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## Trait dissection to study abiotic stress tolerance: From controlled environment to field

Assoc Prof Bettina Berger<sup>1</sup>

<sup>1</sup>The University of Adelaide, Urrbrae, Australia

Tolerance to abiotic stress, such as salinity, heat or drought, is a complex trait with strong genotype by environment by management interactions. We use the approach of trait dissection to establish high-throughput phenotyping approaches suitable for forward genetic studies of component traits. The Australian Plant Phenomics Facility offers access to researchers to a range of phenotyping tools and expertise, both in the controlled environment and field. This presentation will provide examples of (i) phenotyping approaches developed for abiotic stress tolerance traits, (ii) forward genetic studies to identify the genetic loci contributing to abiotic stress tolerance, (iii) and testing the contribution of these genetic loci to overall crop performance in the field.

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## The use of multi-spectral sensing technologies from UAV to enhance mungbean productivity

Ms Shanice Van Haeften<sup>1</sup>, Ms Caitlin Dudley<sup>2</sup>

<sup>1</sup>Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Australia, <sup>2</sup>School of Agriculture and Food Sciences, The University of Queensland, Australia

Mungbean (*Vigna radiata* (L.) R. Wilczek var. *radiata*) is a high protein pulse crop cultivated in the subtropics. Mungbean is economically important in Australia as a main summer rotation crop and high value export. While substantial yield improvements have been made, traditional phenotyping approaches are a bottleneck that limit the evaluation of accessions at the scale required for plant breeding without impacting the rate of genetic gain. Unmanned aerial vehicle (UAV) imaging platforms are evolving as a powerful phenotyping tool and may offer an efficient, field-based, non-invasive approach to evaluate canopy traits across development at a large scale. These platforms have been successfully applied to several major crops, however their potential to advance mungbean research and breeding is yet to be explored. Linking UAV-derived traits with traditional ground-based measures, we will highlight examples of how this technology can characterise fusarium susceptibility as well as dissect senescence dynamics using a highly diverse nested association mapping (NAM) population to identify the level of variation across the population. The variation identified prompted investigations into the identification of beneficial traits of interest across varying field environments. The findings from these investigations will contribute to the genetic and phenotypic knowledge essential for advancement within breeding programs, contribute to the development of predictive models and produce high throughput phenotyping methods accessible.

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## Deriving radiation use efficiency from hyperspectral sensing for enhanced sorghum production

Dr Barbara George-Jaeggli<sup>1,2</sup>, Dr Xiaoyu Zhi<sup>1</sup>, Mr Sean Reynolds Massey-Reed<sup>1</sup>, A/Prof Andries Potgieter<sup>3</sup>, Dr Colleen Hunt<sup>2</sup>, Dr James Watson<sup>3</sup>, Prof Scott Chapman<sup>4</sup>, Mr Kenneth Laws<sup>2</sup>, Prof Andrew Borrell<sup>1</sup>, Dr Yongfu Tao<sup>1</sup>, A/Prof Emma Mace<sup>1,2</sup>, Prof David Jordan<sup>1</sup>, Dr Erik van Oosterom<sup>5</sup>, Dr Alex Wu<sup>5</sup>, Prof Graeme Hammer<sup>5</sup>  
<sup>1</sup>Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Warwick, Australia, <sup>2</sup>Agri-Science Queensland, Department of Agriculture & Fisheries, Warwick, Australia, <sup>3</sup>Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Gatton, Australia, <sup>4</sup>School of Agriculture and Food Sciences, The University of Queensland, Gatton, Australia, <sup>5</sup>Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, St Lucia, Australia

The efficiency with which sorghum crops use intercepted radiation (RUE) affects their maximum productivity. RUE in turn, is affected by crop canopy characteristics, as well as leaf biochemical parameters determining maximum leaf photosynthetic rates. These traits are notoriously slow to measure and have previously not been amenable to selection in breeding programs.

We used hyperspectral sensors attached to a tractor to estimate leaf and canopy traits associated with RUE in large sorghum field trials. Using Partial Least Square Regression we developed models to predict leaf biochemical photosynthetic parameters known to limit C<sub>4</sub> photosynthesis, such as maximum Rubisco and PEP carboxylation rates (V<sub>cmax</sub> and V<sub>pmax</sub>, respectively) and maximum electron transport rate (J<sub>max</sub>) from the canopy hyperspectral reflectance. We also used various vegetation indices to predict canopy characteristics such as light interception and biomass which allowed us to calculate canopy radiation use efficiency for each trial plot.

This is the first time that parameters related to photosynthetic efficiency in sorghum have been estimated for so many different genotypes, showing that significant and heritable variation exists. The predicted values were also used for Genome Wide Association studies to identify the genomic regions associated with canopy RUE and hence improved productivity. Sorghum being such a great genetic model, this may also help elucidate the genetic mechanisms underpinning photosynthetic efficiency and RUE in other cereals.

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## Spatio-temporal patterns of phenology for grain crops revealed from Sentinel-2 satellite imagery

Dr Yan Zhao<sup>1</sup>

<sup>1</sup>The Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, St Lucia, Australia

Crop phenology defines the physiological development of crops across the growing season. Accurate monitoring of phenology and its spatial patterns is critical in precision agriculture by empowering farmers with targeted management decisions. This study explores the feasibility of using the high-resolution Sentinel-2 (S2) imagery to detect the critical phenology stages and the corresponding spatial variations for wheat and barley in three satellite validation trials across Australia (CropPhen project). Specifically, this study develops a comprehensive reconstruction method based on Gaussian Process Regression (GPR) algorithm to reconstruct a daily S2-retrieved optimized soil adjusted vegetation index time series. The growth profiles for the trials are examined and specific feature points are extracted using mathematical algorithms. These features are then contrasted to weekly observed crop growth stages measured in the field. Preliminary findings reveal that the GPR-derived features at the beginning of the time series highly correlates to sowing. The mathematically derived stages from the time series showed high correlations to the observed phenology stages including tillering (two tillers), start of elongation, flag leaf emergence, booting and onset of flowering. Finally, the approach is used to map the spatial variations in phenology stages across all validation sites. This illustrates the capability of S2 can be used to estimate crop growth stages within and across fields. It is envisaged that this approach in detecting crop growth stages from S2 imagery and GPR will aid industry to better inform them on crop management practices relating to pest, disease and harvest logistics at field and farm levels.

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## Assessing plant functioning with plant traits using hyperspectral imagery, radiative transfer models and machine learning approaches

Dr Carlos Camino<sup>1</sup>

<sup>1</sup>Joint Research Centre, Ispra, Lombardia, Italy

As climate change and globalization are changing crop pathogen and pests distribution, accurate plant trait-based health monitoring are increasingly sought after to prevent and detect plant diseases. Suitable remote sensing indicators that link pigments, physiological traits and photosynthesis processes could be crucial to understanding early symptoms of crop health decline. Here, we investigate the feasibility of retrieving physiological crop traits by coupling hyperspectral and thermal imagery with radiative transfer (RT) models to ultimately monitor in crops affected by *Xylella fastidiosa* (*Xf*). In this context, we developed a hybrid approach that uses machine learning algorithms to integrate RT models (e.g., the Soil Canopy Observation, Photochemistry and Energy fluxes (SCOPE) model or the PROSAIL model) with hyperspectral and thermal imagery to estimate structural parameters, leaf biochemical constituents, the maximum carboxylation rate ( $V_{cmax}$ , a proxy for photosynthetic capacity) and tree-crown temperature ( $T_c$ ) as an indicator of transpiration rates. We developed and tested the algorithms in *Xf*-affected almond commercial orchards managed under different water regimes in the Island of Majorca (Balearic Islands, Spain). Results reveal the photosynthetic traits,  $T_c$ , and biochemical constituents were the most effective for the early detection of *Xf*. This work demonstrates the potential of RT models to derive physiological traits using hyperspectral imagery in the context of pest epidemics.

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## Fluorescence and plant pigments quantified from hyperspectral sensors for a/biotic stress detection

Prof Pablo Zarco-Tejada<sup>1</sup>

<sup>1</sup>*School of Agriculture and Food (SAF-FVAS), and Faculty of Engineering (FEIT), University of Melbourne, Melbourne, Australia*

The progress made in hyperspectral remote sensing methods over the last 20 years has enabled the development of new spectral traits linked to plant functioning. Laboratory and field-scale experiments have demonstrated that chlorophyll fluorescence emission is detectable using narrow spectral bands at the 687 and 760 nm oxygen absorption features and at specific Fraunhofer lines within the PS-I and PS-II spectral region. Recent progress with airborne hyperspectral imagers with spectral resolutions ranging from 0.1 to 6 nm FWHM has demonstrated that the solar-induced fluorescence emission tracked photosynthetic changes in vegetation undergoing biotic- and abiotic-induced stress. Other plant traits retrieved from hyperspectral imaging, such as chlorophyll a+b, carotenoids, anthocyanins, and xanthophylls, have demonstrated different sensitivities to early symptoms induced by nutrient and water deficiencies and pathogens. Although a tremendous technological push has made hyperspectral and thermal sensors widely available, main efforts should now focus on interpreting the spectral signatures to understand their potential links with plant photosynthesis and transpiration. Data-driven methods vs. physically-based algorithms will be discussed in the context of new deep-learning and machine learning approaches for crop stress detection using airborne imaging spectroscopy.

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## Practical interventions to reduce calf wastage and herd mortality in northern systems

**Dr Luis Prada e Silva<sup>1</sup>**, Dr Kieren McCosker<sup>1</sup>, Dr Karen Eyre<sup>1</sup>, Ms Eleanor Fordyce<sup>1</sup>, Ms Gemma Somerset<sup>1</sup>, Dr Geoffrey Fordyce<sup>2</sup>, Dr Michael McGowan<sup>3</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Gatton, Australia,

<sup>2</sup>GALF Cattle Pty Ltd, Charters Towers, Australia, <sup>3</sup>The University of Queensland, School of Veterinary Science, Gatton, Australia

Recent results from modelling the Australian cattle herd indicate substantial improvements in the reproductive performance of cows in northern Australia. During the past 45 years, the percentage of cows weaning a calf increased from 42 to 75% and adult cattle mortalities were reduced. Nonetheless, with as many as one million calves estimated to die annually, this level of calf mortality represents a major risk to the industry as it not only presents a clear loss in saleable cattle and decelerates genetic improvement of the herd, but also reinforces the already negative public image about the sustainability of cattle production in Australia. Our main hypothesis is that poor nutrition and environmental stress are the main causes of calf wastage and heifer mortality. Therefore, tailoring available cost-effective interventions to specific situations for control of nutritional and environmental stressors will increase milk delivery to neonates and reduce the incidence of dystocia in calving 2-year-old heifers, resulting in improved productivity and business margins. Ten commercial beef breeding properties have been successfully enrolled into the study and the first round of pregnancy testing is near completion. Property-specific plans to enhance the nutrition of breeding females during late gestation have been developed in conjunction with the collaborating businesses and will be applied later in the dry season. The expected impact from this project is a 5%-units reduction in calf loss and a 1%-unit reduction in herd mortality, representing additional 25 tonnes of sales and a 5% reduction in emissions intensity per 3,000 cattle herd.

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## Productivity, profitability, and sustainability of northern beef systems in a variable climate

Dr Dianne Mayberry<sup>1</sup>

<sup>1</sup>CSIRO, St Lucia, Australia

Long term projections for north Queensland indicate that beef producers will be impacted by higher average temperatures in all seasons, increased atmospheric CO<sub>2</sub>, and an increase in the frequency and intensity of extreme events such as heatwaves and cyclones. Changes to rainfall are unclear, but inter-year variation will remain high. The MLA-funded *Nexus* project aims to explore interactions between the profitability, productivity, and sustainability of livestock businesses in a future climate using bioeconomic modelling of case study enterprises. We also consider how changes to animal and land management may impact greenhouse gas emissions and carbon sequestration associated with livestock production.



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## Can feed additives contribute to methane mitigation in Northern herds?

**Dr Sarah Meale**<sup>1</sup>, Mr Mariano Parra<sup>1</sup>, Prof. Alex Chaves<sup>2</sup>

<sup>1</sup>The University of Queensland, School of Agriculture and Food Sciences (SAFS), Gatton, Australia, <sup>2</sup>School of Life and Environmental Sciences, Faculty of Science, The University of Sydney, Camperdown, Australia

Northern beef cattle grazing systems are responsible for the majority of methane (CH<sub>4</sub>) emissions from Australian agriculture. Feed additives and anti-methanogenic compounds have been tested extensively, with some promising results observed. Unfortunately, very few have been evaluated with forage-based diets representative of Northern Australia. Study 1 evaluated nine additives under *in vitro* conditions for 48 h, to estimate their impact on CH<sub>4</sub>, gas production and rumen fermentation parameters, with Rhodes grass hay as the basal substrate. Five of the additives tested did not influence any parameters. Citral extract and Sandalwood oil, at the highest dose, decreased CH<sub>4</sub> production, but also elicited a reduction in gas production and digestibility. Biochar1 and Biochar2 decreased CH<sub>4</sub> production (P < 0.01) at 48 h, at the two highest inclusion rates, with no change in *in vitro* dry matter digestibility or gas production. Study 2 evaluated the effects of adding 1) control, no additive + sterile water; 2) 1% DM Biochar + ozonated water; or 3) 1% DM Biochar with the addition of minerals post pyrolyzation + ozonated water, to a Rhodes grass hay diet on CH<sub>4</sub> emissions from 3 Holstein steers in a Latin square design. Methane emissions estimated by the sulphur hexafluoride (SF<sub>6</sub>) tracer technique revealed no effect of treatment measured as L CH<sub>4</sub> per day, L CH<sub>4</sub> per kg BW, or per kg of dry matter intake. Unfortunately, despite varying modes of action being examined across the two studies, none of the additives showed significant promise for use in Northern Australian herds.

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## Nitrogen use efficiency and nitrogen loss in northern cattle systems

**Dr Karen Eyre**<sup>1</sup>, Assoc Prof Luis Prada e Silva<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Lawes, Australia

Agriculture produces around 60% of all anthropogenic nitrous oxide (N<sub>2</sub>O) emissions (Eckard et al. 2010). With ten times the global warming potential of methane, N<sub>2</sub>O is a powerful contributor to greenhouse gas emissions and total nitrogen (N) loss is also a significant contributor to inefficiencies in ruminant production. The majority of Australia's beef cattle production takes place on extensive rangelands in northern Australia and although N<sub>2</sub>O emissions from these are low at < 0.2 kg N/ha/year there are 287 million ha of unimproved pasture in the Australian agricultural system. Approximately 40% of the total Australian N<sub>2</sub>O emissions come from animal excreta left on pasture (FAOSTAT 2022) and removing non-productive animals and increasing the nitrogen use efficiency (NUE) of individual animals may be the most economical way to reduce N<sub>2</sub>O emissions from rangelands. At low N intakes cattle are extremely efficient at recycling urea back into the rumen, reducing urinary N loss. Unfortunately, as dietary N increases the NUE decreases as N recycling becomes a less important part of the overall N metabolism of the animal. Manipulation of dietary N and energy levels in the diet can reduce urinary N output but current models do not incorporate N recycling and are not reflective of performance on low N diets. It has been shown that there is variation in NUE in cattle on low N diets (Carmona et al. 2020). We hypothesise that we can use N isotopes in tail hair to identify those cattle that have better NUE thus improving production per ha in the low N operating systems of the northern cattle industry.

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## Environmental stress and reproductive efficiency in northern Australia

**Prof John Gaughan<sup>1</sup>**

<sup>1</sup>*The University of Queensland, Gatton, Australia*

Climate (mostly heat, but also cold) and nutritional (feed and water) stress are common across Northern Australia. The two should not really be separated because the multiple stressor impacts are greater than any single stressor. A third stressor, again more of an impact if animals are already stressed, is walking distance to feed and water. It is also likely that we are seeing an increase in extreme weather events.

Grazing beef cows, even those with a high percentage of *Bos indicus* content although more resilient than *Bos taurus* cows are not immune to the impact of stressors. It is not currently known how the increasing percentage of *Bos taurus* in the north will impact on lifetime performance. Furthermore, there is little evidence of the long-term impact of heat stress on bulls. There is evidence that the DNA in sperm may be permanently affected (DNA fragmentation), resulting in reduced fertility, reduced viable embryos and weaker calves at birth. The first week post mating, and last 2 to 3 weeks of gestation are particularly important. Part of the cow's heat load mitigation is a redistribution of blood flow away from internal organs including the uterus and foetus to the cow's periphery. So, while the cow looks fine, and is effectively dissipating heat, the developing calf is in distress. Reduced blood flow means less oxygen to the calf and reduced nutrient flow. The result is an increase in stillborn calves and smaller, weaker, and immune compromised calves at birth.

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## Community-based food system for traditional African vegetables in Limpopo South Africa

Prof Dharini Sivakumar<sup>1</sup>

<sup>1</sup>*Tshwane University of Technology, Pretoria, South Africa*

### Community-based food system for traditional African vegetables in Limpopo South Africa

Food security and sustainability are major challenges for the food system. Both the provincial and national food systems were affected by COVID-19 and climate changes. Despite being one of South Africa's poorest provinces, Limpopo is also its most agriculturally productive province with 37.4% of the population engaged in it. In Limpopo province, 94.5% of the population has access to food. Providing safe, nutritious foods to everyone without discrimination demands a transformation of the food system. Further, public health plays a vital role in addressing food system challenges, since non-communicable diseases such as diabetes, obesity, and other chronic diseases are directly related to nutrition. Thus, new indigenous foods suitable for modern society can be introduced to diversify diets and reduce obesity and non-communicable diseases.

Community food systems integrate sustainable food production, preparation, distribution, and consumption to improve the environment, the economy, the social environment, and the nutritional health of a particular community. The community food system allows farmers to reclaim more of their profit through direct marketing, local processing, and other value-added activities so that the consumers can reconnect with their food supply, and the community gains financial and economic strength through the creation of jobs. In Limpopo, agriculture and rural development have always been primarily concerned with maintaining food security while eradicating hunger at the household level. In a subsistence economy, women are key suppliers of food and have acquired the skills to process and conserve surplus crops to secure a sustainable supply of food. The presentation discusses how a cooperative group of women cultivate, process, and market indigenous and commercial crops to ensure household access to food and enhance food systems with the private sector. This initiative helped provide adequate, safe, and nutritious food at the household level.

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## Promoting indigenous leadership and ownership of the native food value chain for sustainable outcomes

Ms Sophie Ader<sup>1</sup>

<sup>1</sup>*Uniquely Australian Foods, The University of Queensland, Australia*

The incredibly diverse and unique range of currently underutilised plants found in Australia have the potential to provide incredible benefits and value – to people’s health, to future food security, and to the Australian economy. But when native food value chains are Indigenous owned and led, the benefits and value include even more.

Sophie will talk about the holistic, culturally aligned value chains created through Indigenous enterprises. She will highlight the successes of these Indigenous community-based systems in Australia, by showcasing a number of examples from the Indigenous enterprises currently partnered with the University of Queensland’s ARC Industrial Transformation Training Centre for Uniquely Australian Foods.

She will share the centre’s best practice approach to working with Indigenous research partners, an approach founded on strong relationships based on two-way learning, respect and trust. These relationships allow for the collaborative design of place-based projects which support the establishment, growth and success of Indigenous owned and led enterprises in ways which uphold the rights and aspirations of Indigenous people, and create future leaders of the industry.

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## Potential aquaculture species as emerging food

Dr Glenn Anderson<sup>1</sup>

<sup>1</sup>Department of Agriculture and Fisheries, Queensland, Australia

Fish and other seafood products provide animal proteins that offer a range of health benefits, but for a variety of reasons they are often consumed at comparatively low levels. This could deteriorate as wild catch fisheries face mounting strain, but aquaculture offers an efficient method of producing large volumes of a wide range of fish and invertebrate species that can provide seafood products that suit diverse markets and consumers. Aquaculture also offers opportunities for First Nations peoples to engage in agricultural businesses that provide food security and economic participation from culturally appropriate enterprises. As aquaculture grows in importance, there is substantial effort to further diversify the species being produced and the areas in which they are farmed. For example, there are ongoing efforts to develop the blacklip rock oyster (*Saccostrea echinata*), a tropical species that has the potential to be produced throughout northern Australia. Oyster production requires relatively low capital investment, has low energy and feed inputs, is relatively resistant to short term disruptions, and produces highly nutritious products that can be shipped long distances alive, all of which make it an ideal enterprise even for remote areas. Other species are under development to provide both food and bioremediation services. The grey mullet (*Mugil cephalus*) has the potential to be used to manage nutrients within aquaculture systems and improve damaged aquatic ecosystems while producing an oily-fleshed product that is loved by many. Ongoing diversification of aquaculture products can support healthy communities by providing both nutritious foods and a healthy environment.

