



TEAGASC

Research

Volume 10: Number 4. Winter 2015

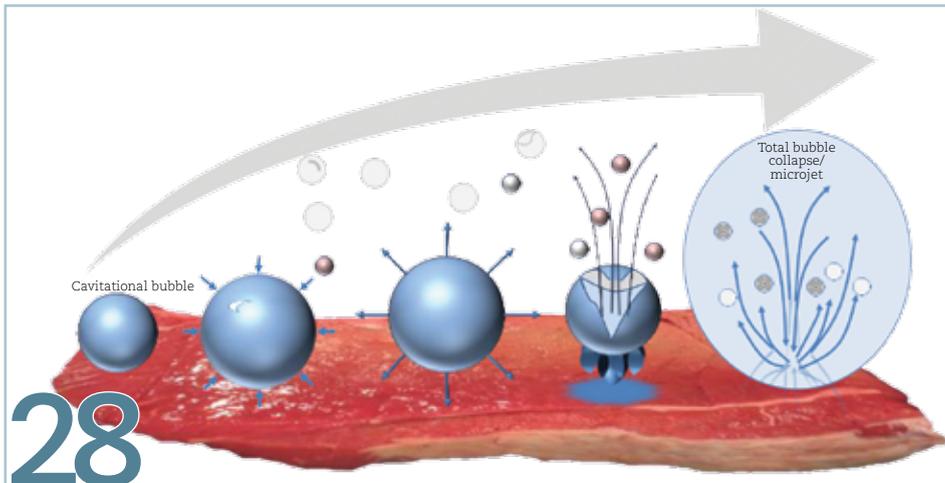
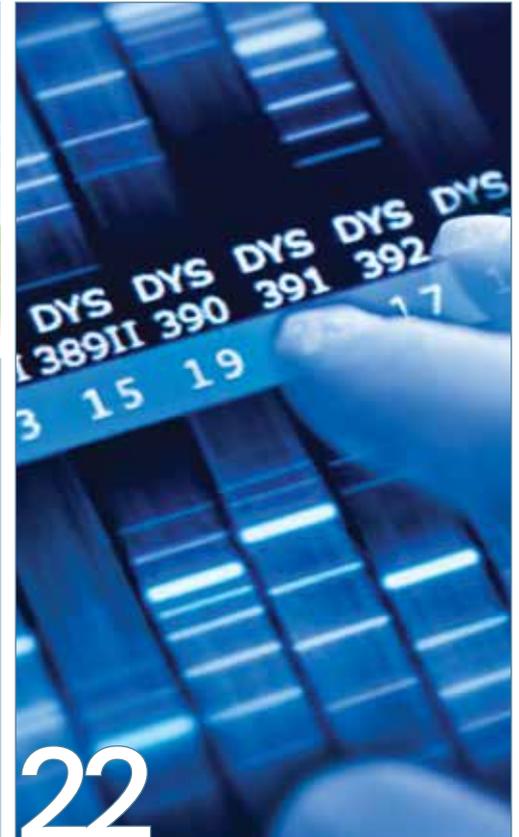
ISSN 1649-8917

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Sustainable food and nutrition security

The future of Ireland's bioeconomy
Whole genome sequencing of cattle
Grass for marginal soils

Contents



3 Editorial
Sustainable food and nutrition security

4 News
4 Celebrating Science Week
5 Mushroom industries 'Harnessing Innovation'
6 IPFN industry workshop

7 Food Security Focus
7 Sustaining the 'Irish potato' in the Ethiopian highlands
8 The Ethiopian highlands: fertile ground for seed potato production?
10 Making the potato work on subsistence farms
12 Putting technology into practice: understanding the adoption of best practices
14 Making science work on smallholder farms
15 Breaking new ground – creating synergies between science and development
16 PROIntensAfrica

17 Feature
17 Science outreach
18 Science Week at Teagasc 2015

20 Animal & Grassland Research and Innovation (AGRI)
20 Alternative breeding strategies using sexed semen
22 Exploiting whole genome sequence

24 Crops, Environment and Land Use (CELU)
24 Festulolium grass for marginal soils
26 Farmland conservation with 2020 vision

28 Food
28 Ultrasound assisted salt diffusion
30 Fortified blended foods using Irish ingredients

32 Rural Economy & Development (RED)
32 New policy impact assessment model – BIO
34 The future is bio
36 Understanding soil testing on dairy farms
38 Costs of production on dairy farms

40 Events

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Cover photo of the Nada family from Ethiopia courtesy of Elizabeth Handy



Sustainable food and nutrition security

According to the latest FAO statistics (2015), an estimated 795 million people (mainly in developing countries) do not have enough food to lead a healthy, active life, and one-in-four of the world's children are stunted. A further two billion individuals suffer from iron deficiency or other micronutrient deficiencies.

Demand for food is growing and supply growth faces a number of constraints. The global population will increase by almost half, with nearly all the growth occurring in developing regions of the world where hunger and poverty are already widespread. Thus, the world's producers will need to provide an estimated 70% more food by 2050 for an additional three billion people, including an extra one billion in the middle class category, in many cases with less land per person, increased competition for scarce water and land resources, and under less predictable circumstances due to increased climatic variability.

An integrated approach is needed to sustainably improve food and nutrition security, covering increased investments in agriculture, social safety nets to protect poor and vulnerable groups, improved global coordination to reduce food price volatility and support for country-led processes for food and nutrition security.

As a critical element of this integrated approach, the world will need to create new scientific and technological innovations resulting from rapid advances in both biophysical and information sciences that can be linked with local knowledge, environmental conditions, farming and changing dietary habits.

In addition to creating new knowledge through investment in research, more effective extension is needed in order to ensure that existing knowledge is transferred to farmers to close gaps in agricultural productivity and sustainability.

As the national body responsible for agricultural research and knowledge transfer in Ireland, Teagasc has a responsibility to support the national effort, spearheaded by Irish Aid, aimed at strengthening agricultural development and reducing hunger and under nutrition in underdeveloped countries. In a time of significant resource constraints, this agenda can be best pursued by aligning and coordinating our efforts and resources with those of other national and international organisations, including Irish Aid and the CGIAR Consortium. This issue of *TResearch* provides some examples of Teagasc's collaborative work of trying to stimulate innovation and promote resilience of local food supplies (see Food Security section).



Dr Lance O'Brien
Foresight and Strategy Manager
Teagasc

Slándáil bia agus cothaithe inbhuanaithe

De réir staitisticí is déanaí na hEagraíochta Bia agus Talmhaíochta (EBT) (2015), níl go leor bia ag thart ar 795 milliún duine (sna tíortha i mbéal forbartha den chuid is mó) chun saol gníomhach sláintiúil a chaitheamh agus tá páiste amháin as ceathrar sa domhan faoi bhun a bhfáis. Tá uireasa iarainn nó uireasaí micreachothaithigh eile ar dhá billiún duine eile.

Tá an t-éileamh ar bhia ag fás agus tá roinnt srianta le sárú maidir le fás soláthair. Tíocfaidh méadú beagnach leath ar dhaoine an domhain, agus tarlóidh an méadú ar fad chor a bheith i réigiúin i mbéal forbartha an domhain áit a bhfuil an t-ocras agus an bhochtaineacht forleathan cheana. Dá bhrí sin, beidh ar tháirgeoirí an domhain thart ar 70% níos mó bia a chur ar fáil faoi 2050 do thrí billiún duine breise, lena n-áirítear billiún amháin eile i gcatagóir na meánaicme, agus i mórán cásanna le níos lú talún in aghaidh an duine, iomaíocht mhéadaithe d'uisce gann agus acmhainní talún, agus faoi chúinsí atá níos deacra a thuar i ngeall ar mhéadú ar an athraitheacht aeráide.

Tá gá le cur chuige comhtháite chun feabhas inbhuanaithe a chur ar shlándáil bia agus cothaithe, a chlúdóidh infheistíochtaí méadaithe sa talmhaíocht, líontáin sábhála sóisialta chun grúpaí bochta agus leochaileacha a chosaint, comhordú domhanda feabhsaithe chun luaineacht praghsanna bia a laghdú agus tacú le próisis arna stiúradh ag tíortha maidir le slándáil bia agus cothaithe.

Mar ghné ríthábhachtach den chur chuige comhtháite seo, beidh ar an domhan nuálaíochtaí úra eolaíochta agus teicneolaíochta a chruthú a bheidh mar thoradh ar ghluaiseachtaí gasta chun tosaigh sna heolaíochtaí bithfhisiceacha agus faisnéise a fhéadfaid a nascadh leis an eolas áitiúil, dálaí comhshaoil, feirmeoireacht agus nósanna cothaithe atá ag athrú.

Chomh maith le heolas úr a chruthú trí infheistíocht i dtaighde, tá gá le leathnú níos éifeachtúla lena chinntiú go ndéanfar an t-eolas atá ann cheana a thabhairt d'fheirmeoirí chun bearnaí i dtáirgiúlacht agus inbhuanaitheacht na talmhaíochta a dhúnadh.

Mar an gcomhlacht náisiúnta atá freagrach as taighde talmhaíochta agus aistriú eolais in Éirinn, tá freagracht ar Teagasc as tacaíocht a thabhairt don iarracht náisiúnta, ar a bhfuil Cúnamh Éireann ina thús cadhnaíochta, atá dírithe ar fhorbairt na talmhaíochta a neartú agus an t-ocras agus an tearc-chothú i dtíortha tearcfhorbartha a laghdú. I dtéarmaí ina bhfuil srianta suntasacha acmhainní, an dóigh is fearr le dul i mbun an chláir oibre seo ná ár n-iarrachtaí agus ár n-acmhainní a ailíniú agus a chomhordú le hiarrachtaí agus acmhainní eagraíochtaí náisiúnta agus idirnáisiúnta eile, lena n-áirítear Cúnamh Éireann agus an Cuibhreannas CGIAR. San eisiúint seo de *TResearch* soláthraítear roinnt samplaí ó obair chomhoibríoch Teagasc maidir le hiarracht a dhéanamh nuálaíochta a spreagadh agus athléimneacht soláthair bia áitiúil a chur chun cinn (féach an rannán Slándáil Bia).

An Dr Lance O'Brien
An Bainisteoir
Fadbhreathnaitheachta agus
Straitéisí, Teagasc

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Published on behalf of Teagasc by:

IFP Media, 31 Deansgrange Road, Blackrock, Co. Dublin.
t 01-289 3305 f 01-289 6406 www.ifpmedia.com
Design: Ciarán Brougham, Martin Whelan
Editorial: Oonagh O'Mahony

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Olivia McAuliffe

Olivia McAuliffe joined Teagasc in 2003 on a contract basis. In 2006, she took on a permanent position in Teagasc's Food Research Centre at Moorepark and today is a Senior Research Officer, at that location. Olivia's research interests focus on the relationship between the bacterial starter cultures used in the production of fermented dairy foods and the bacteriophages that infect them. State-of-the-art developments in genomics and metabolomics provide the tools for a more 'knowledge-based' approach to selection of desirable cultures. By linking genomic traits to phenotypic outputs, her research group is mining the metabolic diversity of starter cultures to select strains with desirable and industrially significant properties, which can impact on both the production and final quality of the product. An in-depth knowledge of properties, such as flavour and texture development, allows starter blends to be 'tailor made' to suit industry needs. This approach also allows for the potential improvement of these and other characteristics in existing strains, which are at the core of the dairy industry. Together with her external collaborators, Olivia's research group also investigates the potential of using bacteriophages, and products derived from them, as biocontrol agents against food-borne pathogenic bacteria including *E. coli*, *Listeria* and *Campylobacter*.

Olivia's research at Teagasc has seen her work on innovation and commercialisation projects with numerous industry collaborators. Throughout her collaborations with a number of leading national and international food companies, Olivia has researched opportunities for the generation of phage-resistant starter cultures for the commercial starter culture industry; developed phage control and detection methods for several dairy plants; as well as exploiting the extensive Teagasc culture collection for cultures, which impart unique flavour and texture attributes for new product development. Her research group continues to work closely with industry, transferring much of the outputs and technology generated to the funding companies. Since being appointed a permanent member of the Teagasc research staff, Olivia has secured over €2 million in funding, much of which has come from private enterprise.

Olivia is also a mentor and supervisor for PhD and MSc students. She is currently overseeing three PhD and one MSc student, as well as supervising post-doctoral and technical staff.

Olivia has contributed as an author to over 75 publications, including 60 journal articles, seven book chapters and 18 senior author publications.

Celebrating Science Week



At a 'Celebration of Irish Science', an event that took place in the Department of the Taoiseach to mark Science Week are (from left to right): An Taoiseach, Enda Kenny, TD; Eimear Gallagher, Teagasc Ashtown Food Research Centre; Frank O'Mara, Head of Research, Teagasc; and Mark Ferguson, Director General of Science Foundation Ireland.

10 Things to Know About...

Six Teagasc researchers featured in RTÉ One television's new science series '10 Things to Know About...', produced by New Decade. Catherine Stanton, Andre Brodkorb, Claire Watkins and Kiera Murphy featured in an episode on gut health. Daire Ó hUallacháin and Sophie Sheriff featured in an episode on water. The shows can be seen on RTÉ Player.



Teagasc's Catherine Stanton on RTÉ One's new science series '10 Things to Know About...'

TED talks



Congratulations to Teagasc Walsh Fellow (and Teagasc Fulbright Scholar recipient) Ruairi Robertson, who was selected to speak at the TEDx Fulbright event in Los Angeles, USA, in September. The talk can be viewed on <https://www.youtube.com/watch?v=awtmTJW9ic8>.

Outlook 2016

At the Outlook 2016 Economic Prospects for Agriculture conference in December, Teagasc economists indicated that overall family farm incomes were down 9% in 2015. Pig prices were down; sheep prices were up, while the output from the tillage sector was down slightly due to lower area. Income levels increased across most farm systems this year, dairy being an exception. Buoyant beef and lamb prices boosted incomes on livestock farms this year. However, average farm income still decreased due to the effect of the falling milk price.

Teagasc economists indicated that family farm incomes could be up by 5% in 2016. Further expansion in milk production, post quota, is expected in 2016. This, coupled with a modest improvement in milk prices, should see dairy farm incomes continue to recover next year. Some of the beef price increase in 2015 is anticipated to be reversed in 2016, as



Trevor Donnellan, Fiona Thorne, Kevin Hanrahan, Thia Hennessy and Michael McKeon at the annual Economic Review and Outlook Conference at the RDS Dublin.

supply of animals increases. A continuing increase in sheep prices and some recovery in both pig prices and grain prices are also anticipated next year. The full Outlook 2016, Economic Prospects for Agriculture report is available at: http://www.teagasc.ie/publications/view_publication.aspx?publicationID=3777

CANtogether conference

Teagasc organised and hosted the first international conference on the Challenges and Innovations in Mixed Farming Systems in November. The conference presented the findings of the FP7 CANtogether project. Participants from 10 European countries attended and the conference was officially opened by Gerry Boyle, Director of Teagasc. The focus of the conference was the sustainability of Mixed Farming Systems from an environmental, economic and social perspective.

International forestry conference

The Extension and Knowledge Exchange Working Party of The International Union of Forest Research Organisation (IUFRO) recently held a conference in Galway. It was jointly organised by Teagasc Forestry Development Department and Oregon State University.

The theme was 'Connecting Research to Practice: The evolving world of extension and knowledge exchange'. A consistent thread among the papers was the need for effective extension to involve a multi-partner approach, including actors such as extension agents, researchers, forest owner co-operatives, industry and other stakeholders. Practice adoption involves taking a 'three dimensional' approach including information leaflets and brochures, group meetings, one-to-one bespoke advice, case study videos, workshops, interactive apps, etc. This signals a trend away from the traditional knowledge-transfer model towards a more multi-dimensional approach focusing on knowledge exchange.



John O'Connell, Limerick, showing IUFRO delegates around his forest where he discussed the harvesting of hurley butts, shiitake mushrooms and firewood from his young ash forest.

Two Irish winners at CommBeBiz Awards

Two Irish projects were named among eight winning projects at the 2015 CommBeBiz Awards. ATBEST: Biogas plant feasibility calculator and VIZZATA: Online software to collect stakeholder opinion (from the FoodRisC project) were the two Irish winners, who will now receive tailored support packages to help them reach their innovation goals, whatever their stage of research or development. Winners will be matched to innovation specialists who can help meet their projects' needs.

"We were looking for ambitious ideas with a unique value proposition clearly differentiated from alternatives already in the marketplace or public domain," said Rhonda Smith, Co-ordinator of CommBeBiz; the EC-funded project working with bioeconomy researchers and their projects to enable effective and speedier transfer of knowledge to the marketplace, to policy-players and for social innovation.

Mushroom industries 'Harnessing Innovation'

The Bord Bia-sponsored, all-Ireland and UK Mushroom Conference and Trade Show was held recently in Monaghan. The conference theme was 'Harnessing Innovation' and brought together growers, scientists and suppliers. Dermot Callaghan, Head of Horticulture at Teagasc and head of the organising committee, told delegates the conference "reflects the progressive and innovative culture in the mushroom industry where entrepreneurial producers grasp every opportunity to increase efficiencies and maximise profits. The industry has a track record of innovating around challenges and today we have one of the most technologically advanced mushroom sectors in the world, which provides a strong platform to meet the challenges of the future."

