programmes that are focused on tackling an economically important abiotic/biotech stress. Similarly, it is necessary to investigate the potential of accelerated breeding technologies, which in effect 'accelerate' the evolutionary process. Essentially, the potential exists to harness the best of both worlds in a manner that capitalises on the inspiration of natural evolution and the advancements made in biotechnology-based processes.







Nitrogen fertilizer formulation: The impact on grassland yield and gaseous emissions

Mary Harty, Teagasc Walsh Fellow
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What effect does switching nitrogen (N) fertilizer formulation have on grass yield, N uptake and gaseous emissions? Mary Harty was awarded the RDS medal for Best Presentation at the Teagasc Walsh Fellowships 2014 seminar for her presentation on this topic.

The ambitious expansion in agricultural production outlined in *Food Harvest 2020* (industry-led strategy supported by Government, for growth of the agricultural sector) includes a 50% growth in milk volume. As Ireland's dairy industry is based on grass production, increasing milk volume will depend heavily on the fertilizer N inputs, which drive grass growth. Any increase in intensification of the dairy sector must take place in the context of reduced greenhouse gas emissions (GHG). Therefore, a focus on strategies that enable the sustainable expansion of the dairy sector is essential.

Agriculture and GHG emissions

In 2012, agriculture was responsible for 31% of Ireland's GHG emissions, with 39% of agricultural emissions arising from nitrous oxide (N_2O) related to the application of chemical/organic fertilizers (EPA, 2014). Switching from calcium ammonium nitrate (CAN), the predominant straight source of N used by Irish farmers, to a urea-based fertilizer, limits the soil-residence period of nitrate, the major substrate for loss of N_2O through denitrification. However, urea is susceptible to ammonia (NH_3) volatilisation; but, this risk can be managed using an effective urease inhibitor. The aim of this study was to evaluate the effect of switching from CAN to urea, urea with the urease inhibitor N-(n-butyl) thiophosphoric triamide and/or the nitrification inhibitor dicyandiamide (DCD) on: a) agronomic: yield, N uptake and apparent fertilizer recovery; and, b) gaseous emissions: N_2O and NH_3.

Figure 1. N_2O Sampling using static chambers.

Figure 2. NH_3 sampling using wind tunnels.

Study design

A collaborative study between the Agri-Food and Biosciences Institute (AFBI) and Teagasc took place over two years at permanent pasture sites located at Johnstown Castle (Co Wexford), Moorepark (Co Cork) and Hillsborough (Co Down). The sites covered a range of soil textures and drainage characteristics. The annual fertilizer N was applied at different rates (0, 100, 200, 300, 400 and 500kg/ha N) in five equal splits; dry-matter yield and N offtake was measured over six harvests; daily N_2O and NH_3 emissions were measured using static chambers (Figure 1) and wind tunnels (Figure 2), respectively.

Results

Results from this study show that, in general, urea treatments reduced N_2O emissions compared with CAN (*one urea treatment, Urea+n-BTPT, did not generate significantly lower N_2O emissions than CAN in one of six site years) (Table 1). Additionally, grass dry-matter yield was not significantly different for urea and CAN (Year two yield data includes data from five of six harvests only). However, some of the urea formulations showed evidence of pollution swapping of N_2O for NH_3. Over the two years, urea with the urease inhibitor (Urea + n-BTPT) successfully maintained yield relative to CAN (Urea + n-BTPT total yield was significantly greater than CAN in one site year; no significant difference was recorded in five of six site years). It also generated equivalent fertilizer recovery in the crop relative to CAN and successfully reduced N_2O in five site years and NH_3 emissions in all site years. Fertilizer formulation strategy has the potential to be a win-win solution for agricultural intensification, enabling reduction of GHG emissions without sacrificing productivity.

Table 1. N_2O Emission Factors (EF) for selection of fertilizer formulations measured over six site years. The EF is calculated as the treatment emissions, less control emissions divided by the N rate applied expressed as a percentage. The International Panel on Climate Change default N_2O emission factor for fertilizer N is 1%; treatments with EF ≥ 1% are shown in bold.

Site	Hillsborough		Johnstown		Moorepark
Formulation/ Year	Year 1	Year 2	Year 1	Year 2	Year 1
CAN	**4.0**	**1.7**	**1.0**	**1.0**	0.8
Urea	0.3	0.5	0.3	0.2	0.2
Urea + n-BTPT	0.4	0.4	0.8*	0.5	0.4
Urea + n-BTPT+DCD	0.1	0.2	0.4	0.0	0.0
Urea + DCD	0.0	0.1	0.2	0.1	-0.1

Note: Year 1 emissions measured from March 2013 to March 2014, Year 2 emissions, measured from March 2014 to YTD end Oct 2014.

This research was supported by: the sustainable nitrogen fertilizer use and disaggregated emissions of nitrogen on grassland (SUDEN) project, which was funded by the Research Stimulus Fund (Department of Agriculture, Food and the Marine); Agricultural Greenhouse Gas Research Initiative for Ireland (AGRI-I) which was co-financed by Council for Forest Research and Development (COFORD) and the Research Stimulus Fund (Department of Agriculture, Food and the Marine); and the Walsh Fellowship Scheme. With thanks to the technical and laboratory staff at the Agri-Food and Biosciences Institute and Teagasc.

Reference

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Biocontol of *Listeria monocytogenes*

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Aidan Casey received the Institute of Food Science and Technology of Ireland medal for his presentation on 'Expanding the possibility for biocontrol of *Listeria monocytogenes* with bacteriophages and disinfectants' at the 2014 annual Teagasc Walsh Fellowships seminar.

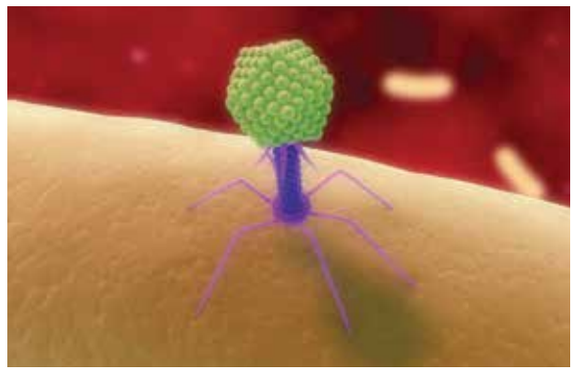
Control of *Listeria monocytogenes* in the food-processing environment is of paramount importance to the food industry, particularly given the number of high-profile outbreaks of listeriosis that have occurred in recent years. Two biocontrol approaches under investigation include the use of *Listeria*-specific bacteriophages and elimination using industrial detergents. Understanding the molecular mechanisms by which these agents interact with pathogenic *Listeria* and how the organism adapts to evade these control measures is a topic of increasing interest.

Exposure of *L. monocytogenes* to industrial disinfectant

To investigate the molecular mechanisms underpinning the response of *L. monocytogenes* to detergent exposure, the organism was grown in the presence of a sub-lethal concentration of the industrial disinfectant benzethonium chloride (BZT), and compared to the strain grown in the absence of the disinfectant. Gene expression levels in the two conditions were compared using RNA-Seq, a recently developed approach to transcriptome profiling, which uses deep-sequencing technologies and provides a precise measurement of levels of mRNA transcripts in the cell at a given time. When exposed to the disinfectant, *L. monocytogenes* responded by both reinforcing the cell wall, and by synthesising flagella in order to allow the bacteria to physically move away from the disinfectant. This work provides an insight at the genetic level as to how this organism is able to persist and adapt to the introduction of this stress in the environment.

Isolation of novel *L. monocytogenes*-specific bacteriophages

Bacteriophages are viruses that infect bacteria and are the most abundant entities in the biosphere. They are ideal candidates for biocontrol of pathogens, given their narrow host-specificity and non-toxic composition. As part of this research, we successfully isolated two bacteriophages specific for *Listeria*



monocytogenes from environmental sources. Initial characterisation of the bacteriophages revealed a host-specificity for *Listeria monocytogenes* strains of the 4b serotype, a clinically relevant serotype of the bacterium that is frequently associated with listeriosis disease outbreak.

Genome sequencing of *Listeria* phages

To identify the genetic determinants for the 4b-specific nature of these phages, whole genome sequencing was performed using an Illumina MiSeq NGS system. The genomic composition, structural architecture and relatedness to other sequenced *L. monocytogenes*-specific bacteriophages were determined. This comparative analysis indicated that both are tailed phages with dsDNA genomes, and specific tail fibre genes were identified as responsible for host-specificity of these bacteriophages. This work has greatly advanced our understanding of phage-host interactions in *Listeria monocytogenes*, and has provided potential tools for biocontrol of this species in the food-processing environment.

Concluding remarks

In summary, exposure of a persistent strain of *Listeria monocytogenes* to BZT resulted in an up-regulation of genes that function in cell-wall reinforcement, chemotaxis and motility of the bacterium.

This research highlights the potential use of bacteriophages as biocontrol agents of *Listeria monocytogenes*, though further work on specific interactions of these phages with their Listeria hosts is needed in order to fully exploit these viruses.

This work was supported by the Teagasc Walsh Fellowship Programme, by the EU 7th Framework projects PROMISE, FOODSEG and by a *safe*food mini-project.





Rhizosphere priming and nitrogen mineralisation

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Conor Murphy won the award for best poster at the annual Walsh Fellowship 2014 for his work on the role of rhizosphere priming effects in soil N supply.

Currently, scientific techniques are inadequate for quantifying the soil's supply of nitrogen (N) over a growing season. In Ireland, the supply of N through net mineralisation varies substantially between soil types, i.e., from 56-220kg N/ha per year. This is largely due to our poor understanding of the myriad of mechanisms that release nutrients from soil organic matter (SOM), particularly biological mechanisms encompassing plant-soil interactions. Developing a better understanding of these mechanisms will enable improved management of agricultural soils for increased N-use efficiency. This is welcomed at a time when increasing costs of N fertilizer manufacture, linked to energy prices, is exerting financial pressure to reduce N use in agriculture.

An emerging biological mechanism that affects soil N supply is the priming effect. The priming effect is where microbes utilise labile carbon from roots (root exudates or senescing plant material) for energy, subsequently mineralising SOM and, thus, mobilising nutrients to plant available pools. However, the impact of the priming mechanism on N mineralisation is poorly understood.

Therefore, the aim of this research was to investigate the importance of this mechanism for N mineralisation in Irish grassland soils. Furthermore, we investigated the effect of nutrient addition and grazing on mineralisation mechanisms. To do this, we coupled continuous steady-state ^{13}C labelling and ^{15}N isotope dilution to measure specific gross carbon (C) and N fluxes from two contrasting soils. The results clearly demonstrated that priming significantly increased N mineralisation but the magnitude of the effect was different for different soils. We showed that the C:N ratio of the primed and basal flux from SOM was significantly different, indicating that priming and basal mineralisation are distinct processes and that the release of labile carbon from plant roots functions as a nutrient-acquisition response. Nutrient additions to soil reduced the mineralisation of soil organic matter and N release in soil by decoupling plant soil interactions. Our results demonstrate that priming effects are an integral component of N mineralisation and should be considered when developing N-management strategies for soils and farming systems.

Steady-state isotope labelling chamber: ^{13}C-labelled CO_2 at ambient concentrations is passed through the chamber over the growth period of the plant. Use of stable isotopes allows for differentiation between photo-assimilated C and soil-derived C in total CO_2 efflux to quantitatively measure plant-C inputs and soil-C outputs.

This research was funded by the Teagasc Walsh Fellowship Scheme.

The contributions of Dr Tom Walsh to soil science and to Irish agriculture: personal reflections

The late Dr Tom Walsh, who was honoured at a recent lecture at Teagasc, Johnstown Castle.

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The following is a brief synopsis of the Centenary Lecture delivered at Johnstown Castle on December 5, 2014, on the occasion of World Soils Day.

Introduction

On the occasion of World Soils Day, and with the International Year of the Soils (2015) almost upon us, it is pertinent to reflect on the importance of soils for mankind and, fittingly, to celebrate the life of an Irish scientist who made an enormous contribution to soil science and to its application to the welfare of the people of Ireland. In today's mainly urbanised world, few people stop to reflect on how soil impacts their lives. Indeed, the same statement could be made about agriculture itself. In brief, soil, that thin 'skin' on the surface of the earth, is vital to almost every aspect of life, and has been instrumental in dictating the evolution of civilised society. Soil is the source of our food, fibre and energy, it filters our water, ensures biodiversity, provides us with antibiotics, and modifies our climate. We build on it, play on it, and are buried in it. In the context of the current concern about climate change, it is important for us to realise the role of soil, as it is both a source of greenhouse gasses and can absorb such gasses, depending on how it is managed.

In short, soil is vital to ensuring global food security and maintaining the quality of our environment.

Rich fertile soils are associated with developed societies, while poor soils are linked to poverty. Like other natural resources, soil is fragile and can be degraded or indeed destroyed. The extent to which we can conserve the earth's soil resources and exploit them for the good of mankind is dependent on our knowledge of this dynamic and biologically diverse material. In the past century much has been learned about soil through the application of the chemical, physical and biological sciences. The land management practices that we have in today's modern and highly productive agriculture are the outcome of evolving science-based studies of the soil. In the context of the evolution of soil science in Ireland and the development of Irish agriculture, one man dominated the 20th century: Dr Tom Walsh.

The soil scientist who shaped Irish agriculture

A brief overview of Dr Walsh's life, which featured in *TResearch* (Volume 9: No. 3. Autumn 2014), highlighted the various milestones in his career, from his humble origins in Wexford to his emergence as a soil scientist in UCD, his role as a scientist and later administrator of An Foras Talúntais and ACOT, his involvement in various national and international organisations, his broader role in Irish society, and his many academic and honorary accolades. The colossus that was Dr Walsh is borne out by the powerful testimonials by people who worked with him. A few of these abridged testimonials are worth mentioning.

"Vision, dedication, creativity, devotion to work, unique capacity to recognise and stimulate students, one of the greatest agricultural scientists of the 20th century, the advancement of science and its application to farming was his greatest contribution."(John Lee, Teagasc Johnstown Castle)

"A remarkable research leader, with a fertile mind, an inspiration to colleagues, vigorous dedicated scientist, truly great human being." (Pierce Ryan, former director of Teagasc)

"Led the first national effort to apply science for the development of agriculture. Teagasc is a fitting monument to Dr Walsh." (Aidan Conway, Teagasc Johnstown Castle)

"Dedicated his genius to the people of rural Ireland." (Ned Culleton, An Foras Talúntais)

"A truly patriotic public servant, energetic, enthusiastic, expansive, charismatic, caring, committed, dynamic, determined, discerning, an amazing confidence builder." (Olive Daly)

As a visionary leader in Irish agriculture, with

Pictured at the Centenary (from left) are: Conleth Hassett; Aine Hassett; Professor Gerry Boyle, Director of Teagasc; Rosemary Buckley (Tom Walsh's daughter); Professor John Ryan; and speakers Naomi Buckley and Joan Walsh.

an impact on other aspects of Irish society, 'Doc Walsh', as he was affectionately and respectfully known, was also a man who never forgot his humble background in rural Ireland. He never let his scientific image divorce him from his roots. He never lost the common touch. Humility was his hallmark.