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## Goat meat a promising source of protein for diet diversity

Prof Louwrens Hoffman<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Bellbowrie, Australia

Traditionally, goats are reared by subsistence farmers to provide meat and milk for the household as well as for trade purposes, unlike on commercial farms where goats are regarded as a source of income and are usually farmed for their meat. In 2020, there were 1.128 billion goats globally with Asia, Africa and Latin America being the largest producers and consumers of goat meat globally. Australia has close to 3.9 million goats and is the leader in world export of goat meat; exporting approximately 95% of production in 2020, with exports totalling 14,147 tonnes shipped weight (swt). Australian goat meat is mainly (97%) exported as frozen carcasses. The US received 60% of Australian exports in 2020, with Taiwan, South Korea, Trinidad and Tobago and Canada also representing important markets. The demand for goat meat is mostly among ethnic groups as it has no religious taboos when compared to other red meat such as beef and pork. Being a niche market product is a major impediment to the expansion of goat meat consumption in Australia with consumers indicating that they are not familiar with goat meat and do not know where to purchase, or how to prepare it. Goat meat is seen as a lean meat with a healthy lipid profile. Being predominantly browsers, goat meat has unique flavours which are readily influenced by the phenolic compounds found in browse – making it an ideal candidate for the discerning modern consumer who looks for provenance in the products they typically consume.

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## Ensuring the future of Taro – a food staple

Dr Bradley Campbell<sup>1</sup>

<sup>1</sup>Centre for Crop Sciences, Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Australia, <sup>2</sup>Centre for Pacific Crops and Trees (CePaCT), The Pacific Community (SPC), Suva, Fiji

Pacific island countries and territories (PICTs) have an abundance of plant genetic resources of their principal food crop staples, but do not have the capacity to exploit their full potential. Part of the reason is that, individually, the countries do not have adequate resources for research and development. Consequently, total food production is in decline and to meet the needs of expanding populations, processed foods are typically imported, leading to a change in diet which has led to epidemics of non-communicable diseases. Traditionally, the staple food of central importance has been the root crop taro (*Colocasia esculenta*) which has been the main source of nutritional security throughout the region and is of immense cultural importance. Several reports have indicated significant levels of genetic erosion for this species. Today taro ranks behind breadfruit, yam, banana and imported rice as a staple food. Where taro is still cultivated, there is a trend towards the growing of a smaller number of varieties selected or bred for high yield in monoculture. To ensure the continued survivability and sustainability of taro production, a multi-faceted approach combining genetic resource conservation, molecular marker screening, trait phenotyping for yield, climate resilience and nutrition profiling, as well as development of AI assisted genetic models for future plant breeding or cultivar selection for farmers is being considered. It is hoped this approach may serve as a template for other neglected orphan crops, which play critical roles in the food networks of communities of developing nations.



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## Establishing a value proposition for bunya nuts as a versatile gluten-free flour

**Mrs. Jaqueline Moura Nadolny<sup>1</sup>**, Professor Odette Best<sup>2</sup>, Doctor Heather M. Shewan<sup>1</sup>, Associate Professor Heather E. Smyth<sup>3</sup>, Professor Jason R. Stokes<sup>1</sup>

<sup>1</sup>School of Chemical Engineering, The University of Queensland, Brisbane, Australia, <sup>2</sup>School of Nursing and Midwifery, University of Southern Queensland, Ipswich, Australia, <sup>3</sup>Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Brisbane, Australia

Bunya nuts are native to South-East Queensland, Australia and, in contrast to most other nut varieties, are high in starch and low in fat. This study investigates the use bunya nut flour, which is naturally gluten-free, by assessing the influence of different preparation methods (untreated with and without inner skin, fermented, boiled and roasted) on the functional and pasting properties of the flour as well as on their *in vitro* digestibility. The functional properties were evaluated by applying standard methods for flour analysis. The pasting properties were investigated using a programmed heating and cooling cycle in a rheometer with a starch cell attached. *In vitro* digestibility was carried out by quantification of starch hydrolysis, considered to provide reasonable predictions of glycaemic index in foods. It was found that untreated flour provides higher foam capacity and emulsification capability. Its starch hydrolysis was slow, which was expected due to the high viscosity of the gel formed during pasting. Boiled and roasted nuts produced flours with increased water absorption, desirable for dough handling. The starch present in these flours was digested rapidly due to its prior gelatinisation during roasting and boiling. Fermented flours showed the highest pasting viscosity and slowest starch hydrolysis. This can happen due to leaching of soluble matter during fermentation, thus concentrating the water-binding compounds and increasing resistant starch formed by retrogradation. This flour could improve gas retention capacity and elasticity of doughs. Overall, the different flours can be used in range of food applications due to the different properties.

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## Carbon as a catalyst to creating resilient food crops and profit

Mr Shane Quinn<sup>1</sup>

<sup>1</sup>Mulgowie Farming Company, Mulgowie, Queensland, Australia

This decade will be seen as the ‘Exponential Twenties’; when the long forecast impacts of climate change are demonstrated to have consequential effects on countries, economies and individual living standards. There is however a positive side to this concept; where we will also see ‘Green Swan’ regenerative solutions emerge as society begins to recognise the necessity to move from incremental solutions to *exponential* ones.

Farmers and rural communities in Australia are confronted by being on the front line of climatic change but “at the end” of consumer supply chains that are only in the early stages of moving from an unconstrained mindset to one recognising real and ongoing constraints that require a return on value to those creating it rather than overwhelmingly to those distributing it.

My goal is to shift thinking and paradigms in our rural social and economic community to demonstrate that our rural food production enterprises could be in the privileged position of being in a better place than most industries to change practices and deliver both increased resilience in nutrition production AND sequester enough carbon in our soils to be net carbon negative.

Society is growing in awareness of just how fragile our food production system is and how important nature based solutions are to this and our climate challenges as whole. The intent of my proposal is to stimulate investable models to fund the transition that needs to occur in regional food production. This systemic approach means that it is not just rural farmers that benefit, but regional engineering, science, manufacturing and education also.

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## Carbon in forest certification

Mr Simon Dorries<sup>1</sup>

<sup>1</sup>*Responsible Wood, Kedron, Australia*

Globally, forest management practices are being influenced and improved through the adoption of voluntary forest certification Standards.

The Australian Standard for Sustainable Forest Management AS/NZS 4708 has recently undergone revision with a focus on the contribution that sustainable forest management systems make to carbon sequestration.

The presentation will outline the performance requirements of AS/NZS 4708:2021 that relate to the management and optimisation of biosequestration in certified forestry systems.

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## The centrality of organic carbon in balancing the multifunctional nature of soils

**Professor Peter Kopittke**<sup>1</sup>, Dr Federico Maggi<sup>2</sup>, Professor Elise Pendall<sup>3</sup>, Professor Petra Marschner<sup>4</sup>, Professor Alex McBratney<sup>5</sup>, Professor Budiman Minasny<sup>5</sup>

<sup>1</sup>The University of Queensland, School of Agriculture and Food Sciences, St Lucia, Australia, <sup>2</sup>The University of Sydney, School of Civil Engineering, Sydney, Australia, <sup>3</sup>Western Sydney University, Hawkesbury Institute for the Environment, Penrith, Australia, <sup>4</sup>The University of Adelaide, School of Agriculture, Food & Wine, Adelaide, Australia, <sup>5</sup>The University of Sydney, Faculty of Science, School of Life & Environmental Sciences, Sydney, Australia

Both human and planetary health are reliant upon the functions provided by soil. Indeed, soil contributes to the six global existential cornerstones for the sustainable development of human societies, being food security, water security, energy security, climate change abatement, biodiversity protection, and ecosystem service delivery. This unique role of soil is because it is 'multifunctional' – it underpins 98.7% of the calories consumed by humans, regulates the climate, is habitat for 25% of global biodiversity, is the largest terrestrial store of water, and cycles nutrients. Despite this complexity, we show that soil organic carbon is critical as it plays a central role in multifunctionality and hence is a master indicator for soil functioning. We show how the use of soil for biomass provision through land-use change has resulted in a decrease in the ability of soil to (i) regulate the carbon pool and thereby contribute to climate change, (ii) cycle the nutrients that sustain plant growth, (iii) protect the biodiversity in the soil upon which the other functions depend, and (iv) cycle the global freshwater supplies. Importantly, we also discuss how this decreasing ability of soil to provide these other functions can be halted and reversed through optimisation of soil multifunctionality for long-term human welfare and planetary survivability.

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## Upsides, offsidess, blindsides: Carbon offsets and insets in Australian agriculture

**Ms Teresa Fox**<sup>1</sup>, Ms Katie McRobert<sup>1</sup>, Mr Richard Heath<sup>1</sup>

<sup>1</sup>*Australian Farm Institute*

'Farming' carbon is about long-term sustainability - improving productive systems and mitigating the detrimental effects of climate change. While agriculture is inherently carbon-extractive, there are many ways to get carbon back into the system to replace what production removes. Opportunities to 'farm' carbon for financial reward are increasing, via offsets trading markets, productivity / efficiency gains, and preferential access to finance. However, it can be difficult for farmers to understand which opportunity is best for their unique situation, or even what opportunities are out there.

Additionally, conversations are now moving from 'offsetting' to 'insetting' carbon. Offsets enable emitters to 'cancel out' emissions by investing in sequestration activities (e.g. purchasing credits for on-farm soil carbon or vegetation); however, once sold the credits belong to the emitter, not the sequester's business. Credible offsets are an important step in moving to a net-zero economy but are not a long-term solution to mitigating climate change impacts. Farmers should also consider insetting carbon. This involves not only putting carbon back into system, but also keeping credits for that work to be accounted against their own business.

This presentation provides commentary on carbon market influences, explains the difference between insetting and offsetting and explores five carbon opportunity pathways available to Australian farmers. This information is provided in the context of recent AFI research and publications including: the Australian Agricultural Sustainability Framework, development of the Carbon Opportunity Decision Support Tool, Farm Policy Journals and Occasional Papers.

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## Australia's carbon market, how did we go so wrong?

Dr Don Butler<sup>1</sup>

<sup>1</sup>*Australian National University, Canberra, Australia*

Australia's carbon market is suffering from a distinct lack of integrity. But abandoning carbon offsets would substantially increase the cost of achieving emissions reduction targets and forego the many environmental and social co-benefits that can be generated from a well-functioning offset market. The complex nature of offset methods, and the high risk of error, means that integrity can only be maintained with a culture of transparency, where administrators expect and actively seek out errors, and move quickly to correct them when they are found. Australia's carbon market lacks both transparency and a culture of correction. Unfortunately, the details of our carbon market remain poorly understood outside the service providers that dominate the 'industry' and work closely with the regulator. To facilitate and encourage the development of a more useful market there needs to be rules that ensure the disclosure of information and require proponents to move off methods (and onto new ones) where they are found to contain material errors. In the short-term immediate action is required vary or revoke low integrity methods and stop projects with low integrity from receiving further credits. Lessons from the carbon market, and similar stories from biodiversity offsets, suggest transparency and effective, independent regulation are even more critical to integrity in environmental markets than in those where buyers can more readily tell the good from the bad, and are more likely to care.

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## A multidisciplinary investigation of an Aboriginal 'centre' of food production

A/Prof Michael Westaway<sup>1</sup>

<sup>1</sup>*The University of Queensland, Australia*

It is clear when we undertake a careful study of past Aboriginal society that across Australia economic systems were not uniform. A staggering variety of resources and their environments were used by Aboriginal people. They held ceremonies of great complexity, often associated with resource productivity, and it is probable that at some sites dramatic intensification of labour demands were employed. Plants were translocated and, in several regions, cultivated, and landscapes were culturally modified through burning and other practices to promote increased economic productivity. Some groups developed increasing sedentary societies and lived in seasonal villages. We need to attach greater importance to understanding diversity in economic and social systems if we are to produce a more authentic reconstruction of the Aboriginal past.

Over the past seven years multidisciplinary investigations in Queensland's Channel Country, have generated important new data to test against hypotheses relating to the nature of Aboriginal food production. I provide an overview of research from a multidisciplinary approach in Mithaka country which is revealing important new insight into the nature of Aboriginal society during the Holocene period.

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## The mines of the Mithaka: Aboriginal sandstone mining in Channel Country

Mr Doug Williams<sup>1</sup>

<sup>1</sup>*Austral Archaeology Pty Ltd, Canberra, Australia*

Application of aerial survey techniques in channel country has allowed us to develop an appreciation for the massive scale of production of grindstones to exploit the seed resources of the region and to feed products into the trade and exchange system. Recording at a more detailed level has provided the opportunity to examine sandstone quarry features in detail. We have recorded a series of grindstone quarry complexes on a scale hitherto unknown in Australia. The results of this study will make a significant contribution to emergent research on Australian Aboriginal food production techniques and study of a cultural landscape over thousands of square kilometres. In the face of climate change, the Mithaka way of life and food production has lessons for contemporary Australian land use.



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## Reconstructing ethnobotany on Mithaka country

Dr Jennifer Silcock<sup>1</sup>

<sup>1</sup>*The University of Queensland /Queensland Herbarium, Charleville, Australia*

Intimate knowledge of botanical resources underpinned Mithaka survival and culture for millennia, however much of this knowledge was lost due to European displacement of Aboriginal people in the late 19<sup>th</sup> Century. A rich ethnographic record survives, primarily in the writings of Alice Duncan-Kemp, who grew up on Mooraberrie in the early 1900s and was cared for and taught by Aboriginal women including the renowned *gdanja* ('herbalist') Mary Ann.

I extracted >450 botanical references from Alice Duncan-Kemp's published writings, and attempted to identify the species involved through extensive botanical field work and comparison with ethnobotanical sources from surrounding areas (including surviving traditional knowledge, published ethnobotanical accounts, early European explorer diaries, the digitised newspaper archive, Herbarium specimen labels and botanical identification books). This information was recorded in a spreadsheet containing all 645 native plants known to occur on Mithaka country, extracted from the Australian Virtual Herbarium database.

Duncan-Kemp recorded ethnobotanical information for c.150 species, and local names for 90. Around half of the 645 species were found in the ethnobotanical record from surrounding areas, and were very likely used in a similar way within Mithaka country. Most plants were used as food sources, followed by medicines and materials for tools, shelters and weapons. Spiritual or ceremonial aspects were noted for 38 plants on Mithaka country and at least 80 plants in the surrounding area.

The Duncan-Kemp record contains ethnobotanical observations of a detail and nature not found elsewhere in Australia, and provides a unique window on complex and intimate human-plant interactions.

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## Archaeobotanical evidence for wood and seed exploitation from an Aboriginal Gunyah Site

Dr Nathan Wright, Prof Andrew Fairbairn<sup>2</sup>

<sup>1</sup>University of New England, Australia, <sup>2</sup>The University of Queensland, Australia

The physical evidence for many activities involving plants in Australia's archaeological record of open-air sites is scant. Both the ephemeral nature of many plant-based activities and the sheer vastness of the landscape upon such activities may have taken place impact the recovery of archaeological evidence. Additionally, much of the landscape upon which plant-based activities occur has undergone significant erosion and modification. However, we show that with appropriate recovery techniques and systematic sampling of sites there is much to be recovered. This paper shows the technical approach undertaken to recover wood, seed, and fruit remains from a Mithaka Gunyah (hut) and its immediate surrounds (southwest Queensland, Australia). Initial analysis of the seeds and woods show a variety of plants being utilised for fuel and possibly food. Both the seeds and woods offer an exciting array of analyses that are rarely undertaken in the Australian context and will yield important data to question around plant-based food use and landscape modification.

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## Caring for Mithaka Country: Combining sustainable Indigenous food and carbon farming with managed grazing

Mr Joshua Gorringe<sup>1</sup>, Ms Shawnee Gorringe<sup>1</sup>

<sup>1</sup>Mithaka Aboriginal Corporation, Australia

Mithaka Country is situated in the Channel Country of far southwestern Queensland, an arid ‘boom and bust’ region of Australia that is known for prolonged drought periods and expansive flooding events. It is essential to Mithaka people to sustainably utilise and protect their homelands for generations to come.

This project aims to re-establish Indigenous production of foods and medicine in combination with managed grazing. The project is actively reconstructing pre-European Mithaka plant use practices and how to understand the current carbon storage in the landscape and how this might help inform approaches on how we maintain more sustainable grazing on country that supports greater carbon storage. If we can inspire the re-creation of more biodiverse and carbon-rich environments on and under land and water can this in turn translate to a return in income from foods, royalties and/or carbon credits to support employment for Mithaka people on Country? By developing more sustainable approaches that support both environment and culture, the project will help to protect the land, water, and culturally significant sites of Mithaka Country. If successful we hope that this method could potentially be replicated in many parts of Australia’s dry interior.

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## Studying animals

Dr Bruce Pascoe<sup>1</sup>

<sup>1</sup>*The University of Melbourne, Australia*

If you want to study the intricacies of the weird and secret behaviour of an animal, it's hard to go past the human.

An interesting creature. The size of the brain encourages the human to think of itself to be superior to all other animals but that is the point at which the humans began to destroy their home.

So where did vanity begin and care of the earth subside? Was it when men thought it would be good to wear jackets with lace at collar and wrist, was it the invention of the cotton mill, the Bible or Koran?

Studying human behaviour is as necessary as any study of our political or social problems.

Once I began reading about early Aboriginal townships I could not help but see that the ingredients for all civilizations contain the possibility of further sophistication. So why kings and queens, armies and oil barons or why their absence?

It is far too simplistic to look at simple strands like capitalism and communism or Christian and Muslim. We need to look at the cores of belief and aspiration.

Aboriginal lore fascinates me, not because I am a participant, but because this society had the ingredients to become as violently ambitious as any other continent. Once again discussions of science or steel are too simplistic. Its not hardware that is important it is philosophy, so I want to know how our people conceived of a role for humans as protectors of Mother Earth and still trade and travel.

What was the philosophic muscle behind this civilization?

I think it is the attitude toward the earth and other humans, strangers or intimates. If you believe as we are beginning to have to that Aboriginal people have been here for 80,000 plus years, why did successive thousands of generations re-endorse the fundamentals of the lore? Where was the hothead, the disaffected, the jealous.

This is what fascinates me and I think it may hold keys for our survival. Don't think lap laps and charcoal, think philosophy and restraint.

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## Frontiers research into food waste in Australia

Mr Tom McCue<sup>1</sup>

<sup>1</sup>*Hort Innovation, Australia*

In 2021, the Australian horticulture sector embarked on developing an Australian Horticulture Sustainability Framework – a guide to help the horticulture sector share its sustainable, ethical, and safe farming practices. A core component of the framework is less waste, focused on reducing all forms of waste in horticultural production.

In 2022, Hort Innovation Australia realigned its Hort Frontiers Strategic Initiative Fund to the Framework. This presentation will discuss the new areas of focus, in particular critical areas of investment in R&D to ensure a response to food waste. This is a necessary part of supporting farm businesses, including assessment and implementation of initiatives to reduce food waste efficiently across the 37 horticultural sectors in a tangible and achievable way.

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## The horticulture sector action plan- bringing a supply chain together to reduce food loss and waste

**Ms Melissa Smith<sup>1</sup>**

<sup>1</sup>Stop Food Waste Australia, Mudjimba, Australia

A staggering one-third of all food produced in Australia is wasted. That is 7.6 million tonnes lost annually and fresh produce remains the most wasted category of food. From farm to fork it constitutes 50% of all food waste.

Food waste is Australia's \$36.6 billion challenge. And when we waste food, we waste the water, energy and land resources used to grow, make, move and sell that food – ultimately adding to GHG emissions. The Foodbank Hunger Report 2021 also reveals one in six Australian adults haven't had enough to eat in the last year

Stop Food Waste Australia is addressing food waste from fresh produce through the Horticulture Sector Action Plan. Co-designed by key stakeholders, the Plan will identify food waste hotspots, and prioritise reduction actions for maximum impact. Existing processes along the supply chain including growing, harvesting, grading, processing, transportation, sale, and safety will be considered in the SAP as part of a holistic approach to reducing food waste. The underlying goal is to improve crop utilisation, profitability and supply chain resilience whilst increasing food donation.

This will create value in ways beyond the obvious upcycling of unsaleable products- improving primary data, building better collaborations and communications in the supply chain, pulling policy levers through government partnerships, identifying R&D projects, understanding consumer behaviours and driving consumption of fresh produce all help to create an ROI of at least 7 to 1 on food waste intervention spending.

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## Defining new markets and opportunities, the role of BSF in creating value from food waste

Ms Olympia Yarger<sup>1</sup>

<sup>1</sup>GoTerra, Canberra, Australia

Globally, food waste is directly responsible for 8% of carbon emissions. One third of all food produced is lost or wasted (1.3 billion tonnes), costing the global economy c.\$940 billion each year. Recycled organic products have previously struggled to return high value or be incorporated directly into the agriculture system. Goterra, a climate technology company that combines insects and robotics to manage food waste, is reshaping how we view recycled organic products. Goterra is not just recycling but valorising food waste that would otherwise go to landfill by converting it into protein - produced from the Black Soldier Fly larvae that consume it. This protein creates a circular economy by feeding it to livestock, realising high value from otherwise wasted food.