Bord Bia estimates the combined North and South mushroom production has a farm gate value of €173 million. UK mushroom production is estimated to be worth £115 million at farm gate level. The majority of Irish production (80%) is exported. Bord Bia reported that mushroom sales remain steady both in Ireland and in the UK, Ireland's most important export market.

Walsh Fellowships seminar winners

At the 20th anniversary Teagasc Walsh Fellowships seminar, organised in partnership with the RDS during Science Week, 13 PhD Walsh Fellow students made oral presentations of their research findings, while 23 people presented posters outlining their research. Leanne Roche, Teagasc, Crops Environment and Land-Use Programme, Johnstown Castle won this year's Best Oral Presentation and RDS medal for her research on 'Selecting nitrogen fertiliser sources for improved yield and reduced gaseous emissions in spring barley production systems'.

The joint winners of the best poster presentation were Gemma Torres Sallan and Sarah Ross. Based at the Teagasc Crops, Environment and Land-Use Research Centre, Johnstown Castle, Gemma Torres Sallan's poster was on 'A question of quality: soil carbon sequestration and storage potential of Irish grasslands'. Sarah Ross is based at the Teagasc Food Research Centre, Moorepark, Fermoy, and her poster was on 'Targeting the glycans of bovine milk fat to reduce *E. coli* infection *in vitro*'.

The winner of the Best Food Research Presentation and the Institute of Food Science and Technology Ireland (IFSTI) medal was Tara Battersby, Teagasc Food Research Centre, Ashtown. Her presentation was titled 'Solving the Irish campylobacter problem'. Articles based on the winning presentations will appear in the spring 2016 issue of *TResearch*.



This year's winner Best Oral Presentation and winner of the RDS medal was Leanne Roche, Teagasc, Crops Environment and Land-Use Programme, Johnstown Castle, Wexford.

IPFN industry workshop

The final industry workshop of the Irish Phytochemical Food Network (IPFN) was recently held at Ashtown Research Centre. The IPFN network, made up of partners from Teagasc and five universities, was established through funding from the Department of Agriculture, Food and the Marine and sought to monitor the fate of bioactive compounds in vegetables from field to fork. The project developed new analytical methods for quantifying these compounds, for optimising their accumulation and retention through agronomy and minimal processing, while also demonstrating their positive effect on beneficial gut microbes. Practical examples on how to incorporate these bioactive compounds into model food stuffs was also presented on the day.



Pictured (from left to right) are speakers at the workshop: Mohammad Hossain, Michael Gaffney (IPFN Coordinator), Dilip Rai and Ita White (all Teagasc); Maria Tuohy, NUIG; Enda Cummins, UCD; David O'Beirne, UL; Francis Douglas, FSAI; Nigel Brunton, UCD; Catherine Barry-Ryan, DIT; and Sinead McCarthy, Teagasc.

Opportunities for Irish food industry in publicly-funded research

Members from the food industry, the technology transfer community, academics, and government organisations attended a Teagasc symposium on technology transfer. The symposium is part of the Teagasc Gateways events series, which are focused on brokering relationships between researchers and research output and industry, to stimulate innovation and commercialisation. The symposium emphasised the value of connecting these different communities and presented examples of best practice from the international stage, with talks by representatives from the OECD, tech transfer offices in the US, the UK and Swedish universities and public-private enterprises in Belgium.

"Ireland's food industry is one of our most important export sectors. To remain competitive globally, firms must continually become more innovative. Outputs from Ireland's public research programmes can act

as a major catalyst for developing new products and new markets but only if carefully exploited by the food industry through a variety of effective technology transfer mechanisms. Teagasc implements a novel approach through its Food Gateways Programme to enable food companies to capitalise from publicly-funded research and thus, contribute to Ireland's economic growth," said Declan Troy, Director of Technology Transfer, Teagasc.



Pictured at a Teagasc symposium on technology transfer are (from left to right): Rhonda Smith, Coordinator of H2020 Bioeconomy support action CommBeBiz; James Cunningham, Newcastle University Business School; Magnus Nilsson, Lund University, Sweden; Gerry Boyle, Director, Teagasc; Lesly Millar-Nicholsen, Director, Office of Technology Management, University of Illinois; and Richard Howell, Department of Agriculture, Food and the Marine.

Top papers in dairy science

Two papers written by scientists at Teagasc, Moorepark are in the *Journal of Dairy Science's* top 20 ranked papers since 2014.

Coming in on top of the list is 'Milk production and enteric methane emissions by dairy cows grazing fertilised perennial ryegrass pasture with or without inclusion of white clover' by Enriquez-Hidalgo, D.,

et al. (March 2014) *Journal of Dairy Science*, 97(3): 1400-12.

Number five on the list is 'Short-term response in milk production, dry matter intake, and grazing behaviour of dairy cows to changes in postgrazing sward height' by Ganche, E., *et al.* (May 2014) *Journal of Dairy Science*, 97(5): 3028-41.



Sustaining the 'Irish potato' in the Ethiopian highlands

Over the last decade, sustainable food security has risen towards the top of the international policy agenda. In response, we have seen the emergence of many strategies to address this challenge. Some of these (such as the Food Wise 2025 strategy) are aimed at the sustainable intensification of domestic agriculture with a concomitant growth in exports, but Teagasc has also initiated an International Food Security strategy aimed at supporting the capacity of developing countries to increase their food production, in collaboration with Irish Aid and international actors.

Five years ago, we initiated a pilot project on sustainable potato production in the Chencha region in the southern highlands of Ethiopia. Globally, potatoes are an important crop in the context of food security and food sovereignty: while it needs significant inputs in the form of nutrients and water, it converts these resources into calories more efficiently than other crops. The bulkiness of the potato crop means that it is difficult to transport over long distances, but it has an excellent nutritional profile making it an important crop for local consumption.

However, producing potatoes on subsistence farms is not without problems. As seed potatoes are tubers (vegetative reproduction) rather than a true seed, viruses and other diseases tend to accumulate with each planting season, which can dramatically reduce yield potential. Formal seed potato production systems produce disease-free, laboratory-tested mini-tubers to provide quality planting material. However, the

formal system in Ethiopia only accounts for 3% of seed produced. As a result, actual potato yields have been far below the potential yields. In the absence of formal seed systems, there is a need to develop functioning farmer-to-farmer, or informal, seed systems. In this context, improved agronomy, better access to seed technical information are key to: maintaining the health status of new seed stocks; improve old degenerated stocks; and, ultimately, obtain higher yields.

Our pilot project, known as the Chencha project, has aimed to improve potato-seed systems among subsistence farmers. Teagasc teamed up with a diverse group of key actors that included: Vita, an Irish NGO working with farmers in the Chencha region; Wageningen University and Research Centre; the Ethiopian Institute of Agricultural Research; Arba Minch University; Irish Aid; the Irish Potato Federation; and the International Potato Centre (CIP). Together, we embarked on a multidisciplinary research-for-development project aimed at:

- Improving the technological aspects of seed potato production systems;
- Improving the agronomy and farm management of the farms that are part of the seed potato production system
- Understanding the societal context of seed potato productions, so that our recommendations for improved practices are of relevance and applicable to the subsistence farmers.

We recruited a team of three Walsh Fellowship PhD candidates to study these three aspects: Abdulwahab Abdurahman, Waga Mazengia, and Yenenesh Tadesse. Together, we designed an ambitious monitoring network of 'nested farmers': Yenenesh followed 20 farmers for her in-depth, socioeconomic studies over a two-year period. Of these 20 farmers, 12 were also assessed in Waga's study of agronomic practices. In turn, six of these 12 farms additionally participated in Abdulwahab's field experiments. This allowed us to truly link the results of the three studies. At the same time, we used statistical modelling to ensure that, at each of the three levels, these farm samples proportionally represented the diversity of farmers and farming systems in the Chencha area.

In this special issue of *TResearch*, the Walsh Fellows, now in their final year, report on their findings.

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The first project team meeting took place at a typical homestead in Chencha, in 2011.



The Ethiopian highlands: fertile ground for seed potato production?

The Ethiopian highlands are densely populated and home to millions of smallholder farmers. The area is blessed with cool temperatures and high rainfall, which should make it fertile ground for the production of disease-free seed potatoes. However, Abdulwahab Abdurahman reports that this may not be as easy as previously thought.

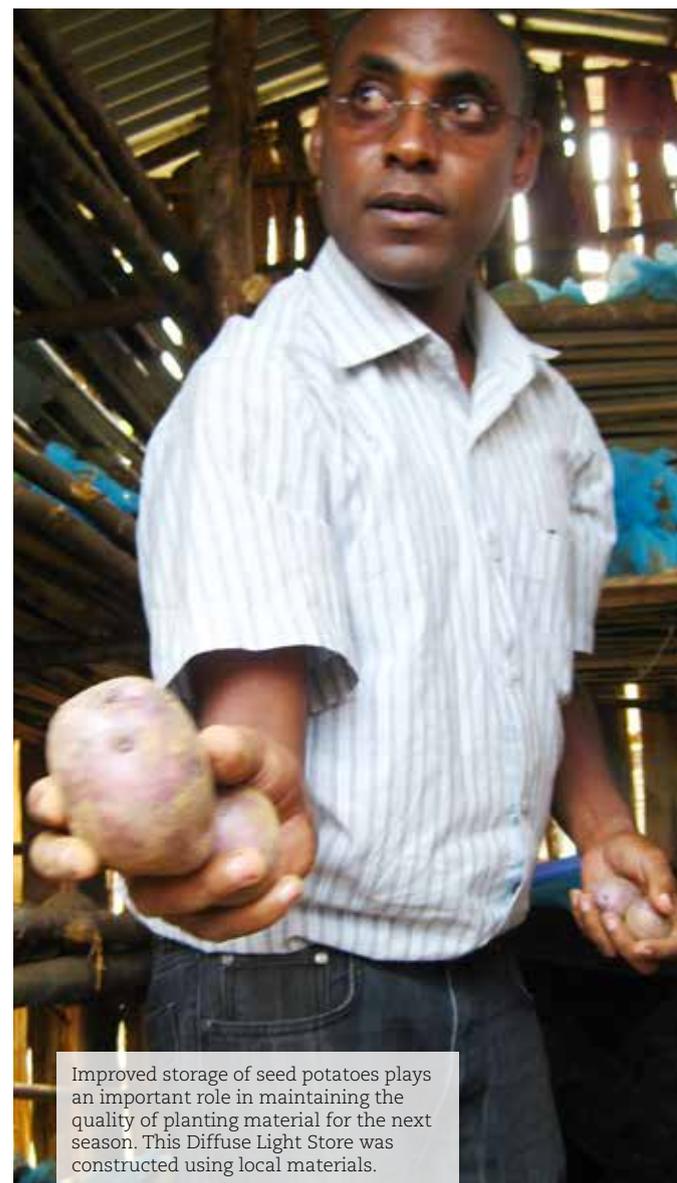
Background

Farms in the south of Ethiopia are very small and highly fragmented: 81% of rural households have less than 1ha and most of these farms are fragmented into smaller plots. The average farm size becomes even smaller in the populous highlands, such as the Chencha district, where 95% of households have less than half a hectare of land. The prospect of increasing crop production by expansion of agricultural land is very unlikely, demanding highly productive and efficient crops such as potato instead.

In Chencha, potato is an important staple crop, with almost every household allocating a small plot of land for the crop each year. Moreover, for poor households it is a hunger breaker because of its short crop cycle compared with cereals. Potato is produced in two growing seasons: the *Belg* season (a short rain season: March to June), during which the bulk of production takes place, and the *Meher* season (a long rain season: July to November). Despite its high potential, however, the actual productivity of potatoes in Ethiopia is very low (8.2t/ha), mainly as a result of the lack of access to quality seed potatoes of disease-resistant varieties.

Seed potato degeneration in Chencha

Seed potato degeneration is defined as the accumulation of pathogens and pests in planting



Improved storage of seed potatoes plays an important role in maintaining the quality of planting material for the next season. This Diffuse Light Store was constructed using local materials.

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Bacterial wilt can cause rapid wilting and rotting of seed and ware potatoes.

material as a result of successive cycles of vegetative propagation causing reduction in progeny yield. We studied the rate of seed degeneration due to virus disease accumulation at three locations in Chencha, ranging in altitude from 2,500m to 2,800m above sea level, starting with laboratory-tested disease free mini-tubers. The results of two successive cycles of propagation in farmers' fields in both the *Meher* and *Belg* seasons indicated the absence of the most important aphid-transmitted viral diseases, i.e., Potato Virus Y (PVY) and Potato Leaf Roll Virus (PLRV), and the presence of mechanically transmitted viruses (PVS and PVX), with no visual symptoms. Indeed, no winged aphids were trapped by yellow water traps in the field. Therefore, in the first instance, we concluded that Chencha is a low-degeneration area for virus diseases and suitable for seed potato production without a need for frequent seed tuber renewal, provided production sites are carefully selected to avoid other soil-borne pathogenic bacteria and that clean material is available.

Reversing degeneration

There was also empirical evidence available that there are simple practices available that can successfully prevent seed degeneration or even reverse it. The best-studied practice is the so-called positive selection: marking vigorous and healthy looking plants before crop senescence and harvesting these plants as seed for the next crop. Positive selection not only slows down degeneration, but can actually improve ('regenerate') degenerated seed over generations. Hence, we started to investigate the mechanisms behind positive selection in improving (regenerating) an otherwise degenerated farm-saved seed.

Bacterial wilt disease of potato in Chencha

However, a wilt disease with the characteristic symptoms of brown rot caused by the bacterium *Ralstonia solanacearum* subsequently affected our trial plots beyond recovery. Bacterial wilt is a soil and seed-borne quarantine disease that causes strong yield declines in ware crops, prevents the use of the tubers as seed, and contaminates the farm for many years. As a result, we adapted and changed the focus of our investigations, to address the emerging and pressing issue of the wilt disease.

Our field observations during the last three years showed that the wilt disease incidence and severity was increasing at an alarming rate from year to year, with complete crop loss in some instances. In the 2015 Belg season, the incidence of the disease had reached 97% per potato farms, based on visual assessment. However, the severity of disease on these farms varied from low infection levels to almost complete infection.

It was not obvious whether the disease is endemic to the district and manifested itself on recently introduced potato varieties, or is a recent introduction brought into the area with infected seed. Understanding the source of the pathogen is crucial to help stop the spread of the disease. For this, the pathogen was isolated from regions of the country known to be both the source of seed potatoes and also endemic for the disease. We subsequently used DNA fingerprinting techniques for the detection, identification and genetic profiling of the pathogen for possible source tracing.



Results and outlook

Our research has shown that *Ralstonia solanacearum* is widely spread in Ethiopia, as well as in Chencha. The bacterium is both seed and soil-borne, and difficult to control by widening the crop rotation; certainly under Chencha conditions it can be latent and, therefore, dangerous if seemingly healthy seed potatoes are transported for planting in warmer, more conducive environments. Moreover, the disease can easily spread through contaminated water and host plants other than potato.

Our research has also confirmed that *Ralstonia* has been endemic in Chencha for many years and is not a recent introduction. Coupled with a low frequency of potato in the rotation, large quantities of bacterial, wilt-free seed will be required to flush the disease from the farming system.

We have identified land in the Chencha region that is free from bacterial wilt and has not previously grown potatoes. This raises the possibility of importing small quantities of tested, disease-free seed, and multiplying these locally to replace local, existing infected stocks. If this local community model proves successful in Chencha, it could be adopted as a model for bacterial wilt mitigation across communities in sub-Saharan Africa.

Bacterial wilt has rapidly developed into a nationwide problem in Ethiopia, threatening the cultivation of potato. In addition to the production model described above, awareness programmes and community-based strategies to increase farm hygiene, as well as designs of an agronomic tool box to control and suppress disease are urgently needed. As a first step in this process, several Ethiopian agronomists have received training on laboratory diagnosis of bacterial wilt disease.

Acknowledgements

This work has been co-financed and supervised by the Teagasc Walsh Fellowships Programme, Wageningen University and Research Centre, and Vita (www.vita.ie).



Making the potato work on subsistence farms

Farm output is increasingly constrained by labour shortages. Use of animal traction is relatively rare and only affordable for better-off farmers.

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Why are subsistence farms in Ethiopia not realising their full productivity potential? In this study, Waga Dersseh holds the farming systems against a scientific light to identify the obstacles, and solutions, to sustainable intensification.

Perhaps contrary to common perceptions, the highlands of southern Ethiopia are characterised by fertile soils and a relatively mild climate. Two rainy seasons allow for two cropping seasons each year without irrigation. The highlands are home to the majority of Ethiopian citizens, most of whom are subsistence farmers. While Ethiopia has seen very rapid economic growth over the last decade, this has materialised largely in urban areas, resulting in rapid urbanisation. By contrast, in rural areas, subsistence farms continue to be characterised by their small size and low productivity. The causes of this agricultural stagnation are manifold, but in this study we assessed the constraints encountered by subsistence farmers, as well as potential pathways to sustainable intensification (i.e. higher outputs without higher environmental impact) of subsistence farms in the Chencha area of southern Ethiopia.

