



TEAGASC

# Research

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## Irish Soil Information System goes live

Schmallenberg - a disease of cattle and sheep

CheeseBoard 2015

Consumer meat quality expectations



AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

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Teagasc | Oak Park | Carlow



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SOILS SPECIAL GUEST EDITOR Rogier Schulte



## Making the most of our land

The number of mouths to feed from each hectare of land just went up. But the ecological footprint that we can afford ourselves just got smaller. This month, the UN revised its projections for population growth: the world's population is no longer expected to stabilise at 9 billion after 2050, instead it is now expected to continue to grow and approach 11 billion people by 2100. These new figures will certainly fuel the debate whether the world is 'running out of land'. Because not only do we expect the world's agricultural land to provide a nutritious diet for all, we also expect it to provide clean water, to store carbon, recycle our waste and provide a home for biodiversity. These competing demands have now brought soil science sharply back into focus. If we are to make the most of our land, we need to understand the 'engine room' of agriculture in all its diversity.

In Ireland alone, we have now identified 213 different soil types, each with its own properties and requirements. This month, the third edition of the National Soil Map was launched by Teagasc and the Environmental Protection Agency. The online Irish Soil Information System that accompanies this map brings together half a century of soil science, and has made this treasure trove freely available to researchers, policy makers and the public.

Already, the new National Soil Map is used for policy-making on the management of our land resource, such as the new delineation of the Areas of Natural Constraint. But, most importantly, it allows us to open a new chapter in agricultural research and to progress towards farm-by-farm advice that is tailor-made for the land. This is a big ask, and will take time to become everyday reality, but in this special soils issue of *TResearch* we preview the science that is already building on the Irish Soil Information System and provide an outline of what we can expect to be rolled out in the years ahead.



**Dr Rogier Schulte**, Leader of Translational Research on Sustainable Food Production at Teagasc. Rogier Schulte was the guest editor of the Soils focus



**Dr Karl Richards**, Head of Environment, Soils and Land Use Department, Crops, Environment and Land Use Programme, Teagasc

## Leas a bhaint as an talamh a oiread agus is féidir

Tá ardú i ndiaidh theacht ar líon na ndaoine a chaitheann a chothú as gach aon heicteár talún. Beidh orainn ár rian coise éiceolaíochta a laghdú, áfach, má tá go leor acmhainní le bheith againn le maireachtáil. An mhí seo, d'athbhreithnigh na Náisiúin Aontaithe a chuid réamh-mheastachán maidir le fás an daonra: bhíothas ag súil go mbeadh an daonra cobhsaí nuair a bhainfí na 9 billiún amach i ndiaidh 2050, ach ní cheaptar anois gur amhlaidh a bheidh an scéal. Táthar ag réamhinsint go leanfar den fhás agus go mbeidh 11 billiún duine ann faoi 2100. Cuirfidh na figiúirí nua seo leis an díospóireacht faoi 'ghanntanas talún' ar domhan. Ní hamháin go bhfuilimid ag iarraidh bia cothaitheach a chur ar fáil do chách ó thalamh talmhaíochta an domhain, tá rudaí eile ag teastáil uainn freisin as an talamh: uisce glan, áit stórála carbóin, áit lenár ndramhaíl a athchúrsáil agus áit ina mairfidh an bhithéagsúlacht. Is éilimh iomaíochta seo agus mar gheall air sin tá an ithreolaíocht go mór chun tosaigh an athuair. Má táimid leis an oiread leasa agus is féidir a bhaint as an talamh, caithfidh tuiscint a fháil ar an dóigh a n-oibríonn cúrsaí talmhaíochta ag an leibhéal is bunúsaí agus an éagsúlacht go léir a thabhairt san áireamh.

Tá 213 cineál éagsúil ithreach sainaitheanta in Éirinn amháin; tá a airíonna agus a riachtanais féin ag baint le gach cineál acu. An mhí seo sheol Teagasc agus an Ghníomhaireacht um Chaomhnú Comhshaoil an tríú heagrán den Léarscáil Náisiúnta Ithreach. Tá Córas Faisnéise faoi Ithir na hÉireann ann a ghabhann leis an léarscáil seo agus tá sé ar fáil ar líne. Tá an t-eolas go léir atá bailithe le leathchéad bliain anuas faoin ithreolaíocht ann. Is taisce luachmhar é atá ar fáil anois go réidh do thaighdeoirí, do lucht ceaptha polasaithe agus don phobal.

Tá an Léarscáil nua Náisiúnta Ithreach in úsáid cheana féin agus beartais á gceapadh faoi bhainistiú ár n-acmhainní talún; bhí sí in úsáid, mar shampla, agus líníocht úr á déanamh ar na Limistéir Srianachta Nádúrtha. Ach is é an rud is tábhachtaí faoin Léarscáil ná go gcuireann sí ar ár gcumas sinn céim chun tosaigh a dhéanamh ó thaobh taighde talmhaíochta de, agus de réir a chéile beimid in ann sainchomhairle a thabhairt do gach feirm ar leith bunaithe ar an gcineál áirithe talún atá ann. Is céim mhór é seo agus glacfaidh sé am é a fhíorú, ach san eagrán speisialta seo de *TResearch* faoi ithreacha, tugaimid réamhamharc ar an eolaíocht atá bunaithe ar Chóras Faisnéise Ithreacha na hÉireann agus ar na rudaí a chuirfeadh i bhfeidhm sna blianta atá romhainn.

**An Dr Rogier Schulte**, An Ceannasaí ar Thaighde Aistritheach ar Tháirgeadh Inbhuanaithe Bia in Teagasc

**An Dr Karl Richards**, Ceannasaí na Roinne Comhshaoil, Ithreacha agus Úsáide Talún, an Clár Barraí, Comhshaoil agus Úsáide Talún, Teagasc

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Cover image of soil biota courtesy of Professor Karl Ritz, Nottingham University.

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## Researcher profile



### Dr Maria Hayes

Dr Maria Hayes, who joined Teagasc in 2008, has a PhD in Microbiology and protein chemistry from the National University of Ireland, UCC, and a BSc in Industrial Microbiology from UCD. As a researcher at Ashtown Food Research Centre, Dr Hayes' main area of research focuses on the use of enrichment technologies for protein and valuable carbohydrate isolation as well as the development of bioassays to screen for compounds and ingredients with health beneficial activities.

Dr Hayes is interested in bioactivities and bioassay development and their use in the identification of ingredients beneficial for heart and mental health and the prevention of diseases associated with metabolic syndrome, including diabetes. She has worked with international collaborators from CSIC Valencia (Spain), Nottingham University (UK), University of Santiago de Compostela (Spain), Wuhan (China), France and Germany and several companies.

Dr Hayes also works on the Marine Functional Foods Research Initiative (MFFRI/NutraMara project), which includes collaboration with five Irish universities.

She has experience in the isolation and characterisation of chitinolytic enzymes from marine waste streams and the generation and characterisation of bioactive carbohydrates, specifically chitinoligosaccharides (COS) from shellfish waste.

Dr Hayes is also a task leader on a number of other research projects, including ReValueProtein and NutriCerealsIreland. These projects explore Irish meat processing streams and cereals, respectively, for recovery of high value protein based ingredients for food and non-food uses. Dr Hayes is also the author of over 35 academic, peer-reviewed international publications and a Springer Book editor of *Marine Bioactive compounds: Source, Characterization and Applications*.

## Science Squad on RTÉ

Teagasc is proud once again to sponsor the latest series of *The Science Squad*, the first episode appearing on October 27. Teagasc will feature in three episodes in this series. In episode one, *What Lies Beneath*, which will broadcast on October 27, 2014, presenter Kathriona Devereux meets Dr Riona Sayers from Teagasc to discuss liver fluke and the damage it can cause on Irish farms. Episode two, *Robotic Milking*, which will broadcast on November 3, 2014,



In episode one of *The Science Squad* Teagasc's Dr Riona Sayers (right) explains what liver fluke is and the damage it can do to presenter Kathriona Devereux.

sees the *Science Squad* return to Teagasc where Dr Bernadette O'Brien talks about the voluntary milking system that allows cows to present themselves for milking as they wish without the presence of the farmer. In *Love your guts!* In episode six, which will air on December 1, 2014, Dr Paul Cotter will speak about his recent study with the Irish Rugby team to examine the impact of exercise and diet on gut microbial diversity. This is the first study that shows exercise increases microbial diversity in humans and, while others have previously shown that diet influences microbial diversity, Teagasc can now report that protein consumption, in particular, positively correlates with microbial diversity. Presenter Kathriona Devereux checks in with Paul and his team to have her own gut health analysed and follows Eoin Myers, one of the group's willing guinea pigs, as he takes part in the next phase of the trial.

## AMIGA summer school

In September, the AMIGA (Assessing and Monitoring the Impacts of Genetically modified plants (GMPs) on Agro-ecosystems) project held a summer school exploring the theme: Environmental Risk Assessment (ERA) of GM crops. The European project aims to provide information about the impact of the cultivation of GM crops in Europe, which has been a bone of contention for some time in Europe.

Writing about the event, Ciara Beausang, a final year student in Environmental Plant Biotechnology in the School of BEES, UCC, said the information provided on statistics, post environmental market monitoring, and communicating the results of GM crop ERAs was put to good use as attendees were divided into groups, assigned a specific GM crop, and tasked with preparing the basis for an ERA. "In our case, the crop was *Fusarium* resistant wheat. We certainly put the speakers' knowledge to use, asking them as many questions as we could about our crops! We also had the chance to learn in the field with the blight-resistant potato trial that is currently taking place at the research centre in Carlow for the AMIGA project."

She adds: "If there is one thing I can take from the summer school, it is that the communication of scientific results is as important as the results themselves, particularly in the case of GM crops."



# PrecisionDairy raises the stakes

Minister for Agriculture, Food and the Marine, Simon Coveney TD launched a new research project, PrecisionDairy, at the National Ploughing Championships. Teagasc and Waterford Institute of Technology's Telecommunication Software and Systems Group (TSSG) were awarded Science Foundation Ireland (SFI) funding in conjunction with a commercial Shannon-based company, True North Mapping (TNM), to undertake the research within the research theme known as 'Future Agri-Food'. The project will use ICT to develop communication platforms to transfer the sensor data to a central database and enrich it with external databases (both animal and grassland) in order to create "big data".

A key outcome will be to provide the end user with real time solutions to both animal- and pasture-based management issues.

Dr Laurence Shalloo, Teagasc, in collaboration with Dr William Donnelly of TSSG, is coordinating the project. Teagasc will be focusing on the development, interpretation and integration of precision technologies in pasture-based systems. TSSG will focus on the development of sensors and biosensors to capture data at farm level, using ICT to develop communication platforms to transfer the data to a central database. TNM will focus on the development of technologies for automated pasture measurement and sensors for monitoring animal activity.

## Tyndall and Teagasc form partnership

Tyndall National Institute and Teagasc recently announced the signing of an MOU, forming a partnership to create smart agriculture technologies that will increase Irish competitiveness in the agri-food sector. Through the partnership, the two organisations will work together to secure maximum EU Horizon 2020 funding and create up to 10 new graduate research positions.

This new strategic partnership will foster and encourage researchers in both organisations to actively explore synergistic and complimentary research opportunities, which will result in an increase in Ireland's European and global competitiveness. The combined expertise at Tyndall and Teagasc will enable the development of new technologies, products and services in the agri-food sector.

The MOU will provide the foundation for a series of projects aimed at making agriculture smarter and more efficient and it formalises an already fruitful partnership with a number of beneficial projects to the Irish agricultural sector currently in progress. One such project is called IBR-Nano, which enables the early detection of the harmful, and highly virulent, Infectious Bovine Rhinotracheitis (IBR) herpes virus, which has a

range of symptoms including respiratory infections; drop in milk production; and foetal abnormalities. This herpes virus can affect an entire herd even though some may be carrying IBR latently with no symptoms, only to infect further members of the herd at a later stage. Novel Nanosensor technology will enable rapid detection of the infected members of a herd, allowing farmers to remove or treat the affected cattle, limiting the spread and minimising risk to the herd. Current laboratory diagnosis techniques can require up to seven days to get a result. The rapid detection abilities of IBR Nano will reduce the need to widely administer antibiotics, cutting the costs to farmers and alleviate animal suffering.

Another project "Flukeless" (funded by the DAFM) is developing new biosensor technologies and coupling these with geographical information systems to determine when and where outbreaks of liver fluke are expected in order to allow farmers to dose their herds in sufficient time.

## Book on Spatial Justice by Teagasc economist

A book entitled 'Spatial Justice and the Irish Crisis' has been published by the Royal Irish Academy. The book, edited by Dr David Meredith, Rural Economy Development Programme, in collaboration with Professor Gerry Kearns (NUI Maynooth) and Dr John Morrissey (NUI Galway) focuses on the key economic and social geographies defining contemporary Ireland arising from the financial crisis. Spatial justice is concerned with 'who gets what and where'. The book offers a nuanced and geographically specific evaluation of everyday concerns of citizens, planners and government officials alike. <http://www.ria.ie/Publications/Books/Spatial-Justice-and-the-Irish-Crisis>



**Dr David Meredith (Teagasc) with Professor Mary Daly (President of the Royal Irish Academy), Prof Gerry Kearns (NUI Maynooth), Prof John Mohan (University of Birmingham) and Dr John Morrissey (NUI Galway) at the launch of Spatial Justice and the Irish Crisis.**

## Sustainable Food Systems Ireland

Sustainable Food Systems Ireland (SFSI) is a new consortium of the largest food and agriculture agencies of the Irish Government and the Department of Agriculture, Food and the Marine. It acts as a point of contact for overseas governments, agencies and other organisations, and can negotiate participation in international food, agriculture and rural development projects.

Covering diverse areas of expertise, SFSI will build long-term relationships across the world to help in developing safe, secure and sustainable food value chains. Consortium members include the Department of Agriculture, Food and the Marine; Teagasc; the Food Safety Authority of Ireland; Bord Bia; and Enterprise Ireland.

The expertise on offer from SFSI can be accessed for help in: formulating agricultural and food sectoral policy, strategies and programmes; building regulatory systems and institutional capability; strengthening food safety at all stages of the supply chain; protecting standards of animal health and welfare and expertise in veterinary services; systems for animal identification and movement control; traceability in the food chain; establishing and improving research and innovation in agriculture and food; knowledge transfer, agricultural education and extension services; the establishment of producer and farmer advisory groups; developing and embedding sustainability programmes at primary and processor levels; creating SME and investment support systems; and the creation and marketing of national or regional brands. SFSI Director David Butler is available to discuss how SFSI and its members can help, contact: Sustainable Food Systems Ireland, c/o Enterprise Ireland, Eastpoint Plaza, Eastpoint Business Park, Dublin 3, Ireland.

## Erratum

The article: Storage conditions and potato glycoalkaloids, which featured in an article is on p16-17 of the summer issue of *TResearch*, contains an error. On Figure 1, the Y-axis should be entitled 'Total glycoalkaloids ( $\mu\text{g/g DW}$ )'.

## Milestones for Success

Presenting *Milestones for Success 2014*, to highlight the headline growth and achievements of the Food Harvest 2020 report, Minister for Agriculture, Food and the Marine, Simon Coveney stated that the agri-food industry is enjoying a period of strong success. Food and drink companies currently account for a 30% share of the ISEQ index and achieved exports sales of €10.3 billion in 2013, up from the baseline figure of €6.05 billion. The value of primary output has also risen sharply and at the end of 2013 was €6.183 billion, which means it has virtually reached the 33% target set by Food Harvest 2020.

The Minister highlighted the fact that industry leaders, assisted by Ministerial trade missions, and State enterprise agencies, have been making strategic capital and capability investments in growth areas such as dairy, whiskey and processed foods.

The Minister noted the tremendous turnaround in employment levels in the food sector where, in the last four years, the number of jobs generated rose by about 4,000.

*Milestones for Success* highlights some of the work being carried out in the industry that are contributing to growth in the industry. Examples include improvements in the skill level and managerial capability of many in the agri-food sector through the adoption of techniques and skills learned from Technology Adoption Groups, BETTER farms, the suite of Enterprise Ireland leadership and management development programmes, Skillnets, Skills for Work as well as from the Bord Bia educational programmes. Furthermore, the report commends collaborative work within the industry, including the Food Innovation Alliance between Teagasc and UCC and the National Agricultural Partnership between Teagasc and UCD; Teagasc's involvement in the Alimentary Pharmabiotic Centre, which explores the commercial opportunities for the pharma and functional food sectors which can flow from this gastrointestinal research; the Enterprise Ireland-led Food for Health Technology Centre; and the new emerging technology centres for dairy and meat processing. Food Works is another example cited, as well as the work and commitment being shown through the nationwide sustainability initiative Origin Green.

## Energising Rural Communities

Speaking at the recent Teagasc Rural Development Conference 'Creating off-farm jobs: Employment and training supports for farm families', Professor Cathal O'Donoghue presented a paper on Off-Farm Employment Challenges for Irish Farm Households. He pointed out that 15 years of growth in off-farm employment for farmers was wiped out in the three-year period post crisis. He said that education and skill levels are important drivers of employment and vulnerability, with those on the lowest skill level five times more likely to lose an off-farm job in a year than those with the highest skill level.

He noted that vulnerability, as measured by farmers without a viable farm income and without off-farm employment, was more pronounced for pension age, and remains an important issue for people of working age. He said reliance on construction employment remains a challenge for off-farm employment and a challenge in relation to reskilling. "Employment growth since the lowest point in early 2012 has seen increased employment in manufacturing, services, and in particular in agriculture," he noted. Adding that the Border area was the most challenged region in relation to working age vulnerability. "However, there is a worrying increase in "Strong" Agricultural areas, where those in dairy have seen higher viability but with other farmers being affected more strongly than in other areas. We see more resilience in areas

with stronger part-time farming tradition such as in the West."

Dr Fiona Thorne of Teagasc outlined the latest Teagasc, National Farm Survey statistics on the viability of farming in Ireland. Dr Thorne told delegates at the conference that the proportion of economically viable farms in 2013 was 35%, which was a slight decrease over the previous year. A further 32% of farm households in 2013 could be considered sustainable due to the presence of off-farm income. Dr Thorne said: "Based on these figures, over one third of all farm households in Ireland could be considered vulnerable, given that they are not economically viable and neither the farm operator nor the spouse holds an off-farm job."

Dairy and tillage farms are the most viable, and the proportion of economically viable dry stock farms remains low, at about 15% for cattle rearing farms. At the conference Teagasc launched its 'Options Plus' programme, aimed at supporting farm families to further develop their farm enterprises, develop alternative farm enterprises, or provide them with guidance on where to access supports that will enable them secure off-farm employment. Teagasc also launched New Diversification Videos that feature eight case studies of farm diversification. The videos will be used as a support for anyone interested in developing an additional on-farm enterprise.

## Teagasc Beef Conference focuses on improving profitability

In October, the Teagasc National Beef Conference, titled: 'Improved Breeding & Feeding of Suckler Cows to Increase Profitability', heard that grazed grass is the cheapest feed and suckler beef producers must optimise the proportion of grazed grass in the total annual feed budget. Speaking at the conference, Teagasc researcher Dr Paul Crosson said that profitability is greatest where the calving date for suckler cows is aligned with the commencement of the grazing season. He pointed out that where there is a long grazing season of 243 days, that a net margin per hectare of €454 can be achieved, whereas if the grazing season is short at just 178 days, then the net margin falls to €185 per hectare, for suckler

calf-to-beef production systems.

