University of Nottingham
Future Food

Exploring new ways to feed the world

Future Food

Beacon of Excellence

nottingham.ac.uk/future-food

2021/22

The University of Nottingham has over 250 researchers working on solutions to challenges across the food system

A field of pearl millet in Senegal, one of our projects examining drought tolerance traits.

Contents

Director's update

2022 has seen a year of change at the Future Food Beacon. Professor David E. Salt stepped down as Director of the Future Food Beacon at the end of July 2022 and Professor Andrew Salter stepped into his shoes to lead the Beacon through its final year. Here, Professor Salt contemplates the Future Food Beacon's achievements.

Launched at the Royal Society in June 2017, over the last five years the Future Food Beacon has done extraordinary things, all through the remarkable efforts of the hundreds of stakeholders (academics, industry, civil society, and government) who actively engaged with the Beacon.

Some of the Beacon's achievements have included:

- Hiring 75 new staff and students, from over 30 countries
- Publishing 103 papers with Beacon staff as first or last author
- Winning 63 external grants, totalling £14.8 million
- 31 projects funded in 32 countries
- MOUs signed with four international organisations including with the United Nations Food and Agriculture Organisation (FAO)
- Collaborative projects at both University of Nottingham Malaysia Campus (UNMC) and University of Nottingham Ningbo China (UNNC), including the new Centre of Smart Food for Health at UNNC
- Engagement with over 250 university colleagues as part of the nine co-production workshops for the Innovation Challenge held at all campuses in 2018
- Biannual Beacon Briefings (each attended by over 70 people)
- 38 newsletters, 161 blog posts, 24 university press releases
- Support for over 60 projects in open competition across all faculties to pump prime new food-related research activities
- Working with government, including contributing to the National Food Strategy, discussions with local MPs, sponsoring a parliamentary debate on the NFS, publishing policy briefs, and engaging directly with Defra and the Food Standards Agency through workshops and campus visits
- Working with over 100 external organisations to co-design research activities across industry, civil society, and government
- Six Nottingham Research Fellows supported to transition to permanent school positions
- £3 million invested in equipment, including at DeepSeq where it played an important role in the university's contribution to the national Covid-19 sequencing efforts
- The establishment of new platforms including the Maker Space workshop (with Plant Science) for rapid prototyping and construction of required materials, and the Ancient and Environmental DNA Laboratory in collaboration with the Faculty of Science, Schools of Biosciences, Geography and Classics & Archaeology, and the Life in Changing Environments Interdisciplinary Research Cluster

Our leadership team, made up of academics from all five faculties and UNMC, and our External Advisory Board, drawn from manufacturing, agriculture, hospitality, our local community and a Brazilian economist, have provided valuable, practical and outward looking advice throughout the establishment and running of the Beacon. I would like to thank all members of the Future Food Beacon community for making the Beacon such a success. It is an exemplar of how challenge-led, transdisciplinary research can be done.

David E. Salt
Director of the Beacon 2017-22,
Faculty of Science

The Future Food Beacon is an exemplar of how challenge-led, transdisciplinary research can be achieved

The triple challenges of Brexit, Covid and the war in Ukraine, together with the threat of climate change, have highlighted the weaknesses of our food systems.

Stakeholders at a workshop exploring how spatial information is communicated, part of the GeoNutrition project.

Overview

I was very proud to be asked to take over as Director of the Beacon until its completion in July 2023. I would like to take this opportunity to thank David Salt for the amazing job he did in bringing the Beacon into existence and ensuring it delivered on its mission to enhance the university's capabilities, research income and output across a broad range of topics relating to local, national and international food systems.

The triple challenges of Brexit, Covid and the war in Ukraine, together with the continued threats posed by climate change, have all highlighted weaknesses in these systems and shown the importance of continued research into the production of affordable, sustainable and healthy food for all.

I would also like to thank Simon Ridgway, who has now left the Beacon, for the remarkable way he managed our finances in such a positive and proactive way.

As you can see from the case studies below, incredible progress is being made on a wide variety of projects. The examples demonstrate the range of expertise available across the university, and it is major testament to the dedication of all involved that so much progress has been made despite the inevitable delays enforced by the Covid pandemic. It is also very pleasing to see some of our Beacon-funded fellows start to settle into university academic positions and our PhD students start to graduate. It is now the responsibility of all involved to maximize the impact of our work through high impact publications and to hopefully secure further external funding. As the work of the Beacon draws to an end, I am delighted that the university has confirmed its commitment to establish the Food Systems Institute, and I look forward to sharing further details with you as they emerge.