We conducted a household survey to create a baseline of the production system, with a view to quantifying the variation in inputs and outputs and identifying constraints for potato production across a variety of farms in the Chencha district. This was followed by a detailed farm survey on 12 selected farms in 2013 to understand the soil nutrient status, agronomic practices, labour requirements, economic return, feed self-sufficiency and related constraints to sustainable intensification. The predominant farming



At harvest time, cereals are commonly uprooted, which may aggravate loss of organic matter from soils.

system of the study area is a mixed farming system with *enset* (*Enset ventricosum*), barley, potato and wheat as the most important crops, and cattle, sheep, poultry and horses as the main livestock types.

Access to inputs for potato production

Uses of improved potato varieties and inorganic fertilizers were influenced by wealth, education and technology adoption of individual households. Poor, non-adopter and uneducated households were constrained by inadequate access to improved varieties and inorganic fertilizers, and by cash shortages. Contrastingly, we found that labour shortage was a cross-cutting constraint across wealth and educational categories, which was related to the high labour requirement of potato production.

Our results suggest that there are three drivers of constraints, for three (amorphous) sectors of the farming community: (1) poverty trap for the poorest and uneducated households characterised by critical shortages of cash and produce for consumption; (2) access to inputs and training for self-sufficient, willing producers; and (3) market access for proficient producers whose farms are open to most of the inputs and have surplus produce.

Pests and inappropriate potato management practices

Pests and diseases affecting potato production included late blight, bacterial wilt, millipedes and vertebrate pests. Most farmers have little knowledge of the causes, or control of these pests and diseases, nor of the crucial role of crop rotation in disease prevention. This may be the result of the limited availability of farming training services. As a result, and in absence of best cultivation, pest and disease control practices, the productivity and economic return from potato production in the area are low. Put simply: potato is a knowledge-intensive crop that demands knowledge-intensive management in order to yield its potential returns.

Nutrient depletion and unbalanced soil fertility management

Soil test results showed widespread phosphorus deficiencies and large contrasts in the soil fertility between homestead (fertility too high) and outer fields (fertility too low). This variation can be explained by uneven farmyard manure (FYM) application, insufficient use of fertilizers, and the common practice of uprooting cereal crops at harvesting, resulting in a persistent but avoidable depletion of soil organic matter and nutrients. Most of the FYM is applied on plots that are near the homestead, with little or no FYM being transported to plots that are far away from the homestead or that have steep gradients.

Labour shortage due to economic migration

All surveyed farms were hindered by labour shortages for crop and animal production. The current agronomic practices developed in a time when there was plenty of labour available. This has changed in recent times, with the onset of labour migration to towns for economic opportunities. Moreover, the positive success of universal primary school education means that children are now less involved in farm operation. These changes might have aggravated labour shortages, particularly for female-headed households, which represent the majority of the farming community. Previously, there was a culture of working together among neighbours at labour peak periods. This culture is now less practised because the farm owner has to feed the labourers, which has become unaffordable with recent increases in food prices.



While many of the highland soils are naturally fertile, unbalanced application of farmyard manure has led to extreme variations in soil fertility.

Low return from animal production

The returns from animal production were very low, with a quarter of the study farms showing negative returns, mainly as a result of low animal productivity (1.75 litres per cow per day) and the high costs of external feed. However, it must be borne in mind that animals have additional benefits that include draught power, transport, provision of farmyard manure and are an asset for the household. In addition, imported animal feed and fodder (in the form of plants gathered in the wild) is the single largest source of nutrients into the farms.

We identified the following pathways towards overcoming these constraints:

1. The diversity of constraints, encountered by different types of households, suggests a need for a pluriform advisory model that provides 'customised advisory packages' that are of relevance in the context of individual farms.
2. For potatoes to meet their potential role in contributing to food security in subsistence farming, there is an urgent need for a specific advisory package on best practices for potato production.
3. Likewise, there is an urgent need for simple, accessible advice on nutrient management, to overcome the extreme variation in soil fertility.
4. The emerging labour crisis calls for: a) transition from full manual labour dependency to small-scale mechanised farming systems, at least for operations like harvesting and threshing; b) facilitating credit access and training for such machineries; c) organising farmers to solve labour demanding operations, such as transporting of farm manure to distant plots and steep slopes, collectively.
5. Low animal productivity may be overcome by improving access to quality feeds and more productive animal breeds.

Acknowledgements

This work has been co-financed and supervised by the Teagasc Walsh Fellowships Programme, Wageningen University and Research Centre, and Vita (www.vita.ie).



Putting technology into practice:

understanding the adoption of best practices

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Potato is an important crop for food security and earning cash among smallholder farmers in Ethiopia. At the same time, potato yields are very low. To improve productivity, agronomists developed and promoted new production technologies. Technological interventions are powerful means to solving many of the challenges in agricultural development. The reality on the ground in rural Ethiopia, however, shows a complex and dynamic picture of potato technological interventions, which often fail to improve farmers' livelihoods. Our study addressed the complexity, diversity and dynamics of technological interventions for improved potato production in subsistence farming, using Chench, southern Ethiopia as the pilot area. Our research questions included: why do some farmers adopt new potato production practices (either wholly or partially), while others adapt or even reject the new practices? To answer this, we assessed farmers' production practices, their socioeconomic context, as well as the actors involved in development interventions and their intervention models.

Social bias

We found that technological interventions for improved potato production show a social bias. For instance, wealthy and medium wealthy farmers have better access to improved potato production technologies than poor farmers. The strategy of the extension service providers is based on using 'model' farmers, because they are unable to reach all farmers

on an individual basis. Model farmers are expected to pass on the lessons to other farmers. However, we found that the majority of farmers, who were interested but not directly targeted by governmental as well as non-governmental extension services, did not adopt the improved production practices such as planting in ridges or storing potatoes in improved storage facilities.

Our findings challenge the common intervention framework that assumes that once improved practices are introduced into a community by 'leading farmers', it will, over time, 'trickle down' to all producers. This is known as the 'leader-laggard' model of adoption. Contrastingly, our results showed that not all farmers with access to technologies make these their practices. Instead, farmers make adoption decisions within a broader context that includes the household resource base (land, labour and cash availability). For example, practices such as land preparation, planting and later cultivation differed among farmers belonging to different wealth categories, which in some cases limited the applicability of improved practices. In addition, cash shortages meant that farmers were not always in a position to follow recommendations on seed tuber size or fertilizer applications. In essence, this means that the cost-benefit ratio of improved practices and varieties differs from farm to farm, which explains why a cohort of farmers will not adopt these practices, even when these have proven effective for other 'leading' farmers.

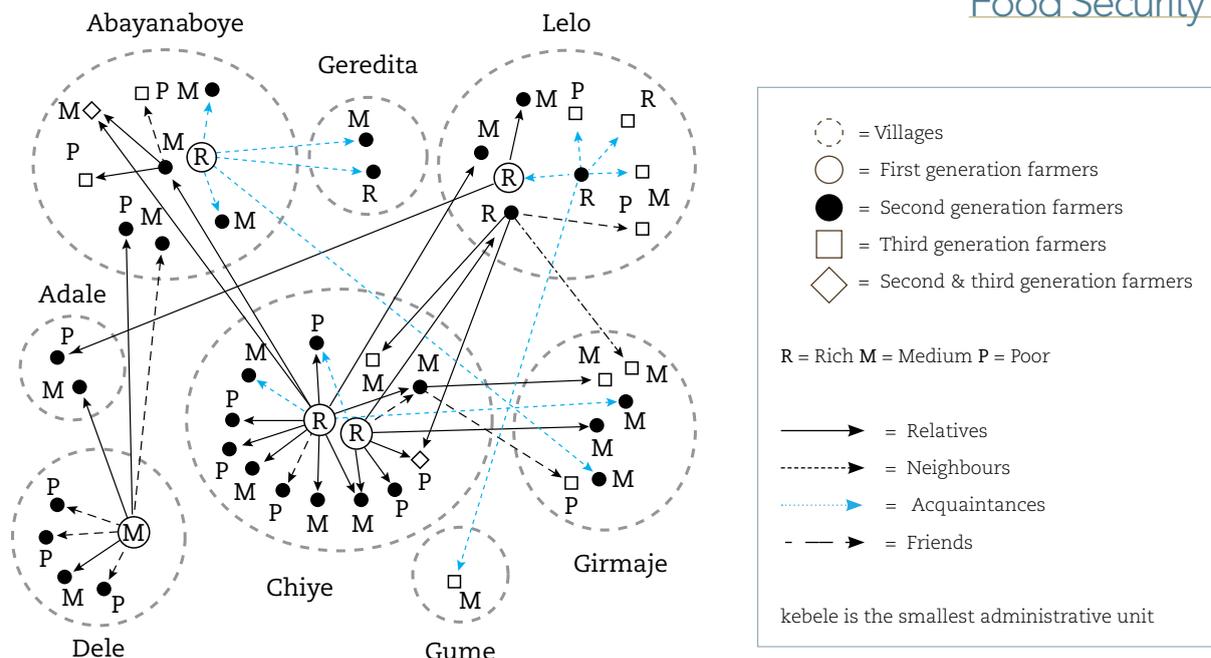


Figure 1. Sharing of seed potato among farmers of different wealth status, between and within villages in Laka kebele.

The role of informal seed tuber multiplication systems

During our research, we found that the ‘informal seed potato distribution system’, in which farmers themselves produce and disseminate seed, played a large role in the diffusion of new varieties, introduced by development interventions, through farmer-to-farmer sharing. We assessed how farmers multiply and share the seed tubers following one such intervention (Figure 1). This assessment demonstrated that not all farmers have equal access to new seed. Instead, access to improved varieties was influenced by the socio-economic characteristics (gender, religion, and wealth) of the farmer providing the planting material, as well as the type of personal relationship (relatives, neighbours, friends and acquaintance) between providers and recipients.

Organisational diversity

Our findings demonstrate that in the semi-formal seed potato system (seed potato producer cooperatives) there is weak interaction between organisational structure and process of quality seed



Yenenesh explains the findings of her PhD to the farmers who participated in her research.

production. These weak interactions can partly be traced to the misalignment between organisational structures that are based on ‘standard production models’, with the social context of seed potato production. The standard production models fail to recognise the influence of social relationship on decision making and cooperative relations. As a result, this organisational structure has a minimal role in influencing how farmers produce and market quality seed potato. The dominance of social relationship makes it difficult to maintain the quality of planting material through cooperation, following the introduction of a new variety. This, in turn, leads farmers to revert to the original practices that fit their particular interests and realities, thus perpetuating the cycle of poor production practices and the degeneration of potato seed.

Ways forward

- The assumption that improved potato production technologies will, over time, ‘trickle down’ to all producers, once leading farmers accessed it, should be revised. Uniform technologies do not fit all farmers because farmers have different farm realities. There should be range of technological options that match the diverse farm realities.
- Inclusive and integrated intervention strategies have to be considered. This ensures farmers across different socio-economic status have opportunities and resources that they need in order to have optimum benefit out of potato technological interventions.
- Interventions in semi-formal seed systems need to shift from ‘standard production models’ and consider a flexible and open extension approach guided by trials, challenges and existing socio-technical and institutional realities. This helps farmers move incrementally toward self-reliant seed system.

Acknowledgements

This work has been co-financed and supervised by the Teagasc Walsh Fellowships Programme, Wageningen University and Research Centre, and Vita (www.vita.ie). The authors also gratefully acknowledge the contribution of farmers through sharing their potato production and marketing experiences.

How can we best translate the science of bacterial wilt prevention into practical advice for this farm family? That is the challenge that Ayano Teyika (left) is trying to address, together with the local agricultural extension officer (far right).



Making science work on smallholder farms

The Teagasc work in the Chencha project is designed to investigate potato seed systems among subsistence farmers in the Chencha region of Ethiopia. It quickly emerged during the initial research that there were many gaps in farmer knowledge about potato production. Therefore, we initiated an in-depth assessment to identify the gaps in information about potato production, to complement the body of work being carried out by the PhDs in the project. Ayano Teyika, a college lecturer in Arba Minch University, is currently completing a Masters in Knowledge Transfer under the Teagasc Walsh Fellow, Masters in Agricultural Innovation Support (MAIS) programme.

During the in-depth research carried out by the three PhD candidates (see preceding articles), it emerged the problems of seed potato production were varied but, instead of the main threat coming from the build-up of virus, a much more serious threat of bacterial disease (bacterial wilt) needed to be tackled. Bacterial wilt is a devastating bacterial disease, which can severely reduce potato yield. The main sources of transmission include seed, soil runoff, irrigation water, potato volunteers, continuous cropping in infected ground. With this in mind, we set about answering the following questions about potato production, with a focus on bacterial wilt:

- How well do farmers understand bacterial wilt and the danger it poses for potato production?
- How can farmers take action to improve their knowledge based on local conditions and science-based recommendation?
- How willing are farmers to become involved in collective/community action to prevent bacterial wilt?

We targeted a group of farmers dealing with the Vita programme (who have higher access agricultural extension and inputs) and a group with no contact (and lower access to agricultural extension and inputs). Focus groups and one-to-one interviews were conducted with over 400 participants, to get an understanding of the farmers' stance on: (1) the socio-economic value of potato; (2) potato production and management; (3) challenges to potato production; (4) knowledge about bacterial wilt and management practices to combat bacterial wilt; (5) social exhaustion (stress) from bacterial wilt; (6) community willingness to protect against bacterial wilt; and (7) knowledge or skill they need both in potato production and addressing bacterial wilt.

Initial results show that communities are aware of bacterial wilt, but many struggle to identify the disease in the field and are unsure how to manage bacterial wilt, both on their own farm and within the community. As this disease is difficult to eliminate, participants show willingness to engage in collective action to combat bacterial wilt. The research also indicates that women and poorer farmers will need more help during collective action, and will benefit from a specifically targeted training approach.

We are currently testing a pilot community-led action to combat bacterial wilt with farmers and local extension officers and will report on outcomes in forthcoming publications.

Acknowledgements

The project is supported by the Teagasc Walsh Fellow Masters in Agricultural Innovation Support (MAIS) programme.



Ayano Teyika,
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Ethiopia
(Not pictured. See main
photograph)

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Breaking new ground – creating synergies between science and development

At the final project workshop in July 2015, the Walsh Fellows shared their results with the farming community that they had worked and lived with for the last three years.



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The development of agriculture is a key building block to healthy economies for countries in Africa. However, across Africa, the balance between food, water and climate change is fragile and increasingly under threat and new technologies and development approaches are required. Research agencies have traditionally lacked the mandate and community outreach to reach farmers, while NGOs have lacked both the research base and business and management acumen. Research-led agriculture, however, has the potential to have a substantial impact on poverty through development of best practices and technology transfer.

Potatoes are an important crop for millions of smallholder farmers across east Africa and is a good example of where good science, linked to good development, can triple yields, improve nutrition and increase farm incomes. In the past, however, it is very evident that the agricultural research and overseas development sectors have failed to combine effectively and to realise this potential.

The recently launched Sustainable Development Goals explicitly call for increased international and local agricultural research investment. This project has represented a microcosm of the success that can be achieved when donors, research agencies,

development organisations and the private sector collaborate to best effect.

Many solutions for higher crop yields are available in scientific papers but are not implemented. The practice of transfer of research into use, is one that Ireland has developed so successfully in Teagasc. Led by the Irish non-governmental organisation, Vita, in partnership with Teagasc, the Irish Potato Federation and many other NGOs and science partners in Ireland and in Africa, an international Potato Coalition to work across six countries in east Africa has been established. The Potato Coalition provides a practical approach, defining the necessary steps to set up a collaborative framework that enables development, science and the private sector to interact.

The three PhDs reported on in this publication are an excellent example of how the Potato Coalition works. Already the best practices regarding control measures for bacterial wilt are being used by communities. Lessons learned about the adoption of technologies are influencing how we target and work with communities. Evidence-based information of the role of potatoes within wider farming practice communities, provides valuable contextual understanding for improving our work in Ethiopia. Building from this work, Vita has embarked on a masters degree project in conjunction with UCD and Teagasc, to see how a community-led approach to potato disease control can be developed.

Vita is delighted to have been a partner in this innovative and exciting project. It has already helped to contribute to the improvement of livelihoods of smallholder farmers in southern Ethiopia, but also points the way for the future of agricultural research collaborating with international development partners to deliver results.

PROIntensAfrica

PROIntensAfrica is intended to develop a proposal for a long-term research and innovation partnership between Europe and Africa for the sustainable intensification of the agri-food system in Africa.

An expected growth in the world population, from seven to nine billion in 2050, and changing diets, will require more food to be available by 2050. The world is facing the challenge to improve food and nutrition security (FNS) globally. Africa faces the twin challenge of maintaining its food self-sufficiency and the diversity of its agriculture while its population is expected to double. Africa has a major role to play in FNS. It is vulnerable today, but has a high potential to develop as a major food basket. This requires, however, a transformation of the African agro-food systems, and calls for joining forces to explore and exploit the potential of African agriculture. As no one size fits all, optimal use should be made of the rich diversity of pathways that exist or can be developed. This requires a profound understanding of the agro-food systems, in combination with the utilisation of instruments that aptly assess the efficiency and effectiveness of different pathways.



