University of Nottingham
Future Food

Exploring new ways to feed the world

Future Food

Beacon of Excellence

nottingham.ac.uk/future-food

2020–2021

Pictured: Yellow maize from Maxcanu community, Yucatan, Mexico - photo by Karla Hernandez-Aguilar.

Contents

The Future Food Beacon is an integrated open-research platform that brings together researchers from different disciplines to collaborate on global food challenges in the era of climate change and pandemic.

Pictured: Ivy Ligowe with drone – photo by Robert Ounsworth.

Introduction

The Future Food Beacon has experienced another successful year. We are now over three years into the life of the Beacon and are continuing to expand on our previous successes. The Future Food Beacon is an integrated open-research platform that brings together researchers from different disciplines to collaborate on global food challenges in the era of climate change and pandemic. Our aim is to deliver food systems that are sustainable, equitable, and provide nutritional and food security for all.

Future Food embraces transdisciplinary research, and our research themes reflect the diversity of work on-going at the university around food:

- Future proofing agricultural systems
- Food for sustainable livelihoods
- Food for health
- Smart manufacturing for food

Our team has continued to grow and develop. A second cohort of the International Agriculture Doctoral Training Programme run jointly with Rothamsted Research has begun, with a third being recruited to start in 2021. The students are drawn from all over the world, with this year's intake coming from Kenya, Ghana, Indonesia, Zimbabwe and the UK. They bring with them expertise and diverse cultural backgrounds that are invaluable to their projects and to the Beacon.

Despite the challenges posed by the COVID-19 pandemic, the restriction of access to laboratories, and the necessity of working from home, our team has risen to the challenge to **successfully win 15 grants, worth £6.1 million**. Our researchers have **published 38 papers**, and together with our wider network **publishing 77 papers** in quality peer-reviewed journals.

Warnings from Oxfam and others indicate that hunger could be one of the biggest consequences of the pandemic, particularly in the developing world.

Overview

The imbalance and challenges inherent in our food system have been thrown into sharp relief by the COVID-19 crisis. The disappearance of products from supermarket shelves, panic buying, demand for seeds from home growers, loss of demand for foodstuffs usually sold in restaurants (and the knock on effect on supplies), and a lack of vegetable pickers are all examples of the fragility of just-on-demand supply chains. The inherent instability of the international markets and the interconnectedness of the global food system have been exposed by the crisis.

Warnings from Oxfam and others indicate that hunger could be one of the biggest consequences of the pandemic, particularly in the developing world. Coupled with the challenges of climate change, the pandemic has highlighted the pressing need for more equitable, resilient and sustainable food systems.

Our contribution

The Future Food Beacon brings together soil science, primary production (crops and livestock), nutritional science, food processing and manufacturing, supply chains and consumer preferences. We also harness the power of digital technologies. All of this is informed by an understanding of the economic, legal, social, cultural, historical and ethical issues that underpin and shape food systems.

We work closely with our colleagues at both our Malaysia and China campuses, and with a wide set of international partners in Africa, Latin America and the Caribbean, and China. We also connect with international organisations such as the UN Food and Agriculture Organisation (FAO). We are therefore uniquely poised to face the challenges of improving food systems in a post-COVID-19 world.

Pictured: Hand threshing teff in Amhara – photo by Martin Broadley.

Snapshot of achievements

Supported submission of **185** **Beacon related grants** (£117m)

95 **supported grants awarded** (£21.9m)

34 **grants awarded to Beacon researchers** (£9.4m)

28 **grants awaiting outcome** (£11.1m)

192 **papers published since July 2017**

92 **papers published by new staff appointed by the Beacon since July 2017**

38 **papers this year in journals spanning multiple disciplines,** including high-impact journals like Science and Nature

360+ **stakeholders from academia, business, civil society and government**

2 **senior group leaders hired**

2 **junior group leaders hired**

6 **Nottingham Research Fellows**

7 **post-doctoral researchers**

4 **technologists**

10 **PhDs in the International Agriculture Doctoral Training Programme** (further 5 to commence in 2021)

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

£2.9m **spent on 31 items of equipment**

£0.4m **committed for new facilities**

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

Pictured: Mesfin Desta and Veronica Guwela - photo by Martin Broadley.