Andrew M. Salter
Director of the Beacon 2022-23,
School of Biosciences

Snapshot of achievements

Supported submission of **279** Beacon related grants (£152m)

134 supported grants awarded (£23.2m)

65 grants awarded to Beacon researchers (£14.8m)

10 grants awaiting outcome (£10.7m)

213 papers published since July 2017 (Beacon researchers only)

43 papers published 2021/22 (Beacon researchers only)

450+ stakeholders from academia, business, civil society and government

2 senior group leaders

6 Nottingham Research Fellows

7 post-doctoral researchers

4 technologists

15 PhDs in the International Agriculture Doctoral Training Programme

12 Innovation Challenge PhDs (2 based at our Malaysia campus)

£2.9m spent on 31 items of equipment

£400k spent on ÆDNA

7 doctoral prizes awarded (£168k)

6 Future Food Fellows awarded

29 Innovation Fund proposals awarded (£549k)

6 projects partnering with EMBRAPA (Brazilian Agricultural Research Corporation) (£124k)

18 partnership proposals funded (£133k)

Case study one: China projects

Antibacterial resistance in livestock farming is a huge challenge. Our researchers are developing solutions.

Using sensors and machine learning to fight antibacterial resistance

Understanding antibacterial resistance in livestock and humans is a hugely pressing issue. Dr Tania Dottorini, Associate Professor in Bioinformatics, leads the FARMWATCH project, using sensors and machine learning to develop strategies to combat antibacterial resistance (ABR). The initiative started in 2019, with joint funding from Innovate UK and the Chinese Ministry of Science and Technology (MoST) and features the participation of notable partners such as the China National Centre for Food Safety Risk Assessment (CFSA), part of the Chinese Ministry of Health, and New Hope Liuhe Ltd., one of the largest feed and livestock producers in China.

Thanks to the high relevance of the subject, FARMWATCH has attracted a lot of attention from academia (thanks to several high profile *publications*), industry (with several other UK and Chinese companies willing to participate in the research), and the media (see for example a *2021 video interview with CGTN* – a group of six international multi-language television channels owned by China CCTV with 80 million viewers, as well as several popular *articles*).

In the wake of FARMWATCH, Dr Dottorini has been appointed Director of the newly established Centre of Smart Food for Health (CSFH) at the University of Nottingham Ningbo Campus (UNNC) in China. The CSFH is part of a larger initiative devoted to promoting research excellence through the collaboration of the UK and Chinese campuses of the University of Nottingham. In addition to acting as a bridge of innovation and expertise across the two countries,

FARMWATCH examines solutions for the poultry industry

the CSFH is designed to create strong ties with wider academia, industry and governmental agencies in both the UK and Chinese territories, to promote initiatives in the fields of food health and safety. Targeting the threat of antibiotic resistance, which spreads from livestock and feed (due to the use of broad-spectrum antibiotics) to the populations of consumers, and to the environment at large, is one facet of CSFH.

At CSFH Dr Dottorini will lead a team dedicated to her next research initiative “Big data and AI early-warning solutions for a healthy food supply (AI for healthy food)”, a follow-up of FARMWATCH. Like FARMWATCH, the strongest element of distinction and innovation in the new work is the use of a combination of machine learning, smart sensing and big-data/cloud-powered analysis to identify hot-spots of infection and resistance, and to pinpoint routes of propagation from livestock to the environment, and to the human population.

The above projects, and the centre as a whole, are expected to have significant impact on the academic and industrial communities, and on the populations of both countries at large. In particular for ABR, the introduction of cutting-edge technologies based on machine learning, smart sensing, cloud computing and big-data analysis will allow for state-of-the-art solutions for monitoring the insurgence and spread of episodes of infection and ABR, and will shed new light on the mechanisms of propagation which are still largely unknown, as already highlighted in initial *publications*.

The UK-China partnership initiated by FARMWATCH is growing stronger, is involving an increasing number of partners, and has already allowed the strengthening of ties between the two countries on the worldwide-relevant theme of ABR.

We are developing alternatives to antibiotics in livestock by way of traditional Chinese herbs.