The latest breeding statistics for Irish suckler herds show that major improvements can be made on many farms when it comes to achieving a calf per cow per year. Teagasc researcher David Kenny said: "The beef genomics scheme launched by the Department of Agriculture, Food and the Marine, in conjunction with ICBF will put Ireland in prime position to implement a genomic selection programme for beef cattle, which should accelerate the rate of genetic gain for improved reproductive efficiency. Teagasc research has underpinned the initiation and continued development of this technology."

## European Commissioner visits Athenry



**Pictured with Maire Geoghegan Quinn, European Commissioner for Research, Innovation and Science (second from left) on a recent visit to Teagasc Athenry are Dr Noel Cawley, Chairman of Teagasc Authority, Professor Gerry Boyle, Director of Teagasc, and Dr Frank O'Mara, Director of Research, Teagasc.**

## Ireland welcomes the 18th World Congress of Food Science and Technology in 2016

Ireland was recently awarded the honour of hosting the 2016 World Congress of Food Science and Technology. The bi-annual event is one of the largest food science conferences in the world. It is organised on a global basis under the auspices of the International Union of Food Science and Technology (IUFoST), a not-for-profit global scientific organisation for food science and technology supporting programmes and projects to increase the safety and security of the world's food supply. The theme for the 2016 Congress will be: 'Greening the Global Food Supply Chain – Through Innovation in Food Science and Technology'. Organisers say it is a fitting theme given the location of the congress in Ireland, the increasing pressures on the wider global food industry in terms of the need for a more sustainable supply chain and the pivotal role of science in overcoming key challenges.

Ireland's competitive bid to host the 2016 Congress was presented by the Institute of Food Science and Technology of Ireland (IFSTI), the recognised adhering body to IUFoST, and was supported by the Irish Government, all relevant State agencies, the higher education sector and representatives of the Irish food sector.

Declan Troy, the Assistant Director of Research in Teagasc, was recently elected as President of the IFSTI. Declan Troy will also be the Chair of the World Congress in 2016, which will facilitate the communication, exchange and sharing of knowledge at the frontiers of food science and technology between Irish and international researchers. It will also promote the advancement of the production of nutritious, wholesome, safe and quality food and drink products while at the same time protecting and respecting the environmental needs of the planet.

The organising committees are putting ambitious plans in place to make this event a most prestigious and memorable one that will showcase both our impressive food research capability and our food production and processing systems.

The plans for IUFoST World Congress 2016 are centred on creating a sustainable legacy for the food science community in Ireland and for all IUFoST adhering bodies and stakeholders. The web site is now launched ([www.iufost2016.com](http://www.iufost2016.com)) where updates to the programme for this prestigious global event can be found. Sponsorship opportunities are detailed at <http://www.iufost2016.com/sponsorship.html>

## International Scientific Advisory Panel



Members of the Teagasc International Scientific Advisory Board (ISAB) are pictured with Teagasc's Dr Frank O'Mara (Director of Research, third from right) and Jane Kavanagh (Head of Research Operations, second from left) during their meeting at Teagasc Ashtown in July. Teagasc established ISAB in 2010 to provide advice and guidance on the strategic direction of its research programmes from an international perspective. This was the last meeting of the current Board, which was elected for a four-year term. The visitors are (from left): Professor Dietrich Knorr (Berlin University of Technology); Professor Geoffrey Campbell-Platt (University of Reading); Dr Tim Mackle (Chief Executive, Dairy NZ); Dr John Kennelly (University of Alberta, Canada and Chairman of ISAB); and Professor Simon van Heyningen (formerly Edinburgh University). Also attending were Professor Oene Oenema (Wageningen University & Alterra Research Institute) and Professor Hervé Guymard (Scientific Director for Agriculture, INRA).

## Seeking Ireland's next generation of food entrepreneurs

Ambitious individuals, with an interest in building an international food or drink business in Ireland, are being sought for participation in Food Works 2015, a business development and training programme designed especially for food and drinks start ups jointly run by Bord Bia, Enterprise Ireland and Teagasc.

Over the past two years, following a competitive process attracting in excess of 150 applications, a total of 43 start-ups from dairy, snacks, meat, seafood and beverages have participated in the Food Works programme.

Applications are now open for candidates interested in being a part of the 2015 Food Works programme. Ideal applicants are ambitious food or drink entrepreneurs, or companies trading for less than four years that wish to target export markets and scale their business. It is envisaged that the company will have an innovative product either already developed or in development. The Food Works programme aims to help these young companies to realise their full potential to achieve significant scale and become major international businesses in markets across the globe while creating new jobs at home. Successful companies will be introduced to suitable investors to help them to fund a scalable business during the programme. See [www.foodworksireland.ie](http://www.foodworksireland.ie)

## KerryLIFE

The Department of Arts, Heritage and the Gaeltacht has confirmed the provision of over €5 million funding for Freshwater Pearl Mussel conservation in South Kerry under the EU's LIFE+ programme.



The KerryLIFE project will run for five years from 2014 working with farmers and forest-owners in the Caragh and Kerry Blackwater catchments, to support sustainable management practices for the conservation of the Freshwater Pearl Mussel (FPM).

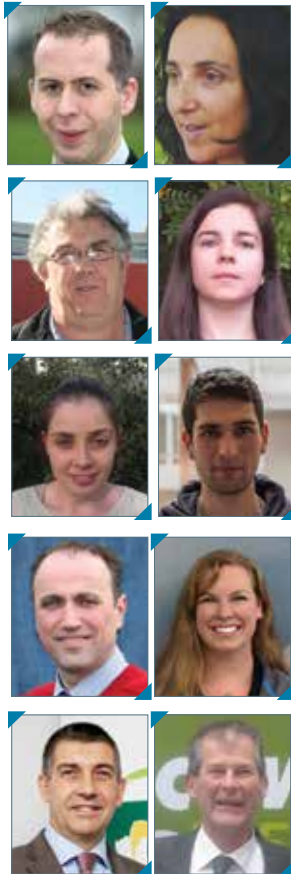
The Freshwater Pearl Mussel *Margaritifera margaritifera* is a long-lived mollusc that is found in coarse sand or fine gravel in clean oligotrophic, fast-flowing and unpolluted rivers and streams. In Europe, the species has undergone a 90% reduction in range and population over the last century. Ireland is considered a stronghold for the FPM and is believed to support approximately 46% of FPM individuals in the EU. However, recent reports found that the conservation status of all Irish FPM populations were 'unfavourable/bad'.

Freshwater Pearl Mussels are sensitive to environmental pressures (e.g., sedimentation, pollution, degradation of habitats). In Ireland, the principal threat to the species is believed to be poor substrate quality as a result of siltation and nutrient enrichment.

## AVTRW meeting

Research staff and students from Teagasc attended the 48th Annual Scientific Meeting of the Irish branch of the Association of Veterinary Teaching & Research Work (AVTRW), which was held in October at the Department of Agriculture, Food and the Marine's laboratories in Backweston. The theme for the AVTRW meeting was 'Animal Health Strategies in the Age of Pathogen Resistance'. Dr Kieran Meade (Teagasc, Grange) is AVTRW secretary and Dr Donal Sammin, the head of the Veterinary Laboratories opened proceedings. Fourteen speakers and a number of posters presented research findings covering a diverse number of bacterial, viral and parasitic infections, diagnosis, treatment and immune responses.

# Breeding a healthier national herd



A multidisciplinary team involving Teagasc researchers and the animal health and breeding industry has been looking at how best to improve the health status of the national herd through optimal breeding programmes.

Breeding is responsible for approximately half the observed changes in performance traits in well-structured breeding programmes. 'Change' here implies improvement (e.g., milk production, growth rate) or deterioration (e.g., reproductive performance). Past deterioration in reproductive performance in the national dairy herd was primarily due to aggressive selection for increased milk production alone, which is now known to be antagonistically genetically correlated with reproductive performance. Once identified, however, remedial action of including reproductive performance in the national dairy cow breeding goal (i.e. the Economic Breeding Index [EBI]) followed. Reproductive performance in the Irish national dairy herd is now improving. A female replacement-breeding goal also exists for beef cattle to negate the impact of selection for increased growth rate on reproductive performance, as a consequence of the known antagonistic genetic correlation between both growth rate and conformation with reproductive performance.

Little is known, however, of the impact of current breeding strategies on animal health. This is simply due to a scarcity of field data on many diseases to elucidate the inter-relationships between performance and disease susceptibility. As evidenced from the rapid success of recently introduced breeding strategies to improve reproductive performance, once the genetic architecture of an animals' characteristic is known and the relevant data are available, breeding strategies can be implemented to achieve progress. The benefit of genetics over management is that genetic gain is cumulative and permanent. It was generally thought that animal health is predominantly management-driven and that animal breeding can offer little to improve herd health. It should be remembered, however, that such statements of the inability of animal breeding to solve the

declining herd reproductive performance were rife just one decade ago. History speaks for itself as evidenced by the improving reproductive performance in the national dairy herd in recent years, concurrent with selection on the national breeding goal, the EBI.

## Animal health breeding research programme

One of the main suites of traits not fully considered in the current dairy and beef national breeding programmes is animal health and disease. Teagasc, the Irish Cattle Breeding Federation (ICBF), Animal Health Ireland (AHI), and ReprodDoc Ltd. have embarked on a large initiative to rectify this and provide Irish farmers with accurate estimates of the genetic susceptibility of each animal to a plethora of diseases. Funding from several past and ongoing Department of Agriculture, Food and Marine Stimulus Research grants have contributed to this initiative. Current focus is on: mastitis; lameness; bovine tuberculosis; Johne's disease (i.e. paratuberculosis); pneumonia; bovine viral diarrhoea (BVD); infectious bovine herpesvirus-1 (BoHV-1/IBR); uterine and ovarian health; and, liver fluke. Genetic variation in susceptibility has been detected in all these diseases but here we briefly discuss the results emanating from a selection of these diseases.

## Bovine tuberculosis

Infection of livestock with bovine tuberculosis has an estimated global cost of €2 billion annually. The primary cost of bovine tuberculosis infection in developed countries relates to its control, with an estimated €63 million spent by the Irish Government in 2010/2011. The project team has documented a strong transmissible genetic component to bovine tuberculosis in dairy and beef, with genetic differences contributing approximately 18% of the variation in susceptibility among dairy and beef animals exposed to the pathogen. Figure 1 illustrates the frequency distribution of progeny tuberculosis prevalence for sires with >50 progeny in >10 herds that had encountered a tuberculosis outbreak. Phenomenal differences among sires exist. If the worse 10% of sires for tuberculosis genetic merit had not been used as parents, the incidence of tuberculosis detected in this sample population would have reduced by 10%;

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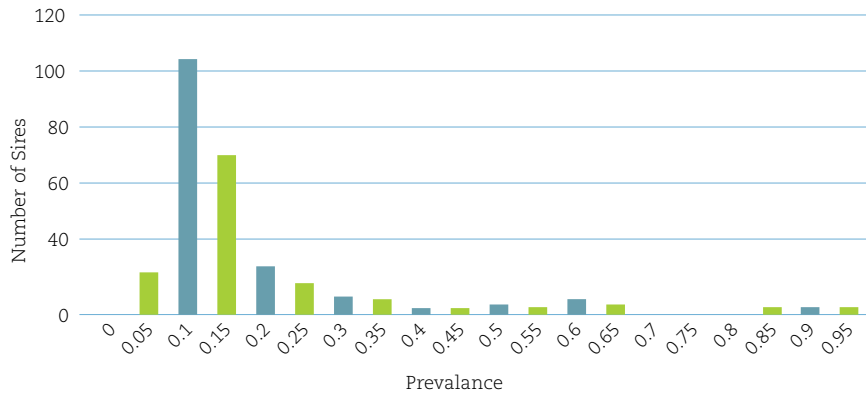


Figure 1. Frequency distribution of mean daughter tuberculosis prevalence in sires with >50 progeny in >10 herds where an outbreak of bovine TB occurred.

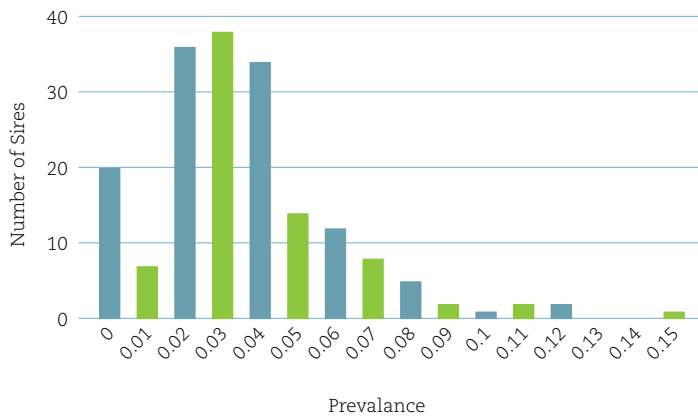


Figure 2. Frequency distribution of mean daughter cystic ovaries prevalence in sires with >30 progeny in >10 herds.

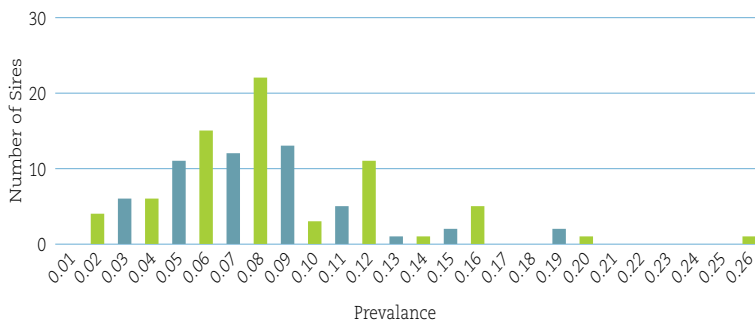


Figure 3. Frequency distribution of mean progeny bovine viral diarrhoea prevalence in sires with >50 progeny in >10 herds.

the impact nationally would be smaller as the dataset included in this study was only from herds where infection with tuberculosis existed. Incidentally, the bull with the greatest daughter prevalence of tuberculosis has the worst milk somatic cell count genetic evaluation of all AI sires in Ireland – illustrating an inter-relationship among diseases.

**Uterine and ovarian health**

Although reproductive performance in dairy cattle is improving, due primarily to the underlying breeding programme in Ireland, the economic cost of reproductive treatments is not being fully captured. Additionally, the underlying causes of extended calving seasons

and the tools to improve reproductive performance more rapidly are not available. In collaboration with Reprodoc Ltd, we investigated the incidence of different reproductive ailments in dairy and beef cattle and the contribution breeding programmes can make to reduce that incidence. Clear genetic differences were detected in reproductive characteristics like post-partum return to normal cyclicity, the presence of cystic ovaries, uterine health and embryo loss. Genetic variation was also detected in a trait describing unobserved oestrus, possibly reflecting either absence or reduced expression or duration of oestrus behaviour. Figure 2 illustrates the mean prevalence of cystic ovaries for sires with >20 daughters in >10 herds substantiating the considerable genetic variation detected.

**Bovine Viral Diarrhoea virus (BVDv)**

The introduction of the national BVDv eradication scheme provided data on the BVDv status of all calves since 2013. Only contemporary groups of calves with at least one BVDv-positive calf, born within 60 days of each other from dams that became pregnant on the same farm, were considered in our analyses. This was undertaken to maximise the likelihood of equal exposure of all dams during gestation. The dataset included >80,000 animals. A direct genetic effect of the calf itself and that of its dam was detected. In fact, 16% of the variation in BVDv susceptibility among contemporaries was attributable to the calf’s genetics with a further 5% attributable to the genetics of the cow herself. Moreover, considerable variation in mean prevalence by sire of calf existed. Figure 3 illustrates the mean prevalence of BVDv in the progeny of sires with >50 calves in > 10 different herds. Similar results have been generated from an analysis by the team for another respiratory disease, Bovine HerpesVirus-1 (BoHV-1), using data generated from dairy herd serosurveillance.

**Conclusions**

Genetic variation in susceptibility to common health and disease traits clearly exist in Irish cattle. Simulation studies we have undertaken clearly show potential to improve genetic resistance to these diseases within an overall breeding goal such as the EBI or the Terminal and Replacement Indices in dairy and beef livestock, respectively. Animal health and disease traits will be included in these breeding goals in 2015. Moreover, our mathematical modelling clearly shows the potential of our estimates of genetic merit in predictive diagnostic ability of succumbing to the disease especially when the heritability is high and the disease prevalence is low.

**Acknowledgements**

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Congenital Schmallenberg virus in a calf displaying torticollis, arthrogryposis, kyphosis and brachynathia inferior (twisted neck, contracted limbs, hunchback and shortened lower jaw).



# Schmallenberg – a new disease of cattle and sheep

Teagasc, UCD and the Department of Agriculture, Food and the Marine have just commenced a research project based at Teagasc Moorepark to address a new viral disease of cattle and sheep that appeared in Ireland for the first time in 2012.

In August 2011, an epidemic of dairy cattle with diarrhoea, milk drop and high temperature occurred in Germany and the Netherlands. Investigations by veterinarians ruled out common infectious agents. When blood samples from symptomatic animals were analysed, a novel Orthobunyavirus, never before seen in Europe, was identified by metagenomic analyses. The virus was named 'Schmallenberg virus' (SBV) after

the town near where it was discovered. Soon after, an epidemic of congenital deformities in SBV infected lambs, calves and goat kids occurred across Europe. SBV now has a pan-European distribution.

While the source of the virus is unknown, it is speculated that SBV infected insects may have been imported into Europe from Africa in cut flowers. Arrival into Ireland most likely occurred as a result of the windborne spread of SBV infected insects from Europe.

## First Irish case

The first case of SBV in Ireland was confirmed in late October 2012 in a bovine foetus in the Cork Regional Veterinary Laboratory. A national Irish serosurvey conducted in late 2012 demonstrated that much of the south and south east of the

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country had been exposed during 2011-2012, while the north and north west remained predominantly unaffected. A more recent study in dairy herds in the south west found no evidence of further spread of SBV in 2013. At this time, SBV appears to be confined to the south and south east of the country. Whether it will spread further north or recirculate within sero-endemic regions during the midge active season of 2014 (April to November) is currently under investigation.

### Spread by midges

Schmallenberg virus is an arbovirus (insect/arthropod-borne virus) transmitted by *Culicoides* biting midges. While midges are recognised as the main source of virus transmission, animal movements may also play a role. SBV has also been detected in semen samples; however this is not a viable source of virus transmission. Vertical transmission in ruminants is not considered a major route of SBV transmission.

### Ruminants affected by SBV

Schmallenberg virus is known to cause clinical disease and congenital malformations in domestic ruminants (cattle, sheep and goats). Exposure to the virus has been demonstrated in many other species such as South American camelids, wild ruminants, dogs and a wide range of exotic zoo species. Exposure to SBV has been investigated in at-risk farmers and veterinarians in Germany and in the Netherlands but no evidence of zoonotic transmission has been found.

### Congenital malformations

Two distinct clinical presentations of the disease have been described: transient SBV infection in the adult animal and the congenital form of the disease. Infection in the naïve animal causes short duration viraemia (few days) resulting in reduced milk yield, diarrhoea and sometimes fever. If viraemia occurs during the gestation susceptible period (cattle day 75-175, sheep day 20-80) transplacental SBV infection can occur, resulting in pathognomonic foetal deformities (congenital SBV) and abortion. The most common macroscopic pathological lesions described include deformed limbs, fused joints, vertebral malformations, malformations of the central nervous system and shortened lower jaw.

### Severe losses in sheep

Some Irish sheep farmers with seasonal lambing flocks suffered significant losses in 2012-2013. Early lambing flocks that were exposed to SBV during the critical gestation susceptible period experienced an epizootic of congenital malformations, non-viable lambs, difficult lambings and other associated problems. Anecdotally, flock owners are reporting increased numbers of repeat oestrous cycles after ram introduction and an increased numbers of barren ewes. The impact on the emotional wellbeing of farmers has also been highlighted. In dairy and beef herds, SBV caused abortions, stillbirths, deformed calves and difficult calvings, but on a lesser scale than in sheep flocks. During the epidemic of 2011 on the continent, both milk production and reproductive performance were significantly reduced in dairy herds. The most significant impact of SBV, however, has been international trade restrictions, particularly in live animals and semen.