The soil scientist and his achievements

Following his PhD at UCD in 1938, Dr Walsh used his extraordinary energy to collaborate with staff in various disciplines, including Professor Eamonn Gallagher, his mentor, and Dr E J Clarke in horticulture. His published output was exceptional, not only in terms of the numbers of publications, but also the variety of topics he addressed, from nutrient-related issues to soil genesis, classification, land suitability, and land management. That he could achieve so much during a period when undertaking research was beset with many constraints is hard to grasp by today's standards. His prolific publications addressed basic and applied issues in soil science and appeared in a range of national and international journals. Dr Walsh was a believer in science communication long before the notion of 'publish or perish' and he firmly believed in accounting for funds invested in research. He was ahead of his time.

Dr Walsh's ground-breaking work on the identification of major and minor nutrients as constraints in Irish soils and their alleviation with fertilizers was a milestone in Irish agriculture. He built on these achievements by forcefully and successfully arguing for public support and financial investment in agricultural research. A major endeavour of his was his insistence on the need for an inventory of the national soil resources of Ireland as a basis for land-use planning and management. As a pre-eminent soil scientist, Dr Walsh understood how soils evolved and their significance to agriculture and mankind. While most of his attention was focused on Ireland, Dr Walsh had a major profile at the international level, especially in the International Soil Science Society. His recognition as Fellow of the American Society for the Advancement of Science is a rare tribute to his international standing.

Monument to his endeavours

Following his prodigious years as a soil scientist with the Department of Agriculture, Dr Walsh's considerable energies were next channelled into the founding of An Foras Talúntais. He built a team of researchers that were to tackle the issue of liming in Irish soils, which was to be a quantum leap in productivity of Irish grassland and arable crops. Similarly, another major constraint was phosphorus deficiency, affecting not only crops but also animal health and wellbeing. Other constraints such as nitrogen deficiency and micronutrient toxicity, such as selenium, were addressed, providing the basis for corrective action. Considerable progress was made in areas such as biological nitrogen fixation in legumes, thus contributing to enhanced output from grassland. Under Dr Walsh's direction, a soil map of Ireland was published (1969) and later a generalised map (1980). Dr Walsh continued to support efforts to document Ireland's national soil resources and to highlight the role of soils in Irish agriculture.

The establishment of Teagasc saw a shift in emphasis in soil research from agricultural production to issues related to the environment; ironically, many emerging environmental problems were associated with overuse of nitrogen and phosphorus and their loss from agricultural land to water bodies. The focus on environmental issues was dictated by policy directives from the European Union and forms the basis of current research programmes at Johnstown, e.g., a catchments and water quality programme dealing with nutrient loss, and greenhouse gas emissions, and biodiversity. A special focus has been on the Irish Soil Information System, which led to the production of the new digitised soil map of Ireland, bringing to completion the earlier efforts of Dr Walsh. The work at Johnstown Castle today is a logical outcome of the early research efforts of Dr Walsh.

Enduring legacy

Though memories of Dr Walsh have dimmed with the passing years since his death in 1988, there are tangible symbols of his legacy. As education of students and mentoring of young scientists were fundamental to Dr Walsh's thinking, the Walsh Fellowships Programme, which so far has educated and trained over 1,000 students, is a fitting tribute to his memory. His contributions to soil science were 'written in stone' in the form of the plinth recognising the Dr Tom Walsh soil laboratory.

The legacy of 'Doc Walsh' endures in other, less evident ways. A world-class soil scientist, endowed with a steadfast conviction of the need to help his fellow men, Dr Walsh set the standards for soil scientists who were to follow him. We are indebted to him. His inspiration enabled some of us to become Fellows of the Soil Science Society of America and the American Association for the Advancement of Science, albeit in the Irish soil science diaspora. At the broader level, Irish agriculture, Irish agricultural research institutions, rural Ireland and, indeed, all of Irish society are the beneficiaries of the efforts of an extraordinary Irish soil scientist and humanitarian, Dr Tom Walsh. Ní beigh a leithéid an arís.

Sara Vero, Teagasc Walsh Fellow, talking at A Pint of Science in May 2014 about novel approaches to soil science.

Public communication of science for the early career researcher

Sara Vero,
Teagasc Walsh Fellow, Teagasc Agricultural Catchments Programme, Johnstown Castle, Wexford and National University of Ireland, Galway

Sara Vero, a Teagasc Walsh Fellow, outlines some of the opportunities available to early career researchers to communicate with broader audiences.

Viewed as critical components of a successful research career, peer-reviewed journal articles and presentations at scientific conferences are often the main route through which research is disseminated. However, they are not the only approach to scientific communications or even, in some cases, the most appropriate. Modern media and international sci-comm events have opened up new and novel opportunities to make the public aware of the research conducted in Teagasc. Many of these opportunities are targeted at early career researchers, in particular post graduates such as those supported by the Walsh Fellowships Programme. The research conducted in Teagasc is of interest not just to academics, but has practical applications for the wider audience of farmers, policymakers and stakeholders. Furthermore, science is increasingly viewed as a form of entertainment and interest by the general public. Using only peer-reviewed publications, essentially excludes a vast audience who may not have access to journals or may struggle with the specialist scientific jargon and format unique to that style of publication.

Popular press

Subsequent to peer-reviewed journals, newspaper and popular press articles are probably one of the most prevalent means of communication. National and local newspapers welcome scientific and environmental stories and interviews, and frequently feature specialist science or farming supplements. Dedicated agricultural newspapers and websites (e.g., *The Irish Farmers Journal*, Agriland.ie and *Farmers Weekly* in the UK) have high readership and allow research findings to reach the key agricultural and farming demographic. In-house publications such as Teagasc's *TResearch* magazine or University publications such as NUI Galway's *Research Matters* also provide an opportunity to keep peers appraised as to ongoing research and current findings.

Podcasts and radio

Radio is often overlooked as a method of public outreach but, according to the Broadcasting Authority of Ireland, 84% of Irish adults listen to radio on a daily basis. This is greater than newspaper readership (80%) or Twitter usage (27%). Radio, therefore, offers an unrivalled opportunity to promote the work of early career researchers. National and local radio stations are often eager to interview guests, particularly on issues of public concern such as water quality, greenhouse gas emissions or farm safety, and some also feature programmes dedicated to particular

topics, such as Newstalk's *Futureproof* science show or RTÉ 1's *Countrywide*. Much of the research conducted by Teagasc Walsh Fellows concerns topics that are of interest to such shows, and they welcome researcher participation from all career stages.

Podcasts are another great option, with many research groups, for example the Ryan Institute at National University of Ireland, Galway, now producing podcast series that are available through their websites and iTunes.

Public talks and events

It's easy to forget that Teagasc's research is important not just to those directly involved in the scientific and agri-food industries, but also to the general public, policymakers and stakeholders. Public talks are a great way to connect with multiple stakeholder groups. Recent years have seen many events such as Science Foundation Ireland's well-known Science Week and the BT Young Scientist Exhibition, both of which are supported by Teagasc. However, there are many others. For example, Pint of Science challenges researchers to explain their work in pubs and bars across the country, which resulted in venues being filled to capacity for events held in Dublin and Cork in 2014. The informal and social surroundings helped to remove the notion of stuffy, dry and boring science, making the event approachable and easy to understand for the general public. Dart of Physics is another great example, in which posters explaining physics concepts were displayed on public transport. Soapbox Science, hosted in Trinity College Dublin in 2014, and upcoming in Belfast in 2015 (June 20), encourages female scientists to showcase their work and use public space as a forum for teaching and discussion. Other examples of national events include: Science Gallery Dublin, which hosts talks and exhibitions, and Bright Club, which mixes science and stand-up comedy at Dame Lane, Dublin. Essential for rural-based audiences are the multiple farm walks and farmers meetings that are held throughout the year across Ireland, which have become vital platforms for translating research findings into practice on the farm. Both primary and secondary schools also welcome speakers.

Frequently forgotten are the various professional associations, e.g., the International Association of Hydrologists, Irish Grassland Association, etc., who genuinely want to hear what their members are doing, and welcome talks, news pieces and articles. Such groups are there to facilitate networking and support students in their careers, and Walsh Fellows should be encouraged to keep in touch with them.

Competitions

It is so common for students and researchers to be daunted at the prospect of presenting on stage before their peers at major scientific events. Effective presentation is a skill like any other, requiring practise in order to become successful. In recent years, scientific communications competitions such as Famelab and Threesis have become popular. These events challenge PhD students to explain their work, usually in a limited time, to mixed audiences of the general public and other scientists. These competitions not only allow an early career researcher to hone their skills and become comfortable with being on stage, but also offer some great prizes, training and feedback. Many events, including Famelab, also have international stages. Teagasc students have been extremely successful in this event, with Walsh Fellow Fergus McAuliffe winning the 2013 international stage, and current Walsh Fellows Ruairi Robertson (2nd place winner in 2014 and 2015) and Sara Vero (finalist 2014) representing Teagasc at the national stage of this event. These events are a great confidence builder, which helps students develop a relaxed and assured presentation style, so they need not be daunted when it comes to conferences, vivas and interviews. Many Irish conferences such as Environ or those overseas, such as the ASA-CSSA-SSSA Annual Meeting also host student sessions with awards for outstanding presentations and posters.

Teagasc Walsh PhD Fellow Ruairi Robertson speaking at the Dalkey Book Festival June 2014 about the role of diet in protecting our gut and brain health.

Benefits of public communication

There are many benefits to performing public outreach, especially during post-graduate studies. The multiple formats by which research can be disseminated, means that there are unprecedented opportunities for early career researchers' work to have a real-world impact. Efforts in this area will also facilitate regular practise and up-skilling, which are essential for well-rounded career and personal development, especially when coupled with training provided to Walsh Fellows by Teagasc and their host universities. Such supervisory bodies and institution PR departments can also provide guidance relating to public relations issues, such as intellectual property and organisation policies. This is by no means a complete list of the avenues available, but an introduction to the methods by which early reseachers such as Walsh Fellow students can promote their work. For more information see:

http://www.britishcouncil.ie/famelab

http://www.pintofscience.ie/, http://soapboxscience.org/ https://dublin.sciencegallery.com/ https://www.soils.org/iys/pedologytalks

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Teagasc's Next Generation Herd, established to validate that genetic selection, based on the EBI, will deliver as expected and continue to do so into the future.

Next Generation Herd

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In 2001, Teagasc Moorepark, in conjunction with the Irish Cattle Breeding Federation developed the Economic Breeding Index (EBI) for dairy cattle, which included performance traits related to revenue (milk production) and costs (fertility). The goal of the EBI was to identify animals whose progeny will be most profitable under future Irish production systems. The EBI replaced what was known as the Relative Breeding Index or RBI, which was solely production-focused. Today, the EBI includes 19 traits related to milk production, fertility and longevity, calving performance, efficiency, beef performance, health and milking management.

While phenotypic performance of the Irish National herd is currently suboptimal (Buckley *et al.*, 2014), analysis of commercial farm data by Ramsbottom *et al.* (2012) has shown that each €1 increase in herd EBI results in a €2 increase in profit/cow/lactation. Genetic gain has increased over time to a modest €11/cow/year in 2011. The incorporation of genomic selection into the national breeding since 2009 has accelerated the theoretical rate of increase in EBI to €38/cow/year (Berry, personal communication).

The Next Generation Herd

The Next Generation Herd was established as a strategic resource to validate that genetic selection based on the EBI will deliver as expected and continue to do so into the future, providing clear and precise indications of the compatibility of cows of extremely high EBI to intensive grass-based production systems. It will also support our ability to enhance the future development of the EBI, and provide a potential nucleus herd to supply genomically selected young bulls into the national breeding programme.

The study

The Next Generation Herd was assembled during 2012, with the purchase of maiden heifers, in-calf heifers, and heifer calves from commercial dairy herds around the country, as well as animals from within Teagasc dairy herds. The first animals (all parity 1) calved in the spring of 2013. Thirty three per cent parity 1 cows were introduced in 2014. The herd is situated at the Dairygold Research Farm in Kilworth. There are two distinct EBI groups; 90 ELITE (extremely high EBI; €249) and 45 national average EBI (NA; €133 EBI) females. To avoid confounding (entanglement) between EBI and the effects of hybrid vigour or specific sire lines, the herd is exclusively Holstein-Friesian and genetic diversity (sire lines) has been maximised. Of the 90 ELITE heifers assembled for the trial in 2012, 40 sires, 83 grandsires and 27 maternal-grandsires are represented. The ELITE females, with an average EBI of €249, are firmly inside the top 1% in the country on the EBI.

Prior to purchase, all animals were subjected to genomic testing and rigorous health screening. Our priority was to assemble a minimal disease herd, negative for the common infectious diseases: IBR,

Table 1. Summary statistics of the Next Generation Herd.

	EBI	Sub-Indices (€)						
		Milk	Fertility	Calving	Beef	Maintenance	Health	Management
ELITE	249	69	142	35	12	12	0	3
NA	133	49	65	25	9	2	0	1

Table 2. EBI group effect on lactation performance.

	ELITE	NA	SED	Significance
Milk yield (kg/cow)	4852	5029	124	**
Fat (g/kg)	45.1	42.3	0.23	***
Fat (kg)	218	212	2.4	*
Protein (g/kg)	36.9	35.2	0.05	***
Protein (kg)	179	178	2.2	NS
SCM (kg/cow)	4984	4958	56.5	NS
SCC ('000 cells/ml)	132	147		NS
Milk receipts (30c/l)	1665	1631	18.8	*
Average body condition score (1-5)	2.94	2.77	0.010	***
Average weight (kg)	486	493	1.5	NS

SCM = Solids Corrected Milk Yield;SCC = Somatic Cell Count (raw mean); SED = Standard Error of Difference; * = P <0.05, ** = P<0.01, *** = P<0.001

BVD, Salmonella, Neospora, Johne's and Leptospirosis. Best practices pertaining to disease screening, bio-containment and biosecurity have been implemented.

The two EBI groups are evaluated across three seasonal pasture-based systems. The three systems represent: 1) intensive grazing; CONTROL, 2) high stocking rate with tighter grazing residuals; LGA, and 3) intensive grazing with additional concentrate feed (+4kg daily) offered throughout lactation; HC. Pre and post-grazing heights were measured using the Rising Platemeter (Jenquip, Feilding, New Zealand). Cows were grazed as six individual management groups, with 30 ELITE and 15 NA cows allocated to each of the three feeding systems. Milk yield was recorded daily using electronic milk meters with milk constituents determined weekly.