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PROIntensAfrica is intended to develop a proposal for a long-term research and innovation partnership between Europe and Africa. Focus is on the improvement of the food and nutrition security and the livelihoods of African farmers by exploring and exploiting the rich diversity of pathways leading to sustainable intensification of African agro-food systems, with support of the relevant policy environment. The partnership proposal will:

- describe the scientific and innovation domains that need further research to identify and implement effective pathways (the what);
- identify the value for both continents in addition to ongoing partnerships and activities (the why); and
- suggest financial and governance structures that can adequately support the partnership (the how).

Pathways to sustainable intensification

PROIntensAfrica is looking into the pathways to intensification tested in previous initiatives such as: mixed farming systems in Burkina Faso; fixing nitrogen levels on legume crop fields in Kenya; optimising productivity on Central African cocoa farms; and highland production systems and sustainability in Madagascar. These kinds of projects are the basis of PROIntensAfrica's case studies, which look at the different intensification pathways that have already been around the African continent, developed by farmers and herders reaching for intensification of agriculture.



Potato farmer Tozene Nada from Ethiopia. Photo courtesy of Elizabeth Handy.

Partners

PROIntensAfrica is a consortium of 23 members from different European and African countries, representing research and platform organisations, themselves well linked to a wide array of partners in their respective regions. The rationale is that, in this way, the consortium in itself reflects a broad partnership. The African partners are: FARA (Ghana), CORAF/WECARD (Senegal); CCARDESA (Botswana); ASARECA (Uganda); AFAAS (Uganda); ARC (South Africa); CSRI-CRI (Ghana); and INERA (Burkina Faso). European partners are: Wageningen UR (The Netherlands); CIRAD (France); UCL (Belgium); SLU (Sweden); IICT (Portugal); Luke (Finland); University of Copenhagen (Denmark); ZEF (Germany); INIA (Spain); NRI (England); Teagasc (Ireland); BOKU (Austria); University of Life Sciences (Czech Republic); University of Szent Istvan (Hungary); and Bioforsk (Norway).

Acknowledgments

Catriona Boyle is leading the PROIntensAfrica social media campaign. Search for IntensAfrica on Twitter, Facebook, LinkedIn and YouTube. Rogier Schulte, Leader of Translational Research on Sustainable Food Production, Teagasc and Lance O'Brien, Foresight and Strategy Manager, Teagasc, are also involved in the PROIntensAfrica project. PROIntensAfrica is funded by Horizon 2020 and by the 23 partner agencies. Sign up for the PROIntensAfrica newsletter at: www.intensafrica.org

Science outreach



Poster session, foyer Animal Bioscience building



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The future of science depends on improved communication to inform debate and promote public engagement, writes Kieran Meade.

Improving communication between scientists of different hues, practitioners, policy makers and engaging the public are all crucial to enabling informed decision making on future science policy, which will determine the progression of science in Ireland. Researchers at Teagasc Animal & Grassland Research and Innovation Centre, Grange, recently participated in a number of public outreach events.

Discover Research Dublin

Discover Research Dublin was held on September 25, 2015 as part of European Researchers Night. This annual event is funded by the EU under the Horizon 2020 framework. Launched by Panti Bliss, and co-organised by Cliona O'Farrelly, this year Teagasc had a research stand at the event. The concept of the night was to open the laboratory to members of the public and allow engagement with researchers. After an introductory talk on the research links between Trinity College Dublin and Teagasc, given by Kieran Meade, Walsh Fellow students then demonstrated DNA extraction and there was even a Meet the Vet area where scientists of the future got to diagnose pregnancy in Ciara, our anatomically correct, cardboard cow. More details can be found at: <http://discoverresearchdublin.com/>

AVTRW conference

The Association of Veterinary Teaching and

Research Work (AVTRW) conference was held in the Teagasc Animal Bioscience Centre in Grange on October 2. The event had more than 60 attendees representing scientists, students and interest groups from all over Ireland, including the Agri-Food and Biosciences Institute (AFBI), University College Dublin (UCD), Trinity College Dublin and the Department of Agriculture, Food and the Marine (DAFM), as well as Animal Health Ireland and industry representatives. The theme of the meeting was 'Inflammatory Disease – New Developments and Approaches to Treatment' and keynote talks were given by David Kerr (University of Vermont, US) on mastitis and by Erin Williams (University of Edinburgh, UK) on uterine disease. Students from each institution also presented scientific posters in the foyer of the Teagasc animal bioscience building. Next year will be the 50th annual meeting of the Irish branch of AVTRW, which will be held in UCD.

The importance of public engagement with science

Engaging the public and teaching the relevance of science is a critically important task for scientists to foster trust and enable improved mutual understanding. Ultimately, informed decision making will enable scientists to harness the potential offered by emerging technological developments, and to have these benefits translated into publically-acceptable end products. Given the challenges that face global agriculture in responding to the challenges of world population expansion and climate change, improving communication both between scientists and with the broader public and interest bodies cannot happen quickly enough.

Science Week at Teagasc 2015



During Science Week 2015, Teagasc research centres and colleges invited local schools to meet their research and teaching staff. It was an opportunity for students to learn about the work Teagasc does to support science-based innovation in the agri-food sector and the broader bioeconomy that will underpin profitability, competitiveness and sustainability.

Science Week is coordinated by Science Foundation Ireland (SFI) Discover, the education-outreach programme of Science Foundation Ireland. Teagasc has been involved with SFI for the past nine years in promoting the importance of science to local schools and colleges throughout the country.

“Science is hugely important for agriculture and food industries and we are delighted to support Science Week, which aims to promote the relevance of science, technology, engineering and maths in our everyday lives and to demonstrate their importance to the future development of Irish society and to the economy,” said Frank O’Mara, Director of Research at Teagasc.

Students visiting Teagasc Moorepark, Co Cork visited the Food Research Centre and Animal & Grassland Research and Innovation Centre where they were given an insight into the research they are conducting, as



Emily Crofton is a Post-Doctoral Researcher based at the Teagasc Food Research Centre in Ashtown Sensory Analysis Laboratory, which is used to determine people’s responses to products as perceived through the five senses – sight, smell, touch, taste and hearing, in discussion with pupils of Dominican College, Griffith Avenue, Dublin.



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Dr John Finnan, Teagasc, Oak Park Crops and Environment Research Programme, explains that Ireland imports 90% of its fuel requirements, and the role that biofuels can play.

well as a tour of the facilities. They were given demonstrations on DNA extraction and isolation, learned about the key technologies that underpin dairy farming and had the opportunity to learn about breeding, grassland management and genetics.

The Teagasc Oak Park Crops Research Centre welcomed third level students from Carlow Institute of Technology and Pearse College, Dublin. Topics on the day included plant pathology and sustainable disease management, plant genomics, the potato breeding programme, bioenergy, crop agronomy and more. They were given demonstrations on potato breeding and GM potato trials carried out on site. This raised the curiosity of students and many questions were put forward and debated with the researchers. Students left with a much greater insight to GM testing and the strict controls and protocols that govern all research carried out by Teagasc. This event was also filmed and broadcast on Irish TV's programme 'Grassroots', which can be viewed at: <http://www.irishtv.ie/grassroots-ep-10>

At Teagasc Food Research Centre, Ashtown, Dublin students from local schools got a glimpse into the weird and wonderful world of fungi, learned about the functional food ingredients that can be harvested from our marine environment and performed sensory analysis of food. Students also took part in a sausage-making demonstration and other meat processing techniques within the meat research labs.

Students from Galway got the opportunity to visit the Animal & Grassland Research and Innovation Centre in Athenry. They were given demonstrations on how science is being used to address issues related to reproduction and parasitism in sheep. Students were shown different sheep breeds and their attributes and role in Irish farming were explored. At the grassland and environment exhibit, they were introduced to different grass and clover species and learned about nitrogen fixation.

Teagasc Kildalton Agricultural and Horticultural College, Co Kilkenny hosted an event exploring soils in agriculture. As 2015 is the International Year of Soils, this was an outdoor event where students undertook some simple field experiments that can be conducted to assess soil quality under a number of different parameters.

The annual Walsh Fellowships seminar took place in the RDS during Science Week (see news). A full report of the winning projects will appear in the spring 2016 issue of *TResearch*.



Teagasc's Veronica Nyhan with students from St Kieran's College Kilkenny on their recent visit to Kildalton College.

Smart Futures

Smart Futures is a collaborative Government-industry-education programme promoting science, technology, engineering and maths (STEM) careers information to second-level students, coordinated and managed by SFI.

Claire Watkins and Cathriona Foley from Teagasc, Moorepark spoke at the Smart Futures event, held at University College Cork. The main aim of these talks was to show students the vast career paths science that can open up and also, the impact that can be made by science to enrich our everyday lives.

Donna McCabe, SFI explains: "Greater student engagement is needed to increase the number of students taking STEM-related courses and to provide talented workers for the future. Recent research carried out by AMARACH shows that the key factor influencing young people's career choices is how they see themselves fitting in. Together, we need to challenge stereotypes so young people can identify with the diversity of people that work in STEM and see themselves fitting in. Having a role model can be hugely empowering, encouraging them to explore opportunities they might otherwise miss."



Jess Coyne, Teagasc, shows the IDB SNP chip to St Colman's College, Fermoy pupils, Fermoy on a visit to Teagasc Moorepark.

Alternative breeding strategies using sexed semen



Sexed semen could potentially revolutionise the cattle breeding industry. Improved capability to either grow the size of the dairy herd or increase beef output from the dairy herd are exciting prospects for the Irish dairy and beef industries.



Improvements in sexed semen technology

The sex of an individual is determined by a pair of sex chromosomes. Oocytes always contain an X chromosome, whereas sperm contain either an X or a Y chromosome. Female offspring are generated when two X chromosomes are combined (XX), and male offspring are generated when an X and Y chromosome are combined (XY). The ability to pre-select the gender of calves was a landmark breakthrough in reproductive biotechnology. Sperm that contain X chromosomes have more DNA than sperm that contain Y chromosomes (about 4% more in cattle). This difference can be detected rapidly using flow cytometry, and is currently the only proven technology for sorting semen. Commercial applications of this technology in cattle have consistently achieved a gender bias of about 90%; however, there was an associated reduction in fertility compared with conventional, frozen-thawed semen (conception rates of about 70-80% relative to conventional semen). There have been a number of recent improvements to the sex-sorting technology: greater sorting speeds; reduced time lag between steps during processing; improved diluents and media; stable pH and temperature conditions; and reduced sperm damage during the sorting process. Indeed, recent studies in Ireland (frozen-thawed sexed semen) and New Zealand (fresh sexed semen) reported that mean conception rates for sexed semen were 87% and 94% relative to conventional

semen, respectively. More recently, a German field study using a frozen sexed-semen treatment in heifers achieved non-return rates equal to those achieved with conventional semen.

Lactating cows and sexed semen

The use of sexed semen technology has largely been restricted to heifers due to poor fertility performance in lactating cows. A field study conducted in Ireland in 2013 indicated that body condition score (BCS) and the number of days in milk (DIM) influence conception rate in dairy cows inseminated with sexed semen. Cows that had a BCS ≥ 3 and were calved ≥ 63 days had greater conception rates and were more suitable for sexed semen use than thinner cows that had a shorter period since calving. By targeting sexed semen use on the highest fertility animals in a herd, all necessary replacements could potentially be conceived early in the breeding season, despite fertility reductions, allowing farmers to use non-dairy sires for the second round of AI (i.e., weeks four to six of the breeding season).

Sexed semen use in expanding herds

In the post-milk quota era, sexed semen use may allow farmers to increase herd size more quickly and to generate replacement heifers from the best dams only, essentially eliminating the low-value dairy bull calf. Expansion from a herd size of 100 to 300 lactating cows was modelled over a 15-year time horizon using three different breeding strategies:

- conventional frozen-thawed dairy semen used for the first AI in heifers and the first and second AI in cows (Conv);
- sexed semen used for the first AI in heifers and the first AI in cows that had a BCS ≥ 3 and DIM ≥ 63 days, with conventional dairy semen used in the remainder of cows at the first AI and all cows at the second AI (SS-Conv); and,
- sexed semen used for the first AI in heifers and

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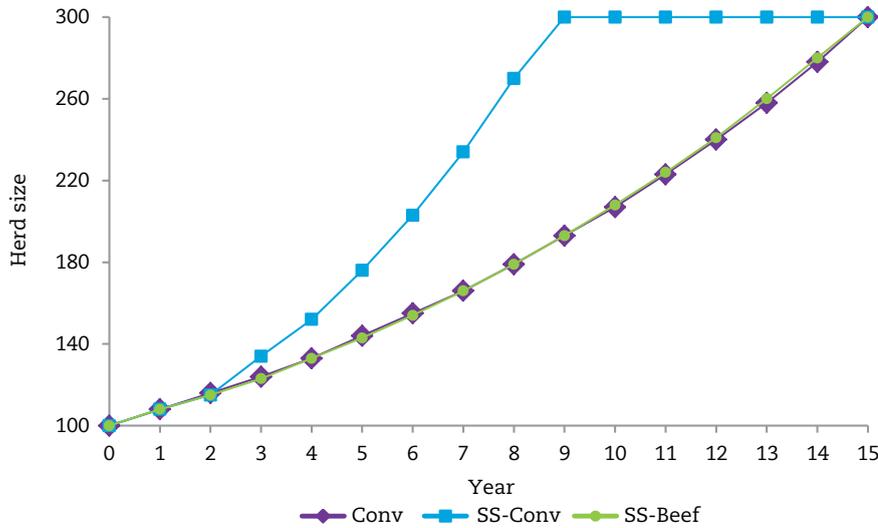


Figure 1. Herd expansion over a 15-year simulation period when using conventional dairy semen (Conv), sexed semen plus conventional dairy semen (SS-Conv) or sexed semen and conventional dairy semen plus conventional beef semen (SS-Beef) in heifers for the first AI and in lactating cows for the first two AI.

first AI in targeted cows (as in SS-Conv), with conventional semen used in the remainder of cows at the first AI and conventional early maturing beef semen (e.g. Aberdeen Angus) used in all cows for the second AI (SS-Beef).

Assuming a sexed semen conception rate of 94% relative to conventional semen, SS-Conv facilitated the fastest herd expansion (Figure 1). The six-week calving rate decreased for the sexed semen herds due to the reduced fertility of sexed semen, with an increased number of cows calving in March and April rather than February. Despite this later calving, the Conv herd reported lower discounted net profit over the 15-year simulation period. Sexed semen use resulted in greater cumulative farm profitability, either through faster herd expansion (SS-Conv + €135,418) or additional revenue from beef sales (SS-Beef + €91,298). The increased rate of expansion for SS-Conv required greater investment in year one to establish facilities and housing to accommodate additional livestock but these facilities were not fully occupied until year seven and resulted in negative cash flows during the initial period of expansion. Although this expansion option may be the best for profitability, the business may become unviable if significant funding is not available to survive periods of negative cashflow during intensive expansion.

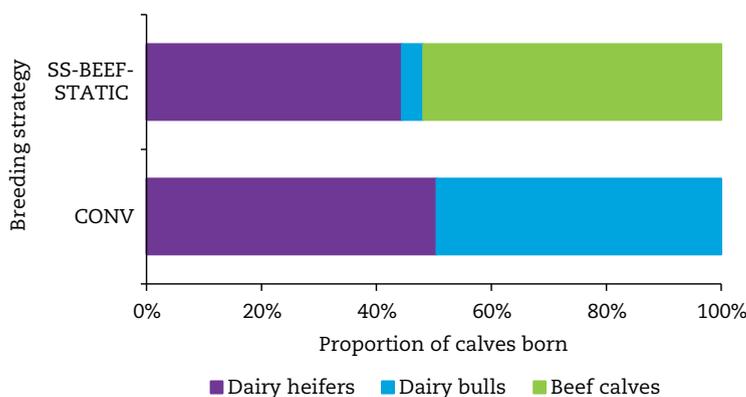


Figure 2. Change in proportion of calf type: The proportion of calves born through AI in a static 80 lactating cow herd when using conventional dairy semen (Conv) or sexed semen plus conventional beef semen (SS-Beef-Static).

Sexed semen use in static herds

Not all farmers will want to expand their herd size. A farmer with a herd size of 80 lactating cows could use sexed semen on all heifers and target the use of sexed semen on the higher fertility lactating cows to generate sufficient replacement heifers in the first three weeks of the breeding season. All other non-sexed inseminations on the lactating herd could be changed to easy-calving, short gestation beef sires (SS-Beef-Static). The resulting beef calves currently attract a premium of approximately €150 over dairy bull calves. Assuming sexed semen conception rates of 94% relative to conventional semen, instead of using 105 conventional semen straws, a farmer could use 48 sexed semen straws and 59 beef straws. Based on the change in type of calves born (Figure 2), the price differential between a male dairy calf and a beef calf would result in a net advantage of €1,920 per year. If the conception rates achieved with sexed semen were equal to conventional semen, this would increase to €2,384 per year. The net advantage from the sale of beef calves, as opposed to dairy calves, will depend heavily on local market conditions such as the sale price of a dairy heifer, premium attracted for a beef calf and semen costs.