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## Opportunities for full crop utilisation in Australia

Dr Pablo Juliano<sup>1</sup>

<sup>1</sup>Commonwealth Scientific and Industrial Research Organisation (CSIRO), Victoria, Australia

The global demand for plant protein ingredients is booming – from \$7.2B today to an estimated \$8.6B in 2025. At present, the Australian food industry is fully dependent on plant protein ingredient imports from China, Europe, and the USA. The manufacture of plant protein ingredients in Australia is a recent venture, with relatively small installations located in Southern Australia and none in Northern Australia.

At the same time, 20-40% of crops, particularly fruit and vegetables, are lost on-farm and in packing houses and legume crops are used for nitrogen fixing in soil without further processing. All this represents major losses to agriculture that could otherwise bring much higher returns to growers.

This presentation will showcase initiatives across the country aligned with the National Food Waste Strategy to halve food losses and waste by 2030. The presentation will highlight with company examples the whole of seed and whole of plant approaches to transform these crops into specialty protein ingredients, fibre, starches and oils, as well as materials. Other opportunities for 100% harvest by upcycling vegetables will also be highlighted together with Australian complementary company creation success stories.



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## Food waste valorisation technology assessment using real options

Dr Jason West<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Australia

Food waste valorisation and upcycling options including volatile acids, polyhydroxyalkanoates, biofuels, energy, and biobased plastics at an agro-industrial scale require long-term financial commitments. Financial assessments using discounted cash flows can undervalue promising valorisation options which may render suitable processes uneconomic. Technologies whose value is underestimated will fail to receive sufficient investment. An alternative approach is the use of real options analysis that effectively caters for uncertain but highly promising opportunities. Options provide the right but not the obligation to invest in a technology. Their value is driven by the possibility of achieving a large gain combined with the option to abandon the technology before overinvesting in its development. The value of the option increases as the uncertainty surrounding the technology increases. Importantly, cost volatility in valorisation processes represents the greatest uncertainty for emerging technologies which should encourage the research and development effort to focus on process rather than product. Properly accounting for cost volatility allows for better calibration of the investment cycle which minimises the risk of technology failure. This session will highlight how real options methods are superior to discounted cash flows in the assessment of technologies that develop new food products, animal feeds, or high-value products from food waste, and produce a more comprehensive assessment of value that accounts for the evolution in technology development.

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## Understanding Supply Chains to Improve Food Security in Remote Queensland Communities

Ms Renae Earle<sup>1</sup>, Mr Adrian Doyle<sup>2</sup>, Mr Chris Boge<sup>2</sup>, Mr Rajaei Masoud<sup>2</sup>, Dr Simone Nalatu<sup>1</sup>, Mr Peter Scuderi<sup>2</sup>

<sup>1</sup>Health And Wellbeing Queensland, Milton, Australia, <sup>2</sup>Arup, Brisbane, Australia

In remote Queensland communities, 12% of food items required to achieve the Australian Dietary Guidelines to Healthy Eating are missing from grocery stores. Where available, they are of poor quality and 36% more expensive than comparable products in Brisbane. Approximately 20% of the cost of food in remote communities is attributable to freight-related expenses, compounded by long, complex supply chains that are prone to disruption. It is well recognised amongst various stakeholders that current supply chain challenges compromise remote food security. As a result, health inequities experienced by First Nations people who live there are continually reinforced. Possible solutions have been identified nationally, for example, freight subsidies, regional distribution hubs, improved transport infrastructure and technology. However, the appropriateness and potential benefit of these solutions in Queensland's First Nations communities is yet to be evaluated, which requires an in-depth understanding of the relevant supply chains. Health and Wellbeing Queensland (HWQld) have partnered with Arup to map the supply chain of five community-identified priority food products (from red meat, chicken, milk, fruit and vegetable food groups) in two remote Queensland communities; one island and one on the mainland. Structured interviews will be conducted with participants across the supply chain (from retailer to producer) who will be recruited using snowball sampling methods. Data collected will inform a consolidated supply chain map and future opportunities and risks. Findings (expected August 2022) will be used to inform interventions within remote supply chain practices that support better food security and health outcomes in First Nations communities.

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## When machine learning meets digital agriculture

Prof Helen Huang<sup>1</sup>

<sup>1</sup>*The University of Queensland, School of Information Technology and Electrical Engineering (ITEE), St Lucia, Australia*

As a data-intensive discipline, agriculture creates huge opportunities for data scientists to be engaged in a series of tasks from data acquisition, management, analytics, prediction to visualisation in the context of digital agriculture. Advanced machine learning techniques developed for computer vision, recommender systems, and pattern recognition can be largely leveraged to handle images, time series and text data produced in various application scenarios. In this talk, we will demonstrate how machine learning can be applied in the agriculture domain and potential challenges we are experiencing.

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## Evolutionary computing for sustainable crop breeding programs

**Ms Kira Villers**<sup>1</sup>, Dr Eric Dinglasan<sup>1</sup>, Professor Ben J. Hayes<sup>1</sup>, Professor Kai P. Voss-Fels<sup>1,2</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), St Lucia, Australia,

<sup>2</sup>Department of Grapevine Breeding, Hochschule Geisenheim University, Geisenheim, Germany

Management of genetic diversity in elite crop breeding pools is a significant challenge to breeders. Loss of genetic diversity limits long-term performance gains, and introducing new diversity is a slow and involved process. As an alternative to truncation selection on genomic estimated breeding values (GEBV), we investigated a genetic algorithm (GA) that aims to maximise genetic gain and minimise diversity loss by selecting sets of parents containing between them chromosome segments with very high breeding values for the target trait. Selection methods were compared in stochastic simulation on a founder population of wheat genotypes and a yield trait. Repeated recurrent selection and intercrossing using the GA was compared to repeated recurrent selection on the yield GEBV, and to selection on a set of indexes combining the yield GEBV and the genetic distance between parents. After 100 generations of selection, truncation selection had exhausted the genetic diversity, while in the GA population considerable diversity remained. In some situations, particularly where the number of parents crossed each generation was relatively small, gain under the GA exceeded that under truncation selection. These results indicate that GA-based parent selection could be a promising method to maintain diverse breeding populations under random crossing and with no significant additional effort to the marker effect calculations involved in a regular genomic selection program.

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## Towards hands-free robotic crop management in protected cropping systems

**Dr Chris Lehnert<sup>1</sup>**

<sup>1</sup>*Queensland University of Technology, Australia*

In this presentation, I will discuss the potential for robotics to help transform the food industry and what it may look like in the future. In particular, I will present our research and development of robotic systems to manage crops in protected cropping systems. This work aims to offer an attractive solution to reducing labour costs in the protected cropping industry by using AI and robotics to perform hands-free harvesting and other labour-intensive tasks. Robotic crop management is a particularly challenging task that requires integrating multiple subsystems, such as crop detection, motion planning, and dexterous grasping. I will touch on different methods we have researched and developed for perception and manipulation in agriculture, what challenges we had to face and what future challenges need to be solved to make robotic crop management in protected cropping a reality.

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## AI and machine learning for genomic prediction in sugarcane

**Mr Chensong Chen<sup>1</sup>**, Mrs Elizabeth Ross<sup>1</sup>, Mr Owen Powell<sup>2</sup>, Mr Eric Dinglasan<sup>1</sup>, Mr Ben Hayes<sup>1</sup>

<sup>1</sup>Centre for Animal Science, Queensland Alliance for Agriculture and Food Innovation, University of Queensland, St Lucia, QLD 4067, Australia, Brisbane, Australia, <sup>2</sup>Centre for Crop Science, Queensland Alliance for Agriculture and Food Innovation, University of Queensland, St Lucia, QLD 4067, Australia, Brisbane, Australia

The sugarcane genome is extremely complex, with high polyploidy and multi-species ancestry. Simple additive models for genomic prediction of clonal performance might not capture interactions between genes and alleles from different ploidies and ancestral species. As such genomic prediction in sugarcane is an interesting case for machine learning methods, which purportedly able to deal with high levels of complexity in prediction. Here we investigate Multilayer networks (MLP), convolution neural networks (CNN), and a classic ensemble approach, the Random Forest (RF) for genomic prediction in sugarcane. The data set was 2912 sugarcane clones, scored for 26,086 genome wide SNP markers, with final assessment trial (FAT) data for total cane harvested (TCH), Commercial cane sugar (CCS) and Fibre content. The clones in the latest trial (2017) were used as a validation set. Comparing to GBLUP with up to three components (additive, dominance, and epistasis), both DL and RF predictions were more accurate than the additive GBLUP but generally lower than extended GBLUP, and RF could overperform the other methods for Fibre content prediction. For CNN models, higher prediction accuracies were achieved by encoding genotype markers as numeric features than categorical signals. For random forest models, prediction accuracy for TCH was increased by using larger decision trees with more features, supporting the hypothesis that this trait is influenced by higher level interaction effects. We conclude Deep Learning and particularly RF may have some utility for genomic prediction for crops with highly complex genomes, particularly if non-additive interactions can be captured with clonal propagation.

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## Quantifying heat sensitivity across temperature gradients accelerates selecting heat-adapted genetic resources

Dr. Ya-ping Lin<sup>1</sup>, Dr. Derek Barchenger<sup>1</sup>, Dr. Roland Schafleitner<sup>1</sup>

<sup>1</sup>World Vegetable Center, Tainan, Taiwan

High throughput phenotyping is one of the key elements of profiling the phenotyping change in different environmental conditions. Phenospex PlantEye F500 is a sensor that can automatically collect 3D multispectral images in the field and transform the images into morphological and spectral parameters. This study phenotyped three hundred *Capsicum annuum* accessions in three seasons: one cool, one mild heat, and one severe heat season. To investigate the response of these digital traits across the temperature gradient, we integrated all the digital phenotypes among the three trials and harvested over half-million data points in total. Each data point has both the phenotypic value and climatic information. A machine learning algorithm is applied to evaluate the association ( $r^2$ ) between these digital phenotypes and temperature gradient for two subjects, the whole collection and each accession individually. For example, the normalized differential vegetation index (NDVI), which showed  $r^2 = 0.44$ , is sensitive to temperature. The cumulative  $r^2$  curve of NDVI shows a dramatic increase at 27°C, suggesting a temperature over 27°C is a stressful environment for pepper. Combining the responses of all traits across the temperature gradient in the accession level could further identify heat-tolerant lines. This field phenotyping experience has shown that high throughput multispectral 3D scanning of crops efficiently accelerates the research on stress-tolerant traits and the identification of stress-adapted genetic resources.

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## Matching crop to environment – advancing nitrogen efficiency in sugarcane

**Dr Nicole Robinson**<sup>1</sup>, Ms Anoma Ranagalage<sup>1</sup>, Dr Jaya Basnayake<sup>2</sup>, Prof Susanne Schmidt<sup>1</sup>, Dr Prakash Lakshmanan<sup>3</sup>

<sup>1</sup>The University of Queensland, School of Agriculture and Food Sciences (SAFS), St Lucia, Australia, <sup>2</sup>Sugar Research Australia, Brandon, Australia, <sup>3</sup>Sugarcane Research Institute, Guangxi Academy of Agricultural Sciences, Nanning, China

Optimising nitrogen (N) use efficiency is an ongoing priority for the Australian sugar industry as it relies on high N fertiliser inputs for profitable yields, while its coastal location in Queensland requires farming systems with reduced dissolved inorganic N losses to improve water quality entering the Great Barrier Reef lagoon. N losses result from a mismatch of fertiliser N availability and crop N uptake. Improved sugarcane varieties with enhanced recovery and use of applied N are a component of the multifaceted strategy spanning crop genetics, management and fertiliser technology required to achieve N loss reduction targets. We present an evaluation of genetic variation in N uptake and use of 40 sugarcane genotypes grown with varied N supply over multiple sites and seasons together with characterisation of N-linked traits with potential for screening in sugarcane breeding programmes.



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## Deep banding of P improves pod yield in Chickpea genotypes

**Dr Vijaya Singh**<sup>1</sup>, Professor Michael Bell<sup>2</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), St. Lucia, Australia,

<sup>2</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Gatton, Australia

Genetic variation in root system architecture (RSA) could play a major role in phosphorus (P) acquisition and uptake from the soil profile. In this study we tested the presence of genetic variation in RSA and its function in P acquisition and uptake for four contrasting chickpea varieties, in response to low and higher P rates, and shallower and deeper placement strategies. Assessment of P response at the late flowering and podding stage showed that the deeper applied P, either in a band or a layer at 20 cm depth, and higher P rates significantly increased the number of nodes, shoot weight, total number of flowers and pods, compared with shallow application method and lower P rates. Ultra-high P rate (5 times more than the standard rate of 30kg P/ha) significantly increased the total root length and root surface area compared with control (no added P), irrespective of P placement strategies. However, there were significant interactions between varieties and P rates and application strategies for RSA parameters. Early flowering varieties had greater total root length and root surface area in response to additional P rates and to some extent to deep placement strategies, whereas the late flowering variety had lower root length and root surface area with standard and control P treatments. Shoot P uptake increased significantly with the added P and/or deeper placed P for early flowering varieties, whereas shoot P uptake for the late flowering variety was significantly less with the shallower application and/or with the control P treatment.

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## Simulating long-term nutrient dynamics to better assess soil fertility in subtropical cropping

**Ms Bianca Das**<sup>1,2,3</sup>, Prof Susanne Schmidt<sup>2</sup>, Mr Jody Biggs<sup>3</sup>, Dr David Lester<sup>4</sup>, Mr Nicholas Bourne<sup>3</sup>, Dr Neil Huth<sup>3</sup>

<sup>1</sup>Tasmanian Institute of Agriculture, Newnham, Australia, <sup>2</sup>The University of Queensland, Brisbane, Australia,

<sup>3</sup>Agriculture and Food, CSIRO, Brisbane, Australia, <sup>4</sup>Queensland Department of Agriculture and Fisheries, Toowoomba, Australia

Soil chemical fertility has steadily declined in tropical and subtropical agriculture. Assessing effect of phosphorus (P), nitrogen (N), and carbon (C) on crop productivity is complex because climate often dictates crop nutrient response, causing suboptimal yield and fertiliser inefficiency. The Agricultural Productions Systems sIMulator (APSIM) model accounts for C x N x climate interactions, but modelling P is constrained by a dearth of suitable data. We simulated P, N, and C dynamics at a 35-year long-term field trial, where a range of N (0, 40, 80, 120 kg ha<sup>-1</sup>) and P (0, 10, 20 kg ha<sup>-1</sup>) fertiliser rates were consistently applied. We parameterised the model by assuming correspondence between conceptual soil P pools and Hedley fractionation pools, and with quantified P adsorption isotherms, measured organic N, C, and charcoal content to estimate organic matter decay coefficients, pool sizes, and C:N ratios. APSIM accounted for variation in mean N export (94 %), crop yield (88 %), and P export (62 %) across the 12 treatments, and reproduced interannual variation in N × P effects for crop yield and N export. APSIM also identified depletion or accumulation of soil P, N, and C in most treatments. P fractionation and isotherm measurements are labour intensive but worthwhile and future efforts should work to consolidate a database for different soil types. Using this P modelling approach will enable better assessment of climate variability on soil fertility and crop productivity, and guide management practices to deliver better fertiliser efficiency and maintain soil organic C.

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## Maintaining soil organic matter to slow fertility decline and reliance on fertilisers

Dr David Lawrence<sup>1</sup>

<sup>1</sup>Agri-Science Queensland; Department of Agriculture and Fisheries, Toowoomba, Australia

Soil organic matter is critical for healthy soils and sustainable agricultural production. This is not 'news' to growers, agronomists, or indeed anyone with a vegetable garden or compost heap at home. We know that healthy soils with high organic matter levels grow better crops that are easier to manage. However, we also know that soil organic matter (SOM) and soil organic carbon (SOC) levels are declining, which means continued grain production and healthy crops are needing more fertiliser, especially for nitrogen (N).

To make sensible decisions, managers must understand how SOM and SOC work, why their levels are declining, the implications for enduring profitability, and what can realistically be done about it.

Data from 500 paired-site across grain regions of Queensland and northern NSW show the effects of land-use and farming practices on SOC levels across the northern grain region. Total Organic Carbon (TOC 0-10 cm) under remnant vegetation of 'agricultural soils' varied from 0.5 to 5.0% and typically declined with long-term cropping to 0.5 to 1.2%, representing up to \$5000-8000/ha of lost natural nutrient capital. The good news is productive pastures with good nutrition were able to raise TOC levels by approximately 1 t/ha/yr compared to continued cropping, and so provide opportunity for long-term management of SOM and SOC in mixed farming systems

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## Enabling the circular nutrient economy

**Prof Susanne Schmidt<sup>1</sup>**, Dr Nicole Robinson<sup>2</sup>

<sup>1</sup>The University of Queensland, School of Agriculture and Food Sciences, Brisbane, Australia, <sup>2</sup>The University of Queensland, School of Agriculture and Food Sciences, Brisbane, Australia

The Circular Nutrient Economy forms part of the circular economy that addresses several of the United Nation's 17 Sustainable Development Goals. Food production of recent decades has been fuelled by mineral fertilisers that are synthesised at high energy cost or mined from finite resources. But the largely linear path of nutrients and mineral fertilisers causes inefficiencies that manifest in nutrient losses and environmental degradation where excess fertiliser is used, and in under- or oversupply of crops where formulations do not match crop needs. Transitioning to the circular nutrient economy will have profound benefits. Less *de novo* fertiliser production and reliance on supply chains to benefit countries without mineral deposits. Investing into nutrient-recovery technologies will enable fertiliser manufacture from waste streams, prevent pollution from wastes, and redesign nutrient supply to soils and crops, supporting soil organic matter and carbon sequestration. Local jobs and customised next-generation fertilisers that synchronise with crop demand are anticipated. Nutrient sovereignty at region and country level, economic gains, efficient food systems, nutritious food and feed, and environmental asset protection are anticipated outcomes. We illustrate steps towards achieving these goals by formulating and testing next-generation fertilisers made from clean recyclates and organic materials, beneficial microbes, and novel biomaterials. The Circular Nutrient Economy requires collaboration across sectors to achieve a future without waste and pollution.

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## Feasibility of Biochar Application for vegetable Production in Rice Field of Timor-Leste

Mr Rob William<sup>2</sup>, Dr Penny Wurm<sup>1</sup>, **Mr Acacio Guterres<sup>1</sup>**

<sup>1</sup>Charles Darwin University, Casuarina, Norway, <sup>2</sup>AI-Com/ACIAR

Vegetables are often grown after a rice crop in irrigation areas in Timor-Leste, however productivity and profitability is very low. Rice hull biochar has shown to be an effective fertiliser for rice and vegetable, but requires very high rates of application (20 to 30 t/ha). Therefore, the present study is designed to add low doses of inorganic fertiliser (Urea and superphosphate) with low doses of biochar (1 and 3 t/ha) to increase production in a high value vegetable and rice cropping system. Gross margin analysis was carried out to determine if the new approaches of using high value vegetable species and low rates of rice-hull biochar and low rates of Urea and superphosphate are economically viable.

This study was undertaken at Maliana Municipality, Timor-Leste, in 2021. The study tested the performance of eight vegetable species on low rates of rice-hull biochar and low rates of Urea and superphosphate application. The Main-plot was dose of rice-hull biochar with 2% N as Urea and 1% P as SP-36 with 3 levels of treatments (0, 1 and 3 t ha<sup>-1</sup>). The Sub-Plots were eight vegetable species Pokchoi, cucumber, capsicum, cabbage, tomato, eggplant, rockmelon and watermelon.

Results of the study showed that application of rice hull biochar with added 2% N and 1% P had positive impacts on vegetable yields of between 28% to 343%, compared to control. Rice-hull biochar application also economically increased farmer profitability from US\$ 135.00 to US\$ 5,000.00 per crop per year for one tenth of a hectare, compared to control. These study findings suggested that low rates of rice-hull biochar application with added 2% N and 1% P positively increased yields of high value vegetable crops and potential to improve farm household income.

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## Defining and designing food systems in Australia

Prof Damian Hine<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Queensland, Australia

Food security is certainly an issue in some communities in Australia. However other first order issues are our food sovereignty, and our responsibility to support the food security of other nations. Due to the export orientation of our own food system, our food production and our agri-food system need to articulate effectively with those of other countries and reflect their needs as well as our own. Climate change of course is the greatest threat to our food sovereignty and has the potential to erode our food security, placing more pressure on Australia in its role as a net food exporter. Tackling climate change while expanding our agricultural output is a balancing act that is already taking shape. In the absence of national policy leadership over the last decade, producers, processors, aggregators, through to retailers, and consumers have been taking direct action to progress to net zero emissions. This has been increasingly supported and led by strategic leadership by national representative bodies. However, our food system remains disintegrated, with agriculture disconnected from the consumer end of the value chain. This session focuses on transformation rather than stasis. We can design the perfect system, but tensions and complementarities among the sub-systems will dictate where the system settles. What are often regarded as unintended consequences of strategies and actions in a disintegrated system could be avoided with system level analysis and planning.