Preliminary results

Average pre-grazing sward height and (standard deviation) for CONTROL, LGA and HC treatments was 10.1 (1.9), 9.7 (2.3), and 9.9cm (2.1), and average post-grazing residual and (standard deviation) was, 5.0 (0.9), 4.1 (0.8) and 4.9cm (0.8), respectively. Concentrate supplementation averaged 295, 314 and 1,038kg per cow for CONTROL, LGA and HC treatments, respectively.

Milk production and udder health

There was no EBI group × feeding treatment interaction observed. The NA cows had a higher milk yield compared with the ELITE (P<0.01), whereas the ELITE had significantly higher milk fat and protein content (Table 2). Consequently, ELITE produced significantly higher yield of milk solids (fat + protein yield). Somatic cell count did not differ significantly. Milk receipt value was €34 per cow higher for the ELITE group based on a milk price of 30 cent/litre (P<0.05). Within the limits of the current study, neither response to concentrate supplementation nor response to restricted grazing differed with the two EBI groups. The response to concentrate

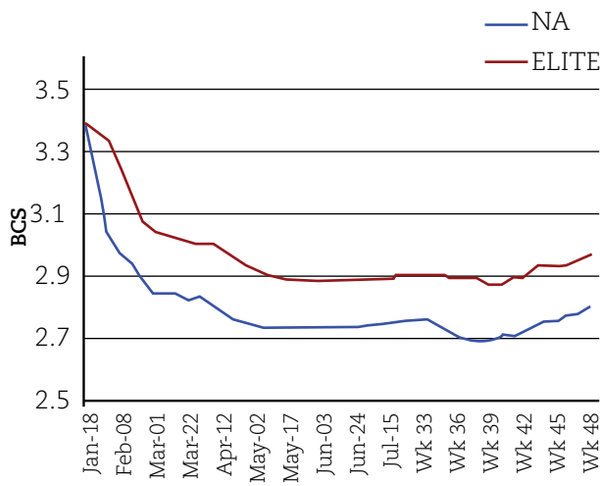

Figure 1. Body Condition Score profile for ELITE and National Average EBI cows.

supplementation was 0.74kg, 0.66kg and 0.05kg, of milk yield, solids corrected milk yield and milk solids (fat + protein kg) per additional kilogram of concentrate offered to the HC treatment compared with the CONTROL. The LGA treatment yielded 199kg less milk, 209kg less solids corrected milk yield and 17kg less milk solids than the CONTROL, as a consequence of grazing to almost 1cm lower.

Body condition score and live weight

On average over lactation the NA cows were numerically heavier (+7kg; P=0.18)) but had lower (P<0.001) body condition score (-0.17) when compared to the ELITE cows (Table 2). The difference in condition score was consistent throughout lactation (Figure 1).

Fertility

Perhaps the most encouraging finding was the large difference in fertility performance. Submission rate in the first three weeks, pregnancy rate to first service, six week in-calf rate and final in-calf rate after 12 weeks' breeding averaged 95%, 60%, 71% and 90% for the ELITE, and 89%, 47%, 55% and 76% for the NA cows, respectively. Consequently, the number of services per cow and the calving to conception intervals were 1.56 and 86 days versus 1.67 and 95 days for the ELITE and NA cows, respectively.

Conclusions to date

The preliminary results of this study are very positive for the Irish dairy industry, indicating the EBI is working to identify more profitable dairy genetics. In this post-quota era, Irish dairy farmers must focus to continue the genetic progress that has been made to remove the greatest constraint to maximising profitability from a seasonal grass-based system, i.e., poor fertility/longevity.

Acknowlegements

Funded by Teagasc Core funding.

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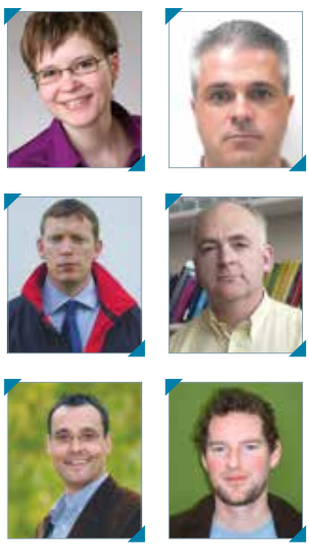
Sustainable intensification improves water quality



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Teagasc and Karlsruhe Institute of Technology researchers have investigated, using 11 years of data, the impact of agronomic practices of an intensive dairy farm on nitrogen concentrations in a karst aquifer in southern Ireland.

Exploring the long-term relationship between agricultural nitrogen (N) loading on a dairy farm and groundwater nitrate (NO_3-) is particularly challenging in perceived areas of high vulnerability, such as those underlain by thin soils and karstified limestone aquifers. The exploration, understanding and interpretation of karst aquifers is complicated by complex flow systems and the variable time lag between the surface and groundwater. There has been limited work relating to long-term farm management and local weather variation with groundwater NO_3- at farm scale and, uniquely, this study was able to explore this complex system. Such sites are an excellent means of testing mitigation measure efficacy as they tend to respond quickly circa one to two years. The Nitrate Directive places mandatory limits on groundwater NO_3- concentrations and the current study investigated the impact of local weather conditions, site specific conditions, time lag and agronomic management to groundwater quality beneath an intensive dairy production system over a 10-year period.

Site study

The intensive dairy farm study site (48.1ha) at the Curtin's Farm, Teagasc Dairy Production Centre, Fermoy, Co Cork is located in a lowland, limestone area, down-gradient of the large River Blackwater (Figure 1). A farm-scale hydrogeological investigation was established in 2001, which also included the measurements of monthly NO_3- concentrations in groundwater from 11 boreholes distributed across the entire site. On-site daily weather data were recorded during the entire study period and evapotranspiration and effective drainage (ED) were calculated. Weather conditions varied considerably between years during the study period. Rainfall averaged 996mm over the 10-year period, whereas the 30-year average was 1,022mm.

Best nutrient management practices have been applied on the farm to reduce N inputs and increase

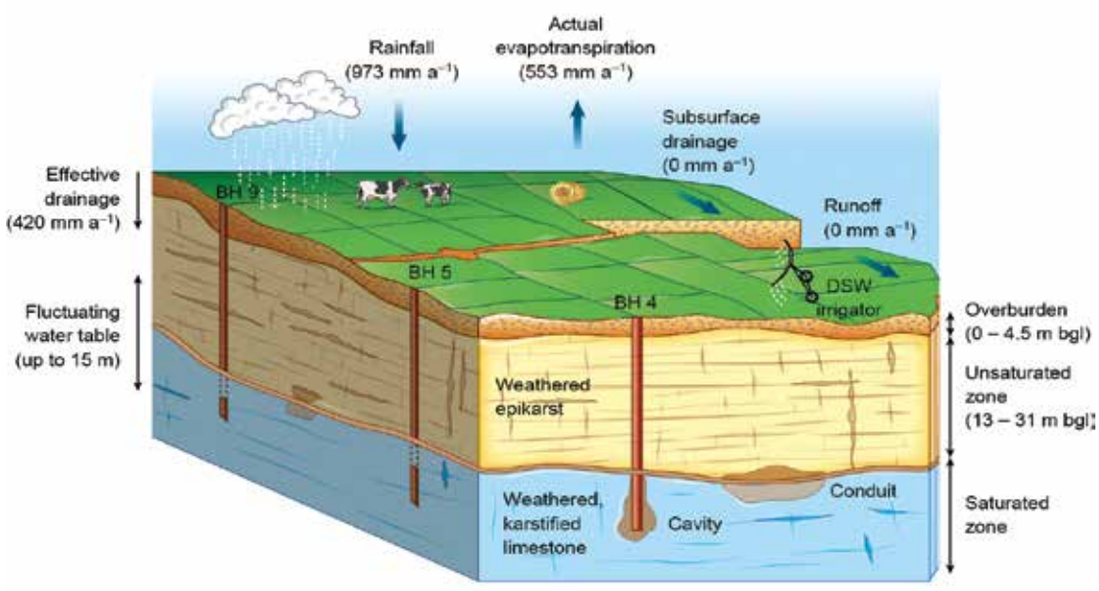


Figure 1. Understanding nitrate occurrence in karst areas takes time and long-term datasets.

farm productivity. During the 10-year study period, the overall dairy herd size increased from 108 to 138 dairy cows (equivalent to a stocking rate increase of 28%). Grazing season length was increased from 231 days in 2001 to a high of 306 days in 2007 and from 2002, was always greater than 272 days. Annual chemical fertilizer N was reduced by 17% (from 300kg to 250kg N/ha) to comply with the nitrates regulations introduced in Ireland in 2007, while annual feed N input was reduced by 35% (from 40kg to 25kg N/ha). The overall reduction in fertilizer and feed N use and increased overall farm stocking rate, were achieved by increasing organic fertilizer application during spring to replace inorganic N application and by increasing grazed grass utilisation at the experimental site. As a consequence of the agronomic and nutrient management changes, milk fat plus protein production increased from 930kg/ha to 1,280kg/ha during the study, while N use efficiency increased for 22% to 36% (Table 1).

Table 1: Farm system characteristics at the study site (2001 to 2011)

Year	2001	2003	2005	2007	2009	2011
Stocking rate (cows ha^{-1})	2.25	2.44	2.63	2.67	2.88	2.88
Total N imputs (kg ha^{-1})	335	328	368	333	277	274
Fat plus protein (tons ha^{-1})	0.93	1.16	1.21	1.13	1.18	1.28
N-use efficiency (%)	22.4	28.0	25.4	26.7	33.9	36.0

Concentrations of NO_3- in groundwater were highly variable throughout the study, but were typically greatest during autumn and early winter. The analysis of NO_3- occurrence data from 2002 to 2011 showed a decreasing trend of mean NO_3- concentrations on the farm from 16.0mg L^{-1} in 2002 to 7.3mg L^{-1} during 2010 and 6.6mg L^{-1} in 2011 (Figure 2). The overall mean concentration of NO_3- exceeded the maximum allowable concentration (MAC) in groundwater defined by the EU Water Framework Directive (WFD) in Ireland (11.3mg NO_3-N L^{-1}) during the first seven years of the study and declined below the MAC for the last three years of the study period (2009, 2010 and 2011). Consistent with the decline in concentrations, the estimated N loss decreased from a maximum value of 76kg ha^{-1} in 2002 to a minimum value of 25kg ha^{-1} in 2011.

In many cases, the explanatory variables of farm-management practices and weather conditions were more important after the estimated one- or two-year time lag was imposed. Over the 10-year monitoring period, the results of this study indicate that a combination of site characteristics (i.e., depth of the unsaturated zone, soil/subsoil and rock thickness), climatic factors (such as rainfall, sunshine and SMD) and agronomic practices (i.e., reduced fertilizer rate, appropriate slurry and dairy soiled water application strategy, minimum cultivation and strategic management of high-risk zones) were important factors influencing NO_3- loss to groundwater. The study has highlighted that variability in both farm management practices and local weather conditions have a large impact on groundwater NO_3-. The reduction in farm-gate fertilizer N use coupled with the increased overall stocking rate (and, consequently, milk production from the site) during the measurement period was indicative of increased N use efficiency on the research farm contributing to increased N retention within the farm system. The results indicate that improved nutrient management practices on a highly vulnerable site, with free-draining soil can have relatively fast impacts on groundwater quality and can lead to an achievement of the water quality targets set by, for example, the WFD into the future.