Conclusions

Utilising sexed semen in heifers and higher fertility lactating cows facilitates accelerated herd expansion and increased profit compared to herds utilising conventional semen only. Combining sexed semen use with conventional beef semen would provide an opportunity for both expanding and non-expanding farmers to generate additional revenue. Furthermore, producing premium quality beef crosses from dairy cows would maintain a vibrant beef industry in Ireland in the face of declining numbers of suckler cows. Reports of advancements in sorting technology and the improved fertility of the frozen semen product are promising. However, further commercial field studies are required before widespread adoption of sexed semen occurs at farm level.

Acknowledgements

Funding from the Department of Agriculture, Food and the Marine under the Research Stimulus Fund is gratefully acknowledged.

Exploiting whole genome sequence

Whole genome sequencing of cattle is now possible at a relatively low cost. This article highlights how it can be exploited through *in silico* imputation and used to improve the accuracy of prediction of animal genetic merit.

What is whole genome sequencing?

The cattle genome consists of almost three billion sites where mutations, subtle changes in the DNA between individuals, can exist. Whole genome sequencing is the determination of the genotype of an animal at each of these three billion sites. Until recently, the high cost associated with generating sequence data resulted in prediction of genetic merit of individuals based on 800,000 of the possible three billion sites; in reality, just 40,000 of these sites are exploited globally to predict genetic merit in most cattle populations. Despite this, genomic predictions are accurate because this small number of sites tag whole chunks of DNA transmitted between generations. However, rare causal variants, which are genotypes that have a low frequency in the population, and that often impact animal performance, are unlikely to be tagged by the DNA markers used on commercial DNA platforms. By exploiting whole-genome information, the causative mutation itself, or DNA markers located very close to the causal mutations, may be included in the prediction algorithm. This will help improve the robustness of predictions across generations and populations or breeds.



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In silico generation of genotypes

Although the cost of sequencing is continuously declining, it is still not feasible to sequence all animals. Instead, a promising approach is to sequence a core set of animals and subsequently use this information to predict (often called impute) the whole genome sequence genotypes of other individuals. This imputation approach results in a large dataset for genomic prediction with imputed sequence genotypes and performance records. The 1,000 Bull Genomes

Project was established with the goal of providing high quality, whole genome sequences of key ancestral animals to facilitate imputation to sequence from commercial DNA platforms. This is an international project involving Ireland and over 30 partners across Europe, the US, Canada and Australia. By choosing key ancestral bulls, relatives of these bulls only need to be genotyped on commercial platforms (at a lower cost), as large segments of DNA inherited from the ancestral bulls can be traced. To date, the 1,000 Bull Genomes Project has sequenced over 1,147 ancestral animals across 27 different breeds and identified over 35 million DNA sites across the cattle genome where variation exists.

Imputation accuracy

It is essential that imputation from DNA platforms to whole genome sequence is accurate to exploit the full potential of sequence. Imputation accuracy from commercial DNA platforms was tested using 70 Holstein-Friesian high density (HD) genotyped animals (approximately 800,000 DNA sites) and 50 Holstein-Friesian BovineSNP50-genotyped animals (approximately 50,000 DNA sites) whose whole genome sequences were also available. Results showed that accurate imputation from the commercial DNA platforms to sequence is achievable. The accuracy of imputation is superior when sequence data from animals of multiple breeds are included in the analysis (Figure 1). This is especially beneficial for rare DNA variants (i.e., genotypes that appear <5% of the time in the population) present in multiple breeds. Imputation accuracy of rare variants was low but has improved as the 1,000 Bull Genomes Project has expanded over time. Imputation accuracy directly from the lower density genotype platform (approximately 50,000 DNA sites) was poor, but improved when a two-step imputation approach was used whereby the approximately 50,000 genotypes were imputed to 800,000 genotypes and then to sequence.

As a result of the strong imputation accuracy achieved, a total of 7,374 Holstein-Friesian sires genotyped on the different commercial genotype platforms have been imputed to whole genome sequence density.

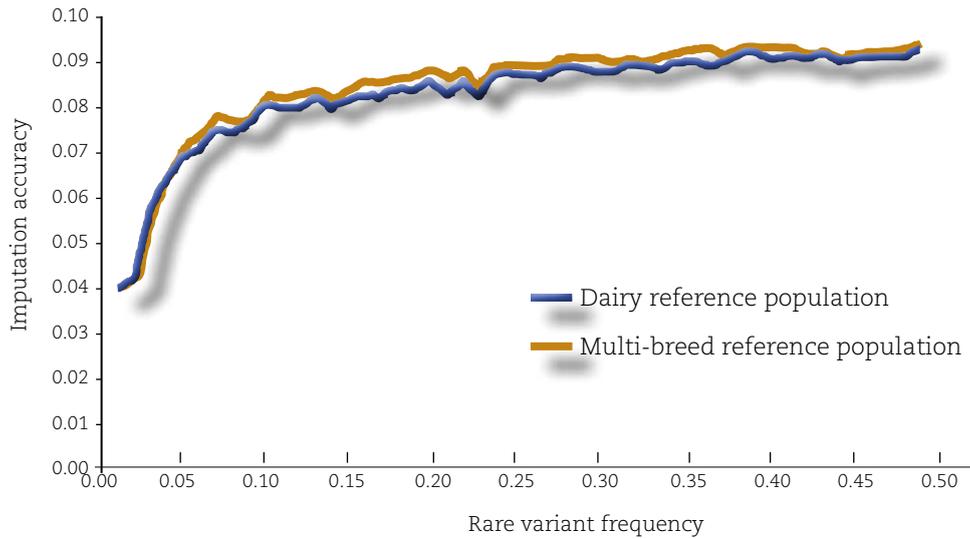


Figure 1. Imputation accuracy of whole genome sequence variants based on their frequency of the rare DNA variant.

Genome-wide association studies

One method to increase the robustness of genomic predictions is to use DNA sites that are in genes that control animal performance. Genes or genomic regions that are associated with genetic differences in performance can be identified through genome-wide association studies (GWAS). This approach searches all DNA sites, either simultaneously or one-by-one, and associates them with performance traits. The identification of genomic regions associated with performance can improve breeding, as animals carrying the desirable genotypes can be identified and these can be selected in a targeted breeding approach. Traditionally, GWAS were completed using commercial DNA platforms. Although genomic regions putatively associated with performance were commonly identified, the causal variant was not identified limiting its usefulness in breeding programmes. By exploiting whole genome sequence, it is hoped that a narrower region of association can be determined and that the causal variant/gene within this region can possibly be identified. However, huge populations of animals are required to ensure success.

GWAS for calving difficulty and interval

An example of a GWAS was recently undertaken in Teagasc, Moorepark on two traits of economic importance, calving difficulty and calving interval. Farmer-recorded data on both traits, as well as the genotypes of several thousand animals were available. Several regions of the genome associated with both traits were identified and plausible candidate genes in these regions were also often identified. For calving difficulty, three genes (SIGLEC12, CTU1 and ZNF615) containing significant ($p < 2.5 \times 10^{-8}$) variants where a DNA change disrupts protein formation were identified. The same genomic region was also associated with calving interval (Figure 2), where the SIGLEC12 gene had the strongest associations ($p < 4.19 \times 10^{-10}$). SIGLEC12 is believed to delay parturition due to a lectin deficiency caused by high levels of sialic acid-binding proteins. The strongest association for calving interval was CCDC88C, a negative regulator of the WNT pathway. This pathway plays important roles in the early stages of embryo development. Therefore, by using sequence data, plausible candidate genes were identified that can be possibly targeted in a custom breeding approach.

Conclusions

Accurate imputation of commercial genotyping platforms to whole genome sequence has facilitated the potential use of sequence data at a minimal cost. The full benefits of sequence are still being developed, though the robustness of genomic predictions across breeds and populations are expected to improve.

Acknowledgements

This research is funded by The Department of Agriculture, Food and the Marine’s Research Stimulus Fund (MultiGS). Data from the 1,000 Bull Genomes Project is gratefully acknowledged.

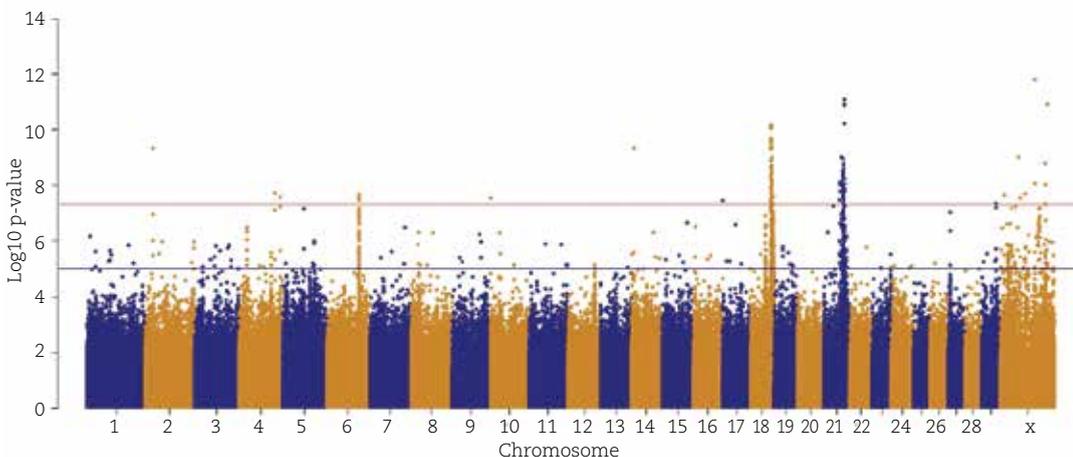


Figure 2. Whole genome associations for calving interval in 4,265 Holstein-Friesian sires.

Festulolium grass for marginal soils



Researchers at Teagasc and the Department of Agriculture, Food and the Marine have been investigating a potential high yielding grass for marginal soils.

What is Festulolium?

The name 'Festulolium' is a combination of *Lolium*, the genus of ryegrass, and *Festuca*, the genus of fescue. All possible outcomes of crosses between perennial ryegrass *L. perenne* (*Lp*) or Italian ryegrass *L. multiflorum* (*Lm*), and meadow fescue *F. pratensis* (*Fp*) or tall fescue *F. arundinacea* (*Fa*) fall under the term Festulolium. Spontaneous, or naturally occurring, hybrids between *Lolium* and *Festuca* are common in nature, but did not receive much attention in agriculture until the 1950s.

Why combine *Lolium* and *Festuca*?

The objective is to capture the best traits of each species for specific climatic conditions. Ryegrass varieties dominate reseeded grassland in western Europe due to their wide adaptability, rapid establishment, very high response to high fertility (particularly added N), and production of long season yields of highly digestible forage. However, ryegrasses suffer from poor persistency and ground cover, especially under climatic stress from water logging or drought, making their use significantly less cost-effective under marginal soil and climatic conditions. Fescues contribute more midsummer growth, deeper rooting, better disease resistance, more drought tolerance and improved winter hardiness leading to greatly improved persistency. However, they have relatively poor palatability and digestibility, are generally less responsive to increased fertilizer and

will not support intensive animal production.

The *Festuca/Lolium* complex of grass species provides opportunities for dealing with trade-offs between productivity versus adaptation. The complex includes many species diversely adapted to climate conditions through plant size, phenology and response of root and leaf growth to temperature and to water deficit of the soil. So far, two major amphiploid types (i.e., using diploid (2x) parents) have been bred using cultivated species. This was done mainly by crossing meadow fescue with either Italian or perennial ryegrass. Further hybrids were also produced by using wild relatives in the broad-leaved fescues such as *F. glaucescens* (*Fg*), the tetraploid (4x) progenitor of tall fescue, and, more recently, *F. mairei*.

These intergeneric hybrids are produced by conventional breeding techniques, and as back-crossing of new hybrids into any *Lolium* or *Festuca* population is always possible at any step of a breeding programme, a lot of introgression forms have also been developed in parallel.

The choice of the appropriate parent combination depends on where the crop will be grown, and on the expected climatic stresses. The presently available Festulolium 'synthetic' varieties are, therefore, a totally new redeployment of the genetic variability in the complex, only distributed at a species scale so far.

A European productivity trial

Until recently, agronomic assessment of Festulolium in the field has been limited by seed availabilities or restricted to particular locations or controlled environments. Since 2012, the European Association for Research on Plant Breeding (EUCARPIA) has conducted a Europe-wide coordinated field experiment of 15 Festulolium varieties and six control

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varieties of the species parents. A network of 10 trials of the same 21 genotypes was set up in eight countries: Belgium (ILVO); Czech Republic (DLF); France (INRA); Ireland (the Department of Agriculture, Food, and the Marine [DAFM] and Teagasc); Norway (Bioforsk/ Graminor); Poland (DANKO); Serbia (IKBKS); and the UK (IBERS and BBRSC). Seed was provided by five European breeding companies: DLF, IBERS, Graminor, INRA, and DANKO. All the trials were sown under the same complete block design with three replications. The trials are being cut under the local conservation or silage cut protocols, generally two silage cuts with three or four other cuts. The Irish field trial is located in Athenry, adjacent to the DAFM National List/Recommended List trials.

The results collected in 2012 and 2013 from the first six European locations showed that the Festulolium varieties performed, on average, positively compared to pure species controls. Between hybrid types, the annual yield appeared to be mainly driven by the ryegrass parent that is combined with meadow fescue; the *Lm x Fp* hybrids performed better, on average, than the *Lp x Fp* hybrids. The unique amphiploid, *Lm x Fg*, had an intermediate response over locations, closer to tall fescue than to meadow fescue.

Ireland's contribution

The Irish trial was sown in 2013 and the first yield results from 2014 are summarised by hybrid type in Figure 1. As can be seen, three of the four hybrid types produced dry matter (DM) yields, in line with the existing commercially available ryegrass varieties included, such as AberMagic.

This trial will continue to do yield tests for a minimum of three, and up to five harvest years. Harvested grass samples from 2015 onwards will be analysed to establish the relative ruminant digestibility of these varieties. Ground cover scores taken annually will record any changes in survival of the sown species over time and, when combined with yield data, will establish their relative levels of persistency.



Athenry Festulolium plots establishing in late July 2013, before first harvests were cut in 2014.

Conclusions

Festulolium varieties have displayed DM yields similar to perennial ryegrass in their first years of production, thus, confirming their potential for use under Irish and European conditions. Further ongoing research will establish their potential performance with regard to sward quality and persistence. This will determine their role in providing a cost effective solution for improving grassland swards in marginal soils and climates.

Acknowledgements

This evaluation was funded by Teagasc and the Department of Agriculture, Food and the Marine.

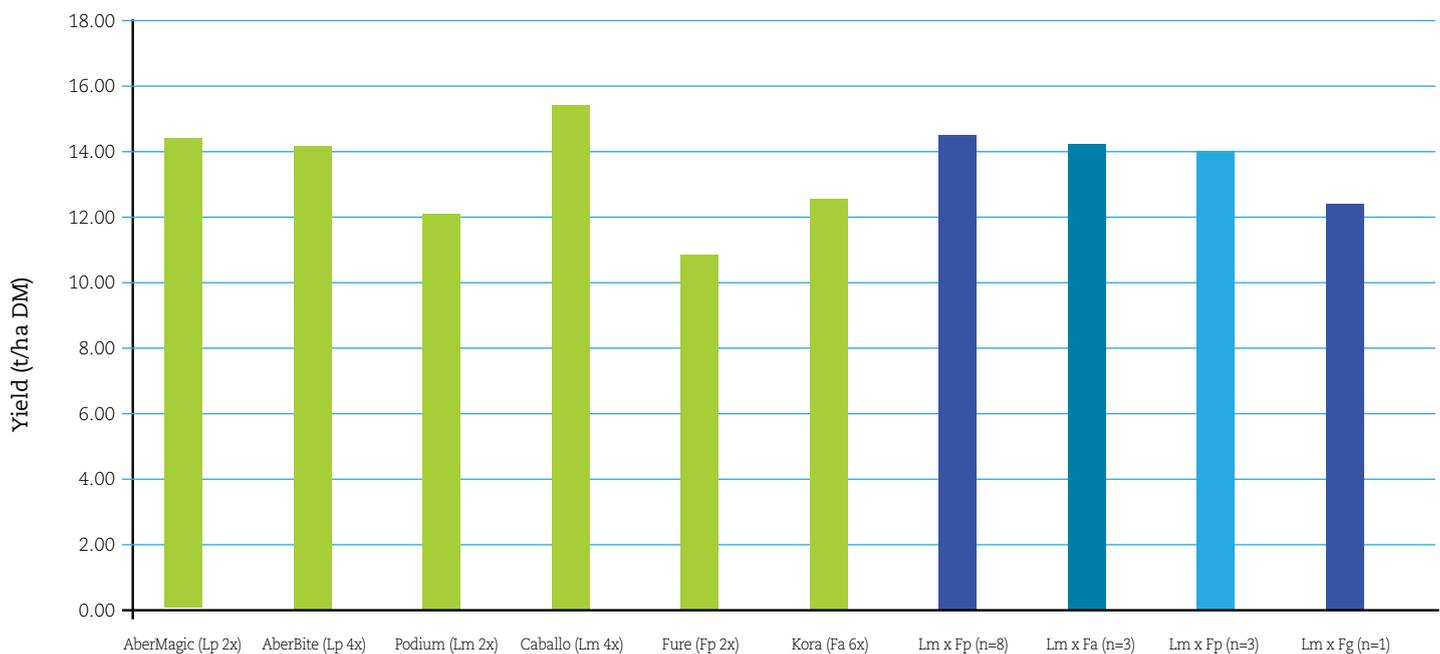


Figure 1. 2014 yields in t/ha DM of 15 Festulolium varieties (grouped by hybrid type) and six pure parental species (perennial ryegrass, diploid and tetraploid; Italian ryegrass; meadow fescue; and tall fescue).