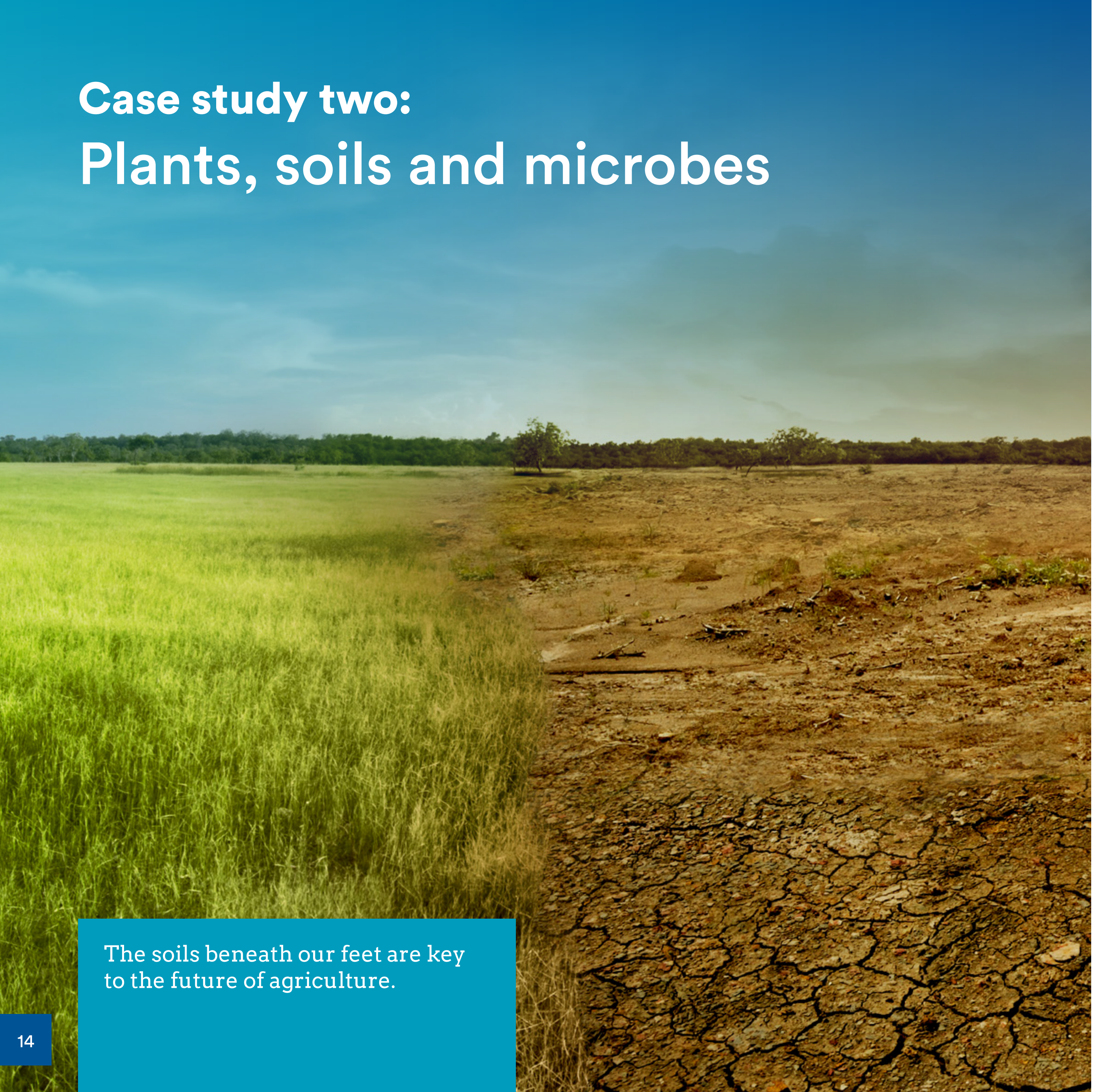
Exploring alternatives for antibiotic use through Chinese herbs and medicines

A collaboration between University of Nottingham (John Brameld, Pete Rose and Serafim Bakalis prior to his move to Denmark) and KPAD (food process analysis and design consultants) in the UK, with Hunan Agricultural University and Micolta Bio Resources (an animal feed additives company) in China, has focused on developing alternatives to antibiotic use in the livestock industry by way of traditional Chinese herbs. Antimicrobial resistance in the livestock industry is a growing concern and alternatives are being sought to help cope with this problem.

The main aim of the project was to produce premixes for animal feeds using Chinese herbs containing bioactive compounds with antimicrobial and/or growth promoting activity. Initially a database of Chinese herbs was developed containing information on several herbs, the alkaloids, polysaccharides and polyphenols they contain and their known functional properties. This allowed the identification of herb extracts (e.g. from magnolia bark, St John's wort and rosemary leaves) as well as pure bioactive compounds which were subsequently used to evaluate their antimicrobial properties via a high throughput robotic system (in collaboration with Miguel Camara in Life Sciences/National Biofilms Innovation Centre). Magnolol and Honokiol (both obtained from Magnolia Bark) were shown to be the bioactives with the highest antimicrobial activities and an Artificial Intelligence (AI) algorithm was developed to predict antimicrobial activities.