Our research work with African partners is led by Future Food Beacon Professor Murray Lark with his long-term colleague Professor Martin Broadley from the School of Biosciences. Our projects continue to grow and develop, with new projects bridging disciplinary fields, working to improve farming and agricultural practices across the sub-Saharan region. We ensure we work closely with local teams and experts.

Towards transdisciplinary understanding of inherited soil surveys: an exploratory case study in Zambia

In collaboration with colleagues in Arts and Humanities, and in partnership with the University of Zambia and University College London, a new project, funded by AHRC and led by Professor Lark, explores inherited soil surveys within the Zambian context. Information about soils – their composition, properties, and status – are essential for policymaking and land management. Legacy soil surveys, including those from colonial and post-colonial periods, should help us better understand and address current agricultural problems.

> "This work will be a significant development in ongoing collaborations between the University of Nottingham and colleagues in Zambia and elsewhere in Africa to find out how farming can deliver nutritious food sustainably under climate change."
>
> Professor Murray Lark, from the Future Food Beacon

Pictured: Examining a soil pit in Malawi – photo by Murray Lark.

In Zambia, colonial-era soil surveys were begun in the 1930s, when Colin Trapnell and colleagues examined vegetation, farming practices and the soil, creating a national Vegetation and Soil Map, published in 1947. This project uses archival research to examine the pedagogical, historical and social dimensions of legacy soil information in Zambia.

Micronutrient Action Policy Support (MAPS) tool

The nutritional value of fruits, vegetables and cereal crops is affected by numerous conditions, one of which is the mineral micronutrients contained in the soil. Micronutrient deficiencies are a widespread global problem. The scale and impact of these deficiencies are unequally distributed due to geographical, socio-economic and dietary factors. Selecting interventions that will correctly serve a particular population is therefore a challenge for both policymakers and scientists.

Pictured: Historical soil survey in Zambia – photo by Richard Webster.

This Bill & Melinda Gates Foundation-funded project develops a tool to visualise the scale and geographic distribution of mineral micronutrient deficiencies. It will be used to inform food system interventions, and the tool can be tailored so that it delivers the greatest impact and cost-effectiveness for different regions.

Translating GeoNutrition

How do we translate research findings into action and affect change? The Bill & Melinda Gates Foundation-funded GeoNutrition programme in Ethiopia and Malawi generated important lessons on mineral micronutrient deficiencies which are now being expanded with the help of Future Food Beacon researchers to reduce mineral micronutrient deficiencies in Zimbabwe. Mineral micronutrient deficiencies (MMNDs) affect the livelihoods and health of more than two billion people worldwide. Women and children in low income countries are most at risk, and alleviating MMNDs remains a challenge if we are going to successfully eliminate hunger on a global scale.

This project is being delivered by Professor Broadley, working closely with Professor Lark. It is funded by GCRF and supports the development of a full MMND survey, run by the government of Zimbabwe. The survey is based on the translated research findings from GeoNutrition work conducted in Malawi.