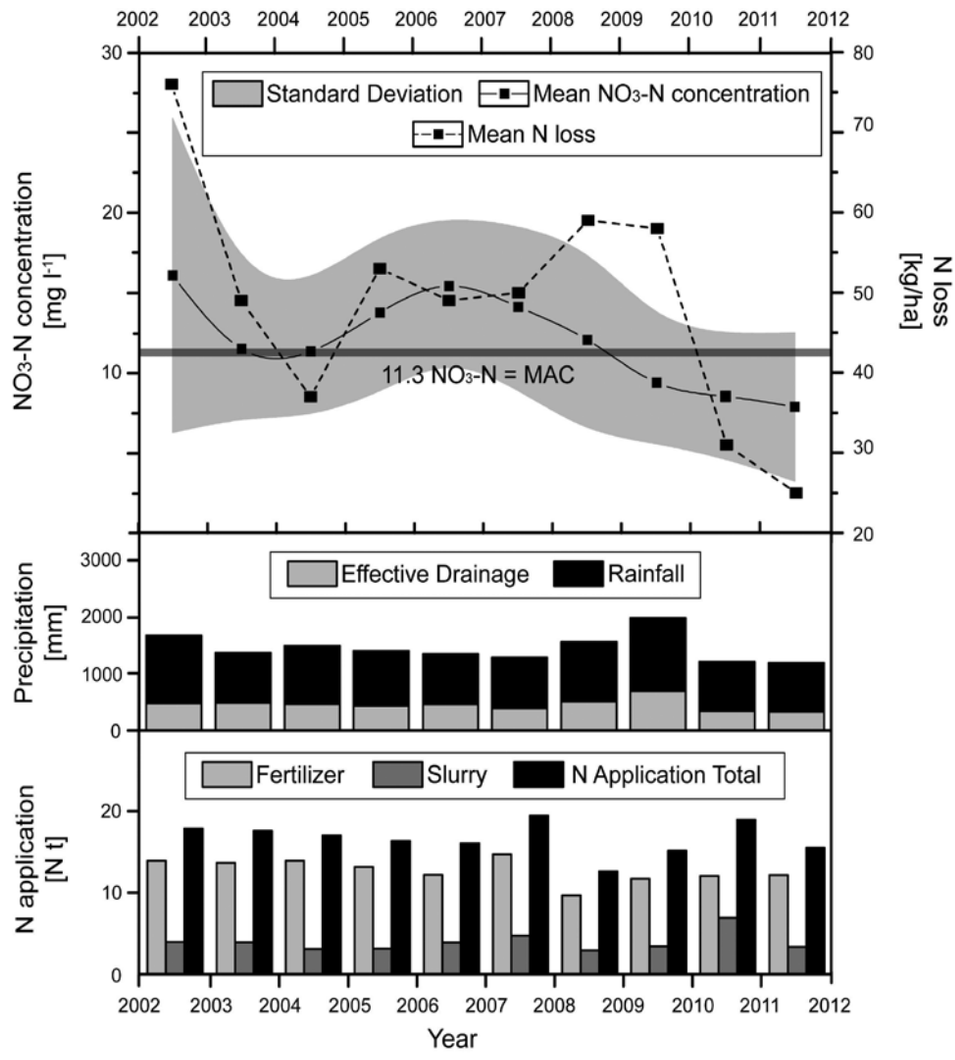
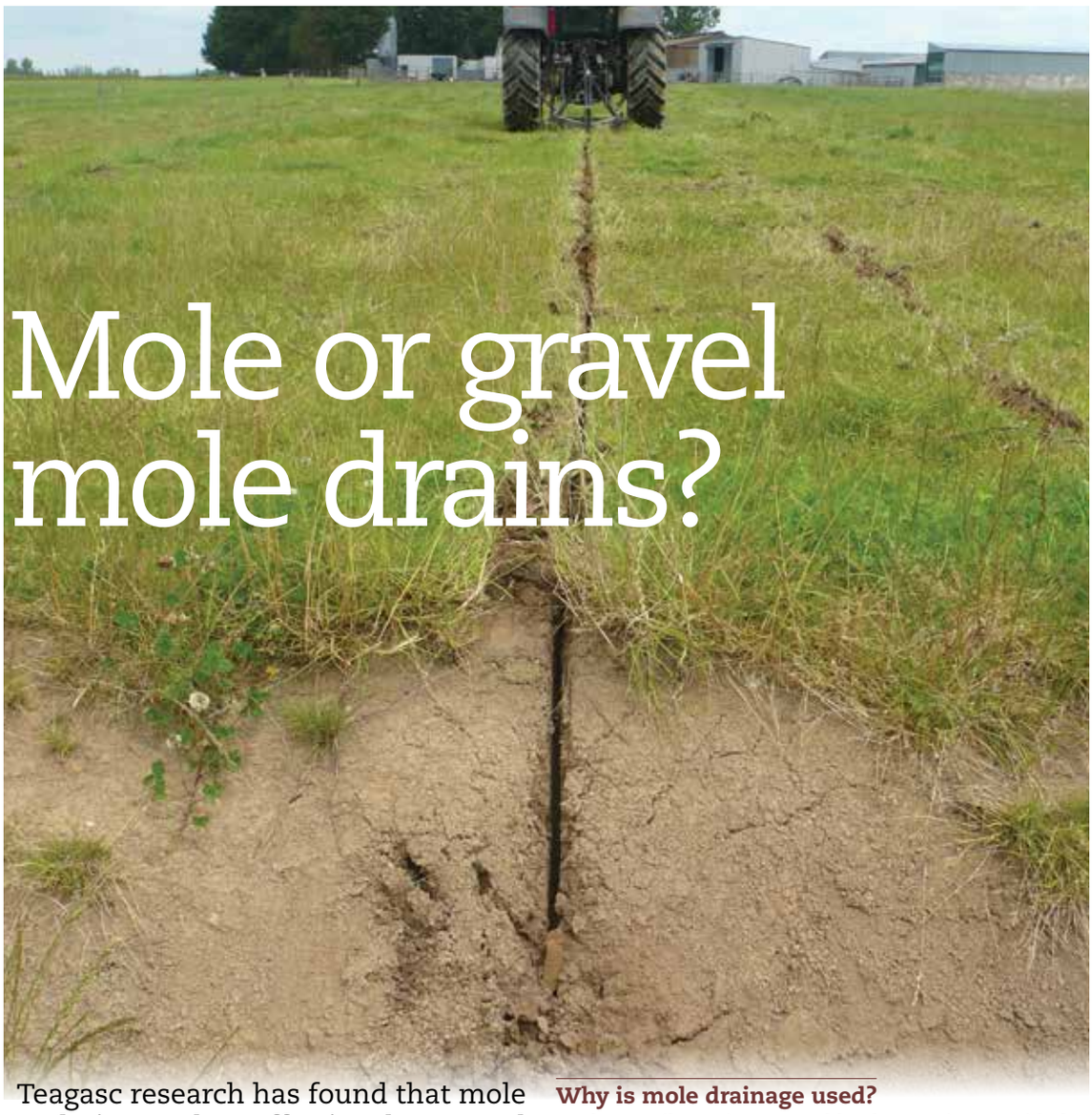


Figure 2. Mean NO3-N concentrations, mean N-loss, total N application and precipitation per year during the study period.



Mole or gravel mole drains?

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Teagasc research has found that mole drains are less effective than gravel mole drains, however they can provide adequate drainage at a much lower long-term cost if regularly reinstated.

Mole drains are unlined channels installed in cohesive soils while gravel mole drains are used in less cohesive soils to prevent channel collapse, and are essentially mole drains packed with gravel. Mole and gravel mole drains are installed as shallow drainage systems in Ireland but many questions remain about different aspects of their use. Farmers and contractors constantly ask questions such as:

- how does the performance of ordinary mole and gravel mole drains compare?
- do sub-optimal installation conditions affect performance of moles versus gravel moles?

These are important questions as gravel mole drains are much more expensive than ordinary mole drains. A project conducted recently at the Teagasc research farm in Solohead answered such questions.

Why is mole drainage used?

Where soils are impermeable, the spacing provided by conventional drainage systems is not sufficient to bring about satisfactory control of the watertable. As such, it is necessary to resort to drainage methods that incorporate soil disruption techniques. These include mole drainage and gravel mole drainage.

The suitability of a given soil for the formation of a stable mole channel is open to debate. While there are some known soils where conventional mole drains have a long life (typically having >45% clay and <20% sand); and, there are others such as fine sandy and gritty soils where gravel mole drainage (Mulqueen, 1985) is clearly called for, there exists a range of soils between these limits where uncertainty exists. Additionally, the soil rupturing required for optimal mole drainage performance is highly dependent on soil moisture content at the time of installation and landowners are often forced to install mole channels in non-ideal conditions.

How were these techniques assessed?

Tuohy *et al.* (2015) looked at the relative performance

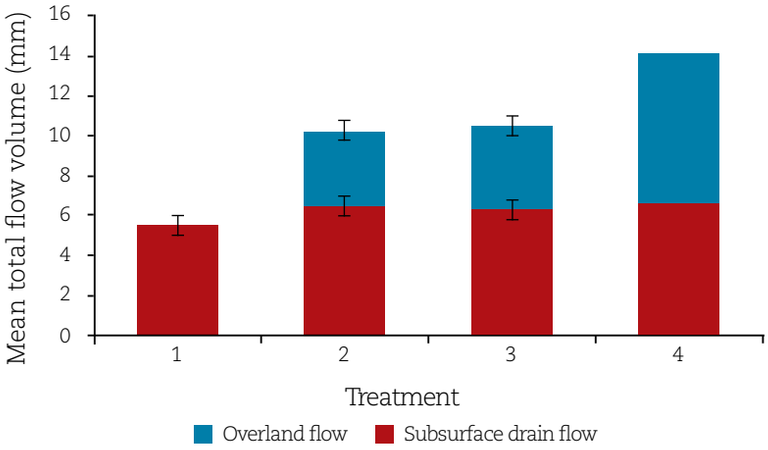

Figure 1. Mean total overland and subsurface drain flow during 12 events from treatments: A (un-drained control); B (mole drains installed in January 2011); C (mole drains installed in July 2011); and D (gravel mole drains installed in July 2011). Error bars show the treatment s.e.m. Mean effective drainage was 20.7mm. Any water not accounted for as overland or subsurface drain flow is assumed to contribute to groundwater recharge.

of two mole drainage treatments (one installed in January and the other installed in July 2011) and one gravel mole drainage treatment (installed in July 2011) on one of these 'borderline' soils where it is unknown which technique is most appropriate. The study was undertaken on the Teagasc Solohead research farm, which is dominated by poorly permeable clay loam textured soils (sand 36%, silt 36% and clay 28%), not ideal for stable mole channel formation. While gravel mole drainage, designed for such situations could be prescribed for the site, the high cost (€1,500/ha to €2,800/ha vs. €125/ha to €300/ha for mole drainage, [Crosson *et al.* 2013]) make this technique unattractive.

Four replicated drainage treatments were established; (A) an un-drained control; (B) mole drainage installed in January 2011; (C) mole drainage installed in July 2011; and (D) gravel mole drainage installed in July 2011. The installation of treatment B was characterised by traction problems on the wet surface and extensive surface and sward damage. This damage was directly linked to the timing of the operation and the associated soil moisture status. Mole channels were, however, installed in good conditions. Surface disruption was minimal during the installation of treatments C and D, due to the drier soil conditions prevailing. High resolution meteorological, overland and subsurface flow and watertable depth data were recorded for 12 independent rainfall events over a one-year period (April 1, 2012 to March 31, 2013).

How well did the systems perform?

Both mole and gravel mole drainage were effective in the removal of excess water off site. The mean total amount drained (Figure 1) via overland flow (OF) and subsurface drain flow (DF) during rainfall events in treatments A, B, C and D was 5.5, 10.1, 10.5 and 14.1mm, respectively. Mean total OF (5.5-6.7mm) did not vary significantly between treatments. Mean total DF was greater from the gravel mole drains (7.4mm) than either mole drain treatment (B: 3.8mm or C: 4.2mm). Gravel mole drainage was generally more effective than mole drainage in removing excess water, with consistently higher peak flow rates and greater total flows. The performance of the mole drainage systems (B and C) were similar throughout and, therefore, were not affected by installation conditions. There was a clear behavioural change in flow response during the study with a distinct decrease in DF relative to OF in all treatments after rainfall Event 4.

Across replicates, the watertable depth was consistently shallower in the un-drained control than in the drainage treatments. Mean pre-event WT depth was 0.65m below ground level (bgl) in treatment A relative to 0.80, 0.80 and 0.87m bgl for treatments B, C and D, respectively, with post-event means of 0.52, 0.71, 0.72 and 0.78m bgl for A, B, C and D, respectively.

Practical application

It was found that, despite the deterioration in effectiveness over time, mole drain flow was maintained, albeit at a lower level, for latter events and the drainage provided was adequate to control WT depth below that of the un-drained control plots. Mole drainage is a temporary measure, which must be repeated in order to maintain effectiveness. It is suggested that, given its low cost, the mole drainage operation could be repeated every two years on this soil type. The cost of gravel mole drainage does not allow for frequent repetition of the operation. Given the disparity between installation costs, it is likely that regularly rejuvenated (two years) mole drains, while less effective than gravel mole drains, could provide adequate drainage on this site at a much lower long-term cost.

The capacity and life-span of mole and gravel mole channels could be improved by the installation of a field drain network, excavated perpendicular to and deeper than the mole drains acting as an outfall. This would shorten the effective length of the mole channels and substantially increase drainage capacity, lessening both the chances of failure and the impact of isolated failures on the whole system. Future research will need to look at the optimum mole/gravel mole channel length in a range of soil types for such combined systems, having mole or gravel mole drainage as a supplementary measure to a field drain network. This would have significant cost implications however, as such field drains cost approximately €5-7/m (Crosson *et al.* 2013). The impact of repeated installation on soil compaction would also need to be evaluated, particularly where installed in sub-optimum conditions.

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Acknowlegements

This research was conducted with the financial support of Interreg IVB NWE Project No. 096D (Dairyman) and the Teagasc Walsh Fellowships Scheme.

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Showing the way to sustainable farming

Making efficient use of scarce resources is the key to the sustainable intensification of farming.

Speaking recently in Washington D.C. about the agri-food strategy up to 2025, Simon Coveney TD, Minister for Agriculture, Food and the Marine, said: "Sustainability will again be at the heart of this new strategy, and it will build on the very strong foundations laid in implementing *Food Harvest 2020*."

Teagasc has aligned its business plan to this policy and this new initiative. It is developing a sustainability demonstration farm at Kildalton Agricultural College providing an effective resource in promoting and transferring the sustainable farming message.

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By 2050, global demand for food will double, which is an unprecedented challenge. Currently, half the world's land area is used for agriculture. Converting more forests and other landscapes to farmland threatens the eco-systems and natural resources that humanity depends on for its welfare and economic wellbeing. Ways must be found to meet the world's food needs from our existing farmland base without compromising future generations' potential to provide for their needs. Ireland has a proven track record of sustainable food production, which we can build on to deliver sustainable food for ourselves and the world.

Origin Green

To reinforce Ireland's sustainable food production credentials, Bord Bia, the Irish Food Board, has developed the Origin Green programme. This is the only sustainability programme in the world that operates on a national scale, bringing together Government agencies, farmers and food producers under a single national food label. Origin Green is independently verified, enabling Irish farmers and food producers to set and achieve measurable sustainability targets to reduce environmental impact and improve economic performance.

The Kildalton Open Source Sustainable Farm

In unity with the national effort to promote sustainable agriculture and its visibility, Teagasc has undertaken the development of a demonstration farm at its Kildalton College farm in Kilkenny. As well as the support of public-sector agencies, like Bord Bia, this initiative is underpinned by private-sector support, most notably by Glanbia Ingredients Ireland (GII) through the funding of a project coordinator. The coordinator will manage the implementation and monitoring of the sustainability conversion plan

for the farm and communicate outputs from the project to farmers, customers and other stakeholders. The plan for the Kildalton Open Source Sustainable Farm incorporates the principles of Origin Green and GII's Open Source® sustainability and quality assurance programme. GII will also actively participate on the steering group and deliver key insights through its business intelligence and customer connections. Another company, Devenish Nutrition, has also committed resources to the project and it is planned to engage additional private-sector partners over time.

GII sees its comparative advantages in sustainability as a key difference between its business and its competitors in global dairy markets and has prioritised the drive to develop sustainability among its suppliers. To this end, GII launched its Open Source® sustainability and quality assurance programme in 2014. Under this programme, all 4,800 farms that supply GII will be audited to comply with a set of agreed sustainability benchmarks. At the launch of the Kildalton initiative in November 2014, Jim Bergin, CEO of GII, said: "Through this new partnership with Teagasc we are confident that we can bring real learning and efficiencies from sustainable farming, ensuring it is relevant to our farmer suppliers."

Rationale for a sustainability demonstration farm

Looking to the future, the largest drivers of change all reinforce the central role of sustainability in agriculture:

- the current CAP reforms place a heavy emphasis on the delivery of environmental goods, as well as efficient food production;
- the finite nature of fossil fuels heightens the need for improved energy efficiency and alternative energy sources;
- the Water Framework Directive changes the emphasis of water protection from the attainment of water-chemistry standards to the achievement of good ecological status in all surface water and the retention of high-status waters where they occur; and,
- the EU 2020 Biodiversity Strategy aims to halt biodiversity loss and the degradation of ecosystem services by 2020.

Climate change presents a double challenge. Increased pressure for agriculture to continue reducing its greenhouse gas emissions and increased weather volatility, necessitating more resilient farming systems.

The Kildalton Open Source Sustainable Farm will help farmers to meet these challenges by demonstrating best practice in sustainable farming to current and future farmers and also to the consumers of Irish food both at home and internationally. It will build on the large body of research work and knowledge-transfer experience in Teagasc and draw on international knowledge to showcase solutions to the economic and environmental sustainability challenges facing Irish farmers.