Farmland conservation with 2020 vision

Efforts should be undertaken to promote and enhance biodiversity throughout the wider countryside.

Daire Ó hUallacháin and John Finn report on a recent conference on conservation of farmland biodiversity.

Agricultural, environmental and ecological policies have undergone major developments in recent years. Governmental strategies such as *Food Harvest 2020* and *Food Wise 2025* aim to significantly increase agricultural output, as part of the development of sustainable production systems. They highlight that: “Environmental protection and economic competitiveness are equal and complementary: one will not be achieved at the expense of the other” (*Food Wise 2025*). The reform of the Common Agricultural Policy in 2013 proposed to promote a more sustainable agriculture through a new ‘green payment’ in Pillar 1. The EU Biodiversity Strategy to 2020 aims to halt the decline of biodiversity and the degradation of ecosystem services by 2020, having failed to do so by 2010.

Against this background, the Teagasc conference, ‘Farmland Conservation with 2020 Vision’, was attended by researchers, consultants, farmers, and policy-makers. Here, we report on some of the main issues that emerged from the conference.

in particular. Although EFAs will, in many instances, maintain some existing habitats, Professor Matthews concluded that due to current prescriptions and design, there will be limited additionality associated with EFA prescriptions, believing that they will result in less than 1% change in land use in arable areas.

Alan, along with others, highlighted that agri-environment schemes, under Pillar II of the CAP, remain among the most important policies for the conservation of farmland biodiversity. These schemes, however, need to be monitored and evaluated such that cost-effective improvements can be made (where necessary) to ensure greater biodiversity and environmental benefits. Furthermore, a move toward ‘results-based’ agri-environment schemes, where payments are based on unit of public good provided, was recommended, as opposed to solely depending on traditional approaches where payments are based on a per hectare basis.



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Current and forthcoming policies on biodiversity and agriculture

The conservation of biodiversity is a key environmental objective for the European Union and its Member States. Although the objectives of ecological and environmental sustainability have traditionally been associated with environmental policy or with Pillar II of the CAP, recent revisions have seen the conservation of natural resources and the promotion of sustainable agricultural systems as key components of Pillar 1 payments, with 30% of the budget being allocated to ‘green payments’. In one of the keynote presentations at the conference, Alan Matthews, Professor of European Agricultural Policy in the Department of Economics, Trinity College Dublin, highlighted the role and potential benefits of ‘greening’ measures and ecological focus areas (EFAs)

Locally-led agri-environmental schemes

Results-based approaches underpin the excellent examples of Irish, locally-led schemes that were presented at the conference. Locally-led schemes aim to address specific, high-priority environmental issues that require a collective response at local level, resulting in significant improvements in the conservation status of specific high-priority habitats and species. Brendan Dunford (Burren Life Programme) highlighted the importance of such schemes being well designed, targeted, managed and appropriately resourced. Brendan explained how these schemes can cement strong partnerships between farmers and agricultural and environmental management agencies. Such partnerships witnessed in the Burren, Aran, southwest Kerry and the Duhallow region, create a very positive attitude towards conservation among farmers and a greater appreciation of the role of farmers by the wider community. Therefore, it is

encouraging to see locally-led, agri-environment schemes, with a proposed budget of over €70 million over the next five years, included in the latest Rural Development Programme.

High nature value farming systems

Many locally-led, agri-environment schemes are likely to be targeted, in the first instance, to regions such as the Burren, southwest Kerry and similar areas of high nature value (HNV) farmland. HNV farming systems are largely dependent on native vegetation for grazing or fodder production, and their conservation is a headline environmental objective of the Rural Development Programme.

There is believed to be in excess of one million hectares of HNV in Ireland. However, Davy McCracken (Scottish Rural College) highlighted that the quantity and quality of HNV is declining throughout Europe, due to the dual threats of intensification and abandonment. In order to address the declines of HNV, there is a need to better understand the distribution of potential HNV throughout the country, such that appropriate management and resources can be targeted to ensure the sustainable management of these systems. Joint presentations by Teagasc and the Institute of Technology, Sligo, demonstrated that significant research has now been conducted in this area (IDEAL-HNV project), such that the distribution of potential HNV can now be ascertained, coupled with environmental and economic drivers impacting on HNV, and their role in providing ecosystem services.

Ecosystem products and services

The EU Biodiversity Strategy to 2020 has prioritised the reversal of biodiversity loss, along with the maintenance and restoration of ecosystem services that biodiversity provides. These services include the provision of food and fibre, the conservation of natural resources (including biodiversity, water and soil), the regulation of water, and carbon sequestration. Alistair McVittie (Scottish Rural College) highlighted that with revisions to agricultural and environmental policies, there are opportunities for an integration of multiple ecosystem services within agri-environmental policy, resulting in ‘multifunctional agriculture’. Unfortunately, the evidence base for assessing multiple ecosystem services benefits is limited. Alistair highlighted the need for additional research in this area to ensure the delivery of multiple services. This research could also help develop and design incentives such as ‘Payment for Ecosystem Services’ to support the delivery of multiple services.

Promoting biodiversity in the wider countryside

The biodiversity conference highlighted that it is important that biodiversity enhancement and conservation efforts are not restricted to extensive areas that already support habitats and species, but that efforts are also undertaken to promote and enhance biodiversity throughout the wider countryside. Judith Zellweger-Fischer demonstrated a ‘credit points system’ employed in Switzerland. This tool facilitated farmers, researchers and policy-makers to assess biodiversity at the farm scale, resulting in a biodiversity score. This approach facilitated farmers with a low score to improve their score and those with a high score to maintain it. The Swiss approach ultimately resulted in a food labelling programme for sustainable and wildlife-friendly foods, incorporating over 15% of Swiss farms that receive a premium for supplying a wide food range to a Swiss supermarket chain. Judith’s presentation highlighted that there are marketing opportunities for food produced in a demonstrably sustainable manner, along with the obvious environmental and ecological opportunities.

Conclusions

Sustainable agriculture is a central theme of many agricultural, environmental and ecological policies. A key message from the conference was that additional metrics are required to help determine the sustainability of agri-systems. Existing metrics, for example, in relation to greenhouse gases (GHGs), are an important component of environmental sustainability; however, sustainability cannot be measured by GHGs alone. Key developments over the coming years will see the inclusion of additional sustainability metrics such as farmland biodiversity and water quality. Sustainability metrics, which incorporate the themes of biodiversity, water quality and GHG, will help ensure that farmers gain market benefits for their existing, verified, sustainable farm practices.

Acknowledgments

The conference received financial support from Teagasc and from the IdealHNV project. IdealHNV is a collaborative research project involving Teagasc and the Institute of Technology, Sligo. The research is funded by the Department of Agriculture, Food and the Marine under the Stimulus Research Funding Programme.

Full proceedings from the conference are available at: http://www.teagasc.ie/publications/view_publication.aspx?PublicationID=3742
For more details on the Ideal-HNV project see: <https://idealhvn.wordpress.com/>



High nature value farmland contains high levels of farmland biodiversity, and is largely dependent on the continuation of low-intensity, extensive farming systems.

Ultrasound assisted salt diffusion



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Researchers at Teagasc and UCC have been looking at ultrasound technology for improved salt diffusion in processed meat products.

Commercial salting techniques involve dry curing or brine curing. In such cases, movement of salt into (and water out of) the meat is regulated by meat composition, salt concentration and curing time. Beyond the negative effects of slow salt uptake on meat quality, long duration of brine salting of meat can also prove expensive in terms of reduced productivity and yields, space required, maintenance cost and corrosiveness of the brine. Furthermore, besides an interest among processed meat manufacturers in speeding up the uptake of salt in meat, achieving uniform salt profiles in meat is also desirable, as research suggests that uniform salt distribution is as important as the average salt content of processed meat. This demonstrates that there is a clear need to provide processed meat manufacturers with a faster and more efficient salting method, which will allow for a more homogeneous salt distribution in meat, and would reduce processing time and improve the quality of the product.

Current salting strategies

Many processed meat manufacturers employ wet salting by immersing meat in brine or by direct injection of brine into the meat. Many factors within the meat structure affect salt uptake, diffusion and distribution. When salt penetration into the meat matrix is too slow and the salt concentration is low, it can affect the quality and may result in growth of pathogens and spoilage bacteria. Consequently, means of reducing the brine time have been investigated and methods such as salting by rubbing or tumbling meat with salt (dry salting), by immersing in a brine or by injection, or a combination of these methods have been examined.

Ultrasound technology

Ultrasound in a frequency range of 20kHz to 50MHz has been employed to induce desired chemical and biochemical changes in food processes and process monitoring applications. Low frequency ultrasound in the range of 20-100kHz is known to enhance several mass transfer processes, including brining of meat. It is well recognised that ultrasound allows faster and uniform diffusion of brine solution into the

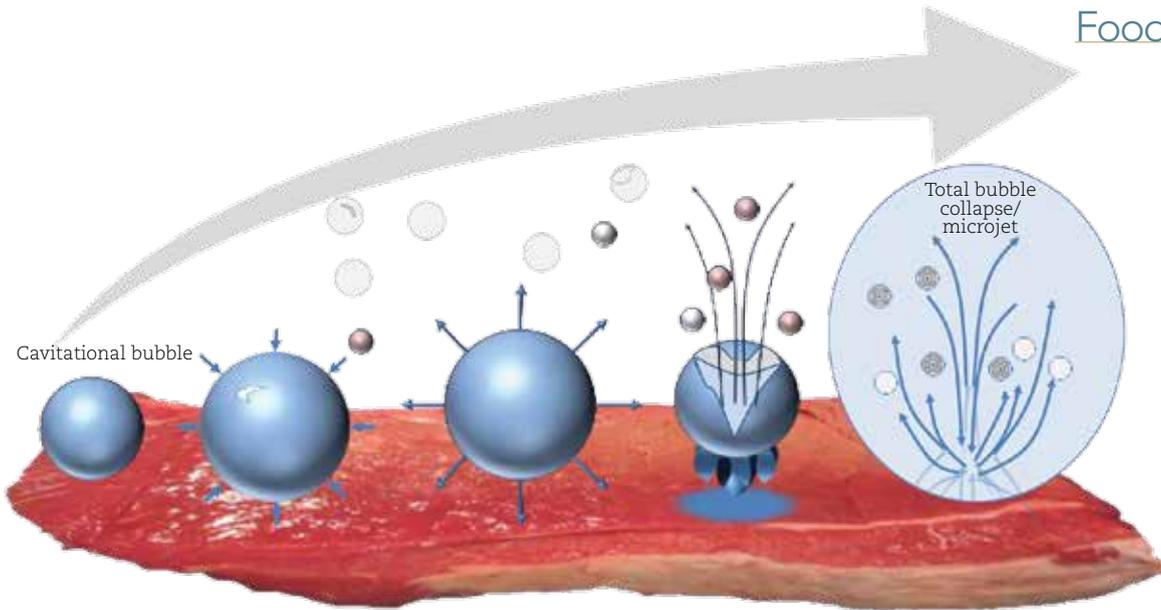


Figure 1. Mechanism of acoustic cavitation.

meat tissues. Various physical and chemical phenomena including agitation, vibration, pressure, shock waves, shear forces, microjets, compression and rarefaction, acoustic streaming, cavitation and radical formation are responsible for the ultrasonic effect. The main driving force for enhancing salt diffusion is acoustic cavitation. When ultrasound propagates through any medium, it induces compression and rarefaction in the molecules of the medium. Such alternative pressure changes cause formation and ultimately collapse of bubbles in a liquid medium (Figure 1). This phenomenon of the creation, expansion, and implosive collapse of microbubbles in ultrasonically irradiated liquids is known as ‘acoustic cavitation’.

Studies carried out by Teagasc have also shown that the application of ultrasound during meat brining enhances salt and water transport. A study carried out by Teagasc highlights that the application of sonication can enhance mass transfer in beef and pork meat tissues. A significant reduction in brining time was observed as shown in Figure 2. Ultrasound improves salt diffusion in the meat matrix by microinjection of brine into the meat through the formation

of microjets as a result of asymmetric cavitation near the solid surface. Changes in microstructure, as a result of sonication, may also improve the diffusion of NaCl into the meat matrix. Moreover, acoustically brined meat exhibits higher quality end product with improved texture. The emerging, high-intensity ultrasound technique employs both physical and chemical effects to alter meat structure with promising results for meat tenderisation and salt diffusion. The high ultrasonic intensity of the waves can generate the growth and collapse of bubbles inside liquids, a phenomenon known as cavitation and some structural effects, such as the so-called ‘sponge effect’ when the samples are squeezed and released like a sponge, and the creation of micro-channels. Therefore, improved physical properties such as water-binding capacity, tenderness and cohesiveness can be obtained by employing ultrasound technology for meat products. Hence, the use of ultrasound during brining may not only produce an accelerated brining but may also influence meat texture.

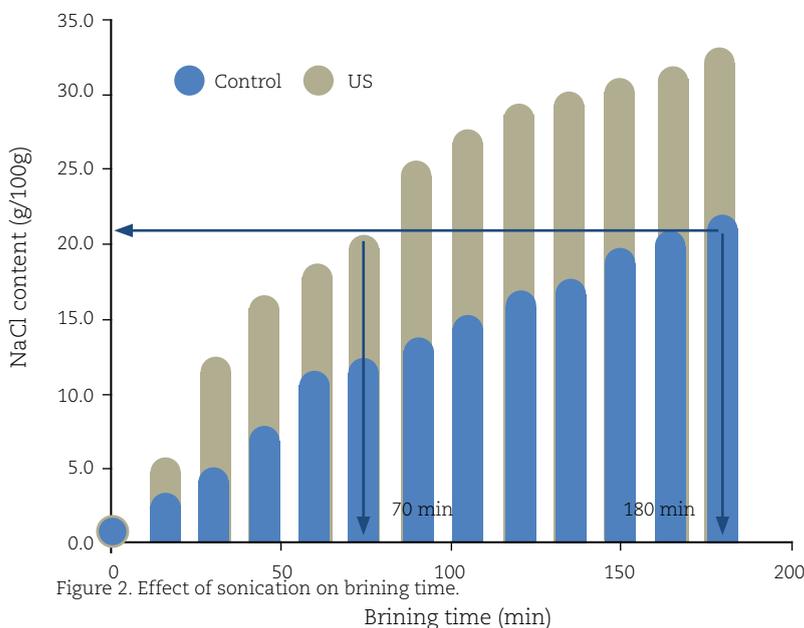


Figure 2. Effect of sonication on brining time.

Conclusions

Ultrasound technology has been demonstrated to enhance salt diffusion in meat matrix by virtue of various chemical and physical effects including cavitation. Ultrasound technology offers the potential to integrate within a conventional brining system with the aim of achieving uniform salt distribution in meat, thereby offering opportunities to reduce overall sodium salt content while improving physicochemical properties of processed meat products.

Acknowledgements

The funding for this project was provided under the Enterprise Ireland Commercialisation Fund Programme of Enterprise Ireland.

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Fortified blended foods using Irish ingredients



Researchers at Teagasc and UCC are looking at the development of fortified blended foods using Irish dairy ingredients and cereals.

70 countries and purchases in excess of US\$ 1 billion of food annually to meet its objectives. The WFP supplies beneficiaries with food baskets containing staples (cereals, pulses, vegetable oil) and very often complemented with special nutritional products including fortified blended foods (FBFs). FBFs are typically intended to supplement the overall diet of food insecure individuals. They are often included in maternal and child nutrition programmes, used in emergency situations and refugee camps, and provided to HIV affected households. FBFs are also targeted at young children (six-24 months old) to help alleviate chronic undernutrition and reduce the risk of stunting.

The latest estimates from the Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD) and World Food Programme (WFP) in 2015, indicate that 795 million people worldwide (approximately one out of nine) are undernourished. The vast majority (780 million) of these food insecure individuals live in developing countries. The United Nations World Food Programme (WFP) assists almost 100 million food insecure people in over

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Table 1. Composition of commercial Kishk sample.

Source	Dry matter (%)	Protein content (%)	Fat content (%)	Carbohydrate content (%)	Salt content (%)	Ash content (%)	Water activity
Lebanon (home-made)	90.4	18.2	10.4	57.4	2.7	4.4	0.562
Lebanon (factory-made)	90.9	17.5	9.2	57.7	5.4	6.5	0.498
Syria (Mādanli)	90.8	11.1	2.4	71.7	4.5	5.5	0.514
Greece (Tarhana)	93.0	11.7	3.5	75.1	2.2	2.6	0.355
Turkey (Karişik Tarhana)	88.7	11.0	1.3	70.9	4.8	5.6	0.577
Turkey (Tarsi çocuk)	88.3	8.7	1.4	75.6	1.9	2.6	0.625
Turkey (Tarsi bebek)	89.9	9.1	1.8	77.5	0.4	1.5	0.587

Fortified blended foods

FBFs have a long history of use for more than four decades as specialised products in humanitarian food assistance programmes. Minimal changes have been made in the formulation of FBFs over that time. However, it is widely recognised that improvements to the formulations of current FBFs are required. Current FBFs distributed by WFP and other humanitarian organisations are primarily composed of dried legume/cereal blends fortified with micronutrients which are then reconstituted by heating with water and consumed as porridge.