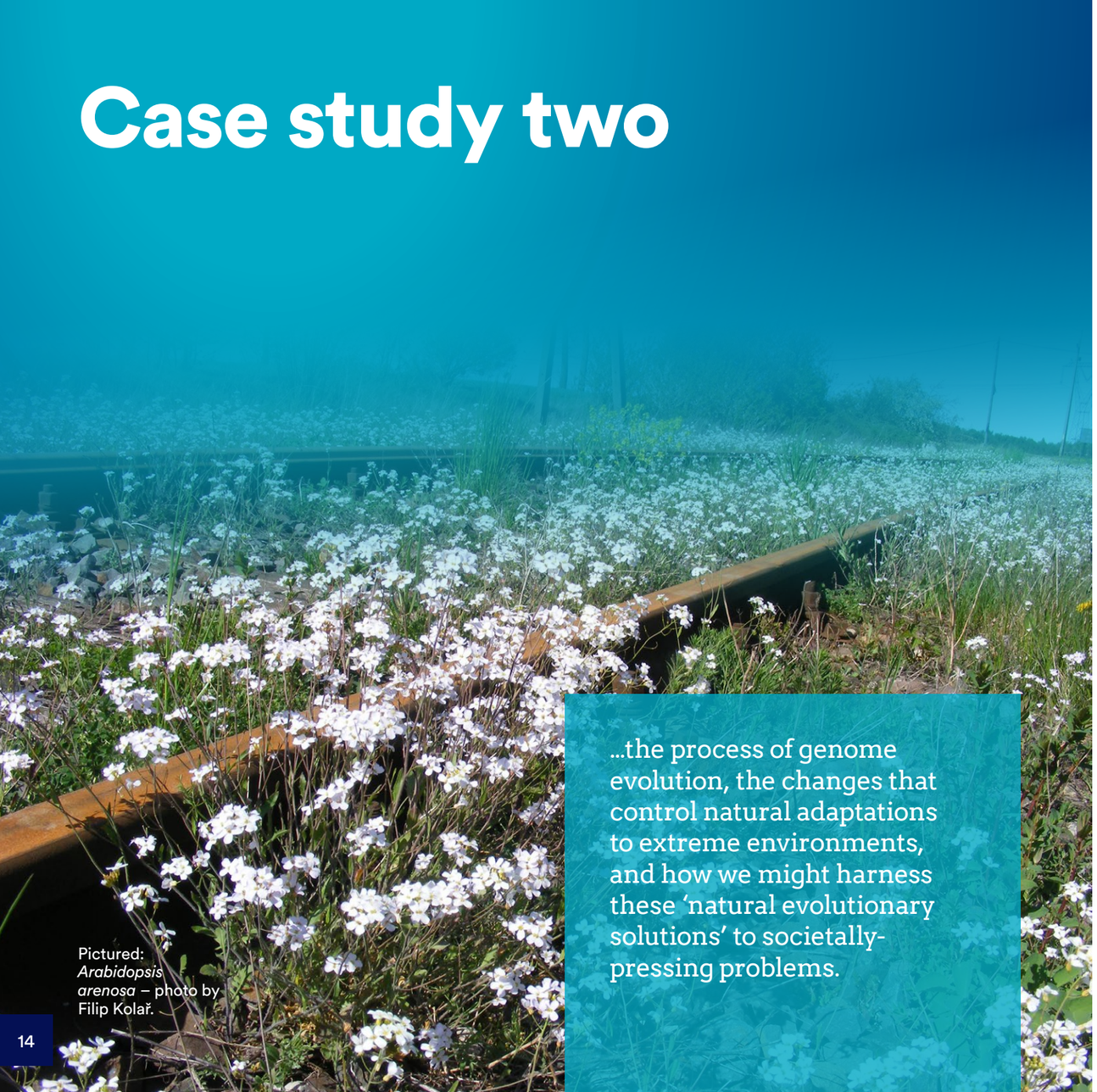
Improving early child development in Malawi

High rates of maternal, infant and childhood mortality and undernutrition are a significant problem in Malawi, resulting in many children failing to reach their educational potential and impacting economic development at the national level. Identifying children at greatest risk and in need of intervention is key to solving this problem.

This ESRC funded project, led by Professor Nicola Pitchford in the School of Psychology working with Professor Lark, will build a new data platform for early child development by integrating numerous data sets, including: early educational outcomes, maternal and infant health, and mineral micronutrients in soil and crops from the Geonutrition study. This will ultimately transform early child development and learning outcomes in Malawi.

Pictured: School children in Malawi - photo by Nicola Pitchford

Case study two



Pictured: *Arabidopsis arenosa* – photo by Filip Kolař.

> ...the process of genome evolution, the changes that control natural adaptations to extreme environments, and how we might harness these 'natural evolutionary solutions' to societally-pressing problems.

As well as working to help solve significant societal challenges, the Future Food Beacon realises that fundamental enquiry is crucial for answering those 'big questions' that inform how we try and improve the world around us.

Upon learning about the Future Food Beacon, Associate Professor Levi Yant moved his research programme that focuses on fundamental questions about the mechanism of evolution to the University of Nottingham to integrate this type of science within the Future Food Beacon. Dr Yant studies the process of genome evolution, the changes that control natural adaptations to extreme environments, and how we might harness these 'natural evolutionary solutions' to societally-pressing problems. His laboratory is pursuing two primary research directions, focusing on:

1. how certain plant lineages adapt to – or even thrive in – particularly challenging environments, such as badly degraded or toxic soils; and
2. the impact of Whole Genome Duplication (WGD): how does WGD occur, and might WGD accelerate evolution?

Funded by the European Research Council and BBSRC, Dr Yant is not only interested in these two questions: he is also systematically determining whether the particular molecular changes that mediate each of these adaptations is repeatable in different species that adapt to them, a line of discovery that speaks to the very predictability of evolution.