In parallel our Chinese partners investigated the *in vivo* effects of pure bioactives and plant extracts on the response of chickens to LPS (Bacterial lipopolysaccharides), E. Coli and Salmonella challenges. Importantly, Magnolol supplementation was shown to improve growth performance, meat quality, breast yield and oxidation stability in broiler chickens, and also enriched the proportion of beneficial bacteria in the caeca, with 300mg/kg Magnolol being the best dietary supplement. Moreover, Magnolia and Rosemary extracts rich in bioactive compounds were produced at both laboratory and pilot scale, with Life Cycle Assessment (LCA) analysis showing that Magnolia Bark was best in terms of the most efficient and environmentally friendly extraction process. In addition, an economic feasibility study indicated that in terms of new product development, Magnolia Bark would be a good investment as a supplement for animal feeds. Finally, the AI algorithm, LCA results and herb database were combined to design a mobile phone application for use by farmers to help advise and manage their use of a supplement.

Overall, we identified Magnolol and Honokiol (both obtained from Magnolia Bark) as the most potent antimicrobials, with Magnolol shown to have positive effects on broiler chicken growth and production when included at 300mg/Kg in the feed. Furthermore, we showed that a feed additive can be produced that has reduced environmental impact, is economically viable and a good alternative to antibiotics. This should then help reduce the use of antibiotics in livestock and therefore the incidence of antimicrobial resistance.



Case study two:
Plants, soils and microbes

The soils beneath our feet are key to the future of agriculture.

Stories from GeoNutrition: How should uncertainty in spatial information be communicated?

Many and varied people have to make decisions about environmental management, be they farmers, policy-makers or managers, and spatial information about environmental variables (e.g., soil properties) is essential for this task. Within the Future Food Beacon, the *GeoNutrition project* is concerned with how soil might limit the supply of micronutrients (e.g., iron, zinc, selenium) which are essential for human health, and how interventions to address deficiencies of these can be targeted efficiently. Large datasets of soil and crop information were collected from smallholder farms in Ethiopia (2017/18) and Malawi (2018), in sub-Saharan Africa. Spatial predictions were made from the data collected from the surveys to generate the kind of information needed to support decisions on interventions, but these predictions are uncertain.

Various statistical methods can be used to combine the field survey data and other data sources (e.g., satellite data) to produce improved predictions and to measure their uncertainties quantitatively. These statistical measures of uncertainty are indigestible for decision-makers. We examined this problem by eliciting stakeholder's opinions on the accessibility of different statistical descriptions of uncertainty.

Our findings confirmed that many of the statistical descriptions of uncertainty are difficult to understand. However, different groups of stakeholders could make sense of information when the measure of uncertainty was linked directly to its interpretation, for example by presenting the probability that the concentration of a nutrient in a crop exceeded a nutritionally significant threshold. Therefore, the GeoNutrition project has used such outputs to present its data.

Presenting uncertain information so that stakeholders can make sound decisions with it is not a simple task and requires perspectives from psychology as well as statistics. *We have shown*, for example, that the same information is interpreted differently if it is `framed' in terms which draw attention to the general idea of nutritional deficiency rather than sufficiency. Our experimental approaches provide a basis for finding ways to frame information so that stakeholders can make robust decisions which reflect their understanding of risks in transparent ways. This is important, because information is costly, and the decisions based on it can have significant effects on people's lives. This is not only true of decisions about nutrition, of course, but applies across many important global issues from the impact of climate change to how we can ensure food and water security. Lessons from the GeoNutrition project are likely to be relevant to all of these.

Stakeholders at an event discussing spatial uncertainty.

Professor Malcolm Bennett holding a pearl millet sample for photographing.

Improving the climate resilience of pearl millet

Pearl millet is a key crop that contributes significantly to food security across the Sahel region in Africa (places bordering the southern edge of the Sahara). It is well adapted to arid and semi-arid conditions, and is generally cultivated in low input agricultural systems. Yields of pearl millet are limited by the soil conditions and rainfall, as the crop is not irrigated. As climate changes increasingly plays havoc with seasons and rainfall in the Sahel region, yield losses are becoming more common. This is problematic as pearl millet is a dietary staple crop for over 90 million people in the region, 90% of which is grown by smallholder farmers. Coupled with climate change is a rapidly growing population. We therefore need to develop more productive, drought tolerant varieties that farmers can grow.

In order to help farmers adapt to these changing conditions, our researchers have been working in central Senegal, alongside partners from ISRA/CERAS and IRD Montpellier, to investigate what happens after pearl millet is exposed to drought. The team examined how 150 different varieties of pearl millet coped after watering was stopped. Data for important traits like yield, root architecture and anatomy were collected using a range of phenotyping approaches. For example, the 2022 trial collected over 3800 samples for root anatomical and leaf ionomic analysis, while approximately 7500 root crown images were taken to understand how root architectural traits like angle is altered by drought. This is in addition to the 3800 root and leaf samples, and 5500 root crown images, taken in 2021. To prepare root samples, plants first had to be harvested from the field, roots were washed and then prepared for imaging and sampling. This was a labour-intensive job that our researchers and partners undertook under very challenging conditions with temperatures often reaching over 45C!