A FIRM-funded research project entitled 'Development of fortified blended foods (FBF) using fermented buttermilk/cereal' has been underway at Teagasc Food Research Centre, Moorepark and the School of Food and Nutritional Sciences, UCC since April 2015, with the experimental work being undertaken by a senior post-doctoral researcher (Yvonne O'Callaghan) and PhD student (Ashwini Shevade). The goal of the project is to develop nutrient dense FBF products using Irish-sourced ingredients (buttermilk powder, BMP; skim milk powder, SMP; and cereal) and fortified with micronutrients (minerals and vitamins) and essential fatty acids, in line with exacting WFP specifications for FBFs. The manufacture of the products is being based on a traditional product called Kishk which



The figures in order of appearance show: (i) Viscosity measurement of a Kishk-based FBF porridge in a Bostwick viscometer at 46°C (main image, top), (ii) Commercial samples of Kishk, and (iii) Standardisation of the procedure for preparation of FBF porridge (above).

is a dried fermented milk /cereal (usually bulgur wheat) product and which is widely consumed in reconstituted form as porridge across Northern Africa and in the Middle East. Kishk is also used as an ingredient in an array of culinary dishes including soups, curry, and chapatti spread. Kishk-based FBFs, containing a dairy/cereal base, will be superior nutritionally to existing legume/cereal FBFs used by the WFP.

To date, analysis of Kishk powder samples, procured mainly from Greece, Lebanon, Syria, and Turkey has shown marked variation in composition (Table 1), especially contents of protein, salt and water. On reconstitution and cooking of the Kishk in water, the consistency (viscosity) and hydration were found to markedly vary with source of Kishk, powder-to-water ratio, cooking time, and degree of shear, probably reflecting carbohydrate content, extent of parboiling, and degree of fibre removal during bulgur preparation.

New procedures

A procedure is currently being developed for Kishk-based FBF (which will contain no added salt) and involves: preparation of fermented milk from reconstituted BMP and SMP; blending of fermented milk with parboiled, dried, and coarsely ground wheat (bulgur), fermentation of the fermented milk-bulgur blend over one to three days under controlled temperature until the required dough consistency is obtained; dehydration of the resultant Kishk dough under controlled temperature; milling the dried cake to a powder with the desired particle size, fortification of Kishk powder with micronutrients. Once the manufacturing procedure is optimised, the effects of the following parameters will be evaluated for their impact on the quality of the base fortified FBFs, i.e., ratio of SMP:BMP in preparation of fermented milk, protein content of the fermented milk, ratio of fermented milk-to-cereal, cereal type, incubation conditions of the fermented milk/bulgur mix, drying conditions of the dough, and milling conditions of the dried fermented milk/bulgur cake. The base FBF powders will be stored at different temperatures to simulate transport and distribution and ambient temperature of recipient countries. The powders will be evaluated for composition, water activity, particle size, mineral profile, colour, vitamin availability and microbiology. On reconstitution of the FBF powders to varying dry matter levels and cooking under different conditions, the resultant porridge will be examined for hydration, rheological (textural) characteristics, vitamin stability, and mineral bio-availability.

Acknowledgement

This work was funded by the Department of Agriculture, Food and the Marine under the Food Institutional Research Measure (FIRM) with project reference no. 14/F/805.

New policy impact assessment model – BIO



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Teagasc's new BIO model analyses the impact of the Food Wise 2025 strategy.

The bio-economy is a very important domestic sector for Ireland. It goes beyond the narrower biotechnology sector definition and focuses on the economic activity attributable to the utilisation of our land and sea resources. This includes, for example, the beverage, infant milk formula and food ingredients sectors and is a major source of net export earnings, accounting for about 19% of exports in 2008, compared with 10% for the agri-food sector.

In addition to its importance to exports, our former colleague Brendan Riordan estimates that the bio-economy contributed almost 40% of net foreign earnings amounted in 2008. In terms of balance of international payments, in 2008, every €100 of exports from the bio-economy generated €52 in net foreign earnings. In contrast, exports from the non-bio sector contributed only €19 in net foreign earnings for every €100 of exports. The main reasons for this disproportionately large contribution to net foreign earnings include: a relatively low import requirement per unit of output; a low share of international ownership and repatriation of profits; a high local multiplier; and a significant inflow of funds from the EU in the form of subsidies and payments.

Impact of food strategy

A key part of any economic development strategy is to assess the potential impact on the economy, of changes that might arise from these strategies, whether it be through changes in output, gross value added or employment. Teagasc has, over a number of years, worked with the Department of Agriculture, Food and the Marine in relation to understanding the impact of food strategies such as Food Harvest 2020 and, more recently, Food Wise 2025.

A modelling framework had been developed with Alan Matthews in Trinity College Dublin to model the economic impact on the wider economy of changes in the bio-economy. These models had been developed as part of PhD studies, including Teagasc Walsh Fellowships.

For the Food Wise 2025 strategy impact assessment, we wanted to move from a relatively ad hoc approach undertaken with PhD students, where we had to

essentially redevelop the model for each analysis to a more systematic approach, where we could update the model more easily when new and better data became available.

We were also interested in extending the bio-economy-focused model to other elements such as the part of the economy based upon the ocean resource in the marine economy. For a number of years, we have partnered with our former colleague Stephen Hynes at the Socio-Economic Marine Research Unit (SEMRU) at NUI Galway in developing economic analytical infrastructures for the marine sector, built upon capacity with the food sector. This was necessary as the state also wished to assess the economic impact of the Harnessing Our Ocean Wealth strategy. As part of this partnership, a contract research officer from NUI Galway has been hosted in Teagasc Athenry, creating links and analytical synergies between the two bio-based sectors.

New bio-economy model

Teagasc and SEMRU recently launched a new model of the Bio-Economy – the Bio-Economy Input – Output (BIO) Model. The event was held at the RDS on September 9, with CEOs and senior officials from most agencies with an interest in the economics of the bio-economy participating. The BIO model studies the linkages between the bio-economy sectors and the wider economy. This model has been developed to assess the output and employment multipliers of public policy initiatives. It was developed by SEMRU of NUI Galway and the Rural Economy and Development Programme of Teagasc, in association with the Marine Institute, under Beaufort Award and Teagasc funding. It builds upon the Central Statistics Office's national more aggregated Input-Output table.

Gerry Boyle, Director of Teagasc, welcomed the outcome of this joint initiative between Teagasc and NUI Galway, where the resources of both institutions, together with the Marine Institute, were brought together to create a powerful analytical infrastructure to assess the impact of public policy and economic change.

Bio-economy sector – great impact on economy

The analysis found that due to the fact that bio-economic sectors locate much of their inputs in Ireland and, because they employ relatively more

people per unit of output, when these sectors increase their sales and, in particular, their exports, they generate a greater impact on the economy. Of the 162,000 jobs in the bio-economy in 2010, there were an additional 45,000 jobs elsewhere in the value chain. As much of the bio-economy is located in rural areas, this impact can have a particularly strong effect on rural job creation.

The creation of the BIO model has also facilitated the investigation of a number of different research questions relating to the marine economy. In considering the impacts of expanding the marine sector in line with the targets set out in the Harnessing Our Ocean Wealth strategy, there is an estimated direct impact of €3.3 billion with an additional indirect effect of €2.7 billion in the wider economy, giving a total impact of over €6 billion. Considering the effect of a large-scale expansion in finfish aquaculture, the model estimates a direct and indirect employment impact of over 1,600 jobs, with an overall economic impact of an increase of approximately €379 million per annum in the wider Irish economy.

Food Wise 2025 and Harnessing our Ocean Wealth

The BIO model provides a framework under which the impacts of changes in output across the wider value chain can be analysed, which is particularly important in the case of agriculture (a primary activity) with extremely high levels of intra-industry trade. For example, when considering milk production, volumes required at the processing scale drive the animal numbers which in turn influences the mix and quantity of cereals produced on a competing land base.

The model has been used to support strategic planning in the recent Food Wise 2025 strategy for the agri-food sector. An analysis of farm level employment growth in response to sectoral expansion scenarios was conducted with indirect impacts from

the BIO model calculated. The strategy targets the creation of an additional 23,000 direct and indirect jobs in the agri-food sector throughout the supply chain from primary production to high value-added product development.

Amaya Vega of SEMRU in NUI Galway emphasised the high multipliers in many of the bio-economy sectors. These are sectors with highest impact on the rest of the economy. Of the 99 sectors in the model, eight of the top 15 and three of the top five multipliers are from the bio-economy sector, with shipping and marine transport having the highest multiplier; forestry products and cattle farming are also among the top five multipliers.

Peter Heffernan, CEO of the Marine Institute, emphasised the importance of analytical infrastructure in supporting the ambitious targets within Harnessing our Ocean Wealth. Economic analysis is critical in decision making in relation to the Atlantic Action Plan that can enable 'Blue Growth', doubling the size of our ocean economy to 2020.

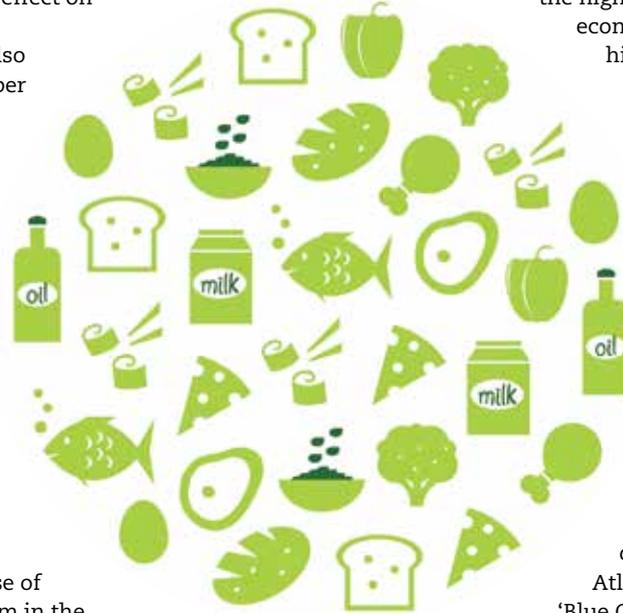
The report, The Bio-Economy Input Output Model: Development and Uses, together with background tables, can be found on the Teagasc website <http://teagasc.ie/publications/>

Acknowledgments

Eoin Grealis of SEMRU (NUIG) and Cathal O'Donoghue of Teagasc developed the BIO modelling framework, while analyses were additionally undertaken by Thia Hennessy, Fiona Thorne and Trevor Donnellan of Teagasc and by Stephen Hynes and Amaya Vega of SEMRU (NUIG).

Funding

This work has been funded by Teagasc and the Marine Institute.



The future

is bio

This article highlights the need to transition to a sustainable, low-carbon bioeconomy and the work of BioÉire, a project that aims to provide the evidence base for this transition in Ireland.



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Imagine the future. It's 2050 and as you wake up, your home anaerobic digester kicks in to heat your home using food waste and grass biomass resources. You consider your options for a sustainable, nutrient-rich breakfast, deciding on a protein-rich shake derived from dairy by-products, an Irish, omega-3-rich juice made from (but, importantly, not tasting of!) previously underutilised fish species and a seaweed-based supplement for an extra boost of antioxidants. You brush your teeth with your trusty bioplastic toothbrush and shower using a range of biobased cosmetics derived from marine discards and shells. You drive to work in the local biorefinery, a centre that processes waste and other materials from the agricultural sector to create multiple products for food, feed, pharmaceutical, cosmaceutical, bioenergy and biochemical markets. Your car is, of course, also powered by biofuel, produced from native biomass crops.

From future vision to reality

While the above scenario may seem overly optimistic, futuristic and downright idealistic, it may be closer than you think. While more than 98%

of the energy and chemicals utilised in 2000 were derived from fossil fuel-based resources, by 2100 more than 95% of chemicals and polymers can, and must, derive from renewable resources (O'Connor, 2015). Indeed, in the face of escalating challenges related to climate change, biodiversity loss, resource scarcity, food security, economic sustainability and growing populations, the need to transition to a more sustainable, low-carbon way of living is increasingly recognised. It is, thus, not a matter of if, but when, society makes this transition.

The future bioeconomy

The bioeconomy concept offers one way to address these challenges, harnessing the use of renewable biological resources and reducing dependence on fossil fuels, while still achieving economic growth. It is a concept that is gaining traction worldwide, coming to the forefront in key policy documents at both global and EU scales in recent years (OECD, 2009; EC, 2012). More recently, nation states are being urged by the EU and OECD to develop tailored national bioeconomy strategies, drawing on domestic strengths, identifying national priorities for development and highlighting the stakeholder groups requiring engagement in the bio-based society. Switching to new modes of growth, the future bioeconomy also draws upon ideas of the circular economy whereby the waste of one sector represents a valuable input to another (for example, agricultural waste for biochemical conversion or forestry pulp for bioenergy creation). Innovation, knowledge and value addition, thus represent essential building blocks of the future bio-based

society to develop new opportunities, products and services from renewable, sustainable feedstocks.

At the European level, the bioeconomy is estimated to provide employment for over 22 million people, with a turnover of approximately €2 trillion (EC, 2012). These lucrative markets producing biofuels, biofertilisers, biochemicals and bioplastics are, however, only beginning to be exploited. Ireland is particularly well placed to capitalise on these opportunities given its abundant natural resources, thriving agriculture and marine sectors, growing forestry development, well-respected food industry and renowned research and development capabilities. The opportunities available are endless and exciting, from the potential revival of the Irish sugar beet industry for chemical biorefining, to the use of animal waste streams for bioenergy creation, to the extraction of valuable proteins and bioactives from underutilised marine resources. Possibilities to harness existing wild, and even pest, cultivations in Ireland also remain, akin to developments in Sardinia where wild thistles are now being utilised to create bioplastics (Matrica, 2015).

BioÉire: a bioeconomy for Ireland

To assess the feasibility and facilitate the pursuit of opportunities, BioÉire is a recent bioeconomy project, which is being led by Teagasc and with partners across the Technology Centre for Biorefining and Bioenergy (TCBB) at NUI Galway, University College Dublin and the Dublin Institute of Technology. Funded by the Department of Agriculture, Food and the Marine, the project aims to evaluate the growth opportunities, policies and initiatives shaping Ireland's transformation to a sustainable, low-carbon economy and identify bioeconomy priorities for Ireland to maximise national income, exports and job creation. BioÉire will identify up to eight key commercial opportunities, assess their technical, economic and environmental viability and make recommendations on the development frameworks necessary to underpin their delivery. A plethora of disparate, and sometimes conflicting, policy strategies currently exist regarding natural resource use in Ireland across agriculture, food, forestry, energy and marine sectors, further complicated by wider separate national development and environmental strategies (for example, regarding waste and health and safety). The need for one cohesive strategy to guide the future

development of the Irish bioeconomy is thus ever pressing. In achieving its aims, BioÉire will provide part of the evidence base required for the development of this national strategy, ultimately changing how we produce, process and recover biological feedstocks.

Conclusion

It is not a matter of if, but rather 'when' governments, industry and society, will transform to a low-carbon bioeconomy. Rather than representing an unrealistic future vision, it is, in a way, returning to the bio-based society of pre-industrial times before the fossil fuel discoveries that have dominated since the 1800s. One crucial difference remains, however, in the application of innovative and novel technologies to extract and process what society needs from nature in a more reliable, sustainable and efficient manner. BioÉire represents one of many steps required in this (re)transition, mapping current resource bases in Ireland and highlighting their future potential against a range of economic, technical, environmental and social checkers. It is one key step in realising your future bio-based morning routine.

Funding acknowledgement

BioÉire is funded by the Department of Agriculture, Food and the Marines Research Stimulus Fund.

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The BioÉire Team are pictured (from left): Pádraic O'hUiginn (TCBB); Kevin McDonnell (UCD); Eilín Walsh (UCD); Bart Bonsall (TCBB); Maeve Henchion (Teagasc); Laura Devaney (Teagasc); Paul O'Reilly (DIT); and Ultan Shanahan (Teagasc).

Understanding soil testing on dairy farms



There are differences in the characteristics of Irish dairy farmers who test their soil on a regular basis compared to those who do not soil test regularly, according to a recent Rural Economy and Development Programme (REDP) Teagasc Walsh Fellowship research project. By contrast, there are no significant differences in the fertilizer costs per hectare between those dairy farmers who test their soil and those who do not.

Overview of the research project

These research findings are the first phase of a more extensive social science-based mixed methods research project examining Irish dairy farmers' use of soil test information, their nutrient management practices and soil fertility (Kelly, 2014). The project had two components: a quantitative analysis of 231 specialist dairy farmers from the 2012 National Farm Survey, which, when weighted, represents approximately 14,000 farmers and 20 qualitative case studies based on in-depth interviews with farmers from the Agricultural Catchments Programme. While latter parts of the project sought to gain a deep understanding of the decision-making behaviour of farmers in relation to soil testing, the first part of the project, reported here, aimed to identify the baseline farm and farmer characteristics of dairy farmers who regularly tested their soil or did not, in order to identify farm and farmer types to target for subsequent on-farm qualitative research.