### Control options

Two inactivated SBV vaccines have been approved in Europe – SBVvax (Merial) and Bovilis SBV (MSD Animal Health) – to prevent and reduce viraemia, respectively. Changing the timing of the breeding season can also be used as a control measure by planning to have the gestation-susceptible period outside the vector-active season. Vector control strategies have also been proposed, such as insect repellents, insecticides, insect screens on farm buildings and disruption of midge breeding sites (removal of dung heaps, preventing stagnant water build up and drainage systems), though only limited efficacy has been reported.

### New collaborative research project

In January 2014, a new research project commenced at Moorepark addressing this new disease. In the first phase of the project a large scale study has been set up on 25 herds in Munster involving 5,000 dairy cows. This will establish the herd and animal-level seroprevalence of exposure to the disease and will also contribute to identifying novel diagnostic methods to determine within herd seroprevalence using bulk tank milk samples. On-farm risk factors associated with SBV infection will be investigated to bridge knowledge gaps in SBV epidemiology and identify potential control methods for the disease in the future. Vector trapping will be conducted to evaluate virus transmission in insect species and to detect SBV. The impact of infection on herd health, calf mortality, prevalence and pathology of congenital defects and reproductive performance will be determined. Additionally, a placebo-controlled multi-site vaccination trial has been started to assess the effectiveness of vaccination in controlling SBV associated problems in dairy cattle. This is a longitudinal project; study herds and individual animals will be monitored prospectively over the next three years. The outputs from this project will uniquely contribute to our understanding of SBV and SBV-like diseases internationally.

### Acknowledgements

The commercial dairy farmers for allowing access to their herds and their data. Isabella Prunner (University of Veterinary Medicine, Vienna) and UCD students for their help during the field work. Merck Sharp Dohm, Ireland, for vaccine and placebo. The Brucellosis Blood Testing Laboratory, Central Veterinary Research Laboratory and Regional Veterinary Laboratories of the Department of Agriculture, Food and the Marine for sample analyses. This research is funded by the Teagasc core programme and the Walsh Fellowship Scheme.

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# Cow fertility: new science - new practices



Irish company Dairymaster has been to the fore in heat detection technology with its MooMonitor system. The newly launched MooMonitor+ allows farmers to monitor their entire herd from their phone.



## Professor Michael Diskin reports on an international cow fertility conference, which took place in May.

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As the world population continues to expand, the demand for increased global food production, and particularly high quality protein, will also increase. Ruminants have the unique ability to convert forage to high-quality milk and animal protein. Efficient reproduction is critical to sustainable dairy and beef cows systems and is, therefore, central to global food production as well as the economic success of individual dairy and beef farms. In Europe, milk quotas, which have been in place since the mid-1980s, will be abolished in 2015. While this affords opportunities to expand milk production, sustained expansion must be based on profitable, efficient, environmental and cow welfare-friendly systems. On a worldwide basis, the average dairy and beef cows

survive only three and five lactations, respectively. Therefore, good cow fertility is a major challenge facing dairy and beef producers and animal health professionals.

The International Cow Fertility Conference: New Science – New Practices, was held in May in Westport, Co Mayo and attracted over 470 delegates from 28 countries. The conference covered fertility in both dairy and beef cows, and, as can be seen from the title, there was a strong emphasis on the transfer of new knowledge from research to farm practice to improve the reproductive performance and efficiency of both dairy and beef herds. Over the past decade, significant progress has been made, not only in our understanding of key biological processes underlying cow fertility, but also in the development of technologies to assist and improve cow reproduction at farm level. Some of the more important developments are covered in this article.

### Automation of heat detection

Detecting the cow in oestrus and inseminating her at the correct times remains a major challenge in all production systems dependent on using artificial insemination (AI). At oestrus, cow-walking activity is increased by up to 400%. Technologies have now been developed that can measure and store cow activity and download this information onto a computer system as cows enter or exit the milking parlour. This is one of the areas where significant progress has been made in recent years, with the development of accelerometers that measure the increase in activity associated with oestrous activity. These systems are gaining popularity in confined non-pasture-based dairy systems. An Irish company, DairyMaster has been at the fore in this area of technology development with its MooMonitor system.

The secretion of progesterone by the corpus luteum controls the oestrous cycle of the cow. Changes in blood or milk concentrations of progesterone reflect the development and demise of the corpus luteum and can be used to accurately predict the time of ovulation in the cow. Technologies that can collect a small sample of milk from the cow, as she is being milked, and measure in-line the concentration of progesterone in the sample are now emerging as a very useful method to predict the most appropriate time to inseminate a cow. Combining automatic cow identification with the progesterone measurement and electronic data capture and storage, computer algorithms can now identify the most appropriate time to inseminate a cow. Field-testing of such in-line progesterone measurement systems is showing significant promise. One such system, Herd Navigator is marketed by DeLaval worldwide.

### Sexed semen

There has been rapid progress in the development of sexed semen technology over the past 10 years. Currently, two million doses of sexed semen are sold annually in the US. Current success rates record a conception rate of between 5-10 percentage points below those obtained with conventional frozen-thawed semen, with 90% of calves born being females. To date the technology has been less successful in separating out 'X' carrying male-generating sperm. The use of sexed semen, particularly, semen generating 90% heifer calves, is now becoming a realistic commercial option for use in heifers and high fertility cows (cows calved > 60 days calved) to produce high genetic merit females for both dairy and beef herds. The remainder of herds can be bred to suitable beef bulls strong on terminal traits. Ultimately, its uptake at industry level will depend on the pricing of the semen and the financial benefits that accrue at farm level from its use. The widespread adoption of sexed semen at industry level could have profound implications for the AI industry.

### Oestrous synchronisation and ovulation control

Major advances have been made in our understanding of the establishment of pregnancy and particularly the role of progesterone – both in the cycle before insemination and during the first week post-insemination. It is now well established that high concentrations of progesterone are required in the cycle preceding AI to ensure high conception rates after AI. The challenge with dairy cows is how the required high concentrations can be achieved, particularly in high-yielding cows, as high levels of milk production

cause a reduction in circulating concentration of progesterone as a result of increased hepatic clearance of progesterone. This new information has been incorporated into hormonal strategies to control ovulation in dairy cows. Such systems, examples of which are commonly known as Double OvSynch and Pre-Synch-OvSynch are gaining popularity in large confined dairy herds across the world because of the improved conception rates achieved. Reported conception rates for such systems are now in the order of 45-50% compared with 30-40% for cows inseminated at an observed standing heat. The application of these procedures, which involve up to five hormonal treatments over a three-week period, is more questionable for pasture-based systems of milk production such as in Ireland. However, they are becoming popular in large confined herds where there are major problems with both heat detection and conception rate.

### Genetics

Over the past 10 years, the inclusion of traits that reflect improved fertility in the breeding indices at up to 40% of the overall index is now beginning to show a modest but very welcome improvement in dairy cow fertility. With the advent and more widespread use of genomic and SNP chip technologies it is expected that this improvement in herd fertility will continue. The next challenge is the inclusion of cow health and intake traits into the indices. Increasing the intake of grazed grass would be particularly relevant to Irish production systems; it would reduce problems with negative energy balance in early lactation and drive milk production from grazed grass. However, this is more challenging because of the difficulty of reliably and cheaply measuring health and feed intake in large numbers of animals. Greater national and international collaboration will be required to make progress with improving health and intake traits.

While significant new knowledge on cow fertility is being generated on an ongoing basis, it is heartening to see how much of this is finding application at farm level. New questions are now being posed including:

- What new products, technologies or hormones will appear and how effective will they be?
- When will we have 'Super Viable Sperm' for AI?
- Can the need for heat detection be eliminated?
- What is the future of AI versus use of natural service bulls particularly in the context of genomic selection and sexed semen?
- Can we accelerate genetic gain to speeds previously unthought-of?
- Impact of prenatal nutrition on lifelong development, health and production – conception to slaughter.
- Data collection, interrogation, decision making from 'Massive Data'?
- Finally, what does the customer really want and how will this impact production systems and the environment?

This conference was jointly organised by the British Society for Animal Science, Teagasc, University College Dublin, the Cattle Association of Veterinary Ireland and the British Cattle Veterinary Association. The full proceedings are available on-line at: <http://journals.cambridge.org/action/displayIssue?decade=2010&jid=ANM&volumeId=8&issueId=s1&iid=9267655>



Three generations of soil science at Johnstown Castle, from left to right: photograph of Dr Tom Walsh, the first director of An Foras Talúntais, with the first Edition Soil Map of Ireland (1969); Dr John Lee (retired) and Pat Sills with the Second Edition Soil Map (1980); and Dr Rachel Creamer and Iolanda Simo, authors of the Third Edition Soil Map (2014).

# Three generations of soil science

“The demands of people all over the world are changing (...) The world itself is becoming a much smaller place because developments in communication and transportation (...) New countries are emerging, world population is expanding but the overall production of food lags behind (...) It is unnecessary to stress the excellence of Irish conditions for the production of meat and dairy produce, and knowledge now coming from our studies on intensive grassland production suggests that we can become one of the most efficient producers of these products per unit of land in the world.”

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At first glance these comments appear to be a contemporary quote from Ireland’s *Food Harvest 2020* strategy. But it is not. It is a vision laid out in a 1967 speech entitled ‘Food in the Future’ by Dr Tom Walsh, the first director of An Foras Talúntais, the predecessor of Teagasc that initiated the National Soil Survey.

As we celebrate Dr Walsh’s centenary year, it is striking how his vision has become reality today, almost half a century later. He recognised the untapped potential of Irish soils to cash in on a growing global demand for food and made it his mission to “grow two blades of grass where only one grew before”. Today, the importance of agriculture is once again recognised, following a lull of more than two decades in which food was cheap and plentiful. The global ‘Food Price Crisis’ in 2008 awoke the world once again to the need to invest in agriculture, and to make the most of the limited area of fertile soil available to humankind. Ireland has shown itself to be well positioned to rise to this challenge: earlier

this year, Bord Bia reported that Irish food and drink exports have increased by 40% since 2009, approaching €10 billion for the first time in history, which places agriculture at the heart of the national recovery.

This success story did not write itself. As Europe emerged from the war, Ireland's economy was on its knees. Eager to build a farming economy, the Government of the day looked to New Zealand scientists for advice. They reported that Irish farming was in such poor condition that "you couldn't possibly grow less grass under an Irish sky" and pointed the finger at Ireland's low soil fertility, poor soil drainage and, most crucially, lack of knowledge.

Enter young Tom Walsh, who had just returned home from the US, with a PhD in Soil Science under his arm. Determined to bring agriculture into the twentieth century through "the objective findings of fact", he convinced the Government to invest in scientific research. He knew that key to producing more food was to optimise soil conditions. Recognising the diversity of Irish soils, he initiated the National Soil Survey, which published the First Edition Soil Map of Ireland in 1969. That legacy lives on to this very day: this autumn the Third Edition is launched jointly by Teagasc and the Environmental Protection Agency at Johnstown Castle, as part of the Irish Soil Information System, which has combined traditional soil surveying techniques ('digging holes') with the latest digital technologies.

The publication of the Irish Soil Information System opens a new chapter in agricultural and environmental research. For the first time, after three generations of soil science, we have a complete picture of the diversity and properties of soils in Ireland. Figuratively speaking, this is equivalent to 'sequencing Ireland's soil genome'. In this special issue of *TResearch*, we show how the Soil Information System is already providing the foundation for the fourth and future generations of soil science.

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A special lecture will be held on December 5, World Soils Day, to mark the centenary of the birth of the late Dr Tom Walsh. The lecture will be delivered by Professor John Ryan on the 'Evolution and Achievements of Irish Soil Science'.

For more information see:

[www.teagasc.ie/events/2014/20141205.asp](http://www.teagasc.ie/events/2014/20141205.asp)

#### **DR THOMAS WALSH (1914-1988)** **MAGrSc, DSc, PhD, LL.D, ScD, MRIA.**

Dr Tom Walsh, a native of Piercestown, Co. Wexford, graduated from University College Dublin in 1937 with an honours BAgSc degree. He received the MAgSc the following year, his PhD in 1941, and he was awarded the DSc in 1947 for his published work. He was awarded honorary doctorates by the National University of Ireland in 1972 and by Trinity College Dublin in 1980 and was elected to the Royal Irish Academy in 1955. When An Foras Talúntais was established in 1958, he was appointed by the Government as its first Director, following a career as a soil scientist at University College Dublin and the Department of Agriculture. He was appointed the first Director of ACOT in 1980 and he retired from the public service in 1983.

Dr Walsh participated actively in a large number of scientific organisations. He was founder member and President of the Agricultural Science Association and of the Fertilizer Association of Ireland, and President of the Soil Science Society of Ireland and the Irish Grassland Association. He was Chairman of the National Council for Educational Awards and of the State Agency Development Co-Operation Organisation (DEVCO). He was Senior Vice-President of the Royal Irish Academy (RIA) and served as RIA Secretary for seven years.

But his interests and expertise stretched well beyond agricultural science. He was a member of the Commission on Higher Education and Chairman of the Garda Training Review Body. His membership of boards and councils of other Irish bodies included the Economic & Social Research Institute, the Nuclear Energy Board, the School of Ecumenics and the Commission for Justice & Peace.

Source: Scientific Papers Dr Tom Walsh Volume I: 1941-1953



# The Irish Soil Information System

The Irish Soil Information System combines traditional and cutting-edge technologies to bring all data on Irish soils together in one map and open-access information system. Dr Rachel Creamer and her team explain the long road to the completion of this third edition, National Soil Map.

properties, as well as their geographical location and extent.

## The need for a Soil Information System

Until recently, approximately half of Ireland had been mapped in detail by the National Soil Survey of An Foras Talúntais, the predecessor of Teagasc, in the form of detailed county soil maps. The General Soils Map was based on an amalgamation of soils information from 12 detailed county maps and an understanding of the soil landscape relationships existing in areas previously not surveyed in detail. This map, created in 1980 by Gardner and Radford, was available digitally at a scale of 1:575,000.

A review of soils data in Ireland found that spatial soils data in Ireland was no longer fit-for-purpose. Data usage of soils maps has developed significantly in the last 34 years since the publication of the second generation General Soils Map. This realisation led to the establishment of the Irish Soil Information System, co-funded as part of the STRIVE programme of the Environmental Protection Agency and coordinated by Teagasc, in collaboration with Cranfield University (UK) and University College Dublin. The objectives of this project were: (1) to develop a new soil map for Ireland at 1:250,000 scale; (2) to identify new and existing soils; and, (3) to provide a detailed description and classification system for all the soil types present in Ireland. This resulting map forms the basis of the soil information system for Ireland and is publicly available at <http://soils.teagasc.ie>

## Soil: the foundation of 'Smart Green Growth'

Ireland faces the contemporary challenge of meeting a range of agri-environmental objectives, in the context of increasing food production in a post-quota environment. Examples include the need to obtain 'good quality' status for all waterbodies, as specified by the Water Framework Directive, the need to protect biodiversity under the Habitat and Birds Directives, the potential for offsetting agricultural greenhouse gas (GHG) emissions through carbon sequestration and the need for sustainable recycling of nutrients under the Nitrates and Sewage Sludge Directives. It has been well documented that the capacity of land to deliver on each of these requirements depends primarily on soil properties and, hence, soil type. Therefore, a comprehensive knowledge of Irish soils is prerequisite to meeting the premise of 'Smart Green Growth' as formulated in the Food Harvest 2020 strategy. This includes an inventory of the diversity of soils and their

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### Developing a soil map

The detailed work completed by An Foras Talúntais, specifically the county maps at a scale of 1:126,720, were used as the building blocks of the new map and information systems. More recent map products, such as the Indicative Soil and Subsoil map completed by Teagasc in 2009, were also included. This wealth of soils information allowed the development of predictive mapping techniques, which are statistical models that describe the variation of soil within and between landscapes. These models were used to predict the location of soil types in geographical areas, which have previously not been described in detail (Figure 1).

These soil-landscape models were generated for the counties of Carlow, Clare, Kildare, Laois, Leitrim, Limerick, Meath, Offaly, Tipperary South, Waterford, Westmeath, Wexford, West Cork, West Mayo and West Donegal.

### Validating the predictive map

The use of predictive mapping to create a soil map is a novel method and Ireland is the first country to use this method on a national scale. Therefore, we conducted a traditional soil survey for 2.5 years to validate the accuracy of the predicted map, resulting in a confidence map. This validation involved the collection of soils data at more than 11,000 locations across the country. This traditional soil survey consisted of two steps. In the first instance, surveyors sampled down to a depth of 80cm to make a field description of the soil type to validate the predicted polygons on the map. In completing this initial survey, a number of new soil types were identified, which had previously not been described. These were particularly prevalent in counties Cork and Donegal, which represented soil-landscape models that had not been described in detail previously.

Having established the degree of accuracy and confidence in the predicted map, we then conducted a second, detailed survey, in which we dug 225 soil pits to describe these 'reference soils' in full detail. These pits were sampled at all horizons down the profile and a suite of laboratory analyses were conducted to allow the classification of the soils, using both the Irish classification system and the World Reference Base (WRB) system, the main unifying classification system used in Europe. Such analyses included: pH, texture; organic matter; total nitrogen; extractable iron and aluminium; bulk density; Cation Exchange Capacity (CEC); and base saturation. In addition, samples were also taken for a number of associated PhD projects measuring carbon sequestration in soils, biological diversity, bulk density ranges etc.

The final map and information system (online database) has been created using a unique combination of new and traditional methodologies and brings together soils data from both the An Foras Talúntais survey and the Irish Soil Information System project. The new soil map of Ireland consists of 58 associations (excluding areas of alluvium, peat, urban, rock or marsh) that are made up from 213 soil series. The information system that supports the map has been designed to hold the complete set of information deriving both from the Irish Soil Information System field programme, as well as the previously existing legacy soils information available for Ireland.