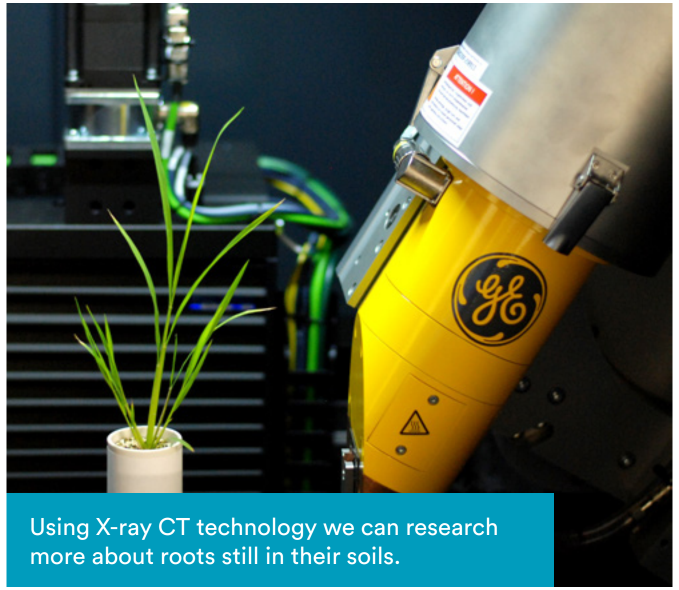
Pearl millet prepared for photographing and analysing.

Harvested leaf and root samples have been shipped back to Nottingham for ionomic and anatomical analysis. For example, preparing anatomical sections using conventional approaches is slow, labour intensive, and requires a high level of skill. Using Laser Ablation Technology (LAT) at our Hounsfield Facility, researchers are able to examine the cellular anatomy of roots at a much faster and more accurate rate. Identifying the genes that control key root anatomical traits, like the size of xylem water transporting cells, will allow breeders to select new crops with improved drought tolerance and nutrient uptake.

Analysing anatomical traits like the size and numbers of cells in a single root image is very time consuming, even for experienced researchers. When LAT generates 20 images for each of the 3800 root samples collected in Senegal, this becomes an impossible task to perform manually. The solution is to exploit advances in AI-based image analysis by colleagues in the Computer Vision Lab at Nottingham. Once root images are analysed, anatomical information for each of the 150 pearl millet varieties can be compared to their DNA differences. This approach (termed genome-wide association studies; GWAS) can identify genes that control traits like the size of xylem water transporting cells. Once identified, these genes can be converted to DNA markers for breeders to select new varieties of pearl millet better adapted to a rapidly changing climate.

Understanding the rhizosphere

Our researchers are developing novel ways to support better crop production through focusing on the rhizosphere – the thin layer of soil directly in contact with roots - and soil microorganisms that form the root microbiome. Plant roots are incredibly important for plant growth and development, but as the climate changes, the resilience of plants to withstand extreme temperatures, droughts or flooding are being challenged. By focusing on soils, and the plant roots within we can better prepare agriculture for a challenging future – ensuring resilient crop yields and good crop health. Soils also have the potential to capture carbon, making our understanding of rhizosphere processes even more important.



Using X-ray CT technology we can research more about roots still in their soils.

Understanding roots in compacted soils

Soil compaction is a challenge for modern farming, particularly in Europe where over half the arable land is prone to this stress. Poor soil management practices such as use of heavy machinery, causes soil to become compacted, making it difficult for roots to penetrate deeper layers rich in moisture and nutrients. This has consequences for the ability of plants to take up these important resources, resulting in decreased yields (up to 25%). When combined with drought, soil compaction can reduce crop yields by up to 75%.

Understanding why roots struggle to penetrate hard soils is the focus of work undertaken by Bipin Pandy, Malcolm Bennett, Sacha Mooney and their teams. Until recently, roots that failed to penetrate hard soils were considered too weak to do so but *their research* has discovered a plant hormone signal which causes roots to stop growing further into the soil. The signal called ethylene is released as a gas from the tips of plant roots into the soil. In loose, uncompacted soils the gas is able to diffuse away from root tips easily. But in hard, compacted soils, the ethylene becomes trapped around the root tip, causing ethylene to build up in root tissues. This build up then prompts roots to stop growing in the compacted soil, hence ethylene acts as a 'stop' signal for root growth during these soil stress conditions.

Experimenting with specific plant mutations allowed researchers to understand that roots no longer able to detect ethylene were now able to penetrate compacted soils. Experiments were conducted in sandy and clay soils, and on rice and *Arabidopsis* (a model plant species closely related to oil seed rape). These findings suggest that, because the same behaviour was observed in different soils and different plant species, reducing ethylene sensing in roots would be of benefit to other crops, soil types and geographies. This opens up opportunities for plant breeders to screen for plant varieties whose roots are less sensitive to ethylene. There is also the opportunity to use genetic engineering or gene editing to selectively block ethylene responses in root tips, as this hormone signal is important for other plant processes like pathogen resistance.