In its work on WGD, Dr Yant's group studies the way that WGD both challenges physiology but somehow also promotes evolution. Doubling a genome is a high-risk, high-gain strategy – managing all the new DNA is a serious problem, causing too many chromosome interactions when cells divide – but gain from a sheer increase in DNA leads to increased evolutionary potential. Remarkably, WGD occurs naturally in some of the most successful species and it carries special agricultural importance: the clear majority of our crops are WGD, including wheat, corn, and sugar cane.

Dr Yant brings a vast network of collaborators to the Future Food Beacon. He works with colleagues in Germany, the Czech Republic, China, Kenya, Belgium, and Spain to seek the answers to these fundamental questions. These collaborations enable true synergy, merging ecology, evolution, genomics, bioinformatics, and microscopy to illuminate the very basis of evolutionary change.

Since coming to the Beacon in August 2018, the Yant lab has published work highlighting the surprising central role of 'gene sharing' – the transfer of adaptive gene versions between species—in a run of studies in *Nature Communications, PNAS,* and *PLOS Genetics.* Additionally, it has published novel collaborations with co-workers in Chengdu, China on cadmium tolerant wheat and work on adaptation to WGD and to toxic soils, which is the basis of a long-standing collaboration between Dr Yant and Future Food Director Professor David E Salt.

Pictured: Meiosis

Case study three

Roots are key to plant stability and growth, and co-cultivation of plant species with specific root microbiota bacterial strains can drive significant and specific changes in root branching patterns.

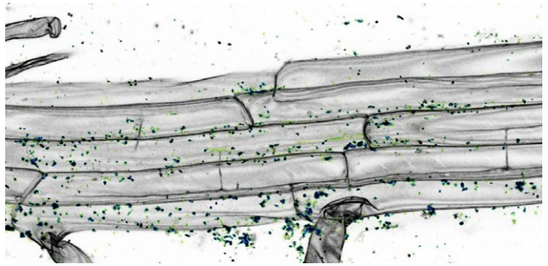
Pictured: Two contrasting plant roots, suberin in yellow – image by Gabriel Castrillo.

Understanding the microbiome of our soils is fundamentally important for the future of agricultural crops. Microbes in the soil colonise plant roots, and can aid plant growth, development and resilience.

Dr Gabriel Castrillo, Future Food Nottingham Research Fellow in Plant Microbiome is researching the relationship between microbes, plants and soil. Gabriel is an early-career researcher and has recently been successful in winning grants from The Leverhulme Trust, the Royal Society, and a joint award from the BBSRC (UK) and the National Science Foundation (US) in collaboration with colleagues from the University of Kansas. Gabriel's research examines the interactions between plant roots and microbes in the soil.

The Leverhulme Trust grant explores the ways microbiota modify plant roots and affect root branching. Relationships between microbes found in the soil and plants is well evidenced in the fossil record. Plants and microbes within the soil have a symbiotic relationship, and this allows branching roots to explore the soil environment, providing the roots opportunity to maximise their ability to capture water and nutrients. Roots are key to plant stability and growth, and co-cultivation of plant species with specific root microbiota bacterial strains can drive significant and specific changes in root branching patterns. Gabriel focuses on the regulatory gene networks that govern interactions between microbes and root branching.

The BBSRC/NSF research will examine the evolution of plant microbiomes under stress conditions, in this case, drought. Drought has devastating effects on plant productivity but the intensity and frequency of droughts is expected to increase in coming years due to climate change. Evidence suggests that soil microbiota may play a role in plant drought tolerance.



Pictured: Colonization of root by bacterial synthetic community – image by Gabriel Castrillo.

Under drought conditions plants often increase their roots, which creates new opportunities for microbial colonisation. Root-associated microbiomes can affect the physiology and health of host plants, and these interactions are shaped by genetic variation in both the host species and the microbiome members. This project will disentangle the relationships between microbial and plant fitness in the face of a shared abiotic stress. This work has important implications for future drought-resilient agricultural crops.

The BBSRC/NSF grant came about through Gabriel's collaboration with Dr Maggie Wagner, whom he first met when they were both postdoctoral research fellows. Gabriel explained: "I think we enjoyed the process of thinking about how to improve our knowledge of the role of microbiomes in improving the health of crops and wild plants under abiotic stresses. I like the experience of working in a very collaborative environment with researchers from different countries and backgrounds. I see this project as an opportunity to learn from another lab and gain experience in managing international projects. I expect important contributions to our field and I hope that this project can help improve agricultural productivity with a concomitant increase in the nutritional quality of food".