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## Whole of system improvement

Dr Muhammad Fadzli Ali<sup>1</sup>, Dr Yanti Nuraeni Muflikh<sup>1</sup>, Dr Oluwamayokun Fadeyi<sup>1</sup>, Dr Ali Akber<sup>1</sup>, Dr Sabrina Chakori<sup>1</sup>, Dr Fathin Ayuni Azizan<sup>1</sup>, Mr Adhitya Kiloes<sup>1</sup>, Mr Mohammad Abdullah Al Mamun<sup>1</sup>, Mr Maryono Maryono<sup>1</sup>, Ms Thi Hai Dang<sup>1</sup>, Ms Julia Checco<sup>1</sup>, **Dr Ammar Abdul Aziz<sup>1</sup>**

<sup>1</sup>*School of Agriculture & Food Sciences, The University of Queensland, Gatton, Australia*

Meeting the increasing demand for food and non-food agricultural products in the face of challenging global environmental, social, and economic change is one of many wicked problems faced by the agri-food systems today. Agri-food systems rely on a complex and dynamic network of diverse value chain actors and stakeholders that link and enable the production, processing, distribution, and consumption subsystems to function. The varying structure of relationships and coordination mechanisms between the value chain actors and stakeholders adds to this complexity. However, solutions are often derived from research focused on a specific subsystem, and quite often, little attention is paid to building a comprehensive understanding of how complex systems are interconnected. To develop strategic interventions at a local, national and global level, there is a need for a wider application of a whole system analytical approach. This talk will share key lessons from more than 35 years of accumulated research in adopting a whole system approach to research in finding solutions to wicked problems in agri-food systems across a range of agri-food products and countries.

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## Towards healthy and sustainable dietary patterns in Australia

Dr Olivia Wright<sup>1</sup>

<sup>1</sup>School of Human Movement and Nutrition Sciences, The University of Queensland, St Lucia, Australia, <sup>2</sup>Centre for Nutrition and Food Sciences, Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, St Lucia, Australia

Dietary patterns, in Australia, and worldwide, are not contributing sufficiently to chronic disease prevention, the achievement of the sustainable development goals or planetary health targets. There are various challenges to achieving higher nutrient density and nutritional variety across the food system. The way forward centres on interdisciplinary collaboration and innovation across the food value chain. This presentation focuses specifically on factors affecting the adherence of consumers to selected dietary patterns and how this information can be utilised to positively influence the entire food value chain.



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## Co-Designing a Market Garden to deliver better health on Mornington Island (Australia)

Ms Renae Earle<sup>1</sup>, [Dr Sunny Oliver-Bennetts](#)<sup>2</sup>

<sup>1</sup>Health And Wellbeing Queensland, Milton, Australia, <sup>2</sup>Arup, Brisbane, Australia

On Mornington Island, food travels over 2,500 kms to reach the local store. When arrives, it costs ~43% more than in Brisbane and is often of poor quality. The impact of this on food security is felt through disproportionately high rates of diet-related chronic disease (40%). However, this has not always been Mornington Island's story. During the 1980s a market garden supplied community with fruit, vegetables and meat contributing to health, social and economic outcomes. Due to various challenges, the market garden closed later that decade. Opening a new market garden is a priority of Mornington Shire Council (MSC) who have partnered with Health and Wellbeing Queensland and Arup to identify a sustainable market garden framework that supports a healthy society. A literature review of local, national, and international successful market garden case studies (n=7) has been conducted. Eight key success criteria were identified, which are being analysed with respect to Mornington Island's environment, workforce, community and traditions. Community consultation has identified potential barriers such as water security and freight/logistics limitations, and strengths including the community's connection to culture and enthusiastic engagement around the market garden. Soil and water testing and spatial community asset mapping are being undertaken to further inform the sustainable market garden framework. The resultant model for a health-promoting market garden will be presented as a Business Case that will assist in attracting funding to drive the required action to counteract currently intractable systemic barriers to a healthy society on Mornington Island.

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## Advancing integrated nutrition research in the Asia-Pacific region

Dr Sinead Boylan<sup>1</sup>

<sup>1</sup>*Commonwealth Scientific and Industrial Research Organisation (CSIRO), Eveleigh, Australia*

Australia faces many diverse nutrition challenges. At the same time, neighbouring populations in the Asia-Pacific region are experiencing the triple burden of malnutrition – the co-existing of undernutrition, diet-related diseases such as obesity, and micronutrient deficiencies. Available data indicates that these conditions are not evenly experienced across regions. While there is political will in many nations, efforts to tackle malnutrition remain largely reductionist and fail to address the range of underlying and inter-related drivers. Developing effective strategies to improve nutrition in the light of food system threats, such as climate change, will need to be informed by more comprehensive evidence. This presentation will outline the extent of malnutrition across sub-regions, the key drivers for identified trends and opportunities for further research.

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## Australia's role in regional food system transformations

**Ms Larelle McMillan<sup>1</sup>**

<sup>1</sup>*Commonwealth Scientific and Industrial Research Organisation (CSIRO), Queensland, Australia*

Australia plays an active role in the Asia and Indo-Pacific regions, as an exporter of agricultural and food products and in our science and innovation capacity and deep partnerships with our regional neighbours. COVID-19 placed significant pressure on our food systems, often amplifying existing challenges. Taking the Pacific region as an example, we know more than 80% of the Pacific depends on agriculture and fisheries for food and income. Climate variability and change, biosecurity issues, fragmented value chains and governance, variable productivity and a declining natural resource base pose significant risks to the nutritional security and economic development of the region. External drivers, such as international market dynamics, further exacerbate some of these risks due to the dependence on food imports.

Overcoming these challenges will require expanding technical capacities and access to finance, markets and technology. Limited access to datasets and foresighting tools constrains evidence-based decisions around risk, resilience, transformation, and associated investment planning.

At the UNFSS, COP26 and other international policy platforms, country and regional leaders declared their intent to strengthen resilience, nature positive production, sustainable consumption patterns and resource use, and called for innovative partnerships and investment models. Key to becoming a research ally for agencies and groups working in the Pacific is building legitimacy, trust and impact. There is a need to shift from discrete technical entry points to impact-focused, development-oriented delivery. This requires multi-sectoral partnerships and networks with an emphasis on scaling the benefits of research in response to evolving regional needs in our dynamic world.

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## Enabling food system transformations in Australia: Insights from the national UN Food System Summit Dialogue

Dr Mellissa Wood<sup>1</sup>

<sup>1</sup>Commonwealth Scientific and Industrial Research Organisation (CSIRO), Queensland, Australia

Current geopolitical crises, such as climate change, the war in Ukraine and the COVID-19 pandemic, have revealed vulnerabilities in Australian food systems and confirmed they are not adequately delivering the nation's health, socio-economic and environmental sustainability needs. As part of the United Nations Food Systems Summit to establish the future direction of food systems and accelerate collective action, CSIRO convened an official Member State dialogue to bring together diverse stakeholders for expert conversations focusing on what science, innovation and actions are needed for achieving sustainable, healthy and resilient Australian food systems by 2030. Five key action areas were identified. They include both top-down leadership and governance mechanisms as well as bottom-up, local scale action and a recognition of how food systems function within the interconnected systems of health, economy, trade and energy. Systemic change involves deep changes not only in the component parts of food systems (technologies, infrastructure and capability) but also fundamental changes to the system itself and the values, regulations, policies, markets and governance that shape it. This work highlighted that social and governance innovations are critically needed to mobilise complex food system change. The dialogues represent the beginning of a necessary national conversation to develop a shared vision for Australian food systems. Initiatives such as CSIRO/UQ's new Food System Horizons initiative can serve as a vehicle to strengthen the science policy interface needed to facilitate food systems transformation.

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## A history of phytosanitary market access research enabling export of Australian mangoes

**Mr Peter Leach**<sup>1</sup>

<sup>1</sup>*Department of Agriculture and Fisheries, Australia*

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## Ensuring product quality through export supply chains: A case study in citrus

**Dr Andrew Macnish**<sup>1</sup>

<sup>1</sup>*Department of Agriculture and Fisheries, Australia*

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## Using data to create value: Interactive market intelligence for export growth

Ms Sarah Goswami<sup>1</sup>

<sup>1</sup>*Queensland Department of Agriculture and Fisheries*

International trade and investment is critical to the Australian economy, providing jobs and economic growth. International trade provides opportunities for the agribusiness sector to expand and for businesses to produce products tailored to the tastes and preferences of global consumers, which for some commodities can result in price premiums. Detailed international merchandise trade statistics are compiled from information submitted by exporters and importers or their agents. This data provides a rich set of monthly information on exports of nearly 500 agricultural commodity groups from Australian ports using several different classification systems. The Department of Agriculture and Fisheries Queensland has automated the processing of this data and built an interactive user interface to enable users to customise trade data insights. This presentation will demonstrate the user interface and examine trade flows from produce originating in Queensland, with a focus on horticulture and opportunities in Asia.

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## International engagements to grow exports

Ms Bianca Carlsson<sup>1</sup>

<sup>1</sup>Department of Agriculture, Fisheries and Forestry

Many rural communities and industries are reliant on trade as we export 70% of all agriculture goods produced. Access to diverse and stable export markets is vital to provide economic opportunities to agricultural industries to export increased production volumes and is considered to be a key factor in achieving the government's Ag2030 goal of supporting industry to accelerate growth towards \$100 billion by 2030. The Department of Agriculture, Fisheries and Forestry (the department) works to obtain new and improved market access, as well as maintain existing access for Australian agricultural exports. The Biosecurity Plant and Sciences Services Division achieves this through market access negotiations with trading partners to facilitate greater export opportunities for Australian grain, horticulture, timber and plant material producers. The department is responsible for leading technical market access negotiations on individual plant commodities with our trading partners and these negotiations aim to reach an agreement on the measures required to reduce biosecurity risks that are posed by the trade. The industry prioritisation process helps inform the department prioritise which market access requests to pursue to ensure efforts and resources are directed towards activities most likely to advance Australia's trade objectives and maximise benefits for agricultural industries. International trade negotiations are complex and resource-intensive affairs and often take many years to complete. Despite this, the department works closely with its overseas counsellors and relies on its relationships with counterpart agencies overseas to progress positive market access outcomes for Australian agricultural industries.



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## Fruit Fly Council supporting exports

**Mr Stuart Burgess**<sup>1</sup> Dr Mila Bristow<sup>1</sup>, Mr Chris O'Connor<sup>1</sup>

<sup>1</sup>*National Fruit Fly Council*

Australia's horticulture industry is an important contributor to the national economy. Total economic value of production in 2020/21 was estimated to be more than \$15 billion, with more than \$3 billion worth of export trade and supporting an estimated 60,000 jobs.

Fruit fly is one of the biggest trade barriers for horticulture products and there are many species of fruit fly that pose a threat to Australia's horticultural industries, both endemic and exotic. The cost of fruit fly in Australia has estimated to be \$600 million due to control measures and international trade restrictions. Horticulture's contribution to Australia's Ag2030 goal of \$100 billion in production by 2030 is significant but also reliant on pest management systems that will support continued increases in productivity, market access and diversification, and maintenance of a reputation for high quality and sustainable produce.

The National Fruit Fly Council (NFFC) provides a unique and long-term solution to the strategic and national coordination of fruit fly management in Australia. The NFFC is a strategic advisory body bringing together those affected by fruit fly and relevant subject matter experts to arrive at recommendations for strengthening the national fruit fly system. The NFFC consists of federal and state governments, industry representatives, and research funders who collectively consider solutions to fruit fly challenges that will lead to a cost-effective and sustainable approach to managing fruit flies, and exotic fruit fly risks, across Australia. Through ongoing engagement with stakeholders and monitoring the progress against the National Fruit Fly Strategy, the NFFC is well positioned to regularly prioritise issues for attention.

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## Horticultural export trends

Mrs Sue Viana<sup>1</sup>, Miss Mimi Doan<sup>1</sup>

<sup>1</sup>*Hort Innovation, Australia*

The horticulture industry is Australia's third-largest agricultural sector and comprises fruits, vegetables, nuts and other products such as flowers, turf and nursery products. Australian horticulture is world-renowned for producing high-quality, safe and sustainable products, and demand for premium produce continues to grow in our key markets thanks to the growing middle-class. In the last few years, Australian horticulture exports have faced several challenges, this has softened demand in many key export markets and resulted in mixed trade performance. Despite these challenges, the industry is continuing to diversify into other export markets and recent trade agreements have presented opportunities for the industry. The Australian horticulture export value currently sits around AU\$2.4 billion, and this figure is expected to rebound as conditions improve.

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## Progress in understanding sugarcane genome architecture and origin

**Dr Angelique D'Hont**<sup>1</sup>, Dr Nathalie Piperidis<sup>2</sup>, Dr Nicolas Pompidor<sup>1</sup>

<sup>1</sup>CIRAD, UMR AGAP Institut, Montpellier, France, <sup>2</sup>SRA, Sugar Research Australia, Te Kowai, Australia

Sugarcane (*Saccharum* spp.) is probably the crop with the most complex genome. Modern sugarcane cultivars (*Saccharum* spp) are high polyploids, aneuploids ( $2n \sim 12x \sim 110-120$ ) derived from interspecific hybridizations between the domesticated sweet species *Saccharum officinarum* and the wild species *S. spontaneum*.

To improve our understanding of sugarcane genome architecture and origin, we are combining genomics and cytogenetics based on specific oligo probes.

The results confirmed a basic chromosome number of  $x=10$  for *S. officinarum*. In *S. spontaneum* rearrangements occurred from a basic chromosome of  $x=10$ , probably in the Northern part of India, in two steps leading to  $x=9$  and then  $x=8$ . Each step involved three chromosomes that were rearranged into two. Further polyploidization led to the wide geographical extension of clones with  $x=8$ . The *S. spontaneum* contribution to modern cultivars originated from cytotypes with  $x=8$  and varied in proportion between cultivars (13% to 20%). Modern cultivars have mainly 12 copies for each of the 10 basic chromosomes with variation between 10 and 13 copies. A few of these copies correspond to entire *S. spontaneum* chromosomes or interspecific recombinant chromosomes. In addition, a few inter-chromosome translocations were found. All 12 hom(oe)ologous haplotypes (BAC clones) from two distinct genomic regions of a typical modern cultivar were sequenced and analysed. Their distribution was then followed among representatives of the *Saccharum* genus. The diversity observed among haplotypes suggested the existence of at least three founding genomes (A, B, C) in modern cultivars that diverged between 0.8 and 1.3 Mya. Two genomes (A, B) were contributed by *S. officinarum* and were also found in its wild presumed ancestor *S. robustum*, and one genome (C) was contributed by *S. spontaneum*. In the regions analysed of this typical modern cultivar, the A genome contributed most haplotypes (9 or 10) while the B and C genomes contributed one or two haplotypes. None of the analysed accessions contained only the A genome or the B genome. These results suggested that *S. officinarum* derived from hybridizations between unknown ancestors that remain to be discovered.

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## Recent insights into the domestication of rice

Prof Robert Henry<sup>1</sup>

<sup>1</sup>*University of Queensland, St Lucia, Australia*

Analysis of the chloroplast and nuclear genomes of wild and domesticated rice populations has provided new insights into the progress of rice domestication. The chloroplast genomes of domesticated rice were found to include only two functionally distinct genotypes despite clear evidence for a much greater diversity of nuclear genomes. This indicates that only two maternal domestications were involved in rice domestication. Both domesticated chloroplast types were found in each of the genetically distinct types of rice, such as indica and japonica. This suggests human dispersal of the two original domesticated rice types and introgression of local wild rice types to generate the different groups of rice found in the worldwide domesticated gene pool today. Evidence for reticulate evolution in rice was found in the discordance of nuclear and chloroplast phylogenies. Further evidence has been found with the characterization of inter-specific wild rice plants in the wild in northern Australia. The generation of high-quality genome sequences for more wild rice species is expected to reveal more of the history of rice domestication. Recent studies of the genomes of wild rice populations in Asia show evidence of gene flow from the domesticated gene pool. The Australian wild rice populations that have been isolated from the domesticated populations of rice in Asia are and are an especially valuable tool for the analysis of the rice genome prior to domestication.

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## Fatal attraction: Why are so many crop plants toxic?

**Prof Ros Gleadow<sup>1</sup>**

<sup>1</sup>*Monash University, Clayton, Melbourne, Australia*

About 5% of wild plant species contain cyanogenic glucosides, bitter compounds that break down releasing cyanide when the integrity of the plant tissue is disrupted, allowing the glycoside to mix with bioactivating enzymes. The proportion of crop plants that are cyanogenic is much higher than is observed in natural communities, with possibly half of all crop species having the capacity to synthesise these compounds. Some crops, e.g., cassava, can be lethal unless processed before consumption. The question is: did humans actively select for cyanogenesis during domestication? Conventional wisdom is that humans have selected for less toxic plants. There is some evidence for glucosinolates in the Brassicas. Domesticated sorghum, on the other hand, is more toxic than its wild relatives. We propose that defence chemicals may have multiple roles in the plant and, in the case of cyanogenic glucosides, evolved for purposes such as managing stress and resources, particularly nitrogen that may give them a yield advantage during the early stages of domestication. This hypothesis is based on our physiological studies of wild and domesticated sorghum, including those native to Australia, and RNAseq analysis of sorghum growing under different environmental conditions sampled at different stages of development. This may explain why humans have a fatal attraction to growing plants that are cyanogenic.

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## Phenotyping innovations to develop climate resilient taro

**Dr Millicent Smith<sup>1,2</sup>**, Dr Bradley Campbell<sup>1</sup>, Ms Jemma Restall<sup>1</sup>, Prof Scott Chapman<sup>2</sup>, Prof Ian Godwin<sup>1</sup>

<sup>1</sup>Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, St Lucia, Australia, <sup>2</sup>School of Agriculture and Food Sciences, The University of Queensland, Gatton, Australia, <sup>3</sup>Centre for Pacific Crops and Trees (CePaCT), The Pacific Community (SPC), Suva, Fiji

Climate change is threatening crop production globally and is particularly impacting smallholder farmers in the Pacific region. Rising sea levels and increased cyclone activity are causing tidal inundations which can contaminate soil with toxic levels of salt impacting on taro (*Colocasia spp.*) cultivation. Utilising genetic diversity is critical to ensure that taro is adapted to current, and future, environments. The Pacific Community Centre for Pacific Crops and Trees (CePaCT) plays a key role in the conservation of food crops and holds the largest collection of taro diversity globally. However, a lack of capacity and tools has constrained the distribution of taro cultivars with known climate resilience. In addition, the absence of a taro breeding program globally has prevented the development of taro varieties which can withstand the multitude of threats posed by a changing climate while maintaining eating quality and yield. Traditional phenotyping approaches are a bottleneck that limit the evaluation of genetic diversity at the scale required. Taro also has unique physiological characteristics which make adapting phenotyping approaches from staple grain crops a challenge. Low-cost, high-throughput protocols have been developed and tested to screen diverse germplasm for adaptation to salinity tolerance. The approach is currently being optimised with partners in the Pacific to screen genebank accessions and at The University of Queensland to phenotype native or naturalised taro wild relatives found in saline environments of South East Queensland.

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## Domestication of macadamia

Dr Craig Hardner<sup>1</sup>, Dr Adele Wessel<sup>2</sup>, Dr Catherine Nock<sup>2</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), St Lucia, Australia,

<sup>2</sup>Southern Cross University, Lismore, Australia

Macadamia is a genus in the ancient Gondwana family Proteaceae, endemic to the sub-tropical rainforest of eastern Australia. The oil-rich kernel in two of the species is edible and highly valued. Macadamia is the only international food crop developed from the Australian flora.

Native populations are genetically and geographically structured suggesting limited dispersal. However, Australian indigenous peoples were aware of macadamia and were part of their diet prior to colonisation with genetic studies indicating limited seed dispersal by Australian aborigines was likely. Macadamia habitat was settled and cleared by Europeans in the mid-19<sup>th</sup> century, but they did readily consume macadamia. Crop development appeared catalysed by local and international botanical interest.

Macadamia was introduced into Hawai'i in the late 1800s and seedling orchards were planted from 1920. Following development of grafting, selections from these orchards were developed into cultivars. The first Australian orchard was planted in 1888 and several enthusiasts lead early development of the crop. However, commercial production of macadamia in Australia expanded from the 1970s using local and Hawai'ian cultivars. Global production expanded in the early 21<sup>st</sup> century using Hawai'ian and local cultivars.

A recent chloroplast study suggested the maternal lineage of Hawaii cultivars was near Gympie, and old trees in parks and backyards may conserve lost diversity. However, new nuclear DNA studies suggests Hawai'i cultivars are derived from seed collected from Mt Bauple. There is great opportunity for genetic improvement in this crop which has only been commercialised for 2-5 generations.