Objectives

This project will establish a sustainability demonstration farm, which will act as a testing-ground for new practices and technologies. These will be demonstrated to students, visiting farmer groups and other stakeholders such as food ingredients customers and policy makers. Working with GII, the conversion plan will start with the dairy unit to transform it into a showcase of sustainable dairy production. Specifically it will:

- be the catalyst for change, providing a unique facility to demonstrate an integrated approach to delivering sustainable food production led by a Teagasc/GII partnership and demonstrating win-win technologies to farmers and other stakeholders;
- educate the next generation of farmers in the concept and practical aspects of agricultural sustainability;
- provide an evaluation platform for emerging technologies on a working farm; and
- disseminate results from the project to help farmers in assessing the suitability of the demonstrated practices for their own farms.

The project will demonstrate ways to sustain biodiversity, aiding species like the Yellow Bunting (pictured).

Implementing the plan

The sustainability plan will cover all aspects of sustainability, encompassing: resource-use efficiency (nutrients, energy, water); landscape management; biodiversity; animal welfare and health; and safety. Economic sustainability of the farm enterprises will underpin the entire plan. The plan will be flexible, to accommodate market and policy changes and will be rolled out on a phased basis:

- Phase 1: benchmarking of the current sustainability performance of the Kildalton farm providing a baseline to measure future changes against. This phase has already begun with the collection of nutrient management data, financial data and soil analysis in 2014;
- Phase 2: implementation of proven technologies and best practices that are 'ready-for-roll-out' such as a detailed nutrient management plan and implementation of the Carbon Navigator;
- Phase 3: redesign and improvement of the farm infrastructure. This includes not only the farm buildings and the college (e.g., water and energy use), but also the ecological infrastructure including existing woodlands and hedgerows. The potential for multiple environmental and production benefits will be evaluated and exploited, e.g., potential for hedgerows to provide shelter for livestock and crops thus helping to extend the grazing season, while sequestering carbon, reducing risk of nutrient loss through overland flow of water and providing a habitat for biodiversity; and
- Phase 4: step-by-step implementation of emerging technologies that are currently being researched in Ireland and abroad. Examples include the use of automated sensor technology for soil, crop and animal management and bio-remediation of soiled water to reduce water use and nutrient loss risk.

The Kildalton Open Source Sustainable Farm plans to be an exemplar of public/private sector cooperation in showing the way to a sustainable future for Irish farmers while providing evidence to international customers of the sustainability credentials of Irish food.

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A Virtual Centre for Crop Improvement: Boosting plant breeding to secure agricultural productivity in Ireland

In the recent round of Research Stimulus funding from the Department of Agriculture, Food and the Marine (DAFM), a consortium of five of Ireland's leading plant and crop research groups was granted just under €3 million to establish a Virtual Centre for Crop Improvement. The initiative is being led by Teagasc and involves a total of 15 principal investigators from the Crops, Environment and Land Use Programme, and partner institutions University College Dublin, NUI Galway, NUI Maynooth and Trinity College Dublin.

Ireland has among the highest yield potential for crops in the world, but the same climate that bestows high-yield potential also demands high levels of external inputs and associated costs (Table 1). Plant breeding has been a major contributor to agricultural productivity over the last 50 to 60 years. One of the most cost-effective strategies for reducing inputs, while maintaining or even increasing yields, is to continue to breed improved varieties of crop plants. Recently, however, yield increases for many crops, especially highly productive cereals, have stagnated. In addition, while genetic improvement of some species has resulted in major yield increases, the rate of genetic gain in others has been less than optimal, largely due to complex genetics or other constraints. In the context of an increasing global population, these trends are worrying. At exactly the point in time when we need to exploit genetic improvement of crop species the most, it is becoming increasingly difficult to achieve productivity gains with conventional breeding, due to the increased number of breeding targets required to achieve yield, quality and environmental objectives. However, these challenges have arisen against a backdrop of huge advances in science, especially in the group of disciplines that can collectively be referred to as biotechnology. While not a panacea, plant biotechnology is an important tool in addressing the societal challenges posed by food production in a changing world, and we urgently need to maximise its potential.

Table1. Estimated costs (€/ha) based on Teagasc costs and returns (2013) associated with applied inputs for the national crop area to mitigate disease (preventative and curative) and supplement soil nutrition (N, P, K).

	Disease costs	Nutrient costs
Winter wheat	115	430
Spring barley	75	298
Winter oats	105	375
Ryegrass	0	106
Beans	72	167

Core objectives

Built around these concepts, the Virtual Centre for Crop Improvement has two core objectives. The first of these is to increase the exploitation of recent/current research in Ireland and abroad to more effectively address plant breeding goals using biotechnology tools. Secondly, the Virtual Centre will build sufficient capacity in Ireland to lead to the identification and development of improved crop varieties for the Irish agri-industry through the exploitation of cutting-edge biotechnology-based approaches. To achieve these goals, the Virtual Centre will align the collective knowledge and resources of the most active plant research groups in Ireland to address four key challenges in Irish tillage and forage agriculture: fertilizer use; crop protection; biotic stresses; and the potential to replace imported crop products with Irish-grown alternatives.

What are the drivers behind the choice of these targets and how could they be addressed on a crop improvement level?

While the increasing cost of nutrient inputs continues to erode the margins of farmers, their application leads to adverse environmental impacts through losses to water causing eutrophication and gaseous emissions, which contribute to greenhouse gases. The requirement for external inputs can, however, be reduced (per unit of productivity) by either increasing the efficiency with which nutrients are acquired by the crop or reducing the requirement of the crop by 'knocking out' non-functional stores within the crop.

Similarly, crop protection products represent a significant annual cost (€3.5 million for oats, €10.5 million for wheat and €13.8 million for barley) to the grower; in particular, disease control costs are considerable in Ireland compared to European competitors, but could be reduced significantly through improved varietal resistance. In the case of Septoria blotch disease (causative organism *Zymoseptoria tritici*), fungicide strategies have led to the emergence of resistance/intolerance to the quinone outside inhibitor and demethylation inhibitor fungicides (QoIs and the DMIs), with the consequence that the succinate dehydrogenase inhibitor (SDHI) fungicides are now key to successful disease control, but their sustainability is highly questionable due to their site-specific mode of action. More specifically, some diseases (e.g. Fusarium head blight) cannot be controlled effectively using fungicides, which represents a significant restriction on productivity or industry expansion that can only be addressed through genetic improvement.

Combating abiotic stresses is equally important. In tillage systems, for instance, winter cereals are inherently higher yielding than spring cereals due to a longer growing season; however, their use is limited by waterlogging, where wet soils, over winter and in early spring, result in crop damage or death. In pastoral-based milk production, the competitive nature of ryegrass pastures could be significantly enhanced if low temperature tolerance could be introduced into swards. This would extend seasonal growth in perennial ryegrass, securing a low-cost fodder supply for livestock industry expansion, while in parallel generating a buffer for the sector against the recurrence of prolonged low temperature spring periods, which precipitated the 2013 fodder crisis.

Finally, despite our capacity for crop production, Ireland still imports significant quantities of crop-based products to fill gaps in supply for specific uses. For example, protein concentrate requirements for pastoral-based production systems in Ireland are currently largely served by importing approximately one million tonnes of soya meal p.a. Similarly, we import approximately €10 million worth of processing potatoes to serve the chipping and crisping sectors. Targeted breeding of faba beans (as a replacement protein crop) and potatoes (for processing) could lead to significant import replacement potential in these instances.

Priority focus

To address these areas, over the next five years, the partners involved in the Virtual Centre will undertake a series of interlinked research projects, adopting a multidisciplinary approach that will span transcriptomics, metabolomics, proteomics, forward and reverse genetics approaches and gene editing. While the generation of molecular biology data on crops has advanced hugely in recent years, the associated phenotypic data required to render these advances truly useful to agriculture has lagged, and generating this sort of data (with specific focus on breeding targets of particular importance to Ireland) will be a central activity of the Virtual Centre. However, even with the increase in critical mass generated by bringing the efforts of a significant portion of Ireland's plant and crop science community to bear on these problems, it won't be possible to address all possible constraints and problems simultaneously, so the Centre will initially focus on the following key crop-trait combinations:

- nitrogen use efficiency (NUE) in wheat, barley and ryegrass;
- disease resistance in wheat, oats, barley, potatoes and beans;
- cold tolerance in ryegrass;
- waterlogging stress in barley and ryegrass; and
- low-temperature sweetening in potatoes.

Benefits to Irish agriculture

Advances in science can take a long time to influence real-world activities. When the science in question is underpinning an already lengthy activity, such as breeding (it takes about a decade to produce a variety of most crops), it's important to ensure that clear routes to deployment of the results are built into the research. Because many of the earlier activities of the Virtual Centre revolve around screening thousands of elite and heritage crop plant lines for the traits that are the focus of the research, one of the first potential benefits of the project will simply be to identify germplasm with varietal potential for the Irish agri-environment. These lines could be adopted quickly and provide immediate benefit in the short term. Other goals within the Centre are to develop novel germplasm via (non-GM) biotechnology-based approaches and to generate genetic or biochemical markers for genes underlying target traits, to augment classical breeding strategies. In the case of grass and potatoes, these tools will be integrated into the existing Teagasc breeding programmes for these species, which already have a track record for implementing novel breeding approaches based on biotechnology. In the case of cereals and beans they will be made available to international breeding companies that produce varieties for the Irish market; an established model already successfully being used within the partnership. These clearly defined routes to market will ensure rapid delivery of the Centre's output to stakeholders, reducing the tillage sector's dependency on inputs and ultimately the sector's cost base. Our vision for the future is a continuing role for the Virtual Centre for Crop Improvement as a driving force for breeding better crop and forage species for Ireland well beyond the initial five years covered by the current funding, and we will seek to expand beyond its original scope during the pursuit of additional funding in the future.

Food intake during pregnancy and baby's long-term health

Researchers are looking at animal models to tackle intergenerational obesity.

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The first 1,000 days, from conception to two years of age, has a major influence on a baby's future health. Nutrition *in utero* is linked to weight in later life. This is because fat cells are particularly susceptible to the food intake of the mother. In modern day society, maternal obesity and/or excessive weight gain during pregnancy are commonplace.

Obese girls often grow up to be obese women who give birth to babies who are destined to be obese themselves. In Europe, 30% of seven-year-old children are overweight or obese. An obese child has more than a 60% chance of being obese in adulthood.

The current guidelines are that a woman with a healthy weight pre-pregnancy (Body Mass Index (BMI) of 18.5-24.9) should gain 11.5-16 kg during pregnancy. The timing of this weight gain is also important. A maximum of 2kg should be gained in the first trimester followed by 0.36-0.45kg per week thereafter.

Why are we interested in maternal nutrition?

Scientists at Teagasc Food Research Centre and the Pig Development Department have long been interested in maternal nutrition. From a human-health perspective, it allows us to develop healthy foods for pregnant women in our efforts to halt this intergenerational obesity. From an animal perspective, it allows us to develop maternal diets to influence fat to muscle ratio in offspring. For example, a commercial pig spends nearly half of its life *in utero*, so it makes sense to target maternal diets to influence offspring birth weight, postnatal growth and body composition.

Why do we need animal models?

Animal models are an essential tool in maternal nutrition research. Human data is predominantly collected through epidemiological studies, where scientists can survey and describe a defined population, looking at patterns, causes and effects of human disease but not easily intervening.

What animal model do we prefer?

Rat and mouse models are a popular choice for maternal nutrition research. We at Teagasc argue that the pig model is more relevant to humans. Rats and mice self-limit their food intake. Therefore, rodent models for maternal over-nutrition must rely on either modifications to diet composition or gastric cannulation. Pigs, like humans, find self-limitation of

food intake difficult. They will often become overweight when given unlimited access to food. In addition, pigs display a meal-eating pattern. They are omnivores and have similar metabolism, digestive tract, cardiovascular system and proportional organ sizes to humans.

What did we do?

At Teagasc, we recently completed two pig trials within this research space. The first study followed 238 Landrace X Large White sows and 1,247 of their offspring from birth to adolescence. The aim of this study was to investigate whether over-eating, at different times during pregnancy, can alter offspring birth weight, growth, skeletal muscle and fat cell health. Selecting sows of normal pre-pregnancy weight allowed us to focus solely on pregnancy weight gain.

What were the results?

Increasing weight gain in early pregnancy affected the rate at which the offspring grew to adulthood. From a pig industry point of view, it also affected the offspring skeletal muscle. Intramuscular fat levels and oxidative muscle fibres were increased. Overfeeding sows in early pregnancy, resulted in offspring whose meat was redder and had higher drip-loss falling within the classification 'red and watery' meat.

Sows that ate more in mid pregnancy, gained less weight in late pregnancy. As a result, their offspring were hungrier when they were born and put on more weight during the suckling period than controls. However, by adolescence the offspring weighed less. Interestingly, their fat cells showed a preference for storing fat rather than releasing it. This may mean that, later in life, these offspring would start to 'pile on the pounds'. From a pig-industry point of view, these animals had reduced backfat and increased lean meat percentage compared to controls, at the time of slaughter.

Mothers who ate more in late pregnancy shifted their offspring fat cells towards fat accumulation. This puts their offspring at risk of obesity in an environment of plenty. Surprisingly, these mothers had better subsequent fertility.

Those mothers that gained the most overall weight in pregnancy gave birth to offspring with hyperactive fat cells. Fat cells function to store and release fat but they also release signals that control appetite and energy balance. Fat tissue is capable of unlimited growth in adulthood. A hyperactive, dysfunctional start may not be ideal. In obese individuals, fat cells are dysfunctional.

We concluded that mothers, who gain more than the recommended weight gain in mid- and late-pregnancy, put their offspring fat cells at risk of dysfunction.

Follow-up study

The second study added maternal weight prior to conception to the experiment. The trial consisted of 158 gilts (maiden sows) and 270 of their offspring. The trial combined body condition (thin or fat) with food intake in pregnancy (low, normal and high food intake).

What were the results?

During pregnancy, thin mothers on a restricted food intake were more stressed (had higher levels of circulating cortisol) than fat mothers. However, overeating in pregnancy resulted in offspring who were more stressed in childhood. Pigs born to fat mothers were fatter, heavier and had less muscle at adolescence than pigs born to thin mothers. We found that milk composition was influenced by the mother's weight at conception. Day-21 milk from lactating

Milk fat is influenced by a mother's weight at conception.

saturated fat and more unsaturated fat) than milk from thin mothers.

Funding

This work was supported by Teagasc under the National Development Plan.

Where do we go from here?