### Applications

The new soils map and information system will be an invaluable tool in developing solutions for sustainable land management

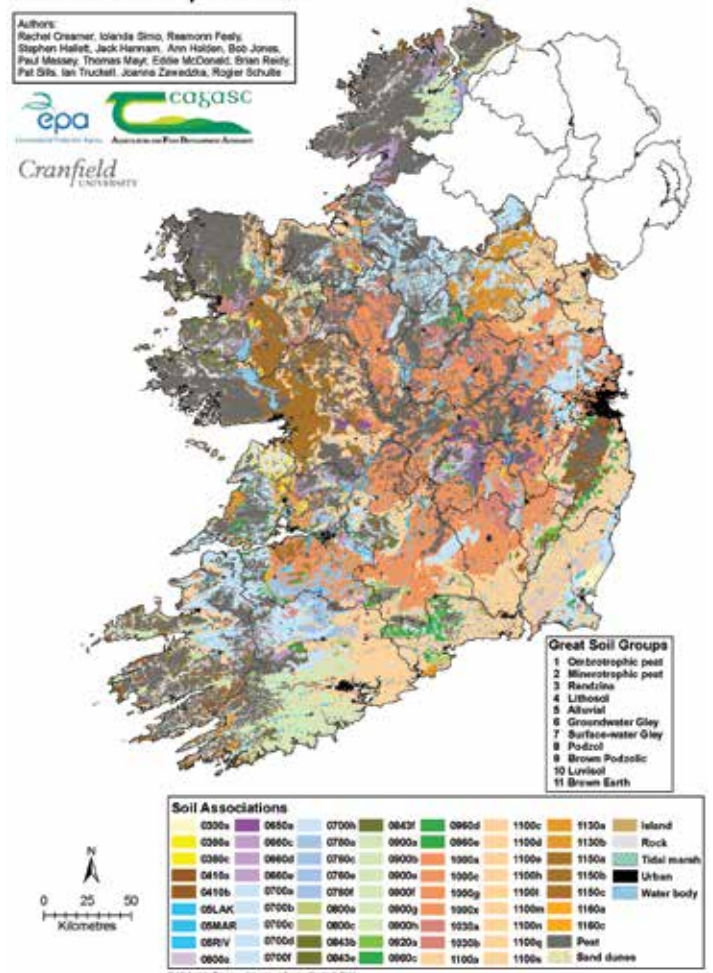
and the agri-environment into the future. Practical examples of the utility of the Irish Soil Information System map for policy and practice include:

- the facilitation of a migration from Tier 1 to Tier 3 GHG reporting to the United Nations Framework Convention on Climate Change;
- the Department of Agriculture, Food and the Marine will utilise attribute maps, developed by Teagasc, of soil properties derived from the 3rd edition soil map to delineate Areas of Natural Constraints (see pages 16-17 in this issue);
- the facilitation of the development of soil-specific nutrient advice by soil subgroup;
- the facilitation of the development of targeted and context-specific agri-environmental schemes; and
- the identification of priority areas and more targeted actions in the ongoing development and review of the River Basin District Management Plan.

### Funding

This project was co-funded by Teagasc and the Environmental Protection Agency (STRIVE Research Programme 2007-2013).

### National Soil Map of Ireland



# Creating a carbon baseline:

## Assessing the sequestration potential of Irish soils

The implementation of *Food Harvest 2020* poses challenges both in terms of meeting the ambitious production targets and meeting sustainability criteria, most notably greenhouse gas (GHG) targets. The EU Climate Change package envisages a 20% reduction in emissions from the Irish non-Emission Trade Sectors (ETS) by 2020. Considering that agriculture comprises 40% of these emissions, there is a clear challenge to increase production in compliance with climate change targets. In addition, both markets and consumers are demanding that agricultural produce generates lower carbon footprints.

The capacity for the sector to reduce emissions by the abatement of methane and nitrous oxide, the principal GHG's generated from agriculture, is limited to approximately 8% of current emissions (Teagasc, 2011). However, soils play an important role as a potential sink of carbon (C). Globally, terrestrial systems can hold up to 2,200 billion tonnes of C, which is five times the C present in the biosphere and 3.5 times the C in the atmosphere. As a result, offsetting agricultural emissions via carbon sequestration is considered one of the primary tools for meeting global climate targets.

For Ireland, C sequestration is attractive as a mitigation option, as management of grassland systems (e.g. fertilisation, grazing) generally enhances sequestration. Indeed, practices that sequester C in grasslands normally increase productivity, which places C sequestration as a win-win strategy. European temperate grasslands have been shown to be a carbon sink, with annual sequestration rates of approximately 1 tonne C per hectare. Considering that grassland comprises 4 million hectares, or 90% of agricultural area, the size of Irish grassland sinks may be considerable. Initial results show that optimising the intensity of herbage utilisation through grazing, cutting and maintaining good nutrient status (nitrogen (N) and phosphorus (P)) increases soil C

sequestration rates in temperate grasslands. As a result, the inclusion of C sequestration into life-cycle assessment of dairy and meat products can reduce the emissions intensity of the produce by over 40%. However, the potential for using soil C sequestration as a mitigation strategy is currently limited by methodological difficulties in both establishing baselines and verifying the strength and permanence of carbon sinks.

From an agricultural point of view, Soil Organic Carbon (SOC) is important because of its central role in soil functioning. SOC acts as a supplier of nutrients for the plants: through mineralisation of SOC carried out by bacteria, nutrients such as N, P, potassium (K), calcium (Ca) are transformed from organic forms (unavailable to plants) to inorganic forms, which can be absorbed by the roots. SOC also adsorbs nutrients onto its surface. The strength of adsorption of nutrients onto the SOC surface is strong enough to reduce leaching and weak enough to facilitate uptake by plant roots. In addition, SOC creates a better structure in the soil as a result of its interactions with the mineral part of soils, creating and maintaining aggregates. Soil aggregation is important for the formation of micro and macro pores, which in turn enhance water holding capacity, aeration, and plant rooting. A better structure also reduces the risk of erosion and appearance of crusts at the soil surface.

### The challenge of measurement

Current input rates of organic C into most soil systems are hard to measure, as input rates of 0.25 tonnes of C are being introduced into a soil pool that typically contains between 70 to 200 tonnes C per hectare. Furthermore, the residence time of C sequestered into the soil may range from days to millennia. To date, the fundamental mechanisms involved in sequestration are still subject to research and, thus far, there are no methodologies available to quantify



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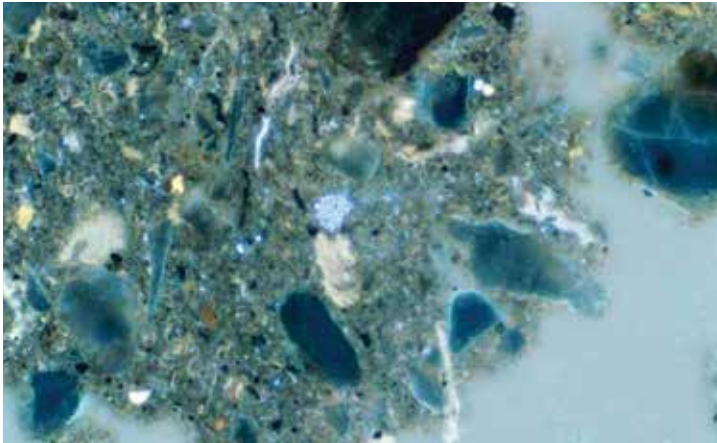
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The architecture of soil aggregates determines whether soil microbes (in the centre of the picture) can reach and break down organic matter. Photo: Professor Karl Ritz

the distribution of C between 'fast' and 'slow' turnover pools. As a result, the reliable assessment of the effects of management on soil C stocks and pools requires the development of methods that establish the potential of soils to permanently sequester C in different fractions

### The role of aggregates in sequestering carbon

The decomposition and conversion of organic material into aggregates is one of the principal C sequestration mechanisms. These aggregates are formed initially by root exudates (such as polysaccharides) and fungal and plant debris. This particulate organic matter (POM) is a temporary binding agent as it is easily degradable by bacteria. Decomposition reduces the size of these aggregates (micro-aggregates), which subsequently become encased in clay particles. Occluded organic matter has a slower turnover than free organic matter, which means that it will have a longer residence time into soils. Eventually, some of the C is incorporated into complexes with soil particles, leading to further stabilisation. Hence, although macro-aggregates contain more organic matter than micro-

aggregates, it is more labile than micro-aggregates organic matter, which is less available for decomposition by bacteria. Therefore, a soil that contains a higher proportion of micro-aggregate carbon will contribute more to long-term carbon sequestration, because its carbon will remain longer in soils.

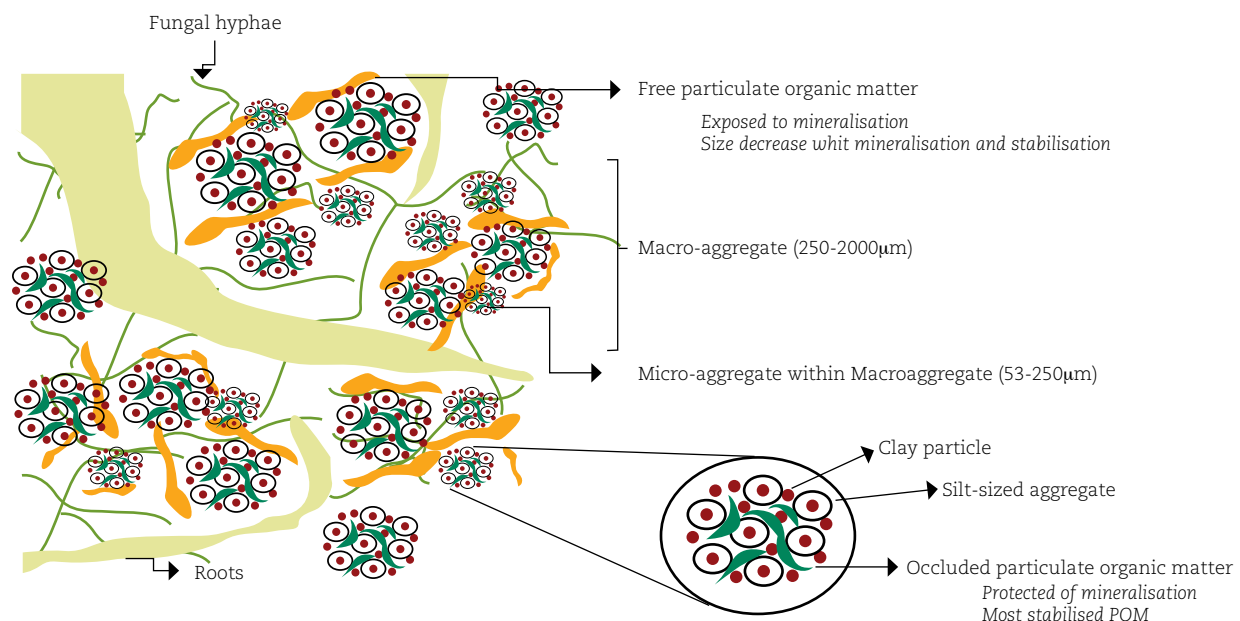
Current Teagasc research by the Irish Soil Information System in conjunction with the Agricultural Greenhouse Gas Initiative for Ireland (AGRI-I) is focused on assessing the quantity and quality of C in soil organic matter. The principal research questions include:

- What are the SOC stocks in agricultural soils and what is the effect of soil type and management on C quantity and quality?
- At what point does 'saturation' of soil C occur and what controls this?
- What is the link between management intensity and rates of sequestration and can we manage grazed pasture systems to increase the rates and absolute amounts of C sequestered?

In summary, C sequestration offers considerable potential to help achieve future climate targets, while also improving soil functioning. Researching the mechanisms of sequestration and developing 'early warning systems' to predict the direction and size of C loss/gain will assist in developing new strategies to both maintain and enhance current stocks.

### Funding

This research is funded by the Teagasc Walsh Fellowship scheme, in collaboration with the Irish Soil Information System (co-funded by the STRIVE Programme of the Environmental Protection Agency) and AGRI-I (funded by the Stimulus Programme of the Department of Agriculture, Food and the Marine).



Visualisation of aggregates and organic matter within the soil matrix

# Soil time lag and water quality



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## What is time lag and how long will it last?

The Water Framework Directive (WFD) in Europe aims, inter alia, to achieve at least 'good' water quality status by 2015 by mitigating the causes of pollution. However, with the implementation of programmes of measures in 2012, many catchments may not achieve good water quality status within this timeframe due to the time lag of nutrient transport from source to receptor. A 'time lag' is the delay that takes place between implementation of new agricultural practices (e.g. improved nutrient management) and the ultimate response by aquatic ecosystems to these changes. This delay reflects the time it takes for nutrients to travel to the waterbody via hydrological and hydrogeological pathways and can range from days to decades. Given this variation, an appraisal of catchment time lag issues offers a more scientifically based timescale for expected water quality improvements in response to mitigation measures implemented under the WFD.

In 2011, Teagasc published a simplified methodology for the calculation of nitrate time lag in a variety of Irish hydrogeological scenarios, based on unsaturated vertical and aquifer flushing times required to reach environmental quality standards (Fenton et al., 2011). The results showed that achievement of good water quality status in the Republic of Ireland for some waterbodies may be too optimistic within the current timeframe of 2015 targets but improvements are predicted within subsequent six- and 12-year cycles. Uncertainty analysis showed that the efficacies of mitigation measures are unlikely to manifest themselves for up to 10 years. The Teagasc Agricultural Catchments Programme aims to pick up on early changes (trends) in water quality and, in doing, so can give guidance with regard to the efficacy of measures before the time lag period has occurred.

We are currently quantifying the first component of time lag – the residence time of water in the soil. We are using a holistic approach, which includes simple (back of the envelope) and complex (modelling and tracer experiments) methods to estimate in situ time lags.

## How can we estimate time lag?

Ideally, time lag is measured via tracer tests, in

which a dye or chemical is applied to the soil surface and its progress through the soil profile is monitored. However, in many cases this approach is prohibitively time consuming and costly. An alternative is to employ computer simulations in which water flow and solute dispersion equations are coupled with soil hydraulic and meteorological input data to simulate contaminant transport (Figure 1). These simulations mimic tracer tests and produce solute breakthrough curves, indicating the removal of contaminant from the soil profile over time (Figure 2). Such curves can be

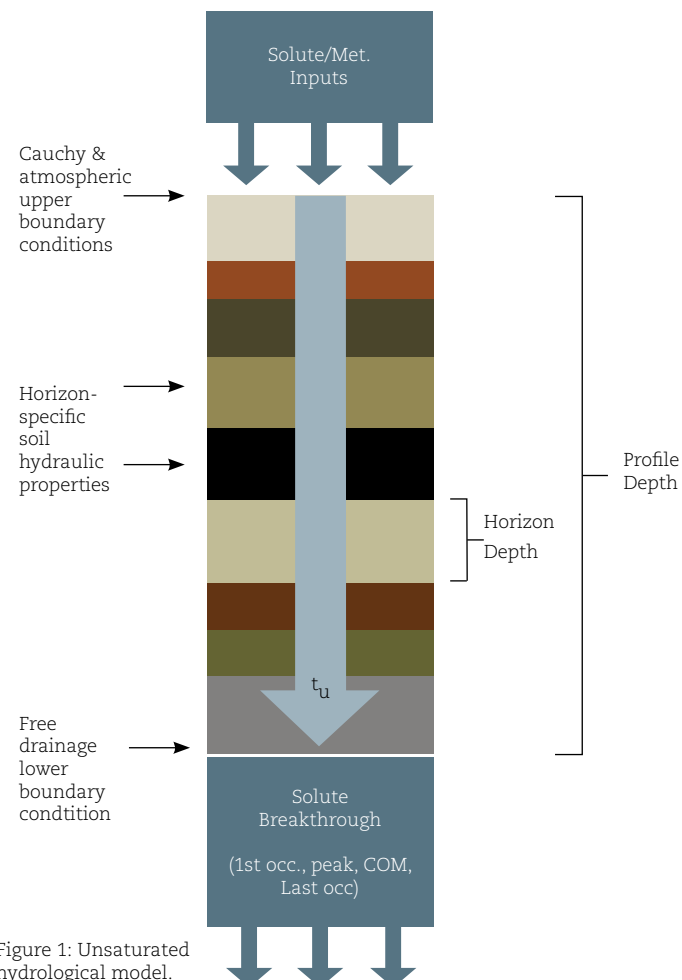


Figure 1: Unsaturated hydrological model.

divided into four sections: first occurrence corresponds to the initial breakthrough of the solute at the base of the profile (indicating when trend analysis should be initiated), peak breakthrough (indicating the highest concentration of solute observed), centre of mass (indicating when the bulk effects of programmes of measures have taken effect), and last occurrence, which is the total exit of solute from the profile.

Vero *et al.* (under review) found that the temporal resolution of meteorological data used in computer simulations influences the shape of the resulting breakthrough curves and, consequently, time lag estimates. It is recommended that hourly, rather than daily, meteorological data should be employed where available. Regarding the soil hydraulic parameter inputs, the study found that results obtained from laboratory tests (e.g. measuring the soil water characteristic curve) as opposed to generic soils data (such as textural class), better reflected in-situ soil conditions and hence improved estimates of time lag. This demonstrates one application of the high quality soil data collection provided by the Irish Soil Information System.

### Why is time lag important for agriculture?

Unless we account for time lag, there is a real risk that any failure to meet water quality objectives may be erroneously equated to either a lack of compliance, or inadequacy of existing measures. In that case, legislation would effectively stipulate that water quality targets are approximated at a rate that exceeds the maximum rates as dictated by hydrology, which is of course physically impossible. Therefore, it would be prudent to assess the expected timelines for meeting water quality objectives, accounting for time-lags, before proposing progressive changes to the current Programmes of Measures currently implemented in the River Basin District Management Plans.

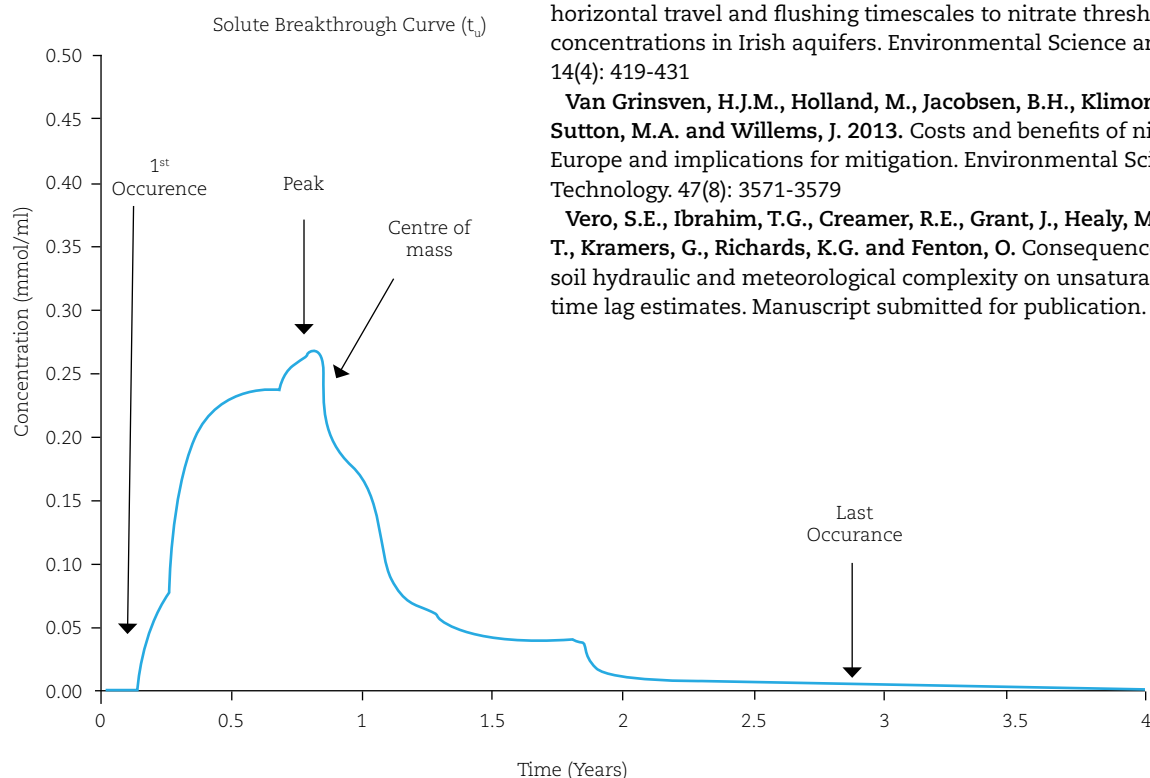


Figure 2: Solute breakthrough graph, showing 1<sup>st</sup> occurrence, peak, centre of mass and last occurrence.



The speed at which nutrients are transported and, hence, the time lag depends on the pore network in the soil. Photo: Professor Karl Ritz.