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## **CnSHELL** gene provides insights on phylogeny and origin of coconut cultivars

**Mr Charles Anthon Cadorna<sup>1</sup>**, Ms Jessica Rey<sup>1</sup>, Mr Ramon Rivera<sup>2</sup>

<sup>1</sup>Institute of Biology, College of Science, University of the Philippines, Diliman, Quezon City, Philippines, <sup>2</sup>Philippine Coconut Authority, Zamboanga Research Center, San Ramon, Zamboanga City, Zamboanga del Sur, Philippines

*Cocos nucifera* (coconut) is an economically important crop in the Philippines. Coconut is the only species in the genus *Cocos* of the family Arecaceae and is widely cultivated for its extensive use in agriculture and industry. The *SHELL* gene has already been identified in oil palm and is responsible for the different fruit forms. In higher plants, the function and expression of the *SHELL* gene is conserved. In this study, we have amplified and analyzed the putative *SHELL* gene region of coconut. The size of the PCR-amplified *SHELL* gene region is approximately 540 bp. BLASTn result of the *CnSHELL* gene sequence showed high similarity with *Elaeis guineensis* shell-specific protein 6 gene. The putative *CnSHELL* gene region was also localized on the genomic scaffolds of *Cocos nucifera* deposited in NCBI and results showed significant hits in the genomic scaffolds of Hainan Tall (HaT), Catigan Green Dwarf (CatD), and Chowgat Green Dwarf (CGD). Sequencing of the *CnSHELL* gene region revealed 5 haplotypes with haplotype diversity of 0.472 and nucleotide diversity of 0.00333. Haplotype network analysis also showed two major clusters which corresponds to the two subpopulations of coconut with independent origins. Based on the results of our study, genetic distinctness between Indo-Atlantic and Pacific lineages of coconut is evident in the sequence of *CnSHELL* which supports the result of previous study using simple sequence repeat markers.



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## Innovation systems in legumes in Africa

Dr Jean Claude Rubyogo<sup>1</sup>

<sup>1</sup>*Pan Africa Bean Research Alliance (PABRA), Nairobi, Kenya*

For two decades, the Pan-Africa Bean research alliance (<https://www.pabra-africa.org/>) has used a demand-led approach to bean variety development engaging with traders and farmers to determine variety selection criteria, advancing lines and releasing the varieties. This has matured into a 'bean corridor' approach to drive our research agenda. Bean markets are highly segmented with differentiated varieties released that respond to farmers and discerning, varied consumers. Increasingly, beans are shifting from being a mere food security crop to a valuable super food with increased investment along the value chain.

Demand-pull and market incentives mean traders look for specific varieties with consumer preferred traits e.g., palatability, short cooking time. This has incentivized farmers to invest in these new varieties and technologies that increase productivity. Variety turn-over and time between release and use has reduced from >10 years to three. The number of seed enterprises has increased from five public organizations in 2003 to 84 in 2021 supplying 19,500 tons. Between 2003-2021, 37.3 million farmers have accessed seed of improved varieties. Consumer demand varieties have created grain business opportunities for 55 large traders and thousands community-based traders. The majority of the latter are women trading 2.8 million tons of beans from about 30 million small holder farmers (62% women). In the last five years there are now > 28 bean processors with 85% managed by women. This transformation in the bean value chain is increasingly incentivizing traders to invest in breeding for specific traits, testing and promoting new varieties.

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## Syngenta – committed to advancing innovation for a more sustainable agriculture

**Mr Eric Brown<sup>1</sup>**

<sup>1</sup>*Syngenta ANZ, Macquarie Park, Australia*

Syngenta is a leading science-based agricultural technology company developing agricultural solutions including insecticides, herbicides, fungicides and seeds for Australian growers for over a hundred years. Syngenta has the most productive Research and Development pipeline in the industry with an annual global investment of over \$1.4 billion to develop new technologies, helping Australian growers overcome challenges and grow safe, nutritious and affordable food.

As an example of our commitment to innovation over the last 4 years we have launched 6 new active ingredients in Australia and our \$2bn investment in sustainable breakthroughs has already seen the launch of two sustainable technology breakthroughs globally (Elestal® (Spiropidion) and MAP BeSide™). Innovation is central to our core values.

Bringing a new crop protection technology to market takes up to 13 years as it goes through a rigorous process, making sure it's safe and sustainable. Active ingredients are not found by chance – they are precisely designed using genomics, physiology & biochemistry, and biokinetics. When we're designing molecules, we're not designing for what we need now or what farmers need today, we're thinking 10, 15, 20 years in the future. What will they want? What will you want on your table in 10-20 years? And how can we design our active ingredients to meet those expectations? That is why a key ingredient for success is understanding our customers' preferences, drivers, buying decisions and their crop value chains.

Market-lead innovation, from the grower to the lab, is what ensures Syngenta will continue to deliver the innovative plant health products we are known for, well into the future.

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## African women in agribusiness – users and creators of technologies/market-led innovations

Dr Eileen Nchanji<sup>1</sup>

<sup>1</sup>*Alliance Bioversity-CIAT, Nairobi, Kenya*

Women are at the forefront of the agri-food system transformation and innovation in Africa. With increasing climate change, demand and supply chains have become disrupted, with many clients not having access to needed resources or farm space to make an adequate income. To address these issues, a review will be presented of how we have been working with women involved in demand-led breeding and in agribusiness. It will include ideas and observations relating to responding to climate change, market demands and the opportunities contributing to a food and nutrition secure world.

Examples from case studies will be presented on how we have built the capacities of women breeders to respond to varietal and trait preferences of diverse value chain actors across multiple crops. In addition, how we have identified and supported women to grow their agribusinesses through value addition with support from public and private sector partners, best practices, and options to scale. Most importantly, women are not only users of agricultural and socio-technical technologies but also are drivers of the adoption of these technologies at scale. This supports and reinforces the need for more gender intentional development projects, where varieties and technologies developed to serve specific gender needs (especially those of women often forgotten) to ensure scaling and high adoption.

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## Market-Led approaches to cocoa, palm oil and cassava variety breeding at the National Research Centre in Côte d'Ivoire

Prof Abdourahamane Sangare<sup>1</sup>

<sup>1</sup>*Centre National de Recherche Agronomique (CNRA)*

The National Center for Agricultural Research in Côte d'Ivoire is responsible for implementing the agricultural research policy. Its mission is to contribute to a competitive agriculture, respectful of the environment and attractive to market. To facilitate technology transfer, CNRA built collaboration mechanisms with agriculture and agro-industry sectors. A successful collaboration mechanism is an active involvement of research and research-development structures with extension institutions and partners in agro-industries for the definition and execution of agriculture priorities. Three examples of such collaboration are presented.

CNRA promotes cocoa production technologies and cocoa varieties with high yielding, early maturing, tolerant to swollen shoot and with beans rich in cocoa butter. The center exclusively produces seeds (coated beans) at the request of the cocoa board every year.

CNRA distributes to farmers and agro-industries seeds in the form of germinated and young seedlings. These varieties are tolerant to Fusarium wilt, with high oil extraction rate is 23% and iodine value of 50 to 55 and a potential yield is 30 to 35 tons of bunches per hectare. Seed production quality is certified ISO 9001:2008.

Cassava is an important staple food in Côte d'Ivoire consumed in various forms by millions of people every day. Cassava roots can be transformed into more than 20 food products. Attiéké is the most widely consumed.

CNRA developed and promotes three high-yielding varieties of cassava, resistant to disease and pests and with nutritional qualities (high and stable dry matter content 38% and Starch content 18%) adapted to local food transformation.

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## ACIAR's approach to supporting agricultural innovation in emerging economies

Dr Eric Huttner<sup>1</sup>

<sup>1</sup>*Australian Centre for International Agricultural Research, Canberra, Australia*

In a global context of increased demand for food, changing diets, and evolving biophysical constraints for food production caused by climate change, ACIAR is aiming to support smallholder farmers move from subsistence to income generation, through the co-development of innovations allowing them to adapt (in the short term) or transform (in the longer term) their farming systems and livelihood.

Recent decades of economic growth in many developing countries provide new opportunities for farming families: more diversified livelihood including off-farm income, improved transport and communication infrastructure facilitating market linkages, expanding literacy and numeracy, slower population growth. At the same time, demands and priorities from communities, based on deep cultural traditions and values, vary widely from place to place. This is the context in which future innovation – connected to markets - has to be conceived, designed, tested, disseminated and adopted and adapted by farmers.

The talk will present several examples of innovations in growing pulses crops from Timor Leste and Bangladesh. We will present market and socio-cultural drivers of interest and adoption of innovation by women and men farmers. The challenges for farmers of effectively capturing, in a practical timeframe, the risk reduction and the environmental benefits of some innovations will be discussed.

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## Advances in demand-led Breeding of dry grain and vegetable runner beans

**Prof Paul Kimani**<sup>1</sup>, Ms Serah Njau<sup>1</sup>, Ms Mable Mulanya<sup>1</sup>, Professor Rama Narla<sup>1</sup>

<sup>1</sup>University Of Nairobi, Nairobi, Kenya

Runner bean (*Phaseolus coccineus* L.), traditionally grown in highlands (>1800masl) of eastern Africa, has not received attention of breeders. Farmers rely on low yielding landraces susceptible to diseases. Fresh produce companies demanded short-day vegetable varieties to reduce costs of artificial lighting required for long-day types. Processors demanded new high yielding vegetable and dry grain varieties with acceptable canning quality. A regional program based at the University of Nairobi was started in 2005 to: i) determine the inheritance of photoperiod sensitivity; ii) develop breeding populations and select for short-day adaptation, grain yield and disease resistance; iii) select short-day vegetable types suitable for fresh market and processing; iv) develop a protocol to evaluate breeding lines for canning quality. Twelve populations were developed from crosses between long-day and short-day genotypes and advanced by single pod descent. Results showed that photoperiod sensitivity is quantitatively inherited with additive gene effects accounting for about 90% of the genetic action. Elite grain-type lines had a yield advantage of up to 67% compared with local landraces. New vegetable lines had a mean pod yield of 16,000 kg ha<sup>-1</sup> without extended light compared to 896kg for the commercial long-day variety. Thirty new lines met market pod quality requirements and were resistant to major diseases. A new protocol for evaluating canning quality in breeding lines was developed. Thirty-five lines exceeded the industrial canning standards. Utilisation of these lines can contribute to increased productivity, reduce production costs, facilitate local seed production and enhance food security and agribusiness.

Key words: photoperiod, vegetable runner bean, inheritance, canning, breeding

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## Extending the breeder's equation to explore prediction opportunities

Prof Mark Cooper<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), St Lucia, Australia,

<sup>2</sup>ARC Centre of Excellence for Plant Success in Nature and Agriculture, The University of Queensland, St Lucia, Australia

The Breeder's Equation provides a framework to help optimise the design of a breeding program. This was relatively straightforward when selection was based on trait phenotypes. Today, breeders either use, or aspire to use, genomic information to improve the effectiveness of their breeding programs. I will share my experiences in how this transition to use of genomic information has required me to think differently about the Breeder's Equation. The prediction-based approaches to be discussed are grounded in an iterative empirical-modelling cycle that operates across two complementary domains: empirical-experimental and mathematical-modelling. The research themes are underpinned by: (1) Two decades of experience breeding maize hybrids for yield and yield stability in the US corn-belt and research partnerships with many colleagues, (2) Advances in crop models that can enhance our ability to test "multiple workable solutions" to improve crop yield and yield stability through breeding and improved agronomy, and (3) Advances in hierarchical Bayesian modelling methods that leverage prior genetic and physiological knowledge for genomic prediction. Further, two strong motivations for investigating such prediction-based approaches are: (1) the need to increase the scale of breeding programs beyond what we can currently achieve by empirical approaches alone, and (2) using the environments we can sample today it is difficult to empirically test, at the required scale, for many dimensions of the projected future Target Population of Environments, given projected climate change scenarios for the rest of this Century.

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## From model organisms to crops: Transferring prediction models

**Dr Owen Powell**<sup>1,2</sup>, Dr Sivakumar Sukumaran<sup>2,3</sup>, Dr Francois Barbier<sup>2,4</sup>, Ms Astrid Welvaert<sup>2</sup>, Dr Pushpavalli Raju<sup>2</sup>, Mr Greg McLean<sup>1,2</sup>, Mr Jason Brider<sup>1,2</sup>, Prof Graeme Hammer<sup>1,2</sup>, Prof Christine Beveridge<sup>2,4</sup>, Prof David Jordan<sup>2,3</sup>, Prof Mark Cooper<sup>1,2</sup>

<sup>1</sup>Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Brisbane, Australia,

<sup>2</sup>ARC Centre of Excellence for Plant Success in Nature & Agriculture, The University of Queensland, Brisbane, Australia,

<sup>3</sup>Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Hermitage Research Station, Warwick, Australia, <sup>4</sup>School of Biological Sciences, The University of Queensland, Brisbane, Australia

A successful strategy for the prediction of complex traits that accounts for the effects of genes, environments, and their interactions will create many opportunities for enhancing the productivity and sustainability of agricultural systems. However, it is still unclear how to best exploit prior information of interactions to improve predictive ability for crop breeding applications. As part of the ARC Centre of Excellence for Plant Success in Nature & Agriculture, we are embarking on multiple interrelated projects exploring mechanistic networks as a common framework to improve the prediction of complex traits in the face of increasingly harsh and variable production environments. Our work encapsulates the development of selection experiments in arabidopsis and sorghum as a resource for; 1. Iterative improvements in our understanding of the networks underpinning tillering, a key regulator of water use in crops, and 2. Algorithmic development of prediction models combining ecophysiological networks with genomic information. We discuss our learnings so far from taking a network view of complex traits and their implications for predictive breeding.



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## Evolutionary systems genetics of plant success

Dr Daniel Ortiz-Barrientos<sup>1</sup>

<sup>1</sup>*The University of Queensland, School of Biological Sciences, and ARC Centre of Excellence for Plant Success in Nature and Agriculture, Australia*

The origin and maintenance of continuous trait variation remain profound problems in ecology and evolution, with significant implications for agriculture, medicine, and conservation. In this talk, I will describe how theories of adaptation have been deployed to study short- and long-term trait evolution. I will focus on explaining how the infinitesimal model of trait evolution breaks down over time as new mutations arise and their frequency change. Modifications of the infinitesimal model are essential for understanding trait evolution in natural populations and increasing predictive ability in agriculture and medicine. However, there is limited progress in formulating a cohesive framework of trait evolution across multiple biological organisation levels and developmental evolutionary time scales. I will show work from my laboratory that introduces system genetics approaches to studying complex developmental and physiological dynamics during adaptation to novel environments. This work has the potential to alter our views on trait evolution with repercussions for the design of molecular and breeding experiments, as well as provide a formal framework for studying the evolution of complex genetic systems.

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## Accelerating plant success: From phylogenomics to agriculture

Prof Barbara Holland<sup>1</sup>

<sup>1</sup>*University of Tasmania, Hobart, Australia*

Twenty years on from the first genome projects, the problem of mapping from genotype to phenotype (G2P) is still one of the 21st century's grand scientific challenges. Better solutions to this fundamental problem would enable improvements across agriculture, medicine, biotechnology and conservation. While techniques such as genome-wide association studies (GWAS) have found many genes associated with traits of interest, for many traits these studies have not revealed as much as was initially hoped. This prompted several recent review papers to call for new mathematical and statistical techniques for associating genotype and phenotype. They argue that novel methods based on evolutionary trees (phylogenies) are needed to understand gene-trait association if we are to ever understand the ~40% of genes that are currently still of unknown function. The key strength of a phylogenetic approach is that, for a trait which has evolved independently multiple times in evolutionary history, we can look for sequence changes that have evolved repeatedly in association with this trait. This idea has been called PhyloG2P, forward genomics or PhyloGWAS. Initial papers show that the idea has great promise, but it is currently underexplored and new mathematical and computational techniques are required to make progress.

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## Crop improvement for climate change

**Prof Charlie Messina<sup>1</sup>**, Dr Tom Tang<sup>2</sup>, Dr Lucas Borrás<sup>2</sup>, Prof Mark Cooper<sup>3</sup>

<sup>1</sup>The University of Florida, Gainesville, USA, <sup>2</sup>Corteva Agriscience, Johnston, USA, <sup>3</sup>The University of Queensland, Brisbane, Australia

A key question today is how to harmonize future crop improvement efforts for regenerative cropping systems that can mitigate further environmental degeneration and improve societal adaptation to climate change. Using a 30 year-long maize experiment in the Central US corn-belt we assessed the capacity of a commercial maize breeding system to produce hybrids adapted to a changing climate. The data include a set of 50 hybrids commercialized between 1930 and 1990, all grown in each of the 30 years of experimentation, tested at three plant populations in various commercial fields per year. These data enabled us to estimate rates of genetic gain by year, and the effects of environment and management on these. Rates of genetic gain were always positive and increased with increasing plant density and rainfall and decreasing amplitude temperature. If breeding objectives and the rate of climate change remain the same this commercial breeding system is producing hybrids and associated crop management practices adapted to climate changes. We argue, however, that it is imperative to change the breeding objectives to create hybrids that can contribute to the regeneration of resources such as water, the circularization of nutrients, and reduction of greenhouse gases emissions. A crop improvement framework for climate change that harness genotype x management levers is needed to harmonize future breeding efforts, and to assess the capacity of other breeding systems (crops and geographies) to adapt.

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## CropGen: A novel tool for optimising sorghum crop design

**Miss Genevieve Durrington<sup>1,2</sup>**, Mr Jason Brider<sup>1,2,3</sup>, Mr Drew Holzworth<sup>1,3</sup>, Professor Graeme Hammer<sup>1,2</sup>, Dr Alex Wu<sup>1,2</sup>

<sup>1</sup>University Of Queensland, Queensland Alliance for Agriculture and Food Innovation, St Lucia, Australia,

<sup>2</sup>Australian Research Council Centre of Excellence for Plant Success in Nature and Agriculture, St Lucia,

Australia, <sup>3</sup>Queensland Department of Agriculture and Fisheries, Toowoomba, Australia

Sorghum is an important food and feed crop globally. Strategies to optimise its yield performance are needed to help meet rising demands in changing future environments. Typically, sorghum is grown as a dryland crop, with water availability being a major limitation for yield. Here we present a new tool, CropGen, for optimising sorghum design and yield performance. CropGen connects the APSIM sorghum model with an evolutionary optimisation algorithm to enable iterative exploration of genotype × agronomy combinations to identify optimal strategies based on a number of objectives, including grain yield, water use, and crop failure risk over diverse production environments. Initial model testing was undertaken using single year simulations both with and without irrigation to explore tillering × maturity combinations and quantify their yield and water use. In the irrigated scenario, optimal yields were achieved with high tillering and long maturity sorghum designs, whereas lower tillering and shorter maturity designs were identified for the non-irrigated scenario. These findings are consistent with known effects of water availability, crop growth, and yield interactions. CropGen was then applied to optimise tillering × maturity designs for Dalby, a key sorghum production region in Australia, by quantifying the yield, water use, and crop failure risks. The nuanced understanding of crop performance over diverse environments generated by CropGen is key in identifying optimal strategies for guiding research and plant breeding efforts to maximise crop improvement.

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## Managing plant biosecurity in the Pacific region

**Dr Andrew Geering**<sup>1</sup>, Dr Richard Davis<sup>2</sup>, Dr Lynne Jones<sup>2</sup>, Dr Kathy Crew<sup>3</sup>, Dr Grahame Jackson<sup>4</sup>, Dr Amit Sukal<sup>5</sup>, Dr John Thomas<sup>1</sup>

<sup>1</sup>The University of Queensland, St Lucia, Australia, <sup>2</sup>Australian Department of Agriculture, Fisheries and Forestry, Cairns, Australia, <sup>3</sup>Queensland Department of Agriculture and Fisheries, Dutton Park, Australia, <sup>4</sup>TerraCircle, Queens Park, Australia, <sup>5</sup>Pacific Community's Centre for Pacific Crops and Trees, Suva, Fiji

The island nations of the Pacific are scattered across a vast expanse of ocean and face many unique plant biosecurity challenges. This talk will focus on biosecurity as it relates to traditional crops such as banana, coconut, sweet potato and taro, and highlight specific case studies to demonstrate difficulties with containing and controlling pests and pathogens in this region. Some of the most serious pests and pathogens such as the coconut rhinoceros beetle and banana bunchy top virus date back 100 years to the period of European colonization but are still proving difficult to control, with new spread pathways still being uncovered. There are other emerging pests and pathogens such as the coconut and banana wilt-associated phytoplasmas, which are likely indigenous to the region but for reasons that are unclear, are increasing in importance. Lessons that have been learnt from these case studies will be discussed and recommendations for the future put forward. Australia has a vested interest in ensuring a strong biosecurity system in this region as it represents a major entry point for pests and pathogens that could affect our northern Australian agricultural industries.

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## What honey bees can teach us about working as a team towards effective honey bee biosecurity in the Indo-Pacific region

Dr Cooper Schouten<sup>1</sup>

<sup>1</sup>*Southern Cross University, Lismore, Australia*

Honey bees are important honey producing pollinators and they personify equality in effective decision making. Faced with the annual life-or-death problems of choosing and traveling to a new home, honey bees stake everything on a process that includes collective fact-finding, enthusiastic debate, and consensus building. By cooperating, the group's collective power is optimised to uncover a diverse set of possible solutions to a problem, to critically appraise these possibilities, and to winnow out all but the best one. This presentation discusses concepts borrowed from the democracy of the hive and draws on honey bee biosecurity research and experiences seeking to improve the effectiveness of beekeeping programs in the Indo-Pacific region.