Pregnant women are a niche, but important, market segment for the foods-for-health category. This is primarily because of a woman's desire to eat healthier at this time and also because of restrictions on vitamin/mineral supplementation and use of prescription drugs. Many companies have launched foods or beverages for pregnant women with various bioactive proteins (casein and whey) and fatty acids (DHA). Teagasc has a proven track record in maternal nutrition and has demonstrated that (a) weight prior to pregnancy and (b) timing of weight gain during pregnancy are important if we wish to maximise efficacy of foods for pregnant mothers. We are ready to partner with industry to deliver economically-viable, scaled-up ingredients with strong scientific data to support a food-for-health claim for pregnant women and for their babies' long-term health. In essence, this requires comprehensive animal and human trials, and we are, at present, seeking funding in this space.

Acknowlegements

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Adding value to meat processing

The so-called 'fifth quarter' in meat processing has many potential uses, as the ReValueProtein project has set out to discover.

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Current demands for sustainable development have highlighted the need, not only for more efficient food production systems, but also for maximising return and minimising waste of our valuable natural resources. Proteins, as indispensable constituents of human food, have more physiological roles than any other nutrient. Meat, and particularly offal, is a rich source of high-biological value protein, as well as minerals, such as iron or selenium, and vitamins from the B group. According to Bord Bia (2013) circa 1.6 million cattle and three million pigs are slaughtered in Ireland every year, an annual turnover of over €3.3 billion. As per *Food Harvest 2020* projections, these figures are set to increase. Boned meat is the primary product arising from this processing chain but Enterprise Ireland reports (2008) shows circa 263kg/head of beef and 19.3kg/head of pig (around 60% and 36% of the live weight respectively) is also generated from what the industry generally calls the 'fifth quarter'. Fifth-quarter products include familiar items such as hearts, liver, tongue, kidneys and tripe, plus more exotic but still edible and valuable parts such as lung, feet, testicles and pancreas. However, these products are mostly marketed at low, neutral or negative values.

Despite recently experiencing a surge in price, due to higher demands from overseas markets for quality offal and from the pet food industry, continuous evaluation of opportunities for higher value from these streams is critical for sustainable growth in the meat sector. As livestock production consumes a considerable amount of natural resources, it also makes social, environmental and financial sense to explore alternatives for these streams, which are currently marketed below their potential.

More value from the food chain

The recovery of high-value compounds from natural sources is drawing renewed attention from academic, public and industrial sectors. The food chain contains many valuable constituents originating from by-products rich in protein, fat, carbohydrate, etc., which are underutilised, despite having important functional and nutritional properties and interesting bioactivity (antioxidant, anti-hypertension, etc.).

Significant scientific work exists on the recovery of compounds from the processing of cereals (phytochemicals, dietary fibres, etc.), fish (peptides, collagen, unsaturated fatty acids, etc.), dairy (whey protein, lactose concentrates/isolates, etc.), and fruits and vegetables (polyphenols, dietary fibres, essential oils, etc.). In the meat industry, proteins, lipids and other small biomolecules can be recovered from low-value streams of the fifth quarter, as well as from the blood, which in Ireland is an underutilised source of proteins of very high biological value. These raw materials are currently either exported or used mainly in animal feeds, with low returns and often a high-associated carbon footprint. Their potential use as food ingredients, natural food processing aids and for human nutrition and health undoubtedly merits further efforts. Recovery of value and optimum usage of available resources can enhance the economic performance and improve the environmental impact of the meat industry.

Higher value applications for protein products

Functional ingredients

While the recovery of lipids and other biomolecules from animal sources have numerous potential applications for the food, nutraceutical and biomedical sectors, the most significant biomolecules to be recovered are proteins. Those exhibiting techno-functional properties such as emulsification, binding, flavour, etc., are of particular interest to the food and beverage sectors, as current efforts to reduce or replace the use of artificial additives in

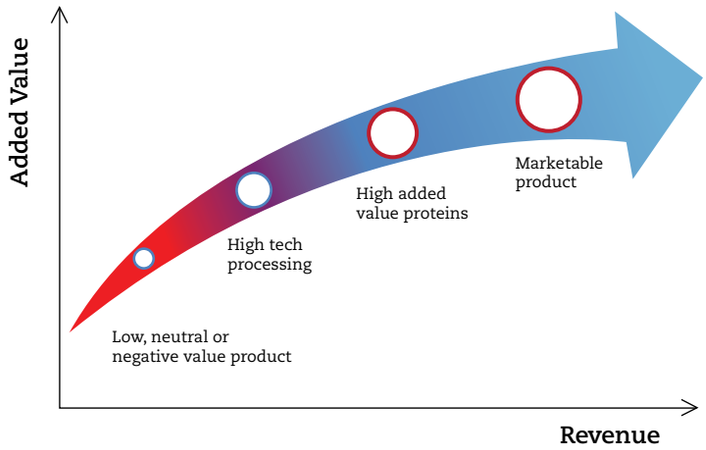

Figure 1: Revalorisation route for the fifth quarter.

processed foods opens a clear opportunity for naturally-derived compounds. Not simply a source of energy or building blocks for our body, proteins can impart or improve texture, stability, appearance and overall sensory characteristics of foods – a distinct appeal to manufacturers and consumers.

Sports and nutrition

The nutritional value of proteins can also be harvested for use in sports and nutritional drinks and supplements. Such products could boost protein intake of target groups such as athletes, the elderly or the infirm. Protein-fortified products are gaining popularity, as the functional properties and nutritional value of proteins are explored. Examples are protein-fortified pasta, bread, breakfast cereals and protein bars. The development of new products could drive significant growth in this area.

Biomedical and cosmetic

Peptides for biomedical and cosmetic applications, as well as collagen for wound repair and tissue scaffolds are other examples of applications that can be developed from extracted proteins. The use of natural biomaterials, such as collagen, as raw materials in tissue engineering is already established, with innovations under testing, (see ReValueProtein), and showing very promising early results.

Functional foods

Functional foods are those capable of imparting an additional health benefit on consumption that goes beyond their basic nutritional value. Proteins are composed of long chains of amino acids, linked by a peptide bond. When proteins are broken down, smaller chains of amino acids are released. This new molecule, a peptide, typically contains from two to 20 amino acids. Although inactive within the protein, released peptides can be separated, concentrated and evaluated for their bioactivity, bioavailability, health-promoting properties, etc. Examples of beneficial bioactivity include antioxidant properties, antihypertensive activity, and probiotics for gut health. Apart from their potential for food and beverage applications, bioactive peptides may hold potential, e.g., for packaging solutions (production of antioxidant/antimicrobial biofilms).

The national approach

Although many companies and research organisations in Ireland and abroad have been pro-active in researching and utilising the fifth quarter, in Ireland a coordinated approach to benefit the industry and society as a whole was lacking until recently. Teagasc researcher, Dr Anne Maria Mullen (Teagasc Ashtown Food Research Centre) is currently leading a collaborative research project – ReValueProtein – comprising a multidisciplinary team (food chemistry, biosciences, tissue engineering, novel and pilot-scale process technologies, food and beverage technology and consumer science) of over 20 scientists from five Irish institutions. The ReValueProtein project aims to establish and optimise protocols to extract, characterise and test proteins and peptides from beef and pork fifth-quarter products for their potential application as functional and bioactive ingredients. This nationally-funded effort will strengthen our knowledge basis and generate technical know-how to support the Irish meat industry capitalise on this excellent opportunity for developing new, added-value products.

After initially characterising the source materials, researchers from the ReValueProtein project are developing efficient systems for extracting functional proteins, exploring the use of new technologies for enhanced processing, and will develop a framework for the scaling-up of selected processes. Consumer attitudes are being explored with a view to developing commercialisation strategies for downstream export products.

New technology for added value

In addition to generating value, ReValueProtein researchers also aim to minimise waste generation and prioritise low-input/low-energy approaches, through the use of emerging technologies. The in-depth analysis of consumer acceptance issues and risk communication will provide a solid basis to achieve the potential benefits from low-value products management. While the project's primary focus is on beef and pork, research outputs will be of relevance to other muscle-food processing industries, as well as a number of other sectors.

Acknowledgements

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Figure 2: Freeze dried protein powders: porcine blood and selected fractions.

Healthy ageing: diet and lifestyle might hold the key to eternal youth




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Ageing population

In almost all countries across the globe the proportion of the population aged over 60 years is expanding at a rate faster than all other age groups. The World Health Organisation has forecast that 25% of the European population will be aged 65 and older by 2050 (WHO, 2014). Ireland is forecast to follow a similar trajectory. The Central Statistics Office expects the percentage of the population aged 65 years and beyond to reach 22% by 2046, with at least half being 75 years and older.

Can old age be defined?

Currently, there is a lack of consensus in defining old age. There are numerous categorisations for older age in the literature, with 45 years and up being defined as the beginning of older age. Older age can also be frequently categorised to differentiate between 'young-old' ranging from 50 to 64 years; 'middle-old' ranging from retirement at 65 to 74 years; and the 'oldest-old' classified as greater than 75 years.

Silver segments

The aim of this research in conjunction with the Dublin Institute of Technology and University College Cork was to examine the food choice attitudes, motives and health behaviours of older Irish adults (over 50 years). Segmentation is commonly used in market research and identifies distinct consumer or market segments with similar characteristics in terms of, for example, attitudes, behaviours or preferences. To this end, diet, lifestyle, and attitudinal data from the National Adult Nutrition Survey were analysed to determine if functionally different segments existed in the population aged over 50 years. This segmentation approach has been previously demonstrated to be an effective tool in identifying different subgroups for targeted intervention programmes. Hence, it is of potential benefit to both public health institutions and the food industry to know whether different older segments exist and how to effectively target these groups with varying policies and food products.

Cluster analysis, which was the segmentation

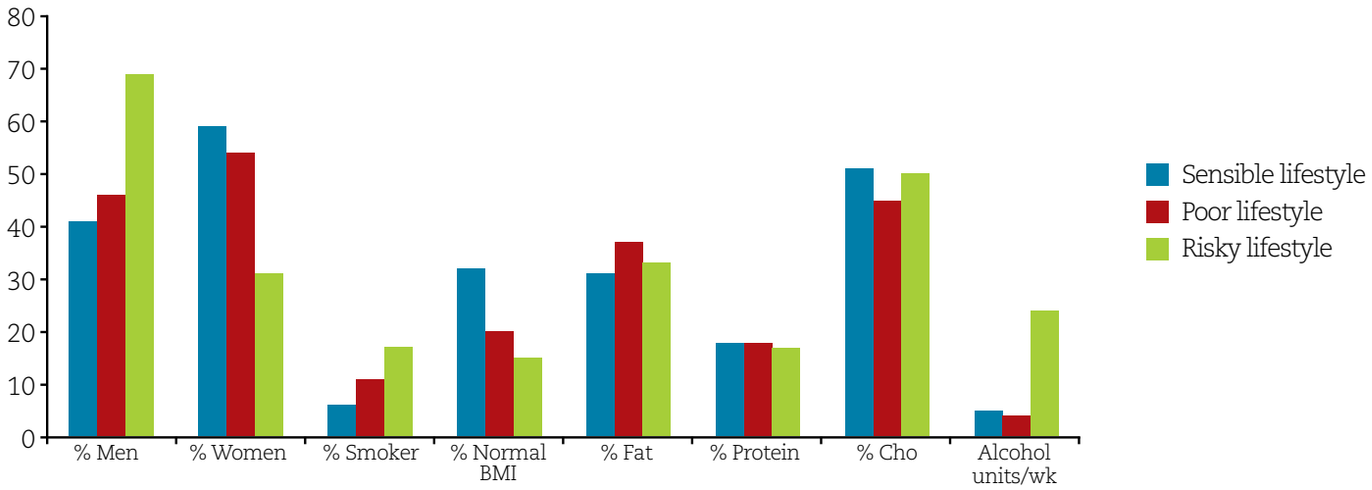

Figure 1. Characteristics of the diet and lifestyle segments of older Irish adults.

approach used, yielded three distinct and meaningful clusters as profiled in Figure 1. The first segment comprised 25% of the population and was characterised by high fruit and vegetable consumption, low alcohol consumption, low fat consumption and moderate levels of physical activity. This segment was named 'Sensible Lifestyle'. The second segment, 'Poor Lifestyle', was characterised by the lowest amount of fruit and vegetables, highest fat intake, lowest alcohol consumption and lowest physical activity levels. This was the largest segment at 58% of the population aged over 50 years. The most outstanding characteristic of the third segment, 'Risky Lifestyle', was the high level of alcohol consumption, with an average intake of 24 units per week, compared to 5 units and 4 units of the first two segments respectively. This group also had low fruit and vegetable intake, moderate fat intake and moderate levels of activity. This was the smallest segment at 17%.

The segments were then further profiled based on attitudinal and socio-demographic characteristics. Membership of the Sensible Lifestyle segment was associated with being female, having excellent self-rated health and spending less time watching television. The average age of this group was 60 years, had the highest proportion of 60-69 year olds and nearly half of the group had attained third-level education. This group also had the highest proportion of those with a BMI in the normal range and the lowest proportion of those overweight with a BMI of 25 to 29.9kgm^{-2}. The level of obesity was similar across the three clusters at 28%, 30% and 29% respectively.

Membership of the Poor Lifestyle cluster was associated with lower educational attainment, with nearly half of the segment having an intermediate education level. There was a relatively even split of men and women, with an average age of 62 years for the group. The group also had the highest proportion of 70+ years. More than 20% of this group rated their health as less than good.

Membership of the Risky Lifestyle cluster was associated with being male, being a smoker and was the segment with the highest proportion of the young old aged 50-59-year-olds. Approximately half of this group had attained tertiary-level education and were more likely to be in the higher social-class categories. This segment had the lowest proportion of normal BMI and the highest proportion of overweight people. The higher physical activity levels in this group may be an indication of a coping mechanism to offset their risky food and drink behaviours.

These analyses have yielded some key insights regarding the older population in Ireland. Only one-quarter of the population are following dietary guidelines and appear to be on a healthy trajectory for healthy ageing. Although the smallest group, at 17%, the Risky Lifestyle group of young old adults are consuming far more than the recommended units of alcohol per week. If the alcohol consumption levels of this segment are not addressed and reduced accordingly, the prospect of healthy ageing is much diminished with the prospect of liver disease more likely. The largest group, which comprised of more than half of the older population, had the poorest quality of diet and also had the highest proportion of older adults aged over 70 years. This is a particularly vulnerable group at risk of malnutrition and its associated complications. This is acknowledged by the 20% of this group who already concede that their health status is poor, despite 67% of the group ranking health as one of the two most important food-choice motives.

Targeted and specific approaches are required to maintain the health trajectory of the healthy diet and lifestyle segment. Public health campaigns should aim to address and highlight the high alcohol consumption of those, mainly men, aged 50-60 years and increase the awareness of the long-term ill effects. However, the largest proportion of the population in the Poor Lifestyle segment would benefit from assistance in making healthier and better informed foods choices. They acknowledge the importance of health and nutrition in making food choices and yet it does not translate into behaviour. They are also the most vulnerable group with the highest proportion of adults aged over 70. This group would benefit from targeted new product development that takes into consideration age-related health issues such as decreased sensory perceptions and specific requirements for many nutrients in an attempt to positively influence eating behaviour and nutrient status in this segment.