### Future objectives

The results, presented by Vero *et al.* will be validated using field tracer studies within two vulnerable catchments. This project and the groundwater transport project conducted by the Teagasc Agricultural Catchments Programme will work together to provide a comprehensive analysis of total hydrologic time lag, which may act as a guide for policymakers, a tool for river basin district managers and promote a better understanding of nutrient transport.

### Funding

This project is funded by the Teagasc Walsh Fellowship scheme.

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# Soil microbial diversity: Does location matter?



Using a multidisciplinary approach, Andrea Richter is identifying links between microbial community structures, soil types, land use and environment.

by Teagasc and University College Dublin (UCD) is establishing how the functionality of soil organisms depends on soil type, land use and geographical location in association with the Irish Soil Information System project. Soil samples for biological analysis, including surface and subsurface soils, were collected over two years at 240 different locations across Ireland.

## Soil biodiversity: 'The below ground Amazon'

Soil ecosystems are highly complex and among the most diverse environmental systems on Earth. One gramme of grassland soil can contain more than a billion organisms, with a diversity of greater than 10,000 different bacterial and fungal species. These organisms are recognised as key players in ecosystem functioning, and are the engine behind most of the processes that take place below the soil surface. Microbes are the drivers of nutrient cycling, they improve plants' ability to absorb nutrients but also protect from environmental stress and disease. Microbes also recycle waste products, get rid of contaminants, purify water by denitrifying nitrates and they are the gatekeepers in the soil carbon cycle. Understanding microbial dynamics, community structure and functioning is essential in order to deliver on the premise of 'smart green growth' identified in Ireland's *Food Harvest 2020*.

## Microbial respiration

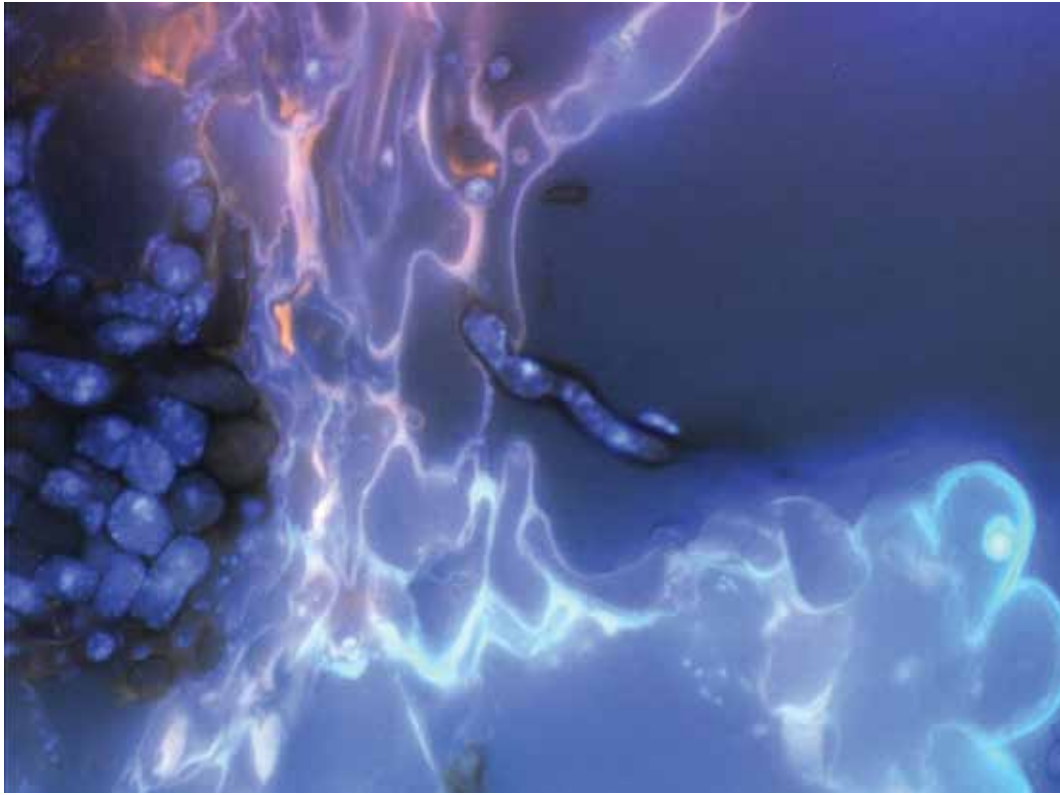
Microbes have a fast regeneration time and are, therefore, good indicators of environmental change. By using soil biology as bio-indicators, changes in soil ecosystems can be identified before an effect on physicochemical properties may be visible. We used the MicroResp™ method to study how different soil biological communities respond to a range of carbon sources found in soil. Seven carbon sources, varying in complexity, were used as substrates for 150 surface soil samples. Results show that abiotic properties, such as total nitrogen, organic matter and pH, significantly enhance the response of a microbial community to a range of soil carbon sources. No clear trend was visible to distinguish between different soil types per se but multivariate analysis of respiration profiles showed a significant effect on the drainage class, indicating that poorly drained soils with high biomass show an overall lower respiration rate per unit biomass. Unimproved grassland sites followed a similar trend

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A joint, large-scale, biogeographical study



The 'engine room' of agriculture: soil biota are responsible for most of the processes taking place below ground.  
Photo: Professor Karl Ritz.

when compared to grassland-improved sites. This difference in respiration rate suggests the presence of a biological community associated with the slower turnover of carbon in soils, whereas communities in improved grassland sites are adapted to larger nutrient fluxes as a result of fertilisation regimes.

### Digging deeper: microbial community structure across soil depths

Our understanding of soil microbial communities is still relatively limited when we are looking at specific soil types or layers below the surface horizon. Subsurface horizons play a major role as carbon sinks and form an environment in which microbes can perform essential functions related to soil formation, contaminant degradation and non-labile carbon cycling. We are now determining if microbial communities of subsurface horizons are specialised for specific environmental conditions or more related to the location of the sample. In other words, this project asks the question: does location matter or, are the abiotic properties more important in shaping the microbial community present? We selected a subset of 270 horizon samples from 80 Irish soil profiles and we are currently comparing community structures using the analysis of phospholipid fatty acids (PLFA) (found as building blocks in microbial cell membranes, which differ between microbial groups) and marker genes (genes present in all living organisms but with slight variations between microbial groups).

### Key species

It is generally believed that a medium to high diversity of microbes in agricultural soils is a good indicator of soil quality. However, recent research findings suggest that species diversity may not be as important as previously thought. Different species can perform similar functional roles (called functional redundancy) therefore a change in community structure related to these species might not affect ecosystem processes. Certain soil processes like N mineralisation however rely on only a few key species, rather than the whole soil community.

By measuring the abundance of functional genes, which are known to enhance nitrification and denitrification, we are now assessing how abiotic soil properties impact on these key species and, therefore, on the nitrogen cycle.

### Conclusion

The main aim of this study is to benchmark the range of microbial communities in Ireland and assess their potential function in nitrogen cycling and carbon respiration across a spectrum of soils and soil depths under improved and unimproved grasslands in Ireland.

The information gathered will help us gain a better understanding of below ground soil community structures. It will provide a baseline for future research, with the aim of identifying indicators of soil quality and functionality.

### Funding

The Teagasc Walsh Fellowship Programme funds this project.

# Breaking new ground on soil biodiversity across Europe



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The EcoFINDERS project is opening the black box of soil processes and studying how below-ground organisms govern the functionality of soils across Europe. The increase in knowledge from this large-scale sampling campaign, co-led by Teagasc, is priceless for policy development in the area of soil health and productivity, explains Dr Dorothy Stone.

Soil provides a wide range of services, including primary productivity, water purification, carbon sequestration and nutrient cycling, all of which have been described in the preceding articles. The majority of these soil processes are mediated by soil biota, which are the driving forces behind most soil based ecosystem services. The European Commission acknowledges the importance of soil biodiversity in the role of ecosystem functioning and the Commission's soil strategy is to protect and enhance soil-based ecosystem services, with a view to promoting sustainable intensification of agriculture. However, while we have a good idea of the role of soil organisms in many of the processes that take place in soils, there is very little information on the geographical distribution and variation in soil biodiversity or the functional capacity of these below-ground communities.

In light of this, the EcoFINDERS (FP7) project was set up in 2011 to address this lack of spatial information on soils and to generate European datasets of soil biodiversity and ecosystem function. Teagasc is the lead partner in the work package dedicated to developing and evaluating indicators of ecosystem functioning, based on the combined knowledge of experts from across Europe. These indicators were measured at 81 sites across Europe: a sampling campaign of unprecedented scale for soil biodiversity. The sites cover a range of biogeographical zones, representing climatic regions that include: Atlantic, Continental, Boreal, Alpine

and Mediterranean. Encompassed in these zones are a range of land uses: arable, grass and forestry and a large spectrum of soil properties (represented by pH, organic carbon, total nitrogen and texture).

## Selecting indicators

We selected a range of biological methods that provide information on the abundance, diversity and functional capacity of organisms found in soils across Europe. There are many biological methods available and therefore, it was essential to select methods that: (1) provide good descriptive information; (2) are cost-efficient; and, (3) are not too laborious to carry out in the field (at time of sampling) or laboratory (during analysis). Table 1 describes the range of methods selected and how they relate to biodiversity or soil functioning. Here, we give three examples that describe the microbial, faunal and functional behaviour of organisms in soil across Europe. These include: (1) fungal diversity; (2) the diversity of Enchytraeid (potworms); and, (3) respiration.

## Fungal diversity (an example of microbial diversity)

Soil fungal diversity across Europe varies in terms of number of species, their relative abundance and distribution according to land use (forest, grassland and arable), soil and climatic parameters. Fungal diversity (Shannon index) was lowest in forestry sites and greatest in arable soils. The highest abundances of DNA (measured by quantitative qPCR) were found in Boreal forestry sites and lowest in Mediterranean soils and in arable sites. Soil pH had a significant impact on the community structures of fungal diversity, showing a positive response to diversity and a negative response to the abundance of fungi.



Biodiversity	Function
Microbial diversity by TRFLP (eDNA)	
Microbial diversity by PLFA	
Functional Genes [nitrification] (eDNA)	
Functional Genes [denitrification] e(DNA)	
Enchytraeid species diversity	
Micro-arthropod species diversity	
Nematode species diversity	
Bait Lamina	
Nitrification potential	
Microbial Respiration: MSIR (Micro-resp)	
Enzyme Activity	

Table 1. Indicators selected

Photo 1. *Enchytraeus albidus*.

### Enchytraeid diversity (an example of soil fauna diversity)

Enchytraeidae (Oligochaeta, Annelida), also known as potworms, were measured as a key faunal group. More than 30,000 specimens of enchytraeids were extracted from 518 soil cores. Specimens were identified to species *in vivo* and then fixed for morphological scrutiny or DNA barcoding. About 170 species were registered, 79 of which had not previously been described. Most of the new species were found in previously unstudied regions of France, Slovenia or Portugal. Diversity patterns showed a regional component at the species but not at the genus level. Changes in enchytraeid communities (such as species abundance patterns) correlate with changes of soil parameters such as pH and C:N ratios, and they are strikingly paralleled by changes in the microbial communities, which suggest that patterns of soil biodiversity across Europe can be predicted based on soil properties and land use.

### Soil respiration (a measure of soil functioning)

Soil respiration was measured using the MicroResp method, which measures the respiratory response of the soil microbial community to a range of carbon sources. We applied seven different carbon sources, from readily available carbon such as glucose, to complex

recalcitrant carbon sources such as alpha ketoglutarate. The Microresp method measures the microbial response to the range of carbon sources; microbial communities that can respire a wider range of carbon sources are considered to have a better functional capacity in relation to C cycling. Respiration was greatest in the forest soils of the Boreal region. This was due to the high organic status of these soils. pH and soil texture also had a significant impact on the respiration potential of the soils.

### Implications

The data collected as part of this project has significantly increased knowledge of soil biodiversity and functioning across Europe. This information is vital to inform policy decisions on the quality of biodiversity in soils across Europe. In addition, this extensive sampling and analyses of soil biodiversity and function, has provided a blueprint of possible indicators for soil quality monitoring at both national and European scale.

### Acknowledgements

This work is part of the FP7 funded project EcoFINDERS.

### Paper in Nature

EcoFINDERS recently hit a high note when it published in *Nature Climate Change* on a new guild of microbes that mediate against climate change. Nitrous oxide ( $N_2O$ ) is a major greenhouse gas and at least 30% can be attributed to microbial cycling of nitrogen in agriculture. Although the reduction of  $N_2O$  to nitrogen gas ( $N_2$ ) by microorganisms is critical for mitigation, it remains uncertain what determines a soil's capacity to act as a source or sink for  $N_2O$ . A key experiment in EcoFINDERS, using soil from Teagasc experimental farms, demonstrated that the soil  $N_2O$  sink capacity is mostly explained by the abundance and phylogenetic diversity of a newly described  $N_2O$ -reducing microbial group, which mediate the influence of edaphic factors. These microbes convert  $N_2O$  to  $N_2$ , which is the benign component of atmospheric nitrogen. Analyses of interactions and niche preference similarities suggest niche differentiation or even competitive interactions between organisms with different types of the enzyme that converts  $N_2O$  to  $N_2$ . The study was recently published in *Nature Climate Change*: Jones *et al.* (2014) recently identified microbial guild mediates soil  $N_2O$  sink capacity. DOI: 10.1038/NCLIMATE2301



# Soils – the nutrient reservoir

## Nutrient cycling in agricultural systems

Increased nutrient efficiency is a key requirement for farmers if Irish agriculture is to meet production growth targets as set out in *Food Harvest 2020* in an environmentally sustainable manner. When used efficiently, nutrient inputs help to attain target crop yields and ultimately a satisfactory return on investment. However, inefficient nutrient input use can erode farm income and lead to negative environmental impacts on our atmosphere and water bodies in the cases of nitrogen (N) and phosphorus (P) respectively. It is, therefore, important that Irish food production maintains its 'green' image, which results in significant marketing and trading advantages. Improving nutrient-use efficiency requires the adoption of management practices on farms that will increase the proportion of these nutrients recovered in farm output and reduce the amount that is lost to water and the atmosphere. To achieve this, it is essential to balance the nutrients available in the soil, originating from the soil's own supply and fertilizers, with grassland and crop requirement and off-take. Nutrient inputs are expensive with farmers spending approximately €613 million in 2013 on fertilizers, one of the biggest single, direct inputs costs on Irish farms.



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## Making nutrient cycling work on the farm

Plant-available forms of macro- and micronutrients are relatively scarce in the soil. Nutrient cycling is important in order to minimise the adsorption of these nutrients into inert forms or their loss into sensitive environments. Cycling is also imperative to make prudent use of the finite global reserves

of nutrients such as P. Soils play a vital role in this cycling; ideally, soils can: 1) safely accept residues from farms, industries and private households and make maximum use of the nutrients in these residues; 2) sustain the biological fixation of N; 3) match the mineralisation of nutrients to seasonal crop demand; 4) maximise the recovery of nutrients by crops as determined by yield limiting factors such as the availability of other micronutrients; and 5) minimise the risk that the nutrients in crops will, in the end, not be effectively harvested and returned to society. Soil properties affect each of these five aspects of nutrient cycling, and the nutrient efficiency research programme at Teagasc, Johnstown Castle is continuously developing new understanding of the extent to which these interact.

## Towards soil-specific nutrient advice

Different soils have varying capacity to produce grass and crops mainly due to certain physical and chemical characteristics, and the biology and climatic environment in which they reside. For example, recent research has revealed that Irish grassland soils have the capacity to supply large quantities of N (23kg to 114kg N ha<sup>-1</sup>, Figure 1) in the absence of N fertilizer inputs (McDonald *et al.*, 2014) through biological N mineralisation processes. Similarly, studies have shown that different soil types have varying capacities to supply P; this opens the scope for soil-specific fertilizer advice (Wall *et al.*, 2012). Therefore, the requirement for external inputs can be reduced per unit of productivity, by increasing the efficiency with which nutrients are acquired by the crop.

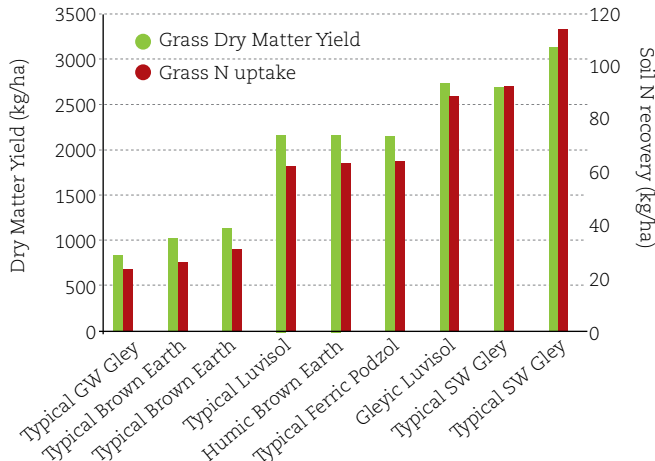
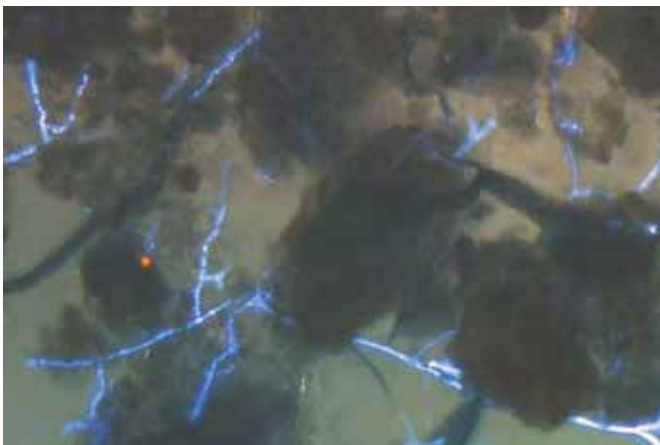


Figure 1. Average soil nitrogen recovery and grass dry matter yield for a range of Irish grassland soils over a five-week grass growth interval under optimised growth conditions

### Getting the balance right

Agriculture cannot be sustained without the replenishment of nutrients removed by crops, as plant growth is dependent upon a continuous supply of mineral nutrients from the soil. Fertilizers are applied to grassland and crops to produce an appropriate level of soil fertility that supports adequate crop growth (and animal performance) and maintain an adequate level of soil fertility by replacing all nutrient off-takes, be they in the forms of milk, meat or crops, (grass/silage). Nutrient deficiency, particularly N, P, Potassium (K) and Sulphur (S) will dramatically reduce output (reduction in annual grass DM production estimated to be  $\sim 1.5t$  DM  $ha^{-1}$  when operating at sub-optimal P and K indices [Index 1 and 2]). At the same time, Ireland has strict targets to meet under the Water Framework Directive (WFD), which requires coherent action by all sectors to reduce nutrient losses to water bodies. The Agricultural Catchments Programme (ACP) evaluates the overall efficiency of the on-farm measures, aimed at minimising the risks from N and P losses from agricultural systems, in six agricultural catchments. A recent census of the soil P status in five of these catchments showed that there was large spatial variability both between and within farms, which reflects historic and current management intensities. Between 74% and 94% of catchment soils had P status at optimum (Index 3) or lower (Index 1 and 2) levels, which have lower risk of P loss (index 4 soils pose a higher P loss risk). These data corroborate an emerging trend in soil fertility at a national level, showing an



Fungal mycelia (showing blue on this image) facilitate nutrient transport through the soil matrix to plants. Photo: Professor Karl Ritz.