Beacon leadership team

David Salt
Director of the Beacon, Faculty of Science

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

Debbie Sparkes
School of Biosciences

Kate Millar
Director, Centre for Applied Bioethics

Andy Salter
School of Biosciences

Tony Pridmore
School of Computer Science

Markus Owen
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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

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School of Biosciences, Malaysia campus

Nik Watson
Department of Chemical and Environmental Engineering

Beacon staff

Professor David E Salt, Director of Future Food Beacon, Professor of Genome Enabled Biology

Professor Murray Lark, Professor of Environmetrics

Associate Professor Levi Yant, Associate 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

Dr Rahul Bhosale, Nottingham Research Fellow in Crop Functional Genomics

Dr Sina Fischer, Nottingham Research Fellow in Functional Genomics

Dr Sally Eldeghaidy, Nottingham Research Fellow in Sensory Science

Dr Gabriel Castrillo, Nottingham Research Fellow in the Plant Microbiome

Dr Michael Pound, Nottingham Research Fellow in Computer Vision

Dr Chris Moore, Senior Research Fellow and Technologist in Genomics

Dr Michael Wilson, Senior Research Fellow and Technologist in Computational Biology

Dr Jonathan Atkinson, Senior Research Fellow and Technologist in Phenomics

Peter Craigon, Postdoctoral Research Fellow

Molly Muleya, Postdoctoral Research Fellow

Carlos Lopez-Viso, Postdoctoral Research Fellow

John Ferguson, Postdoctoral Research Fellow

Simon Ridgway, Associate Director for Operations

Dr Peter Noy, Associate Director for Research

Dr Lexi Earl, Outreach and Engagement Manager

Andrew Edwards, Research Support Officer and Acting Communications Officer

Joanna Smuga-Lumatz, Administrator

Gigi Walker, Administrative Assistant

Guilhem Reyt, Postdoctoral Research Fellow

Sian Bray, Postdoctoral Research Fellow,

Katie Mayes, Postdoctoral Research Fellow

Case study four

The Future Food Beacon has consistently invested in Deep Seq, the University of Nottingham's high-throughput genomics facility. Deep Seq conducts a wide variety of work including many projects for the Future Food Beacon but, like everybody else, it has had to adapt quickly to life under COVID-19.

The Deep Seq team quickly became part of the COVID-19 Genomics UK Consortium in March 2020 and began sequencing SARS-CoV-2 genomes. To date, Deep Seq has sequenced and analysed over 2,500 SARS-CoV-2 genomes supported by Future Food Beacon staff member Dr Chris Moore, embedded in the Deep Seq team. This data has contributed to the understanding of the viral variants present in the population and the transmission patterns of the virus at a local, national and global level.

Professor Matt Loose of Deep Seq explains: "The Future Food Beacon's support has been crucial in allowing us to expand the diversity of technologies available within Deep Seq. An example of one of the Beacon's investments is the Oxford Nanopore GridION X5, which has rapidly become one of the most used pieces of equipment in the lab because of its versatility and convenience. GridION has helped us with our work for the COVID-19 Genomics UK Consortium."

Throughout this period Deep Seq has continued to support Future Food Beacon projects, which have included: developing high throughput robotics solutions for sequencing crop genomes; sequencing genomes of plants adapted to hostile environments; surveillance of antimicrobial resistance in pathogens within the food chain; and analysis of how microbial composition in cocoa bean fermentation affects flavour.

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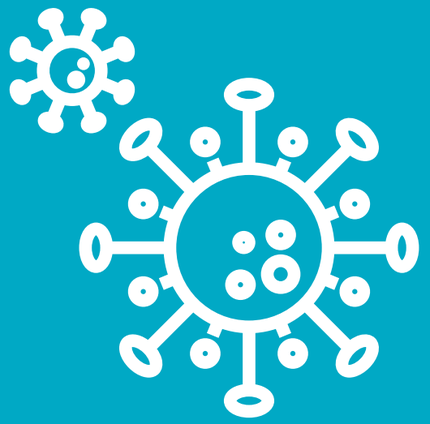

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