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The returns on investment in formal agricultural education

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There are significant private and social benefits to investment by individual farmers in formal agricultural education according to a recent report published by economists from Teagasc's Rural Economy and Development Programme. The findings arose from a study that set out to clarify not only what are the benefits from formal agricultural education but also why those benefits arise.

Benefits of formal agricultural education

Following Nobel-Prize winning economist Gary Becker who first treated investment in education as a capital investment, the Internal Rate of Return (IRR) is often utilised in studying the return to education by comparing the cost of providing education with the benefit from receiving the education. The definition of costs and benefits, however, depends upon the perspective of the particular investor. So, for example, a student or their family will focus on costs and benefits that apply to the student in terms of foregone earnings, course fees and returns in terms of income. This is known as 'the private rate of return'. From the perspective of the State, the benefits relate to the impact on output and other income streams relative to the total cost of providing the education. This is known as 'the social rate of return'.

For the study, there were challenges to accurately calculating these costs and benefits. For example, when examining the impact on total output, the wider supply chain impact had to be factored into the analysis by using data from the Central Statistics Office input-output tables. In terms of benefits, the farm-level financial returns had to be weighted to reflect the structure of the farming population and returns to different farming systems. Detailed description of these methodological issues can be found in the final report on the Teagasc website. A key concern was to ensure that the estimates produced were conservative and credible.

The outcomes of the analysis are presented in Table 1, which shows the resulting IRR on investment to participating in a two-year course of agricultural education. The private rate of return, which is the basis for those contemplating pursuing Agricultural Education, is 8.8% when full employment is assumed. If the youth unemployment rate is factored in the private rate of return rises to 10.4%. This is slightly lower than the private rate of return of 17.0% calculated for Leaving Cert education in Ireland, but substantially higher than that for third-level education at 5.8% (O'Donoghue, 1999).

The farm-based social rate of return is higher at

Table 1. Internal rate of return of formal agricultural education.

Costs	IRR (Benefit:Cost)	
At farm level	Private	Social
Full employment	8.8%	13.4%
30% unemployment risk	10.4%	14.8%
With supply chain impact		
Full employment	n/a	24.5%
30% unemployment risk	n/a	26.3%

13.4% when full employment is assumed and 14.8% when a 30% unemployment risk is assumed. The latter is slightly lower than the social rate of return previously calculated in Ireland for Leaving Cert education of 15.7%, but higher than that calculated for third-level education at 5.7% (O'Donoghue, 1999). By incorporating total impacts on the sector, the social rate of return is the more appropriate measure to be used when considering public sector investment decisions. When the wider supply chain impact of improved agricultural productivity is factored in, there is a very high rate of return of 24.5% and 26.3% for full employment and unemployment-risk assumptions respectively, reflecting the high national multiplier of agricultural production. The IRR's derived in the study suggest that investment in formal agricultural education is a good use of both public and private funds. The analysis confirmed for Ireland patterns in the international literature on returns to education.

Why does formal agricultural education lead to these benefits?

From a review of the literature, the benefits of formal agricultural education are clear. Agricultural education improves a farmer's technical efficiency (the more efficient use of a given amount of resources) and allocative efficiency (choice of better inputs and outputs, leading to a more efficient allocation of resources). There are three main reasons why formal agricultural education improves technical and allocative efficiency:

1) Education – by helping farmers make better use of information and finding solutions to problems makes them better managers, allocating their resources more efficiently.
2) Not only does education help farmers use existing information more competently but they also have better access to required information.
3) Educated farmers are more likely to adopt new technologies or products early because of their access to information and their ability to better distinguish between promising and unpromising innovations.

The study also set out to quantitatively examine the relationship between formal agricultural education and family farm income and the pathways through which farm income is impacted, i.e. increased yields and intensity at farm level (for dairy, cattle and sheep: yield = gross output per livestock unit (LU); intensity = LU per ha. For cereal: yield = gross output per ha; intensity = cost per ha). Analysis using an instrumental variable, random-effects panel model confirmed that agricultural education has a significant and positive impact on family farm income. Another piece of analysis based on system-level production functions confirmed that yields and intensity at farm level were positively and significantly impacted by formal agricultural education. This result was in line with expectations from the international literature, as outlined above, on the positive link between agricultural education and technical and allocative efficiency. There were, however, some differences across farming systems. Within dairying, both yields and intensity are positively affected by attending agricultural college and achieving an agricultural certificate. For the cattle farming systems, both yields and intensity are positively affected by attending agricultural college, achieving an agricultural certificate and attending short courses. In sheep systems, intensity is positively impacted by attending agricultural college, achieving an agricultural certificate and attending short courses. Data shortcomings made it difficult to carry out the analysis for tillage systems.

Implications of the research

In recent years the demand for formal agricultural education has risen significantly. First preference applications to the CAO for agriculture and veterinary courses increased by 31% between 2010 and 2014. In addition, Teagasc has experienced more than a doubling of student enrollments for its flagship agricultural education programmes. At the same time, Teagasc's ability to meet that demand has been resource constrained as, in the recent past, front-line education staff levels declined by a quarter and student teacher ratios doubled.

Using conservative estimates, the analysis carried out for this report for the period 2000 to 2011 showed that there is a significant private and social return to investment by individual farmers in formal agricultural education. The implication of the analysis is that investment in such education, to build human capital, is a good use of public and private funds. The analysis was used to support Teagasc arguments for increased resources to meet the growing demand for formal agricultural education. Meeting this demand will help facilitate access to DAFM-led schemes such as the National Reserve and Young Farmers Scheme. The resultant continued growth in human capital within the agricultural sector will help deliver a key aspect of the 'smart' agenda set out in *Food Harvest 2020* (DAFF, 2010).

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The economics of milk quality

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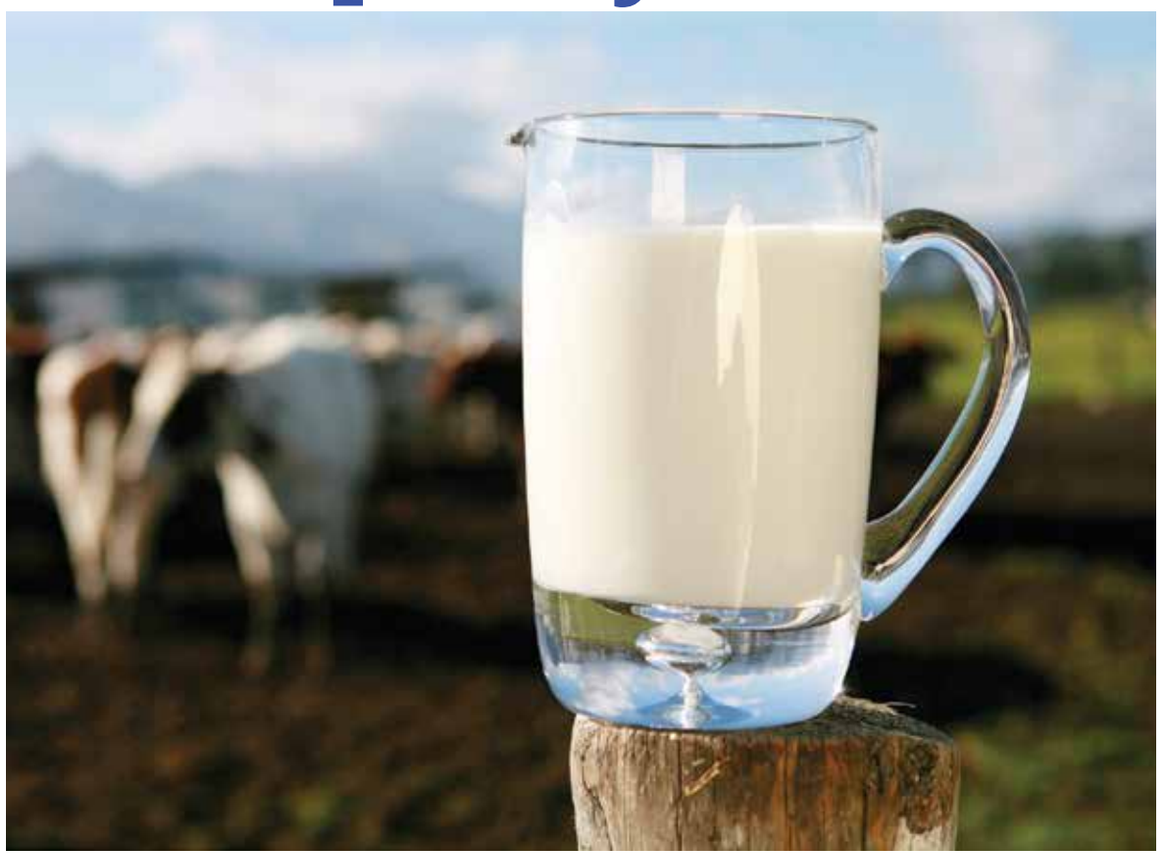

Continued improvements in milk quality are essential if the Irish dairy industry is to grow sustainably and retain competitive advantage in the aftermath of EU milk quota abolition.

Indeed, its importance is underlined by the increasing application of bonuses and penalties by processors across a range of quality parameters in a volatile marketplace for milk. Herd health is a valuable indicator of milk quality and, as such, is one of the key factors affecting the economic efficiency of dairy farms due to, among other things, the higher costs of production associated with animal disease. In this context, recent research undertaken by the authors sought to quantify the productivity and profitability gains associated with reducing somatic cell count (SCC) in milk (elevated levels of which are an indicator of the prevalence of mastitis) using herd-level data from the Teagasc National Farm Survey (NFS). As the economic losses of diseases such as mastitis, are often underestimated by farmers due to mostly hidden effects, the demonstration of resultant economic benefits is important in order to improve animal health 'best practice' at the farm-level.

SCC and profitability

Using monthly milk bulk tank data available for each farm in the NFS since 2008, a weighted yearly average SCC figure was utilised in the economic analysis. This was the first Irish study to explore the issue of SCC and profitability using herd-level, nationally representative data, and to employ panel-data econometric techniques, allowing for the control of the effects of unobserved farm-level heterogeneity (i.e., differences across farms). In so doing, the independent effect of SCC on both yield and margins could be isolated. Model results indicate that, for farms with a SCC of 400 ('000 cells/mL) or greater, there is a 2% reduction in productivity (milk yield per cow) compared to the average, highlighting the potential productivity gains from reducing cell count for those in this category. In addition, the model suggests that a fall in SCC from 400 ('000 cells/mL) to 300 ('000 cells/mL) for an average herd size of 55

cows will likely result in an annual improvement in gross margin of €1,045 or €19 per cow. While this figure is lower than that calculated in a previous study by Geary *et al.* (2012) using the Moorepark dairy systems simulation model (€52 per cow differential in profit), the figure quantified here is based on observed data across a cross-section of dairy farms of all sizes and levels of profitability.

Farmer behaviour influences herd health

A second component of the research was to investigate the factors influencing herd-level SCC. A key finding in this regard is the relative importance of farmer behaviour in managing mastitis. According to the econometric models utilised, farmer uptake of agricultural training and herd management practices, such as milk recording, as well as liaison with extension services are positively related to cell count reduction, all else being equal. Collectively, agricultural training, extension contact and milk recording resulted in an overall SCC reduction of 25% for the average herd. The analysis found that farmers who undertook agricultural training were 10 times more likely to monitor milk quality through milk recording compared to those who hadn't. Similarly, farmers in contact with an extension service and who also participated in a dairy discussion group were seven times more likely to engage in milk recording. Such findings demonstrate the effectiveness of both extension and training programmes geared towards animal health and, in line with previous international research, imply that there is an important role for the extension agent, veterinary advisor and other stakeholders in influencing farmer behaviour. In addition, the analysis also found that a number of other characteristics of the farm are shown to be significantly associated with reduced SCC at the herd-level, including utilisation of eProfit monitoring, AI breeding techniques and extended grazing season.

Despite the inherent economic gains of best practice with regard to herd health the fact remains that some farmers are still not adopting optimal herd management techniques. For this reason a final element of the research involved the identification of farm-level drivers and barriers to the adoption of 'best practice' with regard to mastitis management using both quantitative and qualitative data collection techniques. Firstly, an additional survey on farmers' attitudes to and management of animal health and mastitis was carried out as part of the NFS in autumn 2013. Results indicate that the economic gain resultant from improved animal health and mastitis control was overwhelmingly recognised by farmers. Interestingly, almost three quarters reported that they had learned from previous experience with the disease and had subsequently changed their management practices. The survey data also indicated that farmers recognised the importance of seeking advice and learning from others; of note is the fact that the majority of respondents contend that new methods should first be proven on other farms. One could hypothesise that this removes, somewhat, the risk in implementing novel technologies at the farm-level. Finally, in line with the international literature the 'stick' is found to be better than the 'carrot' in incentivising farmers to improve animal health, i.e., in this instance, farmers report that a penalty imposed on milk with a high SCC is more effective than a bonus offered for milk with a lower cell count.

Regression analysis undertaken on the survey data indicated that those farmers who reported good awareness of the link between animal health and profit and had adequate knowledge of mastitis management techniques, were more likely to undertake practices such as milk recording and separating high cell count cows from the rest of the herd during milking. Conversely, the relationship between farmers' attitudes to animal health and their actual behaviour with regard to hygiene-related practices such as wearing of gloves and teat cleaning, was not as clear. As a result, a number of interesting issues arise in identifying barriers to the uptake of 'best practice' in this regard. These include the possibility of 'routine inertia', i.e., perhaps farmers tend not to deviate from the routine developed around mastitis prevention until there is an indication of infection. To this end, farmer behaviour could be considered reactionary as opposed to precautionary. The fact that an outbreak of mastitis can induce routine change was also reflected in information garnered through the focus groups, undertaken to complement the survey analysis. However, it should be noted that despite this, based on discussions at the focus groups there is a certain amount of 'routine creep', where farmers adjust what they do in response to what is accepted as 'best practice' among their discussion group, for example. To this end, the importance of 'learning by sharing' through such fora has been validated in this analysis. The qualitative component of this research confirmed that, in managing their farms, farmers are making decisions about the particular bundles of technologies and practices they use, on the basis of various trade-offs in terms of time implications, convenience, effort, impact on overall farm profitability, what has worked in the past, and what is considered the norm in terms of their peers. These decisions are made in a context of uncertainty and downstream supply-chain signals and incentives, and the current situation in terms of the herd health status on their farms.