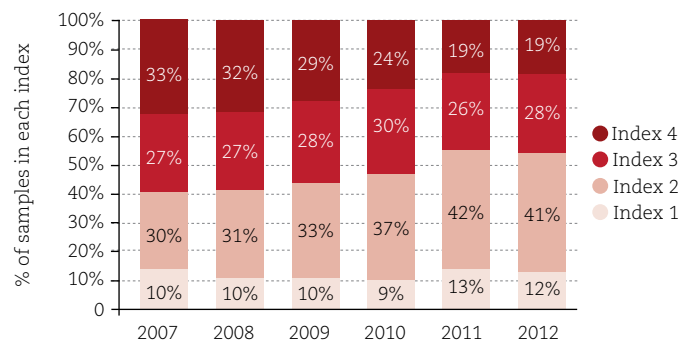
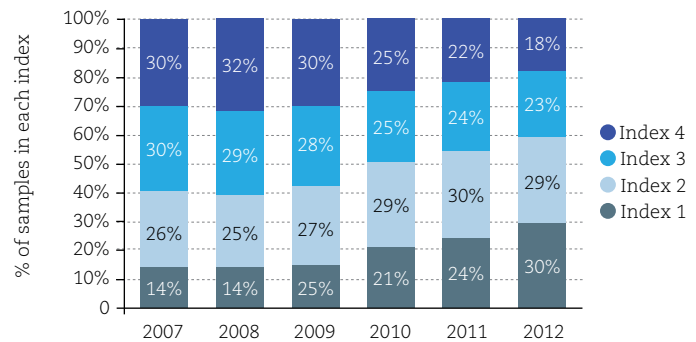


Figure 2. National soil P (blue) and K (red) fertility trends between 2007 and 2013, represented by circa 38,000 soil samples submitted for analysis through Teagasc annually.

overall decline in soil P and K status (Figure 2, Lalor and Wall, 2013). Therefore, it is crucial to get the balance right and maintain soil fertility at optimum levels that allow optimum production while minimising nutrient losses to water.

It has been the responsibility of research staff at Teagasc, Johnstown Castle since the 1940s to develop and help disseminate major and micro-nutrient advice for productive agricultural crops. This is contained in the 'green book'. This work underpins all farming systems from the most intensive dairy systems to the more extensive beef and sheep rearing systems, with the aim of sustaining high and environmentally sustainable levels of production

### Funding

This research is funded by the Department of Agriculture, Food and the Marine and the Teagasc Walsh Fellowship Programme.

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# Productivity at the margins:

## How soil mapping assists in equitable farm supports



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### Introduction

With a proposed spend of €1,370 million, accounting for approximately 30% of total budget over the 2014 to 2020 programming period of the new Rural Development Programme (RDP) and currently extending to over 75% of utilisable agricultural area in Ireland, the Areas of National Constraint (ANC) Scheme is a vital support to the majority of farmers in the State. Payments under the scheme (formerly known as the Disadvantaged Areas Scheme) are targeted at ensuring the maintenance of both productive and environmentally sustainable farming in areas with significantly adverse environmental conditions.

While very important at national level, the ANC Scheme is also one of the European Union's Rural Development Policy with the aim of improving the environment and the countryside by supporting sustainable land management. Areas of constraint are defined as areas "where agricultural production or activity is more difficult because of natural handicaps, including steep slopes in mountain areas, or low soil productivity". The payment scheme has been in place since 1975 to support farming and countryside management in these areas, and to reduce the risk of widespread land abandonment. Currently, 57% of the Utilisable Agricultural Area in the EU is classified as areas of natural constraint, with c. 1.4 million farms receiving direct support under the scheme.

### A new delineation of disadvantaged areas in the EU

In 2003, the European Court of Auditors criticised the designation of areas of disadvantage for farming and the lack of targeting of aid arising from inconsistent use and application of definitions of "disadvantaged area" across Member States. In response, the scheme was reviewed and redefined as those areas suffering exclusively from natural handicaps, and the previous use of socio-economic criteria in classifications was removed. The justification of this approach was

based on the contention that economic and social development in rural areas should be achieved through rural development and cohesion policy measures. The focus of the redefinition was, therefore, to move justification of payments under the less favoured areas (LFA) Scheme solely towards a basis in land maintenance and achievement of sustainable agriculture.

Following expert review and consultation, the European Commission proposed eight criteria for the new delineation of areas of natural constraint based exclusively on limiting biophysical criteria. These were: low temperature; heat stress; soil drainage; soil texture and stoniness; rooting depth; soil salinity, sodicity and gypsum contents; soil moisture balance; and slope.

### Impact of excess soil moisture conditions on farming practices in Atlantic climates

A central challenge to the operation of the initially proposed biophysical criteria in an Irish setting was that the natural handicaps envisaged under the agro-meteorological definitions were primarily based on the effects of higher temperatures, lower precipitation and accordingly low soil moisture content and/or drought type conditions. In Western Europe, however, and particularly in Ireland, the inverse, namely soil moisture excess, is a primary natural handicap.

Excess soil moisture conditions arise from a complex interaction between climatic and pedological variables, including the distribution, intensity and frequency of precipitation, the rate of evapotranspiration by crops and soil, the infiltration and percolation rates of soils, and groundwater and surface water dynamics resulting from landscape topology. Under Atlantic conditions, precipitation is high and annual precipitation exceeds annual evapotranspiration, resulting in positive annual water balances.

In isolation, neither climatic nor pedological variables alone can adequately describe the impact



of excess soil water on the interaction between soils, crops and nutrient dynamics. For example, soils with a low infiltration rate may not be subjected to prolonged excess-soil water conditions in low-rainfall areas, or in areas where high precipitation is limited to short periods of time. Conversely, soils with high infiltration rates may experience extended periods of excess soil moisture in extreme, high-rainfall climates, or in climates where precipitation exceeds evapotranspiration for prolonged periods of time during the growing season.

### Implications for definitions of ANCs

A review was undertaken by Teagasc scientists to examine the impact of excess moisture on farm operation in Atlantic regions in the context of the newly proposed ANC biophysical criteria. This scientific review concluded that excess soil moisture conditions constrain farm practices in challenging farming environments in three primary ways:

1. By constraining grass growth directly, and thereby primary farm productivity;
2. By constraining the utilisation of available herbage by grazing animals or silage harvesting through reduced trafficability of soils, leading to increased requirements for the indoor housing and feeding of farm animals, which is associated with higher direct costs to the farmer; and,
3. By constraining nutrient applications.

Together, these constraints have a significant impact on farm practices and ultimately farm viability.

This review of the proposed criteria, applied to the prevailing biophysical conditions in Ireland, found that none of proposed biophysical criteria, nor any combination of these, satisfactorily described the geographical delineation of areas in Ireland where agricultural productivity was known to be limited (Schulte *et al.*, 2008). The review concluded that the “soil drainage” biophysical criterion for the new delineation of LFAs failed to adequately describe areas subjected to frequent and prolonged excess soil moisture conditions, while the “soil moisture balance” criterion, as proposed, had only been adequately defined for scenarios of soil water deficits and not conditions of soil water excess. The authors



contended that the proposed table of criteria was biased towards delineating LFAs in more continental and Mediterranean climates.

The conclusions of this review were used to support representations to the European Commission on the matter of the proposed criteria for ANC delineation as initially proposed and their inadequacy for application in settings such as Ireland. Based on the strength of the scientific arguments underpinning these representations, a revised set of criteria was issued by the European Commission in 2013 which now include a new criterion, specifically addressing for the first time the issue of excess soil moisture acting as a constraint on farm productivity in Atlantic regions.

### Conclusion

The classification, mapping and delineation of eligible areas of natural constraint is a matter for Member States of the EU and is exclusively conducted in Ireland by the Department of Agriculture, Food and the Marine. However, the scientific support provided by Teagasc scientists has ensured that the unique biophysical conditions prevailing in the Atlantic region are fully taken into account in the newly evolving regulations. The proposed restructuring of the eligibility criteria in the programme ensures recognition of the challenges faced by farmers in a situation of excess soil moisture leading to the maintenance of an equitable application and disbursement of funds and the maintenance of future viable farming activity and rural development in Ireland.

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# Shining a light on soil



Soil analysis is changing, with advances in spectroscopic methods that will bring inexpensive and rapid analysis of soil for farmers and researchers.

For many years now, soil testing using chemical and physical analysis has been routine practice for assessing the quality and function of agricultural soils. Farmers and advisors require information on their soil nutrients, pH, organic matter and minerals so that optimum fertility and soil quality is maintained. Monitoring and measuring these attributes in soils requires robust and reliable methods that can provide important information for farmers and for modelling soil processes into the future.

Traditionally used for identifying compounds, infra-red spectroscopy in the mid and near regions of the spectrum has been adapted for soil analysis with extremely promising results. Infra-red spectroscopy offers a rapid, reliable and non-destructive method for the analysis of multiple soil parameters that avoids the time and costs associated with routine soil analysis.

Soil sampling and testing is at the heart of good nutrient efficiency on the farm, however, conventional soil testing using wet chemistry techniques is both time consuming and costly. New research at Johnstown Castle Laboratories has initiated a soil spectroscopy programme that can provide cheap, rapid and reliable results to farmers on a field-by-field basis providing information on soil quality

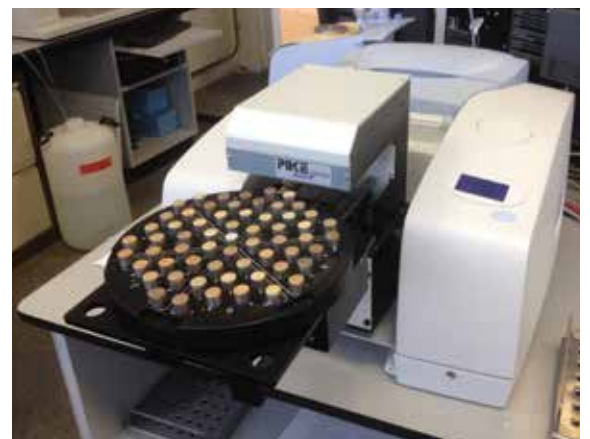
and fertility that is vital for productive agricultural systems.

## What is infra-red spectroscopy?

Infra-red spectroscopy is one of the most common spectroscopic techniques used by chemists to determine functional groups in molecules. It is essentially the absorption of infra-red by materials as the atoms rotate, promoting them to an excited vibrational state. These absorption frequencies are found in the infra-red region of the electromagnetic spectrum and different functional groups in



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Spectroscopic analysis of soil samples using Perkin-Elmer Spectrum 400 at the Soils Analysis Laboratory, Teagasc Johnstown Castle Crops, Environment and Land Use Research Centre

molecules absorb characteristic frequencies of radiation. This information can be represented by an infra-red spectrum, split into regions, the most important of which is often the fingerprint region, which is different for each molecule just like a fingerprint is different for each person.

When infra-red radiation is absorbed by a soil sample, the resulting spectrum gives us a chemical profile of the soil with information about the organic and inorganic constituents of the sample. Interpreting the spectrum of soil sample gives us information about the nature and properties of the soil organic matter and mineralogy, and when we correlate our spectra with reference laboratory data from conventional measurements, we have the potential to predict a multitude of soil attributes from a single spectrum.

### Diffuse reflectance spectroscopy

Diffuse reflectance spectroscopy is used to measure reflectance from a solid sample, and recent advances have shown the application of this technique for the prediction of multiple soil properties from a single spectrum. This technique has been adopted for soil analysis because it is inexpensive, non-destructive and can accurately predict properties such as pH, carbon, iron, aluminium, potassium, magnesium, percentage organic matter and percentage sand, silt and clay. These soil properties have relevance in Irish agriculture from a nutrient management and soil quality perspective.

### Building the tools and capacity at Teagasc

Teagasc Johnstown Castle Laboratories are building the tools and expertise needed to advance our understanding of these new methods for Irish soils by determining the spectral wavebands most suitable for the prediction of relevant soil properties for Irish agriculture. Diffuse reflectance spectroscopy utilises reflected infra-red light to produce spectra from solid samples has proven successful for complex material, such as soil. However, we need to transform these spectra into meaningful results, and chemometrics is the science of extracting the information from a spectral signature by combining with soil data to build a calibration model. Both of these tools in combination will provide us with the ability to predict multiple soil properties from a single spectrum.

### Building a spectral library of Irish soils

The accuracy of predicting soil properties using spectral analysis relies on building a robust calibration model using a large bank of soil data. Our research is currently building a spectral library of Irish soils using archived samples and data from the Irish Soil Information System. The spectral signatures of nearly 900 soil samples and their reference laboratory data are currently being used to build a spectral library of Irish soil types, and the chemometric analysis combine spectral signatures from Irish Soil Information System samples with reference laboratory data to build a calibration model and spectral library. This analysis will build a robust calibration model for the prediction of soil properties from unknown samples. *In situ* measurement of soil properties using hand-held spectrometers provides instant soil results and information on the spatial variation across fields and in the landscape. This will offer farmers an opportunity to assess soil fertility and quality for nutrient efficiency on a field-by-field basis, and these advances will provide Irish agriculture with more cost-effective fertilizer advice and increased efficiency.



Photograph of RemScan, a hand-held instrument for the rapid measurement of total petroleum hydrocarbons (TPH) in soil. Images courtesy of RemScan manufacturer Ziltex. [www.ziltex.com](http://www.ziltex.com)

# The Soil Framework Directive is history

## So, what is the future?



The proposed European Union Soil Framework Directive was officially withdrawn earlier this year. This, however, marks the beginning rather than the end of an era of soil-related policies. Francesca Bampa, Dr Arwyn Jones (European Commission) and Dr Rachel Creamer explain what lies ahead.

Discussions in early 2014 indicated that protecting soils remained an important objective for the Union, despite the fact that, in its present format, the proposal for a Soil Framework Directive could not be agreed by a qualified majority. Consequently, the Commission on April 30, 2014 took the decision to withdraw the proposal for the Directive.

### Emerging soil policies

However, in taking its decision, the Commission stated that it remained committed to the objective of the protection of soil and will examine options on how to best achieve this during the mandate of the next college. This is reflected both in the EU's 7th Environment Action Programme, which guides EU environment policy until 2020; and in an increasing awareness of the importance of soil in other EU policy areas such as agriculture, climate change, development, energy and regional policy. The 7th Environment Action Programme recognises soil degradation as a serious challenge and calls for a binding legal framework to maintain soil quality, using a targeted and proportionate risk-based approach. One example is the Good Agricultural and Environmental Condition (GAECs) of the Common Agricultural Policy, which sets obligatory standards in respect of reducing soil erosion and maintaining soil organic matter levels for farmers in receipt of payments.

### A new approach: land as a resource

During the United Nations 2012 conference on Sustainable Development, known as Rio+20, world leaders agreed on a sustainable goal for land, resulting in a sustainable development goal: zero

### A brief history of the Soil Framework Directive

The proposal for a Soil Framework Directive is part of the 2006 'EU Thematic Strategy for Soil Protection'. This non-legislative approach introduced the concepts of soil protection across the EU, its sustainable use, the preservation of bio-physical functions and the prevention of degradation. It summarised the ecosystem services that soils provide to humankind into five soil functions: 1) production of food and biomass; 2) nutrient cycling; 3) carbon storage; 4) water purification; and 5) providing a habitat for biodiversity. The proposal for a Soil Framework Directive was adopted by the European Parliament, the Committee of the Regions and the Economic and Social Committee. However, discussion in the European Council repeatedly ran into a blocking minority of Member States. In October 2013, the Commission noted that the proposal for a Soil Framework Directive had been pending for eight years during which time no effective action has resulted and would, therefore, examine whether the objective of the proposal would be best served by maintaining or withdrawing it, thus opening the way for an alternative initiative in the next mandate of the Commission and the Parliament.

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# Functional land management:

## How can we get the most from our land?



How can we make sure that ‘growth is green?’ A growing global population, as well as dietary changes are fuelling a demand for increased agricultural output. Concurrently, the agricultural industry is expected to meet increasingly stringent environmental targets. Lilian O’Sullivan reports on a workshop with environmental and agricultural policy makers that explored policy options for ‘Functional Land Management’ that took place in conjunction with the launch of the Irish Soil Information System, for which this special supplement was prepared.

Ireland’s response to the Food Security challenge is captured in the *Food Harvest 2020* policy document (Department of Agriculture Food and the Marine, 2010). Environmental targets include targets such as those set in the Nitrates Directive that sets out a regulatory framework for nutrient management; the Water Framework Directive that requires water bodies to be of good ecological status; the National Biodiversity Plan through the designation of Natura 2000 sites that seeks to halt the loss of biodiversity. This means that there is an urgent and growing pressure on soils to deliver multiple functions simultaneously. This juxtaposition has prompted the development of the concept of Functional Land Management (Schulte *et al.*, 2014).

### Soil functions

Agricultural landscapes provide multiple benefits beyond production that are important to society as a whole. Soil functions refer to the benefits or services that soils provide. Here, these are derived upon the ‘EU Thematic Strategy for soil protection from the European Commission’; five of which are delivered through agriculture:

- **Primary productivity:** refers to agriculture and forestry ‘as we know it’; in the European Union this is driven by the Common Agricultural Policy;
- **Water purification:** is the ability of the soil to purify water from excess nutrients, the demand for which is defined under the Nitrates Directive and the Water Framework Directive;
- **Carbon storage:** refers to the capture of carbon and the maintenance of soil organic matter, both of which are key components of Good Agri-Environmental Conditions (GAEC), as well as the EU Effort Sharing Decision (ESD) and UN Framework Convention on Climate Change (UNFCCC);
- **Habitat:** is the provision of a home or space for soil organisms and biodiversity as defined inter alia by the Habitats and Birds Directives;
- **Nutrient cycling:** is the capacity of the soil to recycle or use external organic nutrients such as manure or sewage sludge; the demand for this function is a derivative of the Nitrates Directive and the Sewage Sludge Directive.

### Matching supply and demand for soil functions

All soils perform multiple functions, but different soils are better at some functions than others. Soil heterogeneity means that challenges to agricultural sustainability will vary by location. The reality is that all soil functions cannot be maximised in all locations at all times. Instead, functional land management seeks to optimise selective functions in specific places or soils so that supply matches demand (Figure 1).

### From theory to practice

Functional Land Management provides a useful theoretical framework to optimise the agronomic and environmental returns – or ‘functionality’ – from our land. But, how can this work in practice, without resorting to delineating and designating areas for land use and management? In principle, the European Union has a history of such incentivisation, largely

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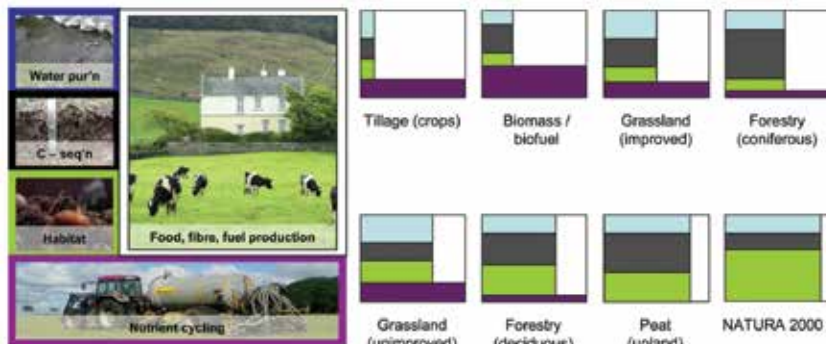


Figure 1. All soils perform all soil functions, but the extent to which each function is performed depends on land use.

through payments under the Common Agricultural Policy, including payments for less favourable areas (European Commission, 2009), designed to support the production of food, fibre and fuel in areas with 'natural handicaps'. Other payments under various national agri-environmental schemes include those aimed at providing a financial incentive to maintain and improve habitats for biodiversity. Therefore, mechanisms for incentivisation are, in principle, already in place.