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## Forest biosecurity: how can we mitigate risk?

[Dr Madaline Healey](#)<sup>1</sup>, Assoc. Prof. Simon Lawson<sup>1</sup>

<sup>1</sup>University of the Sunshine Coast, Sippy Downs, Australia

Forests provide more than 86 million jobs (industry, preservation, or restoration of the environment), supporting the livelihoods of many people worldwide. Aside from the vital ecosystem services provided, forests reduce environmental vulnerability and increase the resilience of ecosystems, landscapes, and the households of the 1.6 billion forest-dependent people. However, invasive pests such as insects, weeds, and diseases threaten forest health and productivity, many of which overlap with agricultural crops. Increased trade, global movement, and a changing climate increase the risk of these invasive threats. To ensure the protection of forests it is vital that the risks posed by invasive pests are minimised and that effective mitigation and response plans are in place should incursions occur. One approach to assist this is the development of coordinated forest biosecurity strategies implemented at national and regional levels. Using examples of invasive Australian pests of *Eucalyptus* and *Acacia* and endemic threats that have become pests of planted and natural forests, we discuss a people-centred approach to forest biosecurity from the farm gate to the international setting. Focussing on Australian Centre for International Agricultural Research (ACIAR) funded projects in Southeast Asia (SE Asia) and Africa, we demonstrate the value of national and regional approaches to forest biosecurity development to mitigate risk and increase preparedness in Australian and global forest settings.

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## Understanding the burden of animal disease in Indonesia

**Dr Dianne Mayberry<sup>1</sup>**, Dr Harimurti Nuradji<sup>2</sup>, Dr Susan M Noor<sup>2</sup>, Dr Yin Li<sup>1</sup>, Dr RA Yeni<sup>2</sup>, Dr Nyak Ilham<sup>2</sup>, Dr Peggy Schrobback<sup>1</sup>, Dr Bambang Ngaji Utomo<sup>2</sup>, Dr Dominic Smith<sup>3</sup>, Professor Indi Dharmayanti<sup>2</sup>  
<sup>1</sup>CSIRO, St Lucia, Australia, <sup>2</sup>BRIN, Bogor, Indonesia, <sup>3</sup>Griffith University, South Bank, Australia

Livestock are critical to human nutrition and livelihoods, and animal health and productivity are under constant pressure from communicable and non-communicable diseases, inadequate access to feed and clean water, injuries, and predation. Investments to mitigate animal diseases and health problems are increasing. Yet where this money is being spent, to address which problems, and what effect it is producing, is poorly documented and badly understood across the global livestock sector, especially in smallholder contexts. The [Global Burden of Animal Diseases](#) (GBADs) programme is a worldwide initiative aimed at building a standardized data sharing platform to systematically collect epidemiological and economic data to assess the overall societal cost of livestock diseases in different production systems around the world. In a case study funded by the Australian Centre for International Agriculture, we are piloting the GBADs framework across poultry, beef, and pig production systems in Indonesia. The aim is to develop and evaluate methods to quantify economic, social, and environmental impacts of disease resulting in information to assist improved prioritisation of resource allocation for animal health, centred on the needs of small holder farmers.



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## Understanding the value of regional biosecurity

Prof Tom Kompas<sup>1</sup>

<sup>1</sup>*The University of Melbourne, CEBRA, Melbourne, Australia*

The average return on investment from biosecurity measures at the Australian border has been estimated by the Centre of Excellence for Biosecurity Risk Analysis at the University of Melbourne to be 30 to 1. Every dollar spent on biosecurity measures at the border thus returns, on average, roughly 30 dollars. These returns can be enhanced by continued engagement with the region on its biosecurity measures and concerns. Although a focus on threats for human health concerns (such as multi-drug resistant tuberculosis and zoonotic diseases) to lumpy skin disease for animal health and pests that may impact the environment is important, this presentation investigates the potential value of regional biosecurity and argues that there is a need for a more comprehensive and system-wide approach to biosecurity in the region, extending the concept of 'shared responsibility' and exploring additional ways in which Australia can help the region both address its biosecurity concerns and implement better biosecurity measures.

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## Understanding roles and experiences of women managing FAW in maize in SEA

Miss Leandra Fernandes<sup>1</sup>, Dr Alison Watson<sup>1</sup>

<sup>1</sup>ASEAN FAW Action Plan, 1 begonia terrace, Singapore

Systems thinking and culture change in agriculture requires a robust understanding of gender roles. Tasks performed by men and women often differ, as well as their knowledge and attitudes. Recognising the different roles that women play in decision-making is, therefore, critical, when designing sustainable plant pest management strategies in food systems. Fall armyworm is an invasive pest that is causing significant damage in Southeast Asian maize crops. Yet, while both men and women are often involved in the production of maize in Southeast Asia, little is known about the gender differences in identifying, monitoring and managing lepidopteran pests, particularly the fall armyworm (FAW).

The aim of this project is to understand the role of women in managing FAW in maize plantations across a range of locations in Southeast Asia to understand opportunities for women's empowerment and improved control of FAW through the adoption of integrated pest management.

Project objectives will be achieved by engaging men and women in interviews as well as Focus Group Discussions (FGDs) to identify gender differences in monitoring and managing maize pests, particularly FAW, including understanding the control strategies used, and time allocated on household and farm activities. The role and knowledge of women in pesticide use and decision making will also be evaluated. The target Southeast Asian countries include Cambodia, Indonesia, Lao PDR, Thailand, Vietnam, the Philippines. This project is a part of the Women as IPM Leaders programme, a key cross-cutting component of the ASEAN Action Plan on Fall Armyworm.

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## Food markets in Solomon Islands –availability, price, and opportunities for improving nutrition

Dr Jillian Tutuo<sup>1</sup>, Dr Penny Farrell<sup>2</sup>, Dr Jessica Bogard<sup>3</sup>, Professor Neil Andrew<sup>4</sup>

<sup>1</sup>World Fish, Honiara, Solomon Islands, <sup>2</sup>University of Sydney, Sydney, Australia, <sup>3</sup>Commonwealth Scientific and Industrial Research (CSIRO), Canberra, Australia, <sup>4</sup>ANCORS, University of Wollongong, Wollongong, Australia

**Background:** In Solomon Islands food and nutrition insecurity rates are high: dietary patterns have significantly changed over recent decades resulting in poor quality diets. Such diets are associated with increasing prevalence of non-communicable diseases and micronutrient deficiencies. The food environment (FE) determines what food people acquire to consume, and it has implications for food and nutrition security. The aim of this study was to provide information to policy makers on the availability and pricing of local and imported foods in the external food environment in Solomon Islands. **Method:** A vendor survey was conducted with food vendors within the market areas and surrounding streets in Auki, Gizo, and Honiara at two time points. A total of 653 and 556 vendors were surveyed in 2021 and 2020 respectively. **Results:** Our findings showed that the availability of food vary across the provinces. Food price also vary and heavily affected by distance to the markets. Disruptions to the food supply chain included the COVID-19 pandemic, climate events, and transport costs – and these impacted food availability and price. Vendors responded to the COVID-19 related economic disruption by decreasing food quantity sold and, in some instances, decreasing price. Vendors emphasised challenges across the food supply chain and other external constraints. **Conclusion:** Food markets are important sources of food to households in Solomon Islands in particular urban areas and contribute to nutrition. A food system approach, focusing on nutrition- sensitive agriculture and fisheries is a way forward in improving food environments and nutrition in Solomon Islands.

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## Strengthening collaboration between the health and agriculture sectors in Fiji

Dr Cathy O'Mullan<sup>1</sup>, Ms Aloesi Dakuidreketi, Ms Rebecca Robinson, Mr David Hickey

<sup>1</sup>*CQ University, Bundaberg, Australia*

Many agricultural 'research for development' interventions are underway in Fiji; however, programs do not always consider nutritional outcomes. Nutrition-sensitive agriculture (NSA) puts a specific nutrition lens on agriculture with the aim of sensitising the agricultural sector to the importance of addressing the nutrition and health aspects of food security. Connecting the dots between agriculture and nutrition is complex and requires multi-sectoral collaboration so that projects can benefit from the expertise of each field. Agriculture, nutrition, and health experts have different vocabularies, approaches and philosophies; not surprisingly, collaboration between such groups can be challenging. As part of a larger agricultural research project funded by the Australian Centre for International Agriculture Research (ACIAR), we conducted a two-phase research project aimed at strengthening relationships between the agriculture and health sectors in the Sigatoka Valley, Fiji to improve nutritional outcomes. By partnering with local agriculture, health and nutrition workers in phase one, the research team developed an approach aimed at bringing the sectors together to deliver nutrition-sensitive interventions at a village level. Phase two involved piloting the innovative approach in a local community.

In answering the research question "How can we strengthen multi-sector collaboration and build research capacity to improve nutritional outcomes in Fiji?" this paper provides insight into an approach that has potential to break down sector-siloes, create a shared understanding and approach to nutrition-sensitive agriculture and enhance intersectoral collaboration in Fiji.

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## PNG school gardens potential for food provision model and agri-nutrition practical learning

Ms Helmtrude Sikas-Iha<sup>1</sup>, Ms Jessica Evelyn Raneri

<sup>1</sup>Adam Smith International, Port Moresby, Papua New Guinea

Papua New Guinea (PNG) has some of the highest global rates of chronic child malnutrition and at the same time, the majority of PNG youth are not attending school. The combination of malnutrition and poor formal education results in significant economic impacts, including loss of productivity and intergenerational poverty. Literature suggests that the longer-term issue for the agriculture sector in PNG is how best to encourage young people to take agriculture as a desirable option, whilst there is little evidence on PNG school food environments and the potential link to child nutrition.

The School Gardens Project (SGP) aimed to improve school food environments and youth agriculture capacity. It established 16 gardens and 5 chicken sheds in 10 primary and 6 secondary schools over a period of 18 months. A cost benefit analysis assessed financial sustainability of the model. A survey was administered to 488 students and 5 teachers from 3 schools to provide data on understanding the school food environments, knowledge and attitudes regarding nutrition and agriculture livelihoods, and student diet quality through a qualitative 24hour diet recall.

Both boarding and day students faced restrictive school food environments, and were found to be consuming diets with little diversity and high prevalence of unhealthy processed food. Students reported facing barriers to healthy eating both at school and home, compounded by limited knowledge on the functional benefits of food groups. The combined garden-poultry farming system was found to be financially sustainable and to have multiple benefits to schools including providing nutritious foods to student meals and a practical agriculture learning environment.

The SGP in PNG demonstrated a financially sustainable model that provided opportunities to improve school food environments and engagement of youth in agriculture.

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## Climate smart and nutrition sensitive agriculture in Tuvalu

### **Mr Alex McClean<sup>1</sup>**

*<sup>1</sup>Live & Learn Pacific Network, Tuvalu*

Pacific atoll island nations such as Tuvalu and Kiribati face numerous challenges in local food production, including rising sea levels, poor soil quality, salinity and lack of land. Furthermore, the effects of the post-colonial disruption to traditional food culture and gardening systems compound the impacts on food and nutrition security, leading to a range of diet related NCD's.

Live & Learn Environmental Education (LLEE), Atoll Food Futures Program (AFF) in Tuvalu and Kiribati sought to address these issues 2019 to 2022 through "Increased community resilience and food and nutrition security through increased production and consumption of locally grown nutritious foods".

Distinctive elements of the program include the deployment of a modular, transportable, sealed wicking bed technology (called "Food Cubes") in combination with an approach of strengthening traditional food and gardening culture as a means of improving food and nutrition security.

Early results are positive and support the use of a multi-faceted approach (including household-level support, engagement with traditional food culture and gardening and development of government support systems for compost production) to deal with systemic food and nutrition security issues.

Lessons learned were not always those expected. At the household level, increased diversity of vegetable crop types rather than specialisation seems to correlate with increased production volumes, while participants often hold an opposing theory of change to the program itself - traditional food culture is seen as an end in itself, not a means to achieving food and nutrition security outcomes.

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## Pacific Island Food Revolution: Innovating Local Solution to combat a health epidemic

Mrs Votausi Mackenzie-Reur<sup>1</sup>

<sup>1</sup>Lapita Cafe Ltd, Port Vila, Vanuatu

The Pacific Island Food Revolution has been leading the way in reshaping healthy eating through local produce that celebrates traditional flavors in the Pacific. It uses an innovative development model - creating media products from Pacific stories and voices and engaging strategic partners to promote and restore Pacific cuisine to its rightful place. We're drawing on traditional Pacific knowledge and food systems which are sustainable and equitable. Pacific food systems preserve rich biodiversity, provide nutritious food, and are climate resilient and low carbon. Through media and partnerships, we're reviving Pacific food systems and culture.

A spin off from Pacific Island Food Revolutions was when the presenter was appointed by the Vanuatu Government as an Agritourism Diversification Program (Prodatif Turism Blong Yumi) Co-ordinator in 2021. Agritourism is a multi-sectoral entity. It needs collaboration from every Government department, NGOs and private sectors.

Agritourism is not about just getting Vanuatu local products to hotels and resorts. It's aim is for visitors to experience and learn about the local unique lifestyles and cuisine. However, Vanuatu cannot expect her visitors to appreciate their local foods and local cuisine if they themselves, the Vanuatu people do not have pride in their own local cuisine.

The NCD crisis in Vanuatu is real and in order to tackle it head on, reduction in the consumption of cheap imported refined foods is essential and the country needs to take a holistic approach to embrace Vanuatu lifestyles through : Pacific Island Food Revolution and Prodatif Turism Blong Yumi.

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## Participatory approaches to improve food environments and fish consumption in Timor Leste

Ms Agustinha Duarte<sup>1</sup>

<sup>1</sup>*WorldFish, Dili, Timor-leste*

As a young developing country, Timor-Leste still has a high rate of malnutrition. One way to overcome this is through increasing the consumption of fish and other aquatic food. These foods are considered to be highly nutritious in micronutrient and protein in which are essential for children's growth, brain development and general health. However, they are often not included in the national level for policy and practices' discussion forum. As a pathway to promote the inclusion of seafood into the discussion, a series of indigenous knowledge, cultural and traditional practices have been documented via recording the recipes that are shared by women and men in five municipalities across the country. These recipes are aimed to guide and inspire every household, families, and restaurants in Timor-Leste to prepare and cook nutritional seafood meal for their daily feeding consumption. Through this aim, we are hoping that Timor-Leste can achieve its national fisheries strategy objectives to consume fish around 10 kg/year.

The project has also been working with a woman group in Beacou, Bobonaro Municipality as a part of innovating fish and aquatic food, such as turning fish into fish powder in order to prolong the usage of fish for a long period when the fish catch production is low. This innovation is aiming to make fish product available throughout the year. The demand for this product is blooming. Now Care International are planning to include the powder into the school feeding program for elementary school in order to diversify dietary.



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## Moving beyond farm best practice for water quality

Mr Ian Layden<sup>1</sup>

<sup>1</sup>*Department of Agriculture and Fisheries, Nambour, Australia*

Nitrogen use efficiency (NUE) and reducing offsite losses in coastal intensive farming systems presents major challenges for both producers and policy makers. Despite substantial investment over the last two decades into increasing the adoption of best management practices (BMPs), suggests that adoption of BMPs alone will not be adequate to address water quality decline in the Great Barrier Reef (GBR) lagoon. However, in many cases producers and their advisors are being asked to undertake complex nutrient management often without any empirical evidence. This presentation highlights that a mix of approaches will be needed to address this wicked problem. It will highlight how even under conservative nitrogen regimes, losses of nitrogen can be substantial and that a more nuanced understanding the agricultural system can provide opportunity for water quality improvement.

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## Stomping out sediment

Mr Paul Jones<sup>1</sup>

<sup>1</sup>*Department of Agriculture and Fisheries, Emerald, Australia*

The Stomping out Sediment project (SOS) was Reef Trust Phase 4 (RTPIV) funded and managed by North Queensland Dry Tropics (NQDTr) NRM group. It aims to work with grazing properties in the Bowen, Bogie, Don and East Burdekin catchments to provide innovative, practical and cost-effective options for graziers to remediate gully systems. Some properties have photographic sites showing a positive pasture response from implementing high density grazing (UHD) techniques.

DAF has been contracted by NQ Dry Tropics to monitor the land condition response to UHD on two major soil types and contribute to training and extension events. The landholders, NQ Dry Tropics, DAF and consultants have selected the demonstration and study areas on three properties implementing UHD. Pasture yield, composition and land condition are monitored on UHD, ungrazed and commercially managed plots.

It can be inferred that to date the UHD implemented has not contributed to improved land condition. The data suggests a lack of difference in the pasture parameters under UHD compared to untreated areas. However, there has been an overriding influence of the good seasonal conditions.

Intensive management may be required, together with wet season spelling over several years, to achieve improved soil surface and organic matter incorporation and an improvement in land condition. A better result is expected on the more fertile and resilient soil types. Prevention of gullies should be a priority and all options for control of existing gullies should be evaluated. Managing contributing sub-catchments for good land condition is a good strategy.

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## Spatial and temporal monitoring of farm practices in Great Barrier Reef catchments

**Mr Kevin McCosker<sup>1</sup>**, Mr Adam Northey, Ms Emily Brooks, Mr Paul Humphreys, Mr Rob Hassett

<sup>1</sup>*Department of Agriculture and Fisheries, Parkhurst, Australia*

The Great Barrier Reef (GBR) is under increasing threat from climate change, extreme weather events, and land-based runoff (sediments, nutrients, and pesticides). The major contributor of loads of these pollutants are the agricultural production systems in river catchments adjacent to the GBR. These agricultural land uses comprise approximately 14,000 farms which manage ~370,000 km<sup>2</sup> or 80% of the total land area. The governments of Australia and Queensland have invested significant public funds in improving how farms are managed with the aim of decreasing pollutant loads and improving water quality in the GBR lagoon.

The Paddock to Reef program monitors the adoption of farm management practices within these catchments, for the five main agricultural land uses (beef cattle grazing, and cropping of grains, sugarcane, bananas, and other horticultural crops). Paddock to Reef manages a geographic information system (GIS) based system to track farm management changes spatially, and over time. Between 2014 and 2021, Paddock to Reef has recorded management attributes on more than 50,000 km<sup>2</sup> of farmland in the highest priority areas of the GBR catchments. The purpose of these data is to enable independent, science-based assessment of the potential water quality impacts of the many programs and projects aiming to improve farm management.

This paper summarises unique features of Paddock to Reef's monitoring and evaluation effort, the main limitations, and possible future enhancements.

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## Using wetland processes to enhance nitrogen removal in farming landscapes

**Ms Carla Wegscheid<sup>1</sup>**

<sup>1</sup>*Department of Agriculture and Fisheries, Townsville, Australia*

Losses of nitrogen from intensive agricultural production areas can lead to elevated nitrogen in downstream aquatic ecosystems, with associated impacts on their health and function. Nitrogen has been identified as a threat to the health and resilience of the Great Barrier Reef, with a target of 70% reduction in end-of-catchment anthropogenic dissolved inorganic nitrogen loads in some catchments flowing to the Great Barrier Reef. This presentation will reveal how wetlands and wetland processes can be used, as part of a whole-of-system approach, to tackle the challenge of reducing nitrogen entering the Great Barrier Reef.

Recent Queensland studies identified denitrification as the key nitrogen removal processes in wetlands. The amount of nitrogen removed through denitrification, and the features required to maximise denitrification, will be explained. Treatment wetlands and denitrifying bioreactors have been trialled in Queensland to reduce nitrogen in run-off and shallow groundwater. The nitrogen removal performance and cost-effectiveness of these systems will be discussed.

The presentation will explain the conditions required for cost-effective nitrogen removal and show how site selection, design and management is critical. It proposes a whole-of-system, 'treatment train' approach to reduce nitrogen loads in agricultural catchments, building upon and complementing best practice agronomic management using treatment systems and wetlands at different scales in the landscape. Replicating and returning natural wetland processes to catchments can sustain agricultural production, improve water quality and the health of aquatic ecosystems, providing multiple benefits.

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## Applying social science insights to enhance outcomes for landholders and the Reef

**Ms Meg Bickle<sup>1</sup>**

<sup>1</sup>*Department of Environment & Science (Office of the Great Barrier Reef), Australia*

Increasingly, practitioners in the agricultural practice change space are utilising behavioural insights to help with understanding landholder perspectives and to inform design and delivery of more effective programs in Great Barrier Reef catchments.

It is now broadly acknowledged that science and facts alone are not sufficient to motivate people to change their behaviour. Years of research have provided a level of certainty about the benefits of adopting many 'best practice' farming practices for both the farm business and water quality outcomes, but the process of changing a behaviour relies on a range of factors. Being able to identify the factors that are relevant to an individual, or group of landholders, makes it possible to address, for example, barriers that may exist at a project or policy level.