Background

Seventy-one per cent of all dairy farmers test their soil. However, 76% of those farmers test their soil because they have to, either for derogation purposes or as a requirement for participating in rural environment schemes, such as REPS. A nitrates derogation allows farmers to operate at a higher stocking intensity than the base standard as set down under the EU Nitrates Regulations. At the same time,

national soil fertility levels are declining and many factors may contribute to this decline. For example, increasingly stringent EU legislation and guidelines regarding on-farm nutrient use is important. In addition, fertilizer sales declined over the period 2001-2011. Potentially contributing to the decline in sales, fertilizer prices were volatile over this period.

From first principles, soil testing is used to assess soil fertility with a view to matching nutrient supply with crop demand, thereby maximising production and profitability while reducing the risk of nutrient transfer to the wider atmospheric and aquatic environment. Soil testing is considered a cost-positive technology; generally soil testers should save money through improved management of required inputs. Soil testing is a key nutrient management practice as it has the potential to deliver a double dividend of increased economic returns to agricultural production while helping to achieve environmental objectives as set down in international agreements such as the EU Nitrates Directive, the EU Water Framework Directive, the Kyoto Protocol agreement and EU 2020 targets to reduce greenhouse gas emissions.

Results

The study provided answers to three questions. First, what are the farm and farmer characteristics of Irish dairy farmers who soil test? Second, what are the characteristics of farms and farmers who soil test voluntarily? Third, are there differences in terms of cost savings between those farmers who soil test and those who do not?

The answer to the first question is that, on average, dairy farmers who regularly soil test are 50 years old, have a farm of 57.6ha and a 64-cow herd. There are two broad categories of farmers who test their soil: those who do so mandatorily, due to a policy-driven incentive or requirement such as REPS or the Nitrates Directive, and those who test voluntarily. In the context of soil testing and soil fertility, REPS and the Nitrates Directive have conflicting objectives of increasing soil productivity (REPS) and restricting nutrient application use (Nitrates Directive). As shown in Table 1, all farmers who test their soil regularly are younger, have larger farms and herd sizes and have higher farm gross margin and gross output compared to those farmers who don't regularly test their soil.

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Table 1. Comparison between all soil testing and non-soil testing dairy farmers.

Variable	Regular soil testers (n=165)	Non-regular soil testers (n=66)
Age	Younger	-
Farm size	Larger	-
Size of dairy herd (Avg)	Larger	-
Farm gross margin (GM) (€)/UAA	Higher	-
Farm gross output (GO) (€)/UAA	Higher	-
Nitrogen (kg)/UAA	Higher	-
Direct cost (€)/UAA	No Difference	
Fertilizer (€)/UAA	No Difference	

Analysis based on t-tests of differences between the 2 groups.
UAA= Utilised agricultural area.

The last two lines of Table 1 address the third research question. They confirm that there is no significant difference between the two groups in relation to direct costs and fertilizer costs per hectare. Potential cost saving is considered a key benefit of soil testing, yet there is no significant difference between the groups in relation to direct costs and fertilizer spend per hectare. Farmers who regularly soil test also use greater quantities of nitrogen, which is most likely linked to more intensive grass production systems. What is potentially a more worrying finding from the research is the almost equivalent average fertilizer expenditure per hectare by farmers who do not test (€155) as those who do (€168).

In relation to the second research question about the characteristics of farmers who voluntarily test their soil, results of a logistic regression shown in Table 2 confirm that farmers with formal agricultural education are almost four (3.69) times more likely to soil test. Farm size (measured by dairy platform) also has a positive impact on the likelihood of soil testing. For each additional (hectare) increase in the size of the dairy grazing platform there is a 5.5% increase in the likelihood of soil testing.

Table 2. Key characteristics of voluntary soil testers.

Explanatory variable	Estimated coefficient standard error	Odds ratio	95% Confidence interval
Dairy platform	0.0535**	1.055	[0.0152667 0.0918649]
	(0.02)		
Formal ag. training	1.3074**	3.696	[0.0486439 2.566285]
	(0.64)		

Log pseudo likelihood -2343.51 Pseudo R² 0.27
Number of observations is 78. *p<0.1, **p<0.05, ***p<0.001
Dairy platform is the size of the grazing area adjacent to the milking parlour.

Implications of the research

Given the anomalies identified during this research, in terms of fertilizer costs, declining soil fertility levels, different characteristics of farmers who do and do not soil test and the mandatory requirement underpinning much soil testing, we suspect, though do not investigate until later parts of the research project, that Irish dairy farmers are not making full use of their soil test results as a decision making input to nutrient management practices. They may



not be doing so for various reasons: farmers might soil test to fulfil mandatory obligations but never fully use results; the introduction of increasingly stringent legislation regarding nutrient use might hinder farmers from reaching optimal agronomic production levels; farmers may, for some reason, not wish to achieve optimal agronomic fertility levels; multiple sources of information from the wider environment such as peers, personal experience, industry, input suppliers and the media may mediate optimal decision making; farmers might only test poor quality soils and so the results show no apparent improvement over time.

Acknowledgements

The authors would like to thank the Teagasc National Farm Survey for the provision of data for this specific piece of research and the Agricultural Catchments Programme for facilitating the qualitative components of the project. This research was supported by the Walsh Fellowship Programme and Teagasc grant-in-aid.

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Costs of production on dairy farms



Analysing the costs of production on dairy farms using Teagasc eProfit Monitor and the Teagasc National Farm Survey

The cost of production on dairy farms is an issue of critical importance to the sector, especially at a time when farmers may be planning expansion in the aftermath of milk quotas and also given the current weakness in dairy markets. Teagasc produces an analysis of dairy production costs on an annual basis using both the eProfit Monitor (ePM) and the National Farm Survey (NFS). These results tend to vary somewhat, which can be the source of some confusion. The ePM typically reports lower costs of production and higher profits. In this article we describe and compare these two data sources and examine the potential causes for differing results.

eProfit Monitor and the National Farm Survey, what is the difference?

The NFS involves the collection of data on an annual basis from a random, nationally representative sample of approximately 1,000 farms. The NFS is a member of the pan-EU Farm Accountancy Data Network (FADN), which uses a harmonised system to collect national statistics on farming across Europe. Data validation

is by the Teagasc data recorder with reference to financial documents.

The ePM is a financial benchmarking tool that is available to all Teagasc clients via the Teagasc website. Data (both technical and financial) are provided by the farmer through the completion of an Input Sheet and can be entered directly by the farmer or (as is more likely) by his/her Teagasc advisor. Advisors select farmers to complete the benchmarking analysis and users are encouraged to repeat the analysis over a number of years. The results generated are not nationally representative as the farms included in the annual dataset are self-selecting and do not proportionally represent the entire farming population.

Table 1 summarises the key features of both systems. While there are some differences in the cost headings used and the calculation of depreciation, the results generated are similar for both NFS and ePM analysis. In order to investigate the impact of any methodological differences, a validation exercise was conducted where the financial results of a farm participating in both the ePM and the NFS were compared. The comparison showed that the difference between the two systems was relatively small. The ePM methodology reported the net margin per litre to be 4% higher than the NFS, suggesting that the methodology used has only a minor impact on the differing results from the two systems.

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Table 1. Summary of key features of National Farm Survey (NFS) and eProfit Monitor (ePM).

	National Farm Survey (NFS)	eProfit Monitor (ePM)
Data collection	Data provided by farmer and verified by Teagasc data recorder with reference to financial documents (invoices, etc.)	Data provided by farmer using input sheet and verified by advisor
Calculation of total costs	Costs grouped into 'Direct' and 'Overhead' categories	Costs grouped into 'Variable' and 'Fixed' categories
Apportionment of costs	Similar to ePM except discussion takes place between recorder and farmer regarding allocation	Variable costs are allocated on the basis of livestock units; fixed costs are allocated on the basis of output
Treatment of heifer rearing costs	Similar to ePM except transfer values are agreed between data recorder and farmer (standardised values used in ePM)	Heifer rearing charge included against Gross Output on Dairy Enterprise report; separate Replacement Enterprise report also produced
Treatment of own labour	Own labour charge not included	
Land charge	No land charge included for owned land	
Depreciation	Replacement method used	Straight line method used based on original asset value
Treatment of inventory	Recorded at year end; fodder crop adjustment calculated	Facility to record inventory available but rarely used
Reports	Whole farm and dairy enterprise reports	

Given the relatively small differences in the methodologies of the two systems, it is most likely that the difference in the results is due to sample issues. As can be seen, ePM farms are, on average, larger, more intensively managed and more productive than NFS farms (Table 2).

Table 2. Characteristics of the average dairy farm in the Teagasc National Farm Survey (NFS) and the Teagasc eProfit Monitor (ePM) (2014).

	NFS	ePM
	(n = 318)	(n = 1,363) ¹
Herd size (cows)	68	97
Total milk production (litres)	351,560	497,901
Stocking rate	2.07	2.17
Yield per cow (litres)	5,170	5,133
Milk solids per cow (kg)	375	402
Milk solids per hectare (kg)	775	872
Grass utilised (kg/ha DM)	7.41	8.5

Data accessed 8/2/2015; additional dairy farmers have completed ePM analysis since this date.

Direct and fixed costs were 13% and 8% lower respectively on the average ePM farm in 2014 (Table 3). The difference in financial

Table 3. Output, costs and profit (cent per litre) for the average dairy farm in the Teagasc NFS and the Teagasc ePM: 2014.

	NFS	ePM
	(n = 318)	(n = 1,363)
Milk price	39.5	39.26
Gross output	38.9	39.43
Total direct costs	14.74	12.90
Total fixed costs	11.16	10.31
Net margin (cent per litre)	12.97	16.21
Net margin (€ per cow)	671	832
Net margin (€ per hectare)	1,386	1,806

performance is more apparent when examined on a per cow or a per hectare basis reflecting the higher rates of productivity on the ePM farms.

In addition to comparing the average farm in the ePM and NFS, we also compared the top and bottom performing farms. The profit differential between the ePM and the NFS was smaller for the top one-third of farms in the two samples but was larger for the bottom one-third. This suggests that the 'best' farms in the two groups are more comparable than the 'poorest' farms, reflecting the fact that the NFS provides a greater representation of poorer performing farms.

Conclusions

According to the results for 2014, the average farmer in ePM was 30% more profitable on a per hectare basis than the average farmer in the NFS. While some of this differential is due to methodological issues, it is more likely that the different samples used in the two systems is the main cause for variation. It is clear that the farmers participating in ePM are larger and more productive than the national average. Furthermore, all of the farms participating in ePM are in active contact with a farm advisor and are evidently benefitting from that interaction.

Acknowledgements

This work is funded by Teagasc core funding.

WHICH DATA TO USE?

There are clear differences in the two data sources, so which is the appropriate one to use? Given the advisory and farm management focus of the ePM system, this is the most suitable data source for farm advisory events where the demonstration of "best practice" is the focus. On the other hand, the Teagasc NFS provides an insight into all types of farming and given the representative nature of its sample it is the more appropriate source to use in presentation of national results and especially in issues pertaining to government policy, economic planning and cross-country comparisons.

Events

DECEMBER

December 9 Teagasc Food Research Centre, Moorepark, Fermoy, Co Cork

Healthy Living Through Nutrition and Sport

There is a growing realisation among the public that combining healthy eating with exercise is key to ensuring a healthy and active lifestyle. Sports people and scientists involved in food, nutrition and sports science have been aware of this connection for some time. In December, scientists and sports people who are experienced in this area will discuss the latest developments in nutrition and sport. Discussions will include: biology of fitness covering a discussion on obesity, fitness and diets; introducing nutritional concepts to children and adolescents; and what does all of this have to do with Teagasc?

Contact: niamh.obrien@teagasc.ie

<http://www.teagasc.ie/events/2015/20151209.asp>

December 10 Teagasc Food Research Centre, Moorepark, Fermoy, Co Cork

Gateways to Food for Health

This event will provide an exciting opportunity for food and ingredient producers to learn about the current trends in food for health research; receive updates on major national and international consumer health concerns; learn about evolving markets for food products in the health and wellness; and hear about supports available from national development agencies, as well as the technology offerings emanating from the UCC/Teagasc Food Innovation Alliance.

Contact: gateways@teagasc.ie

<http://www.teagasc.ie/events/2015/20151210.asp>

December 14 Teagasc Food Research Centre, Moorepark, Fermoy, Co Cork

44th Annual Food Research Conference

This one-day conference provides a platform for postgraduate students to present their research findings in the form of either an oral or a poster presentation.

Contact: FoodResearchConf@teagasc.ie

<http://www.teagasc.ie/events/2015/20151214.asp>

2016 FEBRUARY

February 10-11

Castleknock Hotel, Dublin

CommBeBiz symposium and workshop event 'Bioeconomy Impact 2016'

CommBeBiz, the H2020 Support Action, is hosting the first in a series of annual events designed to link researchers, industry, and other interested stakeholders within the bioeconomy so as to enable effective and speedier transfer of knowledge to the marketplace and policy-players and for social innovation. The theme of the first annual event will be to challenge bioeconomy researchers to critically think about the value, impact and relevance of their research and encourage attendees to develop an action plan for realising the impact of their research.

E-mail: aine.regan@teagasc.ie www.commbebiz.eu/BioeconomyImpact2016

MARCH

March 8

Aviva Stadium, Dublin

Teagasc Technology Foresight Conference

International conference to launch the final report of the Teagasc Technology Foresight 2035.

Contact: lance.obrien@teagasc.ie

March 23

RDS, Dublin

Teagasc Distinguished Lecture Series

The lecture will be delivered by Frank Rijsberman, CEO of the CGIAR Consortium, an international agri-food research organisation that integrates the strategic research of 15 CGIAR Research Centers worldwide. It is the world's largest, publicly funded, international agriculture research partnership. Frank is responsible for driving cultural change to outcome orientation and results-based management across the system, and established the new international organisation at its new

headquarters in Montpellier, France. He also refreshed the CGIAR system-wide strategy, and oversaw the creation of a new portfolio of large-scale research programs for the period 2017-2022.

Contact: ann.tierman@teagasc.ie

<http://www.teagasc.ie/events/lecture-series/>

JUNE

June 10-11

Teagasc, Mellows Campus in Athenry

Farming and Country Life 1916-2016

This event, Farming and Country Life 1916-2016, seeks to commemorate the Rising and to reflect on developments in farming and country life across Ireland over the last century.

The event will host a series of highly interactive villages that will explore all aspects of farming and country life in Ireland. The event will also chart the major developments in the first half of the 20th century.

Contact: michael.diskin@teagasc.ie

<http://www.teagasc.ie/news/2015/201510-23b.asp>

June 19-23

Limerick, Ireland

IALB/EUFRAS/Teagasc 2016 Conference: Innovation Support for a Productive and Sustainable Agriculture

'Supporting the diversity and resilience of land, people and production systems' is the theme of the 2016 IALB/EUFRAS/Teagasc 2016 Conference. During the event there will be potential to engage with participants, particularly those involved in H2020 and EIP projects, and explore how to best support innovation through knowledge transfer methods.

Contact: ialbconference2016@teagasc.ie

<http://www.teagasc.ie/events/2015/Advisory%20DL%206pp%20080615%20Final.pdf>

AUGUST

August 21-25

RDS, Dublin

IUFoST 2016 World Congress of Food Science and Technology

The International Union of Food Science and Technology (IUFoST) is the global scientific organisation for food science and technology supporting programmes and projects to increase the safety and security of the world's food supply. Throughout more than 65 member countries, it represents over 300,000 food scientists and technologists worldwide. Its 2016 Conference, is themed 'Greening the Global Food Supply Chain through Innovation in Food Science and Technology'. Declan Troy, Chairman of the Organising Committee and Director of Teagasc said: "It is fitting that Ireland hosts this congress as it is widely regarded as the 'Food Island'."

Contact: info@iufost2016.com

<http://www.iufost2016.com/>

OCTOBER

19-21 October

University College Dublin

10th International Life Cycle Assessment of Food Cycles 2016

The conference is structured into four broad themes. The first will look at specific environmental processes and services as addressed by life cycle assessment (LCA). Contributions on soil, biodiversity, ecosystem services, water and land use will be considered in this theme.

Theme 2 will look specifically at animal agriculture (of particular importance in Ireland) with contributions on dairy, beef, pigs and poultry, post-farm processing and whole chain studies. Theme 3 will look at interaction with humans and human systems with contributions on crop systems, waste, processing, diet, nutrition, behaviour, and health and food innovation.

Theme 4 will address various aspect of how life cycle assessment (LCA) is used, with contributions ranging from data, methods and tools, through socioeconomic methods, to PEF, labelling and policy.

Contact: sinead.lawlor@conferencepartners.ie

<http://lcafood2016.org/programme/>

For a list of Teagasc's food industry training schedule (food safety, food law, animal welfare, quality assurance, microbiology, cheese making, calculating meat content, laboratory auditing) please see: <http://www.teagasc.ie/food/research/training/schedule.asp>
For presentations from previous Teagasc events see: <http://www.teagasc.ie/publications/>