As part of the launch of the Irish Soil Information System, agricultural and environmental policy stakeholders participated in the first Functional Land Management workshop, at Johnstown Castle, where they were tasked to bring theory into practice. The workshop centred around a typical catchment (see photograph) and policy makers were asked to develop a catchment management plan that would allow the farms in the catchment to pursue Food Harvest 2020 aspirations, while meeting environmental targets. The result was an unexpected level of consensus – but not without a few issues emerging that need further debate.

### Targeting policies: 'chart or chat'?

Notwithstanding the diversity of the stakeholders, there was a high level of agreement on:

- The prioritising of soil functions: overall, primary productivity was ranked the highest priority;
- The catchment management plan. Exceptions were least intensive and most intensive land use types, i.e., commonage areas and tillage areas: no consensus was reached on the optimum role and management of these; and,
- The need for targeting policies towards soil optimisation.

However, opinions diverged on how this targeting could be achieved, ranging from a 'hard' mapping approach to a 'soft' approach tailored around education, knowledge transfer and one-to-one farm visits. A compromise was sought where maps may be used to identify areas where the various types of knowledge transfer are most required.

### Emerging issues

A notable difference emerged with regard to the desired time horizons for agri-environmental policies. While some indicated that agri-environmental policies should include longer term commitments by farmer participants, to ensure a lasting 'legacy' of the financial incentives, others voiced a preference for shorter term agri-environmental policies, explaining how the irreversible nature

### Popular paper

With over 2,000 downloads, the scientific paper, Functional Land Management: a framework for managing soil-based ecosystem services for the sustainable intensification of agriculture, entered the top-10 article list of the journal *Environmental Science & Policy*. It is freely available at: <http://bit.ly/18qezSS>

of some policies may result in a fear for 'policies for life'. This may raise the threshold for the uptake of voluntary agri-environmental policies.

Some results of the workshop will be used in the Soil Status project that assesses Irish policy requirements for soils research, which is due for completion by summer 2015. A full report will be published in an upcoming issue of *TResearch*.

### Acknowledgements

The project, Soil Status, is funded by the Environmental Protection Agency.

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Participants around the model catchment at the recent Functional Land Management workshop.



The highest H<sub>2</sub>S concentrations at 10-second intervals were detected just outside the tractor cab as it was taking a load of SMC to put into a land-spreading trailer.

# Danger of H<sub>2</sub>S in mushroom compost

Following the death of a teenager in 2005 due to hydrogen sulphide gas poisoning during the removal of stored spent mushroom compost for land-spreading, Teagasc has now characterised emissions of the toxic gas associated with this activity and developed guidelines to ensure the safety of operators.



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In the agricultural world, fatal accidents occur every year that are due to poisoning by toxic hydrogen sulphide gas (H<sub>2</sub>S), also known as ‘manure’ gas or ‘slurry’ gas. The reality is that this toxic gas can build up wherever organic-rich material is stored for periods of time, such as liquid manure tanks, slurry tanks, and heaps of organic compost. Under these conditions, the material quickly becomes anaerobic, which favours the growth of bacteria that produce toxic H<sub>2</sub>S gas as a by-product. The gas builds up within the liquid slurry or the compost heap and it is only released into the atmosphere when the slurry or compost is disturbed. A plume of concentrated gas is then released which can kill people and animals within minutes. Concentrations above 500ppm can cause unconsciousness and death in less than a minute while concentrations of 20-500ppm can cause eye and lung irritation and damage. Statutory exposure limits exist to protect workers and, in many countries, including Ireland, these are currently set at 10ppm for 15 minutes (short-term exposure limit

– STEL) and 5ppm for eight hours (time weighted average – TWA). It has been recommended to reduce these to 5ppm (STEL) and 1ppm (TWA).

The dangers of slurry-tank gas are generally widely known among the farming community, where deaths associated with slurry-tank mixing and emptying occur all too regularly. However, the dangers of working with liquid animal manures in other sectors, such as mushroom compost production, are less widely appreciated. A few deaths and serious accidents have occurred around the world associated with liquid manure storage and use at mushroom compost facilities, and these risks should be identified and addressed by compost companies in line with the relevant health and safety guidelines in individual countries. However, the first death due to H<sub>2</sub>S poisoning associated with disturbance and removal of stored spent mushroom compost was reported in Ireland in 2005 – identifying a heretofore unknown risk associated with this activity. Teagasc embarked on a programme of research to identify the patterns of H<sub>2</sub>S emissions in human-occupied zones during disturbance of spent mushroom compost and the results and recommendations are summarised below.

## Outside and inside tractor cabs

Hydrogen sulphide (H<sub>2</sub>S) gas levels were monitored in the human-occupied zone at four Spent Mushroom Compost (SMC) storage sites during SMC removal for spreading on agricultural land. During SMC removal operations, H<sub>2</sub>S gas monitors were mounted on the outside of the tractor, positioned at the SMC periphery and worn by individual tractor drivers. The highest



SMCs stored under cover and protected from rain had lower H<sub>2</sub>S emissions during compost disturbance.

H<sub>2</sub>S concentrations at 10-second intervals were detected just outside the tractor cab as it was taking a load of SMC to put into a land-spreading trailer (Fig 1). Concentrations as high as 454ppm were detected at the outside storage sites and 214ppm at storage sites under cover. The tractor driver is within the closed cab of the tractor during this operation, but, none-the-less, concentrations inside the tractor cab reached as high as 100+ppm at the outdoor storage sites and 51ppm at the indoor storage sites (100ppm is the limit of detection of the personal monitors used by tractor drivers). Thus, H<sub>2</sub>S is clearly infiltrating the tractor cab during the SMC removal operations and, although the concentrations inside cabs are reduced to about a quarter of the concentration outside the cab, in many cases there is only one driver who operates the tractors of both vehicles – the SMC loader and the SMC spreader, so he is exposed to the higher concentrations outside the loader tractor cab when he dismounts. As H<sub>2</sub>S is a gas, the concentration in the air fluctuates as it is dispersed and diluted in the air by air currents and tractor movements, but as it is heavier than air, on still days and when there are no tractor movements there will be a tendency for it to settle in the vicinity and dissipate slowly. Concentrations as high as 250ppm were detected at the edges of the SMC storage areas, up to 10m from the tractor activity – indicating that toxic gas levels can still occur at a distance from the activity itself.

### Outdoor vs. indoor SMC storage

H<sub>2</sub>S gas is produced from organic matter under anaerobic conditions associated with high moisture contents. Our research has indicated that SMCs stored under cover and protected from rain had average moisture contents of 53-65% compared with SMC stored outdoors where average moisture contents were 66-72%; and this was reflected in lower H<sub>2</sub>S emissions during compost disturbance from SMC stored under cover. The lowest H<sub>2</sub>S concentrations measured in this study were at a small SMC storage site where the average moisture content of the SMC was 53-63%. A larger heap stored undercover was not as dry at 62-65% moisture content and this was reflected in higher H<sub>2</sub>S emissions compared with the smaller site. Thus, where possible, SMC should be stored in smaller heaps that are protected from rainfall in order to facilitate drying-out and thereby reduce the potential for high levels of H<sub>2</sub>S to be produced.

The H<sub>2</sub>S levels at the large indoor stored heap were much higher than anticipated, given the much lower moisture content of the material. The large heap stored under cover also tended to get much hotter (36-51°C) than the smaller indoor heap (33-41°C) or outdoor stored heaps (24-36°C) and it is likely that the higher temperatures increase the activity of thermophilic H<sub>2</sub>S-producing bacteria, counteracting the reduced activity due to the lower moisture content, but that hypothesis needs to be tested.

## Recommendations

Given this new information, those who store and handle SMC should review their management system to eliminate or reduce the risk to operators of H<sub>2</sub>S exposure in the workplace. A number of recommendations are given that aim (a) to reduce the potential for H<sub>2</sub>S emissions and (b) to change work practices to minimise exposure risks.

### Recommendations to reduce the potential for H<sub>2</sub>S emissions from stored SMC:

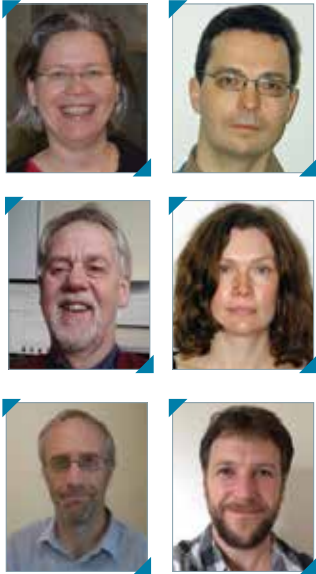
1. Where possible, SMC should be stored under cover (i.e. open-sided barn construction) to prevent rainfall landing on the SMC, thereby decreasing the moisture content and reducing the potential for excessive H<sub>2</sub>S accumulation
2. SMC should be stored in small heaps, where possible, to prevent excessive production and build-up of H<sub>2</sub>S associated with larger heaps
3. SMC disturbance and removal should only be done when wind speeds are at least > 6m/s (moderate breeze) to facilitate dissipation and dilution of any H<sub>2</sub>S emissions

### Recommendations to minimise H<sub>2</sub>S exposure risks when working with stored SMC:

4. Tractor cabs should be maintained in a fit state of repair.
5. Drivers of SMC loader tractors should wear a personal H<sub>2</sub>S monitor and be trained in its operation.
6. Drivers of SMC loader tractors should take a short break every hour away from the SMC storage site
7. Drivers of SMC loader tractors should carry a full face gas mask fitted with an appropriate H<sub>2</sub>S filter in the tractor cab when working with SMC, in case of emergencies, and be trained in its use and maintenance

This article is based on a paper recently published in the *Journal of Agricultural Safety and Health*, where it received a 2014 ASABE Superior Paper Award from the American Society of Agricultural and Biological Engineers. It is available on: <http://t-stor.teagasc.ie/>

# Unravelling the genetic code of ryegrass



Researchers from Teagasc and the James Hutton Institute are working on unravelling the genetic code of perennial ryegrass (*Lolium perenne*), one of the most important forage grasses of temperate grasslands.

seek to understand the genetic basis of important characteristics of this important forage crop in the hope that this information can also contribute to the genetic improvement of the species. One of the key scientific resources required for these goals is the availability of the DNA sequence of the entire genome of perennial ryegrass. Plant cells harbour three different genomes: the nuclear genome and the two major plastid genomes, the chloroplasts and mitochondria. The nuclear genome is by far the largest of these genomes and harbours all the genetic information. Genes are translated into functional proteins, whose actions and interactions result in the expression of traits exhibited by the plant. Breeding seeks to improve key traits, such as yield, but traits targeted for crop improvement are often very complex and controlled by a large number of genes in the genome. The availability of a genome sequence for perennial ryegrass would allow the development of a full catalogue of the genes in the genome, and would provide a platform for understanding how these genes control agronomically-important characteristics such as flowering, seasonal yield distribution and nutritional quality. In addition, genomic selection approaches in breeding require extensive knowledge of the genome of the organism in question.

Perennial ryegrass (*Lolium perenne*) is the most widely grown grass in temperate grasslands. It features excellent palatability and very good sensory properties, which make it the preferred forage feed for ruminants. Ireland's agricultural output is very much based on milk and beef products, which are generated by providing high quality feed for ruminants. One of the priority activities at Teagasc is the breeding of better perennial ryegrass varieties particularly suited to the extensive pastoral production system envisaged under *Food Harvest 2020*. These varieties will be generated via the perennial ryegrass breeding programme at Teagasc. We hope that it will be possible to augment the breeding process using genomic selection approaches similar to those currently used in cattle breeding. In addition, we

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### Next generation sequencing of genome

The genome of perennial ryegrass has been estimated to be approximately 2.8 billion nucleotides (letters of the genetic code) in length, which is comparable to the size of the human genome. It took more than a decade, and the efforts of a global consortium of research groups to decipher the human genome. However, since the completion of the human genome, DNA sequencing technologies have advanced radically. These 'Next Generation Sequencing' (NGS) approaches allow the rapid generation of large quantities of DNA sequence information at a fraction of the cost and in a fraction of the time of previous technologies. While it is still relatively difficult to create a completely finished sequence in organisms with large and complex genomes, such as perennial ryegrass, NGS technologies can rapidly produce partial genome sequences that capture a large proportion of the genes.

### Capturing the gene space

In order to move towards a better level of characterisation of the perennial ryegrass genome, we have just completed the first phase of an experiment to sequence the gene-rich portions of the genome using an approach called 'shotgun sequencing'. In this approach, the DNA from many copies of the perennial ryegrass genome was broken randomly into many millions of short fragments of various sizes. These fragments (reads) were sequenced using powerful NGS-based approaches, and subsequently reassembled into larger fragments, called contigs and scaffolds) representing long stretches of the perennial ryegrass genome (Figure 1). Plant genomes are complex, with a very high content of repetitive DNA, and producing a full draft sequence of each individual chromosome of a plant species requires many additional steps. Thus we did not expect this strategy to produce a complete sequence of the entire perennial ryegrass genome. However, in other plant species, this type of approach has very successfully resulted in sequencing the portion of the genome in which the majority of genes are located (the 'gene space'). This is

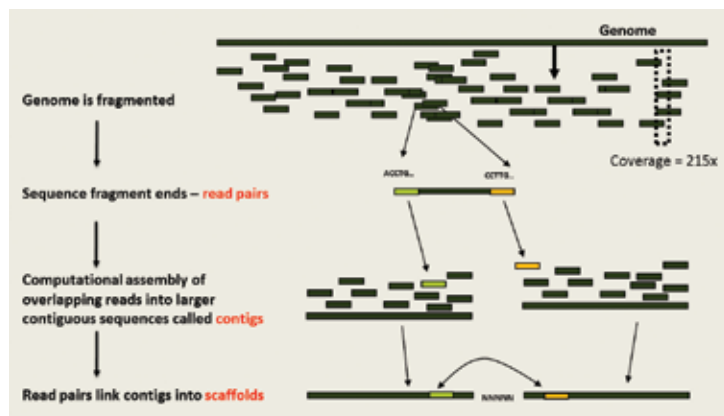


Figure 1. Genome assembly using CLC Assembly Cell, with  $\kappa$ -mer 'word' length of 41 bases, and scaffolded using SSPACE software (Boetzer et al. 2011: *Bioinformatics* 27(4):578-9 with permission).

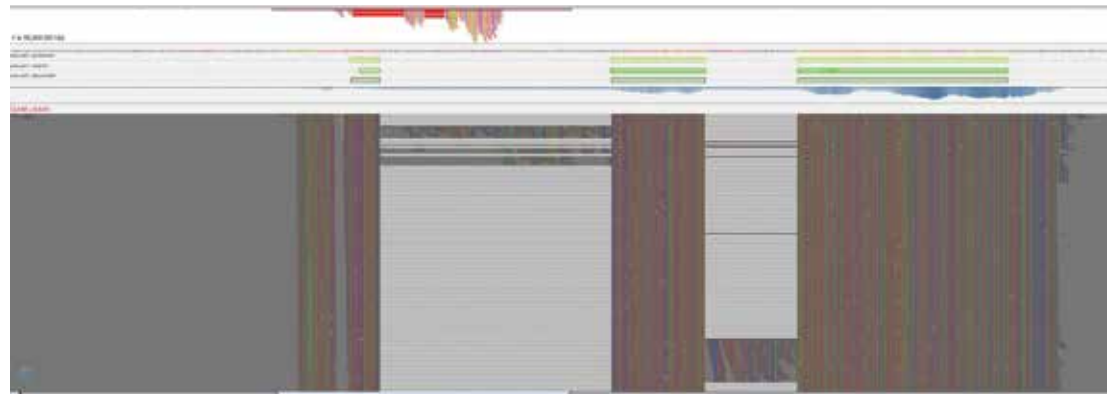


Figure 2: Sample view of RNA-seq reads corresponding to CslF6 gene aligned to genomic scaffold using Tablet software (Milne et al. 2013: *Briefings in Bioinformatics* 14(2): 193-202 with permission) and compared to homology with barley, rice and *Brachypodium* peptides.

because, in plants, most genes occur in large islands of less repetitive DNA located away from the centre of the chromosomes, which harbour large quantities of repetitive DNA. During the shotgun sequencing process, which is based on assembling reads into larger contigs and scaffolds by identifying overlaps between them, the less complex, gene-rich portion of the genome assembles relatively easily. The more complex, gene-poor regions require a much greater effort to assemble. Thus, the majority of the gene space can be captured, relatively cost effectively, using NGS-based sequencing approaches.

### Sequencing of Teagasc ryegrass inbred line

For this sequencing project we used a Teagasc-developed perennial ryegrass inbred line. A range of genomic libraries were made (short insert paired end libraries with an insert size of about 500bp, 3kB, 8kB and 40kB mate pair [MP] and long jumping distance [LJD] libraries) from the DNA of this inbred line and were subjected to massively parallel sequencing using the IlluminaGAII and Illumina HiSeq2000 platforms. After sequencing, resulting read files were trimmed, quality checked and genome assembly started. The paired-end libraries formed the core of the genome assembly and the MP and LJD libraries were used for scaffolding (putting larger junks of assembled DNA into larger assembled stretches). For the genome assembly, the software 'CLC Genomics Cell' (CLC Aarhus, Denmark) was used with a  $\kappa$ -mer (all the possible subsequences [of length  $\kappa$ ] from a read) length of 41. Overall, this resulted in 424,750 scaffolds with a N50 size (N50 is a quality parameter for genome assemblies) of 25,000bp. The total length of the assembled scaffolds is 1.1GB. In other words, we have sequenced and assembled approximately 45% of the total perennial ryegrass genome into fragments, and approximately half of this length is captured in chunks that are 25,000 nucleotides or longer. We are currently in the process of annotating these sequences to identify the positions of genes on the sequences using a variety of approaches, including use of gene prediction models and similarity to related grasses and cereals (Figure 2). This will provide us with a comprehensive catalogue of perennial ryegrass genes, which will be a powerful platform for understanding the genetic basis of many key traits in perennial ryegrass. In addition, we are embarking on the first steps towards using this information to enable approaches such as genomic selection in perennial ryegrass breeding.

### Funding

This research is funded by Teagasc core funding.



# CheeseBoard 2015



**Dr Phil Kelly**  
Teagasc Food Research  
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Dr Phil Kelly reports on the outputs of an all-Ireland cheese research initiative.

In 2010, the Department of Agriculture, Food and the Marine launched a call for proposals under its Food Institution Research Measure (FIRM) inviting a collective all-Ireland approach to address a number of priority issues in relation to the Irish cheese industry. The research call came on foot of the Department's launch of its major food policy document – Food Harvest 2020 – which forecasts a substantial expansion in Irish cheese production.

'CheeseBoard 2015' was adopted as masthead for a successful Teagasc-led proposal in collaboration with University College Cork (UCC), University of Limerick (UL), University College Dublin (UCD) and Agri-Food and Biosciences Institute, Northern Ireland (AFBI) – loosely referred to as the Irish Cheese Research Consortium (ICRC). The '2015' date also coincides with the lifting of EU Milk Quota restrictions and the prospects for increased milk production.

## Drivers of consumer choice

Interpretation of market and consumer trends is of utmost importance at the ideation stage of new product development of any food category. There are many consumer trends currently in vogue, which cheese is ideally positioned to exploit in terms of new product development. Aging population, sustainability, as well as the positive health image protein is currently experiencing, play an integral role in concept ideation for new cheese products or in developing alternative marketing strategies. Teagasc Food Research Centre, Ashtown (Dr Sinead McCarthy), in collaboration with University College Cork, is addressing current consumer issues that will impact on incremental innovation and long-term enduring trends impacting on cheese over the next decade. A range of cheese concepts is employed to convey trending influences.