The Office of the Great Barrier Reef has been applying many of the principles of behavioural science in project design for a number of years. This presentation will reflect on several successful projects delivered under the Queensland Reef Water Quality Program that have applied behavioural science principles. It will also highlight ongoing efforts to embed social monitoring in all Reef practice change projects through a voluntary survey as part of a formalised, Reef wide data collection process. It will be demonstrated that behavioural insights can, on one level, be used to guide new projects as they establish relationships and get to understand the producers they are working with, and on another level be used to inform overall policy and program design.

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## Can insurance help farmers mitigate nitrogen impacts on the Great Barrier Reef?

Dr Peter Thorburn<sup>1</sup>, Mr Jody Biggs<sup>1</sup>, Mr Tony Webster<sup>2</sup>, Ms Larelle McMillan<sup>1</sup>, Mr Russ Mehmet<sup>3</sup>, Ms Claire Wilkinson<sup>4</sup>, Mr Julian Roberts<sup>4</sup>

<sup>1</sup>CSIRO, Brisbane, Australia, <sup>2</sup>CSIRO, Cairns, Australia, <sup>3</sup>Willis Towers Watson, Brisbane, Australia, <sup>4</sup>Willis Towers Watson, London, United Kingdom

Discharge of dissolved inorganic nitrogen (DIN) from sugarcane farms is a major threat to the Great Barrier Reef (GBR). An important pathway to reducing these impacts is to have farmers optimise N fertiliser applications to their crops. For sugarcane farmers, managing N fertiliser is an exercise in risk management; minimising the risk of reduced N application limiting yield. We have developed an original N insurance concept to provide farmers with a new way to manage the risk to yields and reduce the financial risk associated with optimising N applications. This required determining, amongst other things, whether the insurance was structured as an indemnity or parametric product, the spatial and temporal scale at which it was offered, and whether there was farmer appetite for such a product. For the latter problem, we developed a prototype commercial product and had sugarcane farmers in the Wet Tropics “buy” mock insurance. Feedback from the farmers about the concept was positive. Biophysical and financial outcomes of these “purchases” were evaluated over 70 years. The average outcome was farmers being financially better off by >\$8/ha because claims payouts from the insurance policies combined with the savings in fertiliser costs were greater than insurance premiums. Insurance broker’s fees and insurer’s “underwriting profit” were both approximately \$6/ha. If these policies were purchased over 40% of the Wet Tropics region there would be approximately 100 t/year less DIN discharged to the GBR from those catchments. This innovative insurance concept can provide a win-win for farmers and the GBR.

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## Could the zooarchaeological record help shape the future of modern livestock improvement?

**Prof Keith Dobney<sup>4</sup>**

<sup>1</sup>The University of Sydney, Camperdown/sydney, Australia, <sup>2</sup>The University of Liverpool, Liverpool, UK, <sup>3</sup>The University of Aberdeen, Aberdeen, Scotland, <sup>4</sup>Simon Fraser University, Burnaby, Vancouver, Canada

The shift from hunting and gathering to the control and then domestication of plants and animals was perhaps one of the most seismic bio-cultural transitions in the history of our species. This process not only fundamentally changed us and the world we live in, but also transformed a limited range of plants and animals upon which the lives of everyone are now utterly dependant. Whilst archaeologists have been developing ever more sophisticated datasets and models in our attempt to tell the complicated story of where, when and how occurred, the consequences of the so-called Neolithic revolution remain with us, feeding into ever-more heated debates around sustainability, the green agenda, intensive or extensive production, gene editing and even laboratory grown meat - all of which focus on how we'll feed a human population set on exponential growth.

In this talk, I aim to explore the growing realisation (and real possibility) that some of the answers lie in the very remains of these early domestic animals recovered from archaeological sites. Their bones and teeth represent both failed and successful experiments in livestock selection and management that have already been run over the long durée, often in the face of rapid climate change, exposure to new pathogens etc. New approaches and techniques (e.g. extraction and sequencing of ancient DNA) now allow us to mine these remains in a way never imagined – creating a real link from the past to the present.

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## How long have dogs been in Melanesia? New evidence from PNG

**Assoc Prof Tiina Manne**<sup>1</sup>, Professor Bruno David<sup>2</sup>, Professor Ian McNiven<sup>2</sup>, Dr Matt Leavesley<sup>3</sup>

<sup>1</sup>The University of Queensland, St Lucia, Australia, <sup>2</sup>Monash University, Clayton, Australia, <sup>3</sup>University of Papua New Guinea, Port Moresby, Papua New Guinea

Currently the earliest evidence for dog dispersal into the Greater Australian region and surrounds is found in Australia (Madura Cave 3210–3361 cal BP), New Ireland (Kamgot, c. 3000–3300 cal BP) and Timor-Leste (Matja Kuru 2, 2886–3068 cal BP). Previously, the earliest published dog remains for the large continental island of New Guinea was from Edubu 1 (2314–2700 cal BP) in Caution Bay, south coast of mainland PNG. In this paper we discuss the analysis of a dog mandible from Moiapu 1, also in Caution Bay. Although the mandible could not be directly dated, good chronostratigraphic resolution indicates that it confidently dates to between 2573 and 2702 cal BP (95% probability). It was found deeply buried in association with Late Lapita cultural materials, and is currently the earliest known dog remain from New Guinea. Biometric measurements on a small sample of archaeological and modern dog remains from the broader region support previously published models (based on genetic results) of multiple dog dispersals into the Pacific region.



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## The mosaic genome of African cattle: a unique adaptive genetic resource

**Professor Olivier Hanotte<sup>1,2</sup>**

*<sup>1</sup>International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia, <sup>2</sup>The University of Nottingham, Nottingham, United Kingdom*

The indigenous African cattle, with the exception of some West African populations, are ancient crossbred zebu x taurine with ancestral stock domesticated outside the African continent. Following large-scale genome sequencing of many indigenous populations, we now increasingly understand, at a fine scale, the mosaicism of their genome. It provides us with new insights into the history of their diversity at the roots of their unique adaptation and the success of their expansion across African agroecologies. We will present here our latest findings about the genome of African cattle highlighting their history of introduction and dispersion and the importance of these events in relation to their environmental adaptation. These will be put into today's context of rapid changes witnessed by the African continent (e.g. climatic, demographic) with increased demand for livestock products.

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## 500000 years of evolution: What does comparing *Bos-indicus* and *Bos- taurus* genomes reveal?

**Dr Mehrnush Forutan**<sup>1</sup>, Dr Elizabeth Ross<sup>1</sup>, Dr Amanda J. Chamberlain<sup>2</sup>, Dr Loan Nguyen<sup>1</sup>, Brett Mason<sup>2</sup>, Stephen Moore<sup>1</sup>, Josie B. Garner<sup>3</sup>, Ruidong Xiang<sup>4</sup>, Ben J Hayes<sup>1</sup>

<sup>1</sup>The University of Queensland, St Lucia, Australia, <sup>2</sup>Agriculture Victoria, Centre for AgriBioscience, Bundoora, Australia,

<sup>3</sup>Agriculture Victoria, Animal Production Sciences, Ellinbank Dairy Centre, Australia, <sup>4</sup>Faculty of Veterinary & Agricultural Science, The University of Melbourne, Australia

It has been well established that changes in transcriptional regulation underlie much of the phenotypic variation between species [ENREF 15](#). Variation in gene expression is largely due to cis mechanisms where regulatory molecules bind to elements such as promoters and enhancers close to genes to initiate transcription. Transcription start site (TSS) act as an integration region for a wide range of molecular signals to control gene expression levels. In this study we investigate regulatory mechanisms centred around TSS for the first time, to the best of our knowledge, which contribute to the differentiation of *Bos taurus* and *Bos indicus* which diverged up to 0.5 million years ago. Cap analysis of gene expression followed by sequencing was performed on 11 tissues at adult stages, including liver, lung, kidney, thyroid, spleen, muscle, uterus, ovary, blood in *indicus* and liver, spleen, muscle, mammary, heart in *taurus* sub-species, and two tissues in foetus stage, including liver and lung in *indicus* and liver in *taurus* sub-species. Evolutionary differences in TSSs were detected across the sub-species, including translocation of dominant TSS and changes in TSS distribution. The 16% of all single nucleotide polymorphisms (SNPs) located in significant differentially used TSS clusters across sub-species had significant shifts in allele frequency (472 SNPs), indicating they may have been subject to selection. In spleen and muscle, a higher relative TSS expression was observed in *Bos indicus* than *Bos taurus* for all heat shock protein genes, which may be responsible for the tropical adaptation of *Bos indicus*.

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## Functional palaeogenomics reveals how farming drove the evolution of virulence in a-chicken-virus

Dr. Steven Fiddaman<sup>3</sup>, Dr. Evangelos Dimopoulos<sup>1,3</sup>, Prof. Greger Larson<sup>3</sup>, Dr. Adrian Smith<sup>3</sup>, Laurent Frantz<sup>1,2</sup>  
<sup>1</sup>Ludwig Maximilian University of Munich, Germany, <sup>2</sup>Queen Mary University of London, United Kingdom,  
<sup>3</sup>University of Oxford

Over the past 50 years, advances in breeding and animal husbandry, combined with an increase in demand for meat provided unique environmental shifts for pathogens affecting livestock. This is the case of Marek's Disease (MD), a tumor-associated disease of poultry caused by a virus (MDV) that became highly virulent during the second half of the 20th century and which now kills ~100% unvaccinated hosts, and cost ~US\$2 billion/year. The earliest MDV genome sequences characterized, however, date back to 1968, by which point chicken MDV virulence was already established. To understand the genetic changes associated with early virulence increases in MDV, and how fast these evolved, we generated 19 ancient MDV genomes ranging from the Roman period to 19<sup>th</sup> Century using DNA extracted from archeological chicken bones. Leveraging information from timed-stamped MDV sequences we were able to show that rate of molecular evolution in MDV significantly increased in the second half of the 20th, which led to the establishment of virulence independently in Eurasian and North American lineages. Selection analyses further showed that specific sequence patterns (a 4x-proline-motifs:PPPP) in the sequence of a major oncogene (*meq*), have mutated in the genome of post 1960s strains. Transfection experiments showed that loss of multiple proline-motifs in modern genomes likely played an important role in the establishment of oncogenic activity by the virus. Altogether our study demonstrates the importance of ancient DNA as a tool to understand the biological consequences of domestication, and modern agricultural practices for animals and their pathogens.

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## Genomic architecture for complex traits in hybrid populations

Mrs Christie Warburton<sup>1</sup>, Dr Roy Costilla<sup>2</sup>, Dr Bailey Engle<sup>1</sup>, Professor Ben Hayes<sup>1</sup>

<sup>1</sup>Queensland Alliance for Agriculture and Food Innovation, St Lucia, Australia, <sup>2</sup>Agresearch Limited, Ruakura Research Centre, Hamilton, New Zealand

Throughout the world, many agriculturally important plant and livestock species are hybrids. The north Australian beef industry, for example, consists of many breeds and crossbreeds of cattle that originate from two genetically divergent beef cattle subspecies, *Bos indicus* and *Bos taurus*. It has been estimated that these subspecies have diverged from a common ancestor between approximately 275,000 and 2 million years ago. As these subspecies have diverged many generations ago, it is likely that mutations affecting quantitative trait loci (QTL) have developed independently in each. This may reduce the accuracy of multibreed genomic selection and QTL mapping in these hybrid populations. We propose a novel method to identify underlying genomic architecture in these genetically diverse populations. Firstly, we use haplotypes to assign single nucleotide polymorphisms (SNP) to an ancestral subspecies of origin. Secondly, we have developed a subspecies model to allow SNP originating from each ancestral subspecies to have differing effects in the model. By applying this method in a hybrid population of *Bos indicus* and *Bos taurus* heifers, we were able to identify genomic differences between each ancestral subspecies that were not identified in a multibreed genomic evaluation. Significantly, this method identified four subspecies specific SNP that were closely linked to genes that are associated with fertility in other species, but have not previously been associated with fertility in cattle.

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## Opportunities for developing protected cropping in Australia — National RD&E Strategy overview

Dr Elio Jovicich<sup>1</sup>, Vicki Lane<sup>1</sup>, Heidi Wiggerhauser<sup>1</sup>, Dr Melinda Perkins<sup>1</sup>, Edward Mugamba<sup>1</sup>

<sup>1</sup>Department of Agriculture and Fisheries, Australia

Horticulture production systems using protected cropping combine a range of technologies and agronomic practices to address climate variability challenges, crop biological constraints and market opportunities for the Australian horticulture industry. The Australian Protected Cropping Strategy 2021-2030 was released in 2021 to give horticulture growers and businesses, Hort Innovation and industry stakeholders clear direction and priorities for investment in research, development, and extension (RD&E) initiatives that benefit vegetable, berry, nursery, and tree-fruit value chains. This presentation will discuss the Strategy's findings and what they tell us about the growth opportunities for protected cropping across Australia. It will also highlight some of the opportunities, issues, and RD&E activities that are contributing to adoption of this production system in warm environments. While protected cropping in Australia is largely located in temperate climate regions, there is strong potential for expansion of protected cropping in the tropics. These opportunities have been examined recently by the Department of Agriculture and Fisheries in collaboration with industry stakeholders and research groups, focusing on horticultural crops that will benefit from fit-for-purpose technologies that mitigate risks associated with climate variability and assist accessing domestic and export markets.

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## National Vegetable Protected Cropping Centre: glasshouse films to reduce energy use

Prof David Tissue<sup>1</sup>

<sup>1</sup>Western Sydney University, Richmond, Australia

The National Vegetable Protected Cropping Centre (NVPCC) was established at Western Sydney University in 2017 with support from Horticulture Innovation Australia to advance horticulture research in Australia. The NVPCC is supported by an 1800 m<sup>2</sup> high-tech glasshouse facility which consists of one large demonstration/teaching bay and 8 large research bays, which have advanced environmental control systems. In the past five years, we have trialled different cultivars of vegetables (eggplant, cucumber, capsicum, and lettuce) grown under two glasshouse films: smart glass (SG) which is designed to reduce heat-generating wavelengths of light thereby lowering energy costs, and a film (LLEAF) that shifts yellow and green wavelengths to red to increase productivity. Our objectives are to reduce cooling costs and increase resource use efficiency (RUE) without compromising yield and quality. We found that SG reduced cooling costs and increased RUE, but also reduced biologically relevant light that reduced yield, but not quality. LLEAF was particularly valuable in increasing lettuce yield. As part of a recent 5-year project funded by Future Food Systems CRC, we are using data from these earlier trials in the NVPCC to design next-generation glasshouse films with an industry partner to improve spectral qualities that will further reduce energy, water and nutrient use, while increasing fruit yield, nutritional value and quality. Ultimately, protected cropping can contribute to food security in increasingly extreme climate conditions, but only if it is economically viable.

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## Data driven growing – current and future trends for protected cropping

**Mr Marcus van Heijst<sup>1</sup>**

<sup>1</sup>PRIVA, Officer, Australia

The importance of data is becoming more and more apparent in many industries, including agriculture and horticulture. But no more so than in protective cropping.

This industry by its nature involves high level of measurement and control. This leads to the generation of a lot of data. Current trends in the industry see the use of such data, data generated by additional sensors and others forms of data, to help growers and investors achieve consistent yield and quality.

As the industry continues to grow and develop, the need of data driven growing has never been greater than it is today. Going into the future new technologies such as vision technology, machine learning, AI, and robotics are going to play an increasingly important role in assisting the industry.

This presentation will highlight the need for data and how the various sectors in protected cropping are using data currently around the world. The presentation will also explore the future trends in registering and using data.

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## The future of protected cropping in Australia

Mr Sam Turner<sup>1</sup>

<sup>1</sup>*Protected Cropping Australia*

As we move through the challenges of the past 3 years, what are the opportunities and risks for protected cropping?

To look at the future of protected cropping (PC) in Australia we need to look at the 3 Ps:

1. People
2. Planet
3. Profits

First and foremost, the Australian horticulture industry as a whole, and PC in particular, is looking at a tightening labour market. Access to skilled and unskilled talent is likely to be a key limiting factor as the industry grows to support a swelling global population. This challenge will force firms to be more creative and proactive in the targeting and acquisition of human capital into their businesses. It will also mean that businesses will need to change their structures and processes to improve labour use efficiency and increase reliance on automation and systems.

The planet and sustainability considerations are already heavily influencing business decisions. As social license and regulatory burden increases, growers and farming businesses will need to have a clearly articulated and actioned sustainability plan. This will largely be driven by consumer and retailer demands for more accountability into the future. Unfortunately, this risk and burden will likely be passed onto growers.

To retain profitability into the future, growers will need to be able to increase their flexibility and business resilience to take advantage of opportunities. Growers in the future will retain more value on farm through product and market innovation to move themselves further down the value chain towards the end consumer/purchaser.



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## The three 'E's of vertical farming success

Mr Douglas Elder<sup>1</sup>

<sup>1</sup>*Intelligent Growth Solutions (IGS), Edinburgh, United Kingdom*

There are three key questions any grower looking to invest in the world of vertical farming should ask themselves. Can their chosen system grow excellent crops, in an economically viable manner, with environmental sustainability at the heart of its operations? At IGS, we call this the three Es of vertical farming.

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## Medicinal Harvest - Indoor multi-tiered medicinal cannabis facility

Mr Andrew Olley<sup>1</sup>

<sup>1</sup>Medicinal Harvest, Warwick, Australia

Medicinal Harvest is a federally licenced cultivator of medicinal cannabis, located in South-East Queensland. All cultivation is carried out in a high-tech indoor facility, with the first crop planted in June 2021. The Medicinal Harvest facility is an example of a successful, commercially run protected cropping business. With the full environmental control of an indoor growing system, the facility produces consistent, high quality medicinal cannabis flower bud. Yields are also consistently high and no pesticides are used.

Some of the facility highlights are:

- Multi-tiered growing with rolling racks to maximize the canopy space.
- Staggered crop planting with up to seven plant stages represented at any one time
- An NFT growing system combined with LED lighting.
- Full environmental control achieved via air conditioning, dehumidifiers, UV filtering.
- Multiple rooms for the different stages of cultivation and production, each with separate environmental control.
- Utilisation of rainwater with the backup of bore water via a reverse osmosis system.

Sustainability is a key driver underlying the Medicinal Harvest business model and has been carefully integrated into the facility design. For instance:

- The water from our growing system and the facility's atmosphere is recycled.
- An onsite solar farm provides 100 percent of the facility's power during daylight hours.

Medicinal Harvest is positioned neatly in the supply chain as an Australian owned, boutique grower of sustainably produced medicinal cannabis.

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## Recent advances in genomic prediction in dairy using multi-omics resources

**Dr Amanda Chamberlain**<sup>1</sup>, Dr Ruidong Xiang<sup>1,2</sup>, Dr Lingzhao Fang<sup>5</sup>, Dr Iona Macleod<sup>1</sup>, Dr Zhiqian Liu<sup>1</sup>, Dr Edmond Breen<sup>1</sup>, Dr George Liu<sup>4</sup>, Dr Albert Tenesa<sup>3</sup>, Dr Simone Rochfort<sup>1</sup>, Dr Tim Luke<sup>6</sup>, Dr Christy Vander Jagt<sup>1</sup>, Claire Prowse-Wilkins<sup>7</sup>, Prof Mike Goddard<sup>1,2</sup>

<sup>1</sup>Agriculture Victoria Research, Bundoora, Australia, <sup>2</sup>The University of Melbourne, Parkville, Australia, <sup>3</sup>The University of Edinburgh, Edinburgh, United Kingdom, <sup>4</sup>United States Department of Agriculture, Beltsville, USA, <sup>5</sup>Aarhus University, Aarhus, Denmark, <sup>6</sup>CSIRO, Hobart, Australia, <sup>7</sup>University of California, Davis, Davis, USA

It is now widely acknowledged that genetic variation for complex traits largely falls in non-coding genomic regions and therefore affect regulation of gene expression. Also, genomic prediction accuracy and persistence across breeds and generations can be improved by using causal variants in the model. At Agriculture Victoria we have used multiple and varied sources of information (multi-omics) that detail gene expression, it's regulation and the resultant molecules, to determine which genetic variants in the bovine genome are most likely to be causal variants for dairy traits. In this presentation we will detail the latest work that shows that QTL associated with gene expression and RNA splicing, detected from 16 tissues using ~5000 samples, explained ~70% of the heritability for 37 complex dairy traits. Given the importance of expression QTL and the large datasets now available in cattle we will also present a new method which correlates gene expression with genetically predicted phenotype that outperformed transcriptome wide association studies in detecting causal genes. Other omics data sets have proved to be informative for selecting causal variants in the past. However, with a global focus on the functional annotation of the bovine genome there are now many more datasets available for use in prioritising variants. The most recent analysis prioritising all bovine variants according to their impact on dairy traits used greater than 22 multi-omics datasets and demonstrated that many identified variants with a high probability of affecting the dairy traits studied.