There are a number of benefits from this work for the future of agriculture.

- Crop roots are able to access nutrients deeper in the soil, supporting the growth of larger, healthier crops.
- Crop varieties with extensive roots systems are able to secure deeper and more reliable water sources, making them more resilient to withstand periods of drought.
- Modelling suggests that crops with deeper roots bury more carbon in the soil, facilitating efforts to sequester carbon from the atmosphere.

Soils and microbes

The ability of plants to take up the correct amount of nutrients from the soil is hugely important for growth and energy. Gabriel Castrillo and his team *discovered* that plants have a 'sealing' mechanism supported by microbes in the root, vital for the intake of nutrients. This mechanism controlling root sealing influences the composition of microbial communities inhabiting the root, and the microbes then maintain the function of this mechanism – a beneficial symbiotic relationship. Up until now, the contribution of microbes to the function of regulatory mechanisms of nutrient diffusion in plant roots was unknown.

All living organisms have evolved structures to maintain stable mineral nutrient states. In plant roots, these structures comprise specialised cell layers that function as gatekeepers to control the transfer of water and vital nutrients. Cells forming these layers must be sealed together in order to perform their functions. These seals must maintain integrity in the presence of microbes. In Arabidopsis roots, two main sealing mechanisms have been found in the root specialised cell layer: Casparian strips (sealing cells together) and suberin deposits (influencing transport across cell plasma membranes). Dr Castrillo's new research shows how these sealing mechanisms incorporate microbial function to regulate mineral nutrient balance.

Therefore, root "sealing" mechanisms and the microbes colonising the root combine to control mineral nutrient uptake in the plant. The microbes tap into the plant's hormone signals to stabilise root permeability against stress in environmental nutrient availability, thus enhancing plant stress tolerance. Knowing this, scientists, plant breeders and farmers are able to develop microbial-based strategies to improve water and nutrient uptake efficiency in crops, incredibly important as climate change wreaks havoc on water availability in soils. Such strategies could also help harness carbon dioxide through carbon sequestration.

We are discovering the relationship between roots and microbes.

Case study three:
Beacon funded projects

Professor Andy Salter and colleagues at a Rank Prize symposium exploring future global protein requirements.

Future Proteins

As the Future Protein Platform moves into its final year it is pleasing to see the associated projects generating data that will feed into publications, future grant applications and, of course PhD theses. One major change is that, in taking on the Directorship of the Future Food Beacon, Andy Salter, while still being very much involved in Future Protein, has handed over the leadership to Professor John Brameld (from September 2022).

It was excellent to see the work of the Platform highlighted at the Future Food Beacon Symposium in September. Professor Festo Massawe and Dr Jo Gould were joined by Postdoctoral Fellows Molly Muleya and Carlos Lopez Viso, and PhD student Kamil Szepe, to provide an excellent overview of the progress made in different aspects of our work. Festo and Andy were also joined by Carlos, Kamil and PhD students Niki Tsoutsoura and Noriane Cochetel in presenting at a Rank Prize Symposium on 'Meeting Future Global Protein Requirements' in the Lake District in early October.

Bambara groundnut seeds and pods.

These meetings are deliberately designed to bring together early career researchers and more experienced scientists and it was an excellent opportunity to share our work with researchers from the rest of the UK and parts of Europe.

Each of our projects is producing exciting new protein sources that we are able to assess within the now well-established nutrient analysis facilities, largely funded by the Beacon. This includes the in vitro digestion system established by Molly Muleya (working with colleagues around the world in the Infogest Network). Molly has generated some preliminary data confirming that this system compares well with published in vivo data for humans. Hannah Dallas (PhD student) has commenced a trial directly comparing, for the first time, the value of bacterial and insect (mealworm) protein as alternative components of fish feed (for trout), which will also be used to assess the accuracy of our in vitro system in predicting digestibility. Noriane Cochetel is working with her industrial sponsor (ABAgri) to determine the in vitro digestibility of a range of single cell and plant sources of protein prior to conducting some in vivo chicken trials. Dr Yin Sze Lim, and PhD student Ann Jo Tee, have also established an in vitro digestion system at our Malaysia Campus, which is being used to screen the impact of fermentation of Bambara Groundnut on protein digestibility. In addition to her work on in vitro digestion, Molly has now published her work developing a *database* of amino acid digestibility to assess the quality of protein consumed in *Malawi*. This clearly demonstrates the vulnerability of populations who are highly reliant on cereal crops as their primary source of protein.