### Reduced fat/salt cheeses

A survey of retailed Cheddar cheese, undertaken at Teagasc Moorepark (Professor Tim Guinee), indicated significant intra- and inter-brand variation in salt content. Salt variation was more pronounced in 'mild' labelled cheese than in the 'mature' category. Thus, it is advised that more attention needs to be paid to the control of salt addition during manufacture.

Meanwhile, a large database has been compiled throughout ripening following the experimental preparation of 36 cheddar cheeses that probed the effects of three levels of salt at different fat contents (full-fat, reduced-fat and half-fat). Lowering the fat content of cheddar from 33% to 16% results in significant increases in the firmness, fracture stress and fracture strain of the cheese. Reducing salt content from 1.7% to 0.91%, on the other hand, had the opposite effect.

During simulated cooking tests, fat reduction increased the work required to stretch melted cheese, while lowering salt content had the opposite effect – flowability increased. Overall, the effects of reducing fat and salt are interactive, e.g., the effects of reducing salt content depend on the level of salt reduction, fat content, and also the particular property of the cheese.

Meanwhile, University of Limerick's (Professor Martin Wilkinson) collaboration with Teagasc-led large-scale cheddar cheese trials tracked the effects of reducing salt and fat levels on the microbiology and enzymology of cheeses during ripening. Some differences in the release of intracellular enzymes were noted in cheeses made with a commercial-mixed culture starter. Flow cytometry is being used to monitor the response of starter strains to various salt concentrations according to the percentage of live, dead or permeabilised cells, while the Pearce activity test is providing insights into changes in cell autolysis and intracellular peptidase release during storage. This information will be used subsequently to optimise the selection of starter blends for reduced salt and fat.

### Cheddar cheese manufacture

Another approach at University College Cork (Professor Douwe van Sinderen) for optimising flavour development in half-fat reduced salt cheese via culture manipulation and selection is being realised through the application of a combination of post-genomic methodologies and biochemical screening and evaluation in model systems. Comparative genomic analysis is being performed on lactococcal strains for which complete genome sequences are publicly available and which have been sequenced as part of this project. Phenotypic properties e.g. peptidase activity, lipolysis and free amino acid metabolism have been investigated to assess the contribution of these strains to early flavour development during ripening of half-fat, reduced-sodium cheeses. Data from these analyses will be combined with the presence/absence of genes from the genomic analysis to deliver markers for selection of novel starters for half-fat, reduced-sodium cheese.

### Applications for cheese curd

Building on its expertise on rennet casein-based cheese matrices, University College Dublin (Professor Dolores O'Riordan) is focused on exploring the crucial influence of calcium-chelating salts (CCS) on the manufacture and functionality of low-fat processed cheese. It is now established that the widely used CCS, sodium phosphate and citrate interact with calcium and casein in very different ways. Citrates form soluble chelates with calcium and increase protein solubility substantially, whereas phosphates form insoluble

complexes with calcium and are less effective in increasing casein solubility. This deepening understanding of the interaction between CCS, casein and calcium allows functional processed cheese matrices to be formulated from casein curd with a bespoke mineral profile without the use of calcium chelating salts – a potentially important means of reducing the sodium content of such products.

### Cheese as a vector

Teagasc Moorepark (Dr Linda Giblin and Dr Tom Beresford), in conjunction with UCC (Professor Kevin Cashman), is investigating the ability of vitamin D-fortified, reduced-fat cheddar cheese to deliver vitamin D to the body. Vitamin D deficiency (25(OH)D serum level of < 20ng/ml) has been implicated in skeletal and non-skeletal health disorders, including obesity. A murine trial is investigating the health benefits of a 12-week diet containing vitamin D-fortified, reduced-fat cheddar cheese. Body weight is measured throughout the trial and, at the end blood and tissue will be harvested to assess the health benefits at a cellular level. Supporting tissue culture work looks at the interaction between adipocytes, cheese digests and vitamin D, with particular emphasis on storage and bioactivation.

### Prediction of trans fatty acids

Teagasc Ashtown (Professor Gerry Downey) is developing a rapid and non-destructive method to predict naturally-occurring (NT), industrially-manufactured (MT) and total trans fatty acids (TT) in Irish dairy products such as cheddar cheese, butter, dairy spreads using near-infrared (NIR) and Fourier-transform mid-infrared (FT-IR) spectroscopy with multivariate data analysis. Gas chromatography analysis provided reference chemical data. Models for NT, MT and TT predictions in each type of dairy product have been developed. Models based on NIR or FT-IR predicted NT and TT content in butter with acceptable accuracy; best models showed very high correlation coefficients and low prediction errors for both NT and TT measurement. However, model performance for the predictions of NT, MT and TT in cheddar cheese/dairy spreads and MT in butter was poor.

### Funding

This research was funded by the Department of Agriculture, Food and the Marine's Food Institution Research Measure (FIRM)

### References

For further information, visit the project website: [www.cheeseboard2015.com](http://www.cheeseboard2015.com)

### CheeseBoard 2015

Project coordinator: Dr Phil Kelly.  
Project investigators: Professor Tim Guinee (Teagasc Moorepark); Professor Martin Wilkinson (UL); Professor Douwe van Sinderen (UCC); Professor Paul McSweeney (UCC); Professor Dolores O'Riordan (UCD); Dr Tom Beresford (Teagasc Moorepark); Dr Linda Giblin (Teagasc Moorepark); Dr Diarmuid Sheehan (Teagasc Moorepark); Dr Paul Cotter (Teagasc Moorepark); Professor Gerry Downey (Teagasc Ashtown); Dr Sinead McCarthy (Teagasc Ashtown); Dr Kieran Kilcawley (Teagasc, Moorepark); Dr Mary McCarthy (UCC); and Dr Ann Fearon, (AFBI).

# Consumer meat quality expectations



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Senior Lecturer, Department of  
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Agrifood Business and Spatial  
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Opportunity exists in the use of extrinsic cues to convey messages of quality to the consumer, who has historically used intrinsic cues to make quality judgments.

As global meat consumption continues to grow, communication with consumers is an important consideration for the meat industry, especially in developed markets.

The global market for meat is expanding. Along with growth in population and income, changing consumer preferences is a key driver of demand. A paper published by Henchion *et al.* (2014) highlights the changing quality requirements of discerning consumers and considers the implications of these on quality expectations. In this article, some global meat consumption trends are presented, with attention drawn to the importance of establishing relevant and effective cues (signals) to communicate about different aspects of quality, particularly in markets where meat consumption per capita may have peaked.

## Trends in meat consumption

Aggregate global meat consumption grew by almost 60% between 1990 and 2009 with per capita consumption increasing by 25% during the same period (Henchion *et al.*, 2014). Population and income growth provide an explanation for much of this. However, growth rates varied by meat type; upward for white meats and downward for red meats. This pattern reflects the real price of beef being higher than poultry and pigmeat in most countries, and also

differences in product characteristics and consumer perceptions.

In the context of a growing world population and favourable global economic projections, meat consumption is expected to continue to increase. Most growth is expected from Asia, Latin America and the Middle East. In contrast, overall consumption is expected to decline in some developed countries. Furthermore, meat consumption per capita seems to have peaked in some countries and individual preferences, based on changing demographic characteristics, increased health and dietary awareness and increased interest in meat production systems, animal welfare and food safety, will increasingly influence meat consumption. Thus, while developed countries offer the opportunity for higher margins, changing consumer preferences demand that considerable attention be given to producing differentiated meat products to maintain sales. Furthermore, the industry must pay attention to consumer requirements relating to all stages of the supply chain and ensure effective communication of relevant need-satisfying product benefits.

Most consumers do not spend a lot of time in assessing the relative benefits of an array of products. They filter out 'superfluous information' and base their assessments on a small number of information cues. These cues hold specific meanings for consumers that are related to need satisfaction, and thus guide choices. Therefore, when introducing new quality attributes, companies face challenges, firstly,

in attracting consumer attention and, secondly, in ensuring that desired meanings are embedded in the minds of the consumers. In the case of beef, this could present a particular opportunity as well as a challenge. Historically, beef consumers have relied on *intrinsic* information cues (inherent visible characteristics of the product, e.g., colour) to make quality judgments. However, due to a relatively weak link between intrinsic cues and experienced quality, many consumers' quality expectations were not being reached. This undermined consumer confidence in the sector and resulted in dissatisfaction. Misplaced reliance on intrinsic quality cues is, in part, due to the limited availability of meaningful *extrinsic* cues (information related to the product that is not physically part of the product, e.g., quality labels) to support quality judgements. Thus, opportunity lies in the use of extrinsic cues to convey all forms of quality and the challenge lies in ensuring that these are used and valued by consumers.

### Meat quality research

To support consumer quality assessments, research is currently underway in Teagasc and elsewhere, to improve understanding of the molecular or biological components of meat quality. This is expected to be beneficial in terms of optimising quality management systems and providing quality assurance. Furthermore, some supply chain systems have already been developed that identify and control production and processing factors that affect aspects of quality. For example, the Palatability Assured Critical Control Point (PACCP) system predicts the palatability of the final product based on information about the animal and how it was produced and processed. Quality labels associated with such systems have the potential to replace traditionally used intrinsic cues and better align consumer expectations and experiences. Importantly, communication of these systems requires the creation of a meaningful connection/link between the product quality label and the consumer's quality expectations.

### Motives for choosing meat

In developed countries, in addition to requiring consistently high eating quality, higher order motives can play a central role in food choices. For example, meat choice criteria can involve moral and ethical considerations combined with desires for healthier products. While consumers are able to evaluate eating experiences, it is not possible for them to personally assess if a meat is produced in an environmentally and ethically sound manner. They have to trust that what is communicated via extrinsic cues is true. Such credence attributes place particular demands on the meat supply chain system, e.g., in terms of the need to follow, document and validate particular practices. Bord Bia Quality Assurance Schemes have operated on this principle for many years, where schemes that are independently verified and audited provide the 'platform for consumer promotion of product quality'.

### Creating cues for choice

As previously mentioned, consumers filter out much of the available information. Added to this is that selection and use of cues is not standard across consumers. This suggests that creating cues that support quality evaluations across a range of purchase motives, while challenging, may be useful. Indeed, designation of origin and geographical indication bestow specific quality characteristics on many foods that span a range of purchasing motives (including

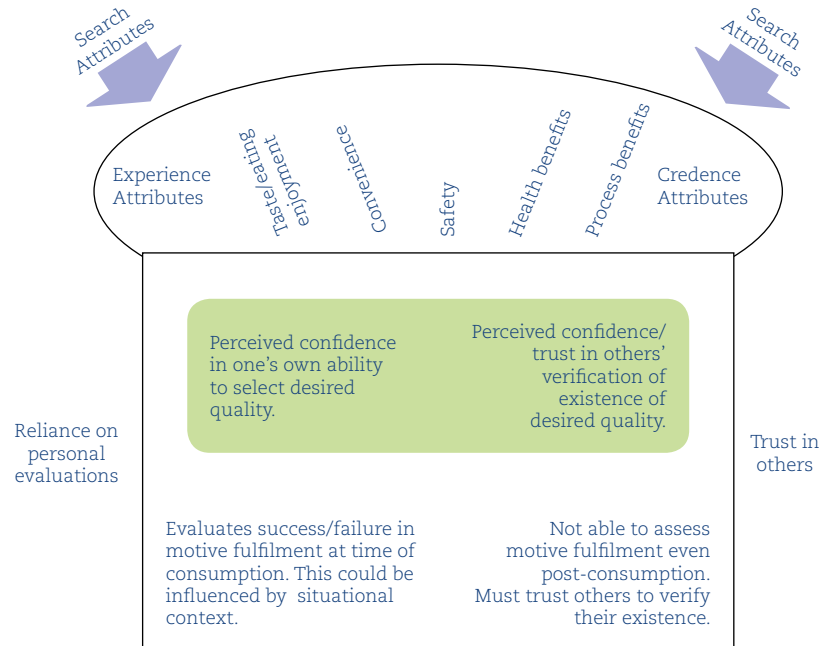


Figure 1: Quality evaluations: the role of trust in others and confidence in self.

eating enjoyment, sustainability and egalitarianism). Furthermore, labels relating to animal feed have been noted as important in inferring safety/health quality, while region-of-origin labelled meat has strong appeal for health-orientated consumers. However, it is the translation of these cues into quality expectations that will determine choice.

### Market segmentation

In trying to use the wide range of quality attributes that influence choice, or to create new quality attributes, it is important to understand how consumers form quality expectations. Historical, social and cultural factors need to be taken into account. Thus, market segmentation is necessary to ensure that meaningful links can be created between products and consumers. A range of market opportunities exist for meat, from differentiation based on experience attributes (e.g., sensory) to credence attributes. Extrinsic cues will most likely play a greater role in the future in forming expectations of experience quality, due to the aforementioned shortcoming of intrinsic cues. The potential market positioning approaches are many and varied, and the implications for different stages within the supply chain need to be considered.

In conclusion, there is ample room for the development of consumer-led differentiated meat products for high-value markets. Improved understanding of the consumer perspective in relation to quality will support this. The authors are currently conducting an international review to identify the quality attributes of importance in different markets. Results from this are expected to be available early in 2015.

This article is based on: Henchion, M., McCarthy, M. Resconi, V. and Troy, D., (2014) 'Meat consumption: Trends and quality matters'. *Meat Science*, 98: 561-568.

### Acknowledgement

This project is funded by the Department of Agriculture, Food and the Marine's Research Stimulus Fund.

## Events

### NOVEMBER

9-16 November

Teagasc locations nationwide

#### Science Week

Teagasc proudly supports this initiative, which is coordinated by SFI Discover, the education-outreach programme of Science Foundation Ireland, by holding events at its Research and Education Centres. The aim of Science Week is to promote the relevance of science, technology, engineering and maths (STEM) in our everyday lives and to demonstrate their importance to the future development of Irish society and to the economy.

Contact: [catriona.boyle@teagasc.ie](mailto:catriona.boyle@teagasc.ie) <http://www.scienceweek.ie>

12-13 November

Clarion Hotel, Cork City

#### Cheese Symposium 2014

Organised by Teagasc in collaboration with University College Cork and INRA (French National Institute for Agricultural Research), this 9th Cheese Symposium is an international event hosting 35 speakers from 17 countries, including expert key-note presentations. The symposium incorporates topical thematic areas in cheese research such as; Health & Cheese, Cheese Quality, Structure Function, Safety, Sensory & Flavour Chemistry, Processability & New Technologies, and Cheese Markets and Trends. Key note presentations will be given by internationally renowned experts from both academia and industry.

[http://www.teagasc.ie/events/2014/cheese\\_symposium/](http://www.teagasc.ie/events/2014/cheese_symposium/)

Follow the cheese symposium on Twitter @cheesesymposium

13 November

Tullamore Court Hotel

#### National Agrienvironment Conference 2014

The Conference will focus on the environmental policy challenges facing Irish agriculture. Delegates will be addressed by a strong panel of experts in agri-environment, environmental economics, agricultural catchments and environmental sustainability. In the afternoon delegates will hear updates from various agri-environmental research projects followed by a session dedicated to Greening and EPA's under the Common Agricultural Policy. The Conference will provide an important update for advisers, consultants, policy makers and farmers who work directly or indirectly with implementing or devising agri-environmental measures. Register for this event on <http://www.eventbrite.ie> or contact Jane Neylon (e-mail: [jane.neylon@teagasc.ie](mailto:jane.neylon@teagasc.ie); Tel: 091 845 211), places are limited so pre-booking is essential. <http://www.teagasc.ie/events/>

19 November

Red Cow Moran Hotel, Dublin

#### National Dairy Conference

The abolition of milk quotas in the spring of 2015 opens a whole new era for the dairy industry, presenting opportunities for young, well-trained farmers to enter the milk production business, exploiting the natural resource that grass production gives Ireland. The Conference is jointly organised by the Department of Agriculture, Food and the Marine and Teagasc and will cover three main themes: the market opportunities for the Irish dairy sector to 2025; the management of risk in a post-quota environment; and the on-farm efficiencies required to drive profitability at farm level. There will be a range of high-level international and domestic speakers to address these themes in separate sessions followed by a panel discussion with relevant stakeholders in each instance. Attendance is free but registration is essential.

<http://www.agriculture.gov.ie>

### DECEMBER

1 December

Shelbourne Hotel, Dublin

#### Teagasc/IFA International Conference on Family Farming (by invite only)

The UN Food and Agricultural Organization (FAO) has designated 2014 as the International Year of Family Farming (IYFF), which aims to raise the profile of family farming and smallholder farming by focusing world attention on its significant role in eradicating hunger and poverty, providing food security and nutrition, improving livelihoods, protecting the environment, and achieving sustainable development. Teagasc, in association with the IFA, will hold a major international conference with President Michael D. Higgins as keynote speaker. The 2014 IYFF will promote broad discussion and cooperation at the national, regional and global levels to increase awareness and understanding of the challenges faced by smallholders and help identify efficient ways to support family farmers.

<http://www.teagasc.ie/events/2014/20141201.asp>

December 2

Slieve Russell Hotel, Ballyconnell, Co. Cavan

December 9

Teagasc Food Research Centre Moorepark, Fermoy, Co. Cork

#### Milk Quality Workshop

The programme for this workshop will include: The effect of milk cooling on milk quality; detection and enumeration of spores in milk; the effect of feed on milk quality; and, mineral concentration in milk. Registration is free.

Contact Niamh O'Brien; Tel: 025 42313 or [niamh.obrien@teagasc.ie](mailto:niamh.obrien@teagasc.ie)

4 December

Teagasc Food Research Centre Moorepark,  
Fermoy, Co. Cork (10:00 – 15:00)

#### Opening the Gateways to Dairy Process Innovation

This Gateways event is a showcase of ideas for ambitious food enterprises – find out about our research and development activities, technologies and supports for the food industry. This unique forum is free of charge and will address the exciting commercial opportunities arising within the dairy industry at this time of milk quota abolition. Attendees will experience presentations by national and international speakers and will have an opportunity to experience at first hand an exhibition of the Teagasc research and development capabilities focused on the dairy sector. Contact: Sheila Morgan; Tel: 025 42603 or [gateways@teagasc.ie](mailto:gateways@teagasc.ie)

5 December

Teagasc Johnstown Castle, Wexford (9.30 am-4 pm)

#### Teagasc Walsh Fellowships Seminar 2014 (by invite only)

Teagasc's Walsh Fellow Postgraduate students will deliver short presentations and the RDS Medal will be awarded for best student presentation. This will be followed by Tom Walsh Centenary lecture (see below). Places limited – please RSVP as soon as possible.

Contact: [hilary.king@teagasc.ie](mailto:hilary.king@teagasc.ie) <http://www.teagasc.ie/research/>

5 December

Teagasc Johnstown Castle, Wexford

#### Centenary Lecture celebrating Dr Tom Walsh (by invite only)

Following the Walsh Fellowships seminar (see above), a special lecture will be held in Johnstown Castle, Wexford to mark the centenary of the birth of the late Dr Tom Walsh. Dr Walsh was the first Director of An Foras Taluntais (AFT), and later of ACOT (AFT and ACOT merged to form Teagasc in 1988) and made fundamental contributions to the development of Irish agriculture, the economy and society. The lecture will be delivered by Professor John Ryan on the 'Evolution and Achievements of Irish Soil Science'. Professor Ryan is himself an internationally distinguished soil scientist and was the recipient of the prestigious International Service in Agronomy Award for 2004 from the American Society of Agronomy. Places limited – please RSVP as soon as possible.

<http://www.teagasc.ie/events/2014/20141205.asp>

For a list of Teagasc's food industry training schedule please see: <http://www.teagasc.ie/food/research/training/schedule.asp>  
For presentations from previous Teagasc events see: <http://www.teagasc.ie/publications/>