Learning by sharing

This research provides insights for the effective communication of knowledge transfer. Based on this work, it is clear that the perceived usefulness and perceived ease of use of technologies and practices around animal health are important summary ideas for understanding technology and practice implementation for both disease prevention and intervention. The analysis indicates that farm-level routines change over time, in response to trial and error, learning and critical events. To this end the importance of results driven knowledge exchange and the facilitation of farmer 'learning by sharing' has been highlighted. Understanding the process by which farmers recalibrate their management strategy, and the intervention points around which this is likely to happen, is essential in order to provide appropriately timed and configured knowledge transfer support.

Acknowledgements:

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Further reading:

Dillon, E.J., Hennessy, T. and Cullinan, J. (2015). 'Measuring the economic impact of improved control of sub-clinical mastitis in Irish dairy herds.' *The Journal of Agricultural Science*. Available on *FirstView* at: http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=9500197&fileId=S0021859614001178

Geary, U., Lopez-Villalobos, N., Begley, N., McCoy, F., O'Brien, B., O'Grady, L. and Shalloo, L. (2012). 'Estimating the effect of mastitis on the profitability of Irish dairy farms.' *Journal of Dairy Science, Vol. 95.*

A review of the financial status of Irish farms and future investment requirements

Recent research conducted by Teagasc economists examined the financial status of Irish farms and the investment required at farm level in Ireland to reach *Food Harvest 2020* targets. The main results of the report are outlined in this article.

Summary findings

- On average, Irish farms have a sound financial structure. Existing debt-to-asset levels on Irish farms are low by European standards.
- Dairy farmers are the most active investors in Irish farming and this situation is likely to continue post quota removal.
- Significant investment and bank credit will be required across the farming sector if the targets set out in *Food Harvest 2020* are to be achieved.
- Sound financial planning on the part of farmers, in conjunction with the banking sector, will be critical to safeguarding farmers from financial stress particularly in an era of more volatile output and input prices.

The financial status of Irish farms

Using Teagasc National Farm Survey (NFS) data, the report finds that investment and debt on dairy and tillage farms were significantly higher than on livestock farms over the last decade (Figure 1). Not all farmers carry farm-business related debt; in 2013 40% of farms are recorded as having a farm debt by the Teagasc NFS. The average level of debt on all farms (farms with and without debt) in 2013 was €24,000, with dairy farms recording the highest level of debt at an average of approximately €62,000 for all dairy farms, and an average of approximately €94,000 for those dairy farms that have debt. In 2013, the NFS shows a closing balance of debt of €1.9 billion across the 80,000 farms represented by the survey.

Earlier work by Teagasc economists has shown that the Irish dairy sector is internationally competitive, but, in an increasingly volatile output and input

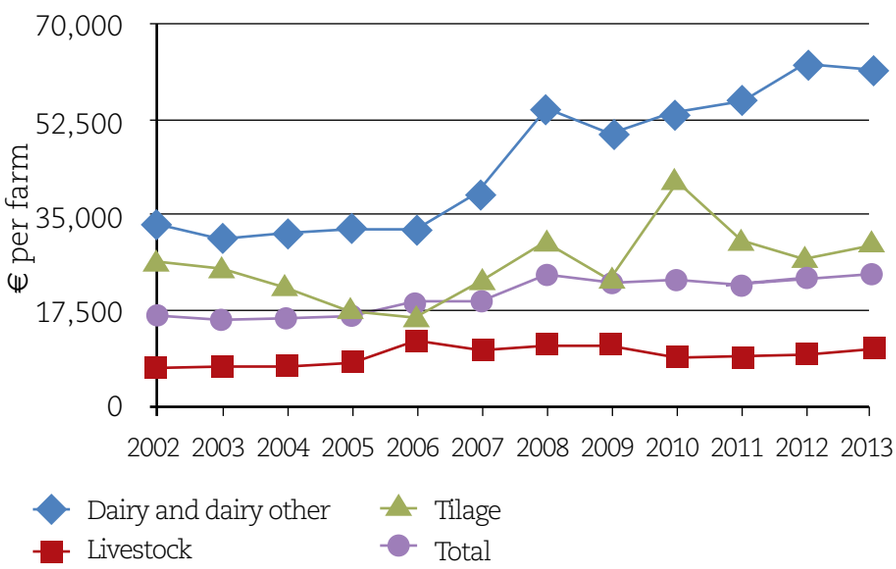

Figure 1. Average debt levels on Irish farms (2002-2013)
Source: Teagasc National Farm Survey, various years.

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price environment, the ability to demonstrate resilience and a sound repayment capacity will be particularly important for future development.

A comparison of various financial ratios of farms across the EU indicates that, on average, Irish farms have relatively low debt-to-asset ratios (Figure 2). So, while Irish dairy farming enjoys a competitive advantage in cost terms within the EU, the level of debt and the financial status of Irish dairy farms also provides Irish farms with an advantage over competitors across the EU.

Summary of the farm financial indicators and investment needs towards 2020 – pigs

An analysis of Teagasc PigSys data shows that the efficiency of the Irish pig industry continues to improve despite tight financial margins.

Food Harvest 2020 set ambitious expansion and efficiency targets for the Irish pig sector. Further capital investment will be required from financial institutions to achieve these targets. Most importantly, a reduction in dependence on merchant feed credit must be achieved as this credit is negatively impacting on the cost of pig production in Ireland. An elimination of merchant credit and its replacement by lower cost, direct bank financing would decrease the cost of pig production in Ireland and, thereby, allow the Irish pig industry to become more internationally competitive.

An expansion of the Irish sow herd size to 200,000 sows was part of the Pig Industry Development Strategy to 2020. The additional 56,000 sows required to meet this target would require an estimated investment of €280 million at current prices. However, increasing the size of the sow herd will be challenging, given that it has been in contraction in recent years. Therefore, a more likely and prudent scenario is for pig producers to maximise the output potential of their existing herd through an increase in the number of pigs produced per sow and (where possible) the achievement of higher sale weights. The cost of this extra investment would be €539,000 for the average sized pig unit, and an aggregate of €141 million for the pig sector as a whole.

Table 1. Milk production and investment under the three price scenarios

	Weak scenario	Steady scenario	Strong scenario
Pre-existing dairy farms			
Investment required (€million)	1,066	1,241	1,942
New entrants			
Investment required (€million)	612	232	n/a
Total investment	**1,678**	**1,474**	**1,942**

Source: Authors estimates based on FAPRI-Ireland model and Teagasc National Farm Survey data.

Milk quota removal and investment on dairy farms

Despite the constraint of the milk quota system, investment has been ongoing on dairy farms. Almost €2 billion (net of subsidies) was invested in the 2007 to 2013 period. This investment supported consolidation in the dairy farm sector with average milk output per farm growing by 32% over the same period.

It is estimated that a further investment of between €1.5 and €1.9 billion will be required over the next five years if Ireland is to achieve the *Food Harvest 2020* target of increasing milk output by 50% by 2020. The investment required varies with the milk price outlook. At lower milk prices (weak scenario), greater investment is required as individual farms engage in lower rates of expansion and greater numbers of new entrants are required to achieve the 50% growth target. Some of this investment, such as the investment in livestock, is likely to be funded from internal sources rather than bank credit.

It is important to note that farmers' expansion plans will be significantly influenced by the economic environment. Milk price volatility will be an inevitable feature of dairy markets in the coming years, but the general trend in milk prices is upwards. While an expansion of the sector is most likely to occur, the pace and magnitude of that expansion will be dictated by the returns to milk production at farm level.

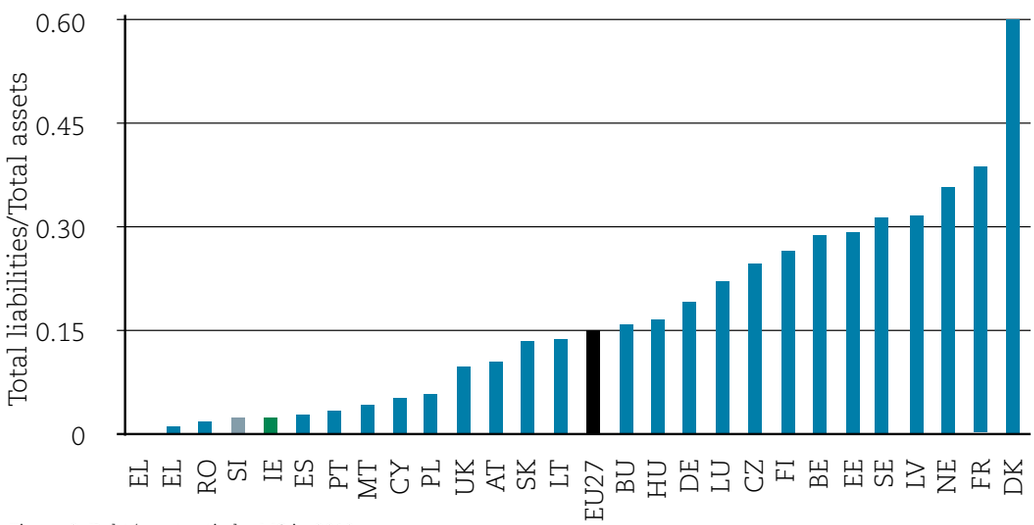

Figure 2. Debt/asset ratio by MS in 2012
Source: DG AGRI EU-FADN.

Acknowledgements

The authors would like to acknowledge the support provided by Bank Of Ireland for this research. This report was launched at Bank of Ireland HQ on January 14. The full report is available at: http://www.teagasc.ie/publications/2015/3453/BOI_Teagasc_Investment_Report.pdf

Events

APRIL

April 29 — *Teagasc Food Research Centre, Ashtown, Dublin 15*

Making Sense of Food: What can Sensory Science do for your product?

Sensory Food Network Ireland is organising its first industry themed sensory workshop, to coincide with its official Ministerial launch of the network. The workshop will demonstrate how sensory science can help a food business deliver products with the sensory characteristics consumers want. The programme includes presentations from research and industry leaders, interactive demonstrations and an opportunity to network.
Contact: SensoryFoodNetworkIreland@teagasc.ie

MAY

May 12 — *Teagasc, Moorepark, Fermoy*
May 15 — *Cavan Crystal Hotel, Cavan*

Pig Research Dissemination Day

The Pig Development Department is holding the first Teagasc Pig Farmers' Research Dissemination Day, which will cover the broad array of research projects currently ongoing. The event will provide attendees with the most up-to-date research results and the opportunity to meet with researchers and postgraduate students.
Contact: pigdepartment@teagasc.ie

May 19 — *RDS, Dublin*

Teagasc Land Use Change Workshop (am)
Farm Succession and Inheritance Conference (pm)

Teagasc, in conjunction with the RDS, are organising two half-day conferences. The morning session will address Land Use and Land Mobility is a complementary driver of future productivity growth in Irish Agriculture. Prior to the Succession and Inheritance Conference, a Land Use Change workshop will take place from 10.45 until lunch.
The afternoon session will look at Farm Succession and Inheritance from 14.00 to 17.00. The objectives of the conference are to provide an overview of and insights into the latest research being undertaken by Teagasc concerning farm succession and farm inheritance.

JUNE

June 3 — *Teagasc Food Research Centre, Ashtown, Dublin 15*

Prepared Consumer Foods: Innovative technologies and opportunities for a sustainable and competitive Prepared Consumer Foods Sector

This unique forum provides an exciting opportunity for the prepared consumer foods (PCF) and related industries to experience first hand, best practice models of innovation that are in place across the PCF sector and the broader food processing industry. There will also be other topics discussed, including successful case studies from the PCF sector, support from National Development Agencies, and the impact of tax changes for Research and Development. A range of technology offerings emanating from the UCC/Teagasc Food Innovation Alliance will also be displayed.
Contact: gateways@teagasc.ie

June 20 — *Teagasc, Mellows Campus, Athenry, Co Galway*

Sheep 2015, Major Open Day

This is the major sheep industry event for 2015. There will be a very strong emphasis on technology transfer with 10 villages covering: breeding, grassland, hill sheep, nutrition, flock health, environment, education, wool, marketing and the Teagasc Research Programme. Visits to the Teagasc Sheep Demonstration farm will also feature. A series of workshops will run throughout the day covering practical aspects of sheep husbandry from: dosing, selecting lambs for slaughter, dealing with lameness, selecting ewes and rams for breeding etc. It is expected that the sheep breed societies will have significant exhibits of their sheep with some also having their national championships at the event. It is expected that there will be in excess of 100 trade stands. A significant meat industry display and cooking demonstration will also feature. The organising committee consists of representatives from: Teagasc, UCD, Sheep Ireland, Bord Bia, the Department of Agriculture, Food and the Marine and the *Irish Farmers Journal*.
Contact: norina.coppinger@teagasc.ie

June 29-30 — *RDS, Dublin*

NutraMara Conference and Expo: Harnessing marine bioresources for innovations in the food industry

This major forum will allow exchange of new ideas and business opportunities from marine bioresources for industry exploitation by the food sector. The main theme of the event is: Harnessing marine bioresources for innovations in the food industry. The Conference will focus on science-based innovations and major technological challenges for market up-take. An exhibition will also take place, which will showcase innovative technologies and opportunities in marine bioresources for the food industry. Abstracts of original research or covering topics of commercial appeal are invited to be submitted (for oral or poster presentations) by May 15, 2015.
Contact: nutramara@teagasc.ie www.nutramara.ie

JULY

July 1 — *Teagasc, Animal & Grassland Research & Innovation Centre, Moorepark, Fermoy, Co. Cork*

Sustainable Expansion - Teagasc Dairy Open Day at Moorepark

This National Open Day will be held at the Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark. It is set against the backdrop of milk quota abolition, volatility in milk price and a positive market outlook for dairy products due to significant growth in world demand. Attending this event is a necessity for all dairy farmers and stakeholders in the Irish dairy industry.
Contact: Margie.Egan@teagasc.ie

SEPTEMBER

September 7-10 — *University of Stuttgart, Hohenheim, Germany*

Perennial Biomass Crops for a Resource Constrained World

Perennial crops offer a sustainable and efficient way of producing biomass. Because of their specific features, such as low nutrient demand and stress tolerance, they can also be grown under marginal site conditions. The GrassMargins project, coordinated by Teagasc, is organising this meeting which will present advances in the agronomy, physiology, breeding, plant biotechnology, genetic resources, farm scale production, processing and life cycle analysis of perennial biomass and fibre crops, mainly with regard to their potential to be grown on marginal lands. The call for abstracts will open on March 1 and will close on May 31, 2015. Deadline for full papers September 10, 2015.
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For a list of Teagasc's food industry training schedule (food safety, food law, animal welfare, quality assurance, microbiology, cheese making, calculating meat content, laboratory auditing) please see: http://www.teagasc.ie/food/research/training/schedule.asp
For presentations from previous Teagasc events see: http://www.teagasc.ie/publications/