Carlos Lopez Viso continues (together with some of our separately funded PhD students) to work on improving the efficiency of production, and nutritional composition, of mealworms. We have established a relationship with a major mealworm producer (Ynsect, based in France) who are now providing us with a high-quality source of insects and, using the genome sequenced through the work of the Beacon, we have identified key genes for proteins involved in mealworm growth and composition. Working together with Ynsect, and colleagues at the University of Newcastle, we will shortly be submitting grant applications to use novel, non-GM technologies to manipulate the expression of the genes to produce more protein-rich larvae.

PhD student Niki Tsoutsoura, working with Professor Festo Massawe and Sean Mayes, has made major advances in identifying Quality Trait Loci in the genome of the protein rich plant, Winged Bean, which impacts on its nutritional value. Niki is currently in Malaysia collecting further samples from field trials of different varieties. Kamil Szepe (who is part funded by Quorn) has successfully developed methods to obtain F. venenatum (the fungal species used in producing Quorn) variants with improved AA biosynthesis and confirmed isolates with significantly improved production of leucine. This will, hopefully, help the company in further improving the nutritional value of their products. PhD student, Joseph Godrich, working with Dr Jo Gould, has produced some valuable data on the impact of processing (particularly popping) on reducing the activity of anti-nutritional factors (which impair protein digestion). Finally, Hina Kamal has made considerable progress in the extraction of protein from food waste. Her findings on the use of 'green' solvents for the extraction of protein from dairy and non-dairy food products have recently been *published*.

Overall, all members of the platform have made remarkable efforts to recover from the inevitable delays due to the Covid pandemic and we look forward to seeing more results and publications in the coming year.

The pods on a Bambara groundnut, a potentially important future crop.

Varieties of maize from Mexico.

Palaeobenchmarking Resilient Agricultural Systems

2022 was another great year for the PalaeoRAS team as most of the projects are coming to the end of their data collection phases and more of the team's work was disseminated to international audiences. Karla Hernandez Aguilar and Ali Ben Mustapha (both Geography) undertook fieldwork in Mexico and Jordan, respectively. Bowen Deng's (Computer Science), Rik Rutjens's (Maths) and Amit Kumar's (Geography) innovative approaches to image analysis, plant, and drought models, respectively, continued to develop and become more complex. In the lab Aneesh Lale, Faidra Katsi and Jordan Robson (all Biosciences) have continued growth experiments with a view to understanding the impacts of heat and water stress on plant systems, and how we can best measure these. The Ancient and Environmental DNA lab was opened in June 2022 and Andrew Clarke (Biosciences) is now leading on a number of new projects using this important new facility.

It was great to see PalaeoRAS work presented at international conferences this year, including: Annegreet Veeken (EGU, Vienna), Ali Ben Mustapha (Forum for Global Challenges, Birmingham), Faidra Katsi (European Palaeobotany and Palynology, Stockholm) and Rik Rutjens (Sensitivity Analysis of Model Output, Florida State). Some of the first publications from the PalaeoRAS postgraduate researchers have also come out this year. Anne led a paper on 'Pollen-based reconstruction reveals the impact of the onset of agriculture on plant functional trait composition' in *Ecology Letters* and Amit led a paper on 'Multi-model evaluation of catchment-and global-scale hydrological model simulations of drought characteristics across eight large river catchments' published in *Advances in Water Resources*.

As we reach the end of 2022 many more papers are approaching submission and the PalaeoRAS PGRs have plans in place to submit their theses! We're planning a celebration of their amazing work at a workshop in the spring of 2023.

Case study four:
Royal Society Summer Science

Cocoa pods and their beans on display at the Royal Society exhibition.

During the first week of July, a team of researchers from the Future Food Beacon travelled down to London to join the Royal Society Summer Science festival.

After a competitive selection process, endless organising, liaising with external suppliers, and sourcing cocoa saplings, we were finally ready to share our awesome research on cocoa fermentations with the public. Our exhibit, *From tree to bar: A journey through chocolate*, took visitors from the cocoa farm with its cocoa trees and pods to the fermentation box and the importance of microbes, before allowing them to taste the final product: chocolate!

Not many people know that chocolate is a fermented product. But the fermentation process is key to developing final flavours in the chocolates that we all know and love. However, the fermentation process is largely done on cocoa farms, and has been an uncontrolled, spontaneous process. Farmers will split the cocoa pods they harvest, revealing a sticky white pulp covering the cocoa beans. The pulp and beans are put into wooden fermentation boxes and left for five to seven days to ferment. During that time, microbes from the surrounding environment (from the boxes themselves, the beans and pulp, the pods, leaves, soils, and even workers' hands) colonise the beans and start to break down unwanted compounds (like the acidity, astringency and bitterness that characterise the flavours of the unfermented beans) and introduce new flavours that we can then taste in finished chocolate bars – notes that include florals, nuts, red fruits, citrus, smoke, or caramel.