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## Predicting nitrogen use efficiency in cattle using nitrogen isotope fractionation in tail hair

**Dr Karen Eyre<sup>1</sup>**, Assoc Prof Luis Prada e Silva<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Lawes, Australia

New technologies are changing the ways we can predict phenotypes in livestock. We are no longer limited to the genomic information of animals, but can integrate information from the epigenome, transcriptome, and microbiome to better gauge how an animal will physically present in its environment. Additionally, new methods and ideas from beyond agriculture highlight new approaches that can open the door to new traits. One of the challenges facing the northern Australian beef industry is selection of cattle that are able to cope with the harsh environment and low quality pastures. Cattle vary in their nitrogen use efficiency (NUE) both for growth and reproductive performance however traditionally NUE is assessed in environments that are not reflective of that of northern Australia. Selection of cattle with greater NUE on nitrogen (N) deficient diets has the potential to maintain or increase production and reduce environmental pollution by decreasing urinary N output. Isotopic fractionation of N isotopes occurs between the diet and animal tissue due to enzymatic processes preferentially interacting with <sup>14</sup>N rather than <sup>15</sup>N leading to greater urinary excretion of <sup>14</sup>N and retention of <sup>15</sup>N. Thus, the concentration of <sup>15</sup>N in body protein is negatively correlated with the NUE of the animal. As NUE increases the amount of N excreted decreases and more <sup>14</sup>N is retained. Analysis of <sup>15</sup>N concentrations in tail hair of growing steers on a low crude protein diet showed that steers with lower <sup>15</sup>N had lower urinary N losses and higher NUE. It can also be correlated with reproductive performance, cows identified as having a greater propensity to being pregnant or lactating had significantly lower <sup>15</sup>N concentrations on their tail hair during the dry season when pasture quality was lowest. Tail hair is simple to collect, transport and store and the segment analysed can be selected based on when the diet quality was lowest. On low CP diets small differences in NUE can result in the difference between loss of body condition and maintenance.

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## Recent innovations in the use of Nanopore sequence in predictive livestock agriculture

Dr Loan Nguyen<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Brisbane, Australia

Oxford Nanopore Technologies' (ONT) portable sequencing devices have enhanced our ability to address system-level problems through the possibility to directly sequencing unmodified-DNA and RNA molecules in real-time with no limit in read length. We have used ONT data in a range of agriculturally focused research studies, including genome assembly (Ross et al 2022), epigenetic aging clock generation (predicted animal age with an accuracy of 0.71 ; Hayes et al. 2021), characterization of important structural variants related to Poll status in Brahman (Lamb et al. 2020) and coat colour in Nellore cattle (Trigo et al. 2021), and analysing metagenomes (Ong et al. 2022), parentage testing (Ross et al 2021), and even for genomic prediction of important traits (Lamb et al 2021). Lamb et al. 2021 has shown that low coverage ONT data can be used for in situ genomic predictions which are near identical to SNP array-based predictions ( $r > 0.92$ ), suggesting the potential of on-farm genomic prediction. Our findings based on different approaches using ONT demonstrate the versatility and potential of this technology and may be of interest to researchers in different areas of science.

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## Genetic control of longitudinal trait change in human populations

**Dr Kathryn Kemper<sup>1</sup>**, Prof Mike Goddard<sup>2</sup>, Prof Peter Visscher<sup>1</sup>

<sup>1</sup>IMB, Brisbane, Australia, <sup>2</sup>University of Melbourne, Melbourne, Australia

Most studies analyse the mean differences between groups. In the case of genome wide association studies, the groups are defined by genotype at a SNP allele (e.g. CC, CG, GG) and the analysis determines if the mean differences between the groups consistent with a linear effect. An alternative question is to ask if the spread (or variance) of the a group is dependent on the SNP genotype. Such type of analyses are part of a general approach to investigate genetic control of trait variance. In this study we use a large population of 50,117 individuals from the United Kingdom with repeated measures to investigate genetic control of trait change over time at the locus and genome level for 8 anthropometric traits. We find evidence at the locus and/or genome level for genetic control of variability for height, sitting height, BMI and weight. Further study of these traits show that longitudinal trait change can partially explain our findings. We detect substantive genetic variation in longitudinal trait-change and show that polygenic scores for longitudinal change correlate with disease incidence.

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## On-farm genotyping as a management and selection tool of the future

Mr Harrison Lamb<sup>1</sup>, Dr Loan Nguyen<sup>1</sup>, Prof Ben Hayes<sup>1</sup>, Dr Elizabeth Ross<sup>1</sup>

<sup>1</sup>Queensland Alliance for Agriculture and Food Innovation, St Lucia, Australia

Portable DNA sequencing technology, popularised by Oxford Nanopore Technologies' MinION sequencer, has the potential to provide a revolutionary management tool for producers. On-farm, near real-time, genotyping has a number of applications in predictive agriculture as well as disease diagnostics. To test the utility of portable sequencing technology for on-farm genotyping we have developed a pipeline for on-farm genotyping to be used in Australia's northern beef industry. The pipeline calls and impute genotypes on the fly during live sequencing and calculates genomic estimated breeding values, as well as perform parental verification. A reference panel of 1,208 animals and 48 million SNPs was used to accurately call and impute. Using 0.1x sequencing coverage, genomic breeding value correlations as high as 0.94 (n=64) were achieved when comparing results to SNP arrays. With the capacity to multiplex up to 96 animals on a single Oxford Nanopore Technologies flow cell, the cost of this method could rapidly approach that of SNP array genotyping. The added benefits of near real-time results, the ability to genotype structural variants and methylation and the capacity to customise the analysis on-farm will provide producers with a revolutionary management tool.

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## Diversity in agricultural landscapes for pollinator diets

Prof Helen Wallace<sup>1</sup>

<sup>1</sup> *Environmental Futures Research Institute, Griffith University, Queensland, Australia*

Pollination is a critical process in agricultural landscapes to ensure crop production. Pollinators, primarily bees, collect crop pollen during flowering, but crop floral resources alone are insufficient to sustain pollinator populations throughout the year. We used DNA metabarcoding to identify the floral resources used by both honeybees and stingless bees in agricultural landscapes in Australia and Papua New Guinea.

We found that trees are critical for stingless bees as sources of pollen, nectar and resin throughout the year. During crop flowering, stingless bees preferred macadamia to avocado pollen, and flew up to 700m to access macadamia flowers. When crops were not flowering, stingless bees foraged widely on tree pollens and small quantities of pollen from a diversity of species. Stingless bees in both forest and garden landscapes collect from very similar resin sources, mostly *Corymbia* spp and *Syncarpia* spp. Honeybees in Papua New Guinea foraged heavily on trees for both pollen and nectar, even in landscapes where trees were scarce. Common tree species for bee diets were *Leucaena leucocephala* and *Syzigium unipunctatum* for pollen and *Helicia latifolia*, *Horsfieldia hellwigii*, *Pometia pinnata* and mistletoe for nectar.

Our research highlights the significance of trees as pollen, nectar and resin resources for honeybees and stingless bees in tropical and subtropical agricultural landscapes. The findings suggest bees will travel long distances to seek out tree resources in landscapes where they are scarce. We suggest that increasing trees in the landscape will help to improve pollinator diets and thus maintain pollinator health.



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## On-farm diversity increases productivity and carbon sequestration opportunities in smallholder farming systems

Dr Joel Buyinza<sup>1</sup>, Mr Athanase Cyamweshi<sup>2</sup>, Dr Awol Toib<sup>3</sup>, Prof Catherine Muthuri<sup>4</sup>

<sup>1</sup>Agroforestry Research Program, National Forestry Resources Research Institute (NaFORRI), Kampala, Uganda, <sup>2</sup>Rwanda Agriculture and Animal Resources Development Board (RAB), Kigali, Rwanda, <sup>3</sup>Department of Plant Biology and Biodiversity Management, Addis Ababa University, Addis Ababa, Ethiopia, <sup>4</sup>World Agroforestry (ICRAF), Kenya

Smallholder farmers are vulnerable to the effects of environmental degradation since their lack of economic resources restricts access to alternative livelihoods. Recent agroforestry research and development efforts in Africa, such as the Trees for Food Security (T4FS) project, have prioritised scaling up trees in fields and farming landscapes to enhance and sustain crop yield, food security, ecosystem services and resilient livelihoods. In Uganda, studies have demonstrated that integrating trees (*Cordia africana* and *Albizia coriaria*) in smallholder farming systems can result in a 27-32% increase in coffee and common beans yields when farmers regulate tree shade through canopy pruning. Moreover, when trees are pruned, the branches can be converted into firewood while the plants underneath, such as coffee, beans and maize, can benefit from the additional sunlight and organic matter, prolonging the period of intercropping. Conversely, studies conducted on *Faidherbia albida*, one of the trees commonly intercropped with cereals in Ethiopia, show that pruning reduced above ground biomass and grain yield by 30% and 27%, respectively, despite the higher water uptake by unpruned trees. Studies in Rwanda show that *Alnus acuminata* agroforestry significantly contributes to carbon sequestration while providing local needs for stakes for climbing beans, wood, and soil fertility improvement, as well as contributing to regulation of climate variability. These studies have demonstrated that increasing tree density and diversity in farmers' fields and farming landscapes is a cornerstone of system intensification that could eventually contribute to more resilient livelihoods, while contributing to carbon sequestration in smallholder farming systems.

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## Data and digital solutions for managing natural capital on farm

**Dr Madeline Mitchell**<sup>1</sup>

<sup>1</sup>Food Agility CRC, Australia, <sup>2</sup>RMIT University, Australia

Managing carbon, biodiversity and other forms of natural capital has the potential to boost the resilience of individual farms and supply chains as well as contributing to industry, corporate and national emissions reduction and environmental goals. However, barriers to effective measuring, monitoring and reporting on natural capital include a lack of accessible and cost-effective data collection methods and decision support tools. In this talk, I will discuss Food Agility Cooperative Research Centre projects focused on developing these data-driven tools, including the Rangelands Carbon project and the Cool Soil Initiative. Rangelands Carbon is a collaboration with Australian Agriculture Company (AACo) and other university and research partners that aims to provide an accurate and affordable way to estimate carbon in Australian rangelands landscapes. This will inform decisions supporting holistic land management and participation in the carbon market. Cool Soil Initiative is a paddock to product partnership in the grains supply chain to improve soil health and reduce greenhouse gas emissions on-farm. The data collected provides insights back to growers as well as allowing corporate partners to report on their progress towards scope 3 emissions reduction goals.

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## Agroforestry reduces erosion and increases income over maize monoculture in Northwest Vietnam

Dr Nguyen La<sup>1,2</sup>, Mr Hung Do<sup>2,3</sup>

<sup>1</sup>Soils and Fertilizers Research Institute, Hanoi, Vietnam, <sup>2</sup>World Agroforestry in Vietnam, Hanoi, Vietnam, <sup>3</sup>Swedish University of Agriculture Sciences, Uppsala, Sweden

Variants of agroforestry were compared with business-as-usual monocultures on sloping lands in northwest Vietnam. Longan+mango+maize+forage grass was compared with maize alone and sonra (*Docynia indica*)+coffee+forage grass was compared with coffee alone. Maize and coffee yields under the agroforestry systems were decreased due to their reduced areas within agroforestry plantings. However, annual incomes under agroforestry were increased above the monocultures, with maize in agroforestry returning \$US1870/ha compared with \$US 1248/ha for maize alone and coffee in agroforestry returning \$US 1491/ha compared with \$US 948/ha for coffee alone. Agroforestry provided earlier returns from the forage component, and a longer return period from the fruit trees. From the second year to the fourth year after planting, the agroforestry systems reduced soil loss by 21 to 74% compared to the monocultures. Soil movement downslope resulted in terrace formation under agroforestry, with soil volumes of 0.26 m<sup>3</sup> (maize agroforestry) and 0.43 m<sup>3</sup> (coffee agroforestry) per metre terrace after five years. Diversifying plantings confers some resistance to extreme weather effects and price instabilities. Further comparisons should measure carbon sequestration.

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## **AgCarE – helping landowners measure and capitalise on improving natural capital condition**

**Dr Greg Leach<sup>1</sup>**

<sup>1</sup>*AgForce, Brisbane, Australia*

*AgCarE* underpins AgForce's moves toward a Natural Capital approach to managing rural property, recognising and rewarding sustainable practices and enabling increased income streams for agricultural enterprises. *AgCarE* is a whole-enterprise assessment tool that measures natural capital condition at the property level and incorporates specific commodity sustainability measures including environmental, social and governance (ESG) elements, climate risks and mitigation, and activities that enhance natural assets. Development of *AgCarE* over five years by AgForce members has sought to place landowners at the centre of the story, providing them choice on how they measure natural assets and convey confidential data in interactions with external parties.

Data collection is developed to meet recognised scientific, government and industry standards. Incorporated into the *AgCarE* assessment are metrics that identify and measure ecological values contained within State and Commonwealth legislation, an internationally recognised carbon accounting methodology specifically designed for agricultural sector (Food and Agricultural Organisation of the United Nations (FAO), EX-ACT), commodity metrics developed from industry best practice, ESG elements formulated from national and international sustainability standards, climate risks and mitigation questions sourced from government and industry, and natural capital metrics from proven scientific data.

The *AgCarE* Reference Panel, with recognised Australian natural capital experts, is happy that scientific integrity requirements are met in a representative measurement of natural capital condition. The Panel supports the verification and audit mechanisms in the *AgCarE* program and its linkages with measurement requirements for biodiversity, environmental-offset and carbon markets. *AgCarE* provides the sustainability credentials governments, retailers and financiers are asking for.

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## Impact of dung beetle body size on greenhouse gas (GHGs) emission

Mrs Jakia Sultana<sup>1</sup>, Prof Nigel Andrew, Dr Tim Schaerf

<sup>1</sup>University of New England, Australia

Dung beetles (Coleoptera, Scarabeinae) are key soil invertebrate taxa that may mediate greenhouse gas (GHG) emissions from cattle dung. The ability of dung beetles to alter GHG emissions may be directly related to their body size. Here, we assess the influence of different-sized dung beetles to reduce the emission of three major GHGs (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O) from cattle dung. It was a laboratory experiment where we used three larger size and three smaller size of dung beetles and two control treatments: soil only and soil + dung. The larger species of dung beetles were *Onitis alexis*, *Onitis caffer*, *Onitis pecuarius* and smaller species of dung beetles were *Onthophagus binodis*, *Onthophagus gazella*, *Onthophagus australis*. We measured three major GHGs emission at day 1- 4, day 8 and day 15 using a Gasmeter machine. The emission of CO<sub>2</sub> increases until day 3 in all species then gradually decreases, however, in case of CH<sub>4</sub> production decreased substantially from day 2 in presence of dung beetle compare to absence of beetle. The biggest change in CH<sub>4</sub> production occurred at day 4 – the production reduced 50 %. In this regard, larger species are more potential as large beetles are most efficient in case of dung removal – there by aerate the dung faster, gradually reduce the emission of CH<sub>4</sub> fluxes.

Keywords: Greenhouse gas, emission, cattle dung, dung beetle, body size.

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## Perspectives on livestock and One Health

**Dr Jimmy Smith<sup>1</sup>**

<sup>1</sup>*International Livestock Research Institute (ILRI), Nairobi, Kenya*

The One Health approach has risen to prominence in recent years, recognizing it is a requirement to save trillions of USD and billions of lives. This presentation will explore opportunities for adopting a One Health approach to address three of today's major challenges at the intersection of human, animal and environment health: food safety, anti-microbial resistance and zoonoses. It considers in particular opportunities from a livestock perspective in low- and middle-income countries, where the challenges, but also the opportunities are immense.

COVID-19 has left no doubt that pandemics are costly – to lives and economies, and the still-growing USD20 trillion cost has dwarfed previous estimates. A next, more fatal and more transmissible pandemic must be prevented.

And there are options to act now; from simple, affordable opportunities to make food safer without banning traditional markets where over 70% of livestock foods are sourced in LMICs. Integrated, multi-partner engagement such as the CGIAR AMR hub can address AMR challenges through capacity building and integrated interventions. And better animal disease surveillance is key to prevent future pandemics. Improved capabilities across all dimensions – human, animal and environment health with innovative data collection and connection approaches along with with new science for diagnosis and detection hold much promise. Institutional coordination at every level is mandatory and could be fostered through a 'GAVI for pandemics'.

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## Global challenges and solutions for implementation of antimicrobial stewardship in veterinary medicine

**Prof Glenn Browning<sup>1</sup>**

<sup>1</sup>*Asia-Pacific Centre for Animal Health, Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Parkville, Australia*

While much of the attention on the problem of antimicrobial resistance has focussed on monitoring and documenting levels of resistance in bacteria, the solution to the problem rests in optimal antimicrobial stewardship – ensuring that we use the most appropriate antimicrobial drug when it is needed and that we do not use antimicrobial drugs when their use is not warranted, as the major driver of antimicrobial resistance is overuse and misuse of antimicrobial drugs. The challenges to implementation of antimicrobial stewardship can vary widely between different countries and is highly dependent on the efficacy of regulatory controls on the acquisition and uses of antimicrobial drugs, in both domestic animals and humans. However, many of the solutions are similar. Changes in antimicrobial use in livestock are only likely to occur when all users are sufficiently aware of the problem and are provided readily accessible solutions to the problems that they seek to solve with antimicrobial drugs. Education about the need for optimal use of antimicrobial drugs needs to reach not just veterinarians and paraveterinarians, but also farmers. This education needs to be accompanied by education about biosecurity, vaccination and disease diagnosis. Accurate disease diagnosis needs to be readily available and affordable if we are to see animals treated with antimicrobials only when they are needed. Guidance about the use of antimicrobials needs to be accessible and locally relevant. Finally, once these measures are implemented, their efficacy needs to be evaluated to ensure that they are having the desired outcome.

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## Collaboration – Queensland’s One Health Response to Japanese Encephalitis

Dr Joanne Mollinger<sup>1</sup>

<sup>1</sup>*Biosecurity Queensland, Brisbane, Australia*

In late February 2022, Japanese encephalitis virus (JEV) infection was simultaneously diagnosed in domestic pig herds in Queensland, New South Wales and Victoria followed closely by South Australia in early March. JEV infection is a mosquito-borne infection that is a notifiable disease in both animals and humans in Queensland. Animals and people can become infected with JEV through the bite of infected mosquitoes. In response to the JEV detections in domestic pigs, the Consultative Committee for Emergency Animal Diseases (CCEAD) was convened on 28 February 2022. Further investigation identified a genotype IV virus closely related to that isolated from a fatal human case of Japanese encephalitis (JE) in the Tiwi Islands of the Northern Territory in March 2021. Human cases were reported in south-eastern Australia from early March 2022, and the outbreak was declared a Communicable Disease Incident of National Significance by the Australian Chief Medical Officer on 4 March 2022. The focus of the response and ongoing JEV management is to support the public health sector to mitigate risks to human health through collaboration between animal and human health authorities with the active involvement of industry. This includes coordinating with public health authorities to ensure affected properties implement appropriate vector management through biosecurity planning; detection of clinical cases of JEV in both humans and animals; and retrospective and prospective surveillance to aid the epidemiology of this event. Collaboration from a One Health perspective has been a key focus in supporting and managing JEV in Queensland.



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## One Health at work: A systems dynamics model of brucellosis in Jordan

Assoc Prof Simon Reid<sup>1</sup>, Dr Haitham Taha<sup>1</sup>

<sup>1</sup>The University of Queensland, Herston, Australia

Brucellosis is a highly infectious zoonotic disease associated with different livestock species. Jordan has one of the highest reported incidences of human brucellosis in the world, caused by *Brucella melitensis*. The current control program for brucellosis in sheep relies on vaccination through veterinary clinics, and in humans through education campaigns to reduce exposure to high-risk animal secreta (birth fluids) and unpasteurised animal products. A systems dynamics simulation model was developed to allow a better understanding of the drivers of brucellosis in Jordan, which is mainly associated with sheep husbandry and consumption. The model showed that *Brucella* transmission among sheep and between sheep farms and sheep markets (Local markets) are the main drivers of human brucellosis incidence. Farmers' visits to veterinary clinics are a critical intervention point for the control of brucellosis because they are the focal point for contact between sheep owners and veterinary services regarding access to vaccination, advice and services on testing and culling. The simulation model allowed "testing" of multiple interventions including an integrated One Health intervention. This is the first time that the relative efficacy of different interventions for brucellosis have been explored. The results showed that many standard interventions are predicted to be ineffective and that integrated One Health interventions may be highly cost-effective.

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## Pig apocalypse, chicken nirvana and dangerous Australians; One Health Research within QAAFI

Dr Lida Omaleki<sup>1</sup>, Associate Professor Patrick J. Blackall<sup>1</sup>, Dr Conny Turni<sup>1</sup>

<sup>1</sup>Queensland Alliance for Agriculture and Food Innovation, University of Queensland, St Lucia, Australia

Key aspects of One Health research, an active area within QAAFI, will be covered in this presentation. The use of antimicrobial agents and the development of resistance in livestock bacterial pathogens, including those zoonotic pathogens, has been a pressing issue for intensive livestock industries and has led to popular press headlines like “Pig Apocalypse”. Our research has demonstrated only minimal resistance in key bacterial respiratory pathogens infecting