After fermentation, the beans are spread out to dry in the sun, before being bagged up and sent to a central distribution point. From there, cocoa beans are sold to chocolate makers, like Luisa's Vegan Chocolates, who roast, grind, winnow, and conch the beans into chocolate liquor. From this liquor, the chocolate is tempered before bars are made.

Dr Sally Eldeghaidy (left) and Elina Chrysanthou at the exhibition.

Our research has been investigating different microbes present in the fermentations of three different farms from Colombia. Our researchers travelled to Colombia in 2019 to participate in the harvests, and, using Nanopore MinION hand-held DNA sequencers, took samples of the fermentations and the surrounding environments. This has generated a huge dataset of microbes which we are currently identifying. If we know which microbes are present in different fermentations, we will be able to work with farmers to help prevent fermentations from going badly, or from developing unwanted flavours. Eventually we might be able to work with farmers to develop specific flavours for chocolate makers too!

All this research was showcased through our Royal Society exhibition. There are four videos on *YouTube* that were featured at the exhibition: on cocoa farming, chocolate flavour, chocolate making, and chocolate and the brain. Our exhibition was well received by the public and we were featured in a number of news articles, including on *BBC News*, *BBC Business*, ITV, BBC Radio Nottingham, and BBC Radio 5. Our researchers worked incredibly hard throughout the week, talking to people, guiding them through chocolate tastings, and creating microbial prints.

We would like to thank the funders who made our participation at the Royal Society possible: BBSRC IAA, University of Nottingham Faculty of Science, Society of Applied Microbiology, Society for Experimental Biology, and the Future Food Beacon. Also, thanks to the University of Reading for gifting us some of their cocoa saplings and pods, and to Luisa's Vegan Chocolates for making all the samples and supporting us in the week!

Dr Tristan Dew elaborates on fermentation in cocoa to visitors at the Royal Society exhibition.

Beacon leadership team

David Salt
Former Director of the Beacon, Faculty of Science

Andy Salter
Director of the Future Food Beacon

Richard Emes
School of Veterinary Medicine and Science

Matt Loose
School of Life Sciences

Tania Dottorini
School of Veterinary Medicine and Science

Malcolm Bennett
School of Biosciences

Rebecca Ford
School of Biosciences

Kate Millar
Director, Centre for Applied Bioethics

Tony Pridmore
School of Computer Science

Markus Owen
School of Mathematical Sciences

Darren Wells
School of Biosciences

Martin Broadley
School of Biosciences

Richard Hyde
School of Law

Ramiro Alberio
School of Biosciences

Anne Touboulic
Business School

Heike Bartel
School of Cultures, Languages and Area Studies

Richard Worrall
Head of Food Innovation Centre

Kevin Sinclair
School of Biosciences

Festo Massawe
School of Biosciences, Malaysia campus

Nik Watson
Department of Chemical and Environmental Engineering

Beacon staff

Professor Andrew Salter
Director of the Future Food Beacon, Professor of Nutritional Biochemistry

Professor Murray Lark
Professor of Environmetrics

Professor Levi Yant
Professor in Evolutionary Genomics

Assistant Professor Tristan Dew
Assistant Professor in Molecular Phenomics

Assistant Professor Andrew Clarke
Assistant Professor in Archaeogenetics

Assistant Professor Guillermina Mendiondo
Assistant Professor in Translational Crop Science

Assistant Professor Rahul Bhosale
Assistant Professor in Crop Functional Genomics

Assistant Professor Sina Fischer
Assistant Professor in Functional Genomics

Assistant Professor Sally Eldeghaidy
Assistant Professor in Sensory Science

Associate Professor Gabriel Castrillo
Associate Professor in Plant Microbiome

Associate Professor Michael Pound
Associate Professor in Computer Vision

Dr Chris Moore
Senior Research Fellow and Technologist in Genomics

Dr Jonathan Atkinson
Senior Research Fellow and Technologist in Phenomics

Dr Peter Craigon
Postdoctoral Research Fellow

Dr Molly Muleya
Postdoctoral Research Fellow

Dr Carlos Lopez-Viso
Postdoctoral Research Fellow

Dr Jordan Robson
Postdoctoral Research Fellow

Simon Ridgway
Associate Director for Operations

Dr Peter Noy
Associate Director for Research

Dr Lexi Earl
Outreach and Engagement Manager

Joanna Smuga-Lumatz
Administrator

Gigi Walker
Administrative Assistant

University of Nottingham
Future Food

Discover more about our world-class research

nottingham.ac.uk/future-food

SB-future-food@nottingham.ac.uk
@UoNFutureFood
/future-food-beacon
blogs.nottingham.ac.uk/futurefood

Published February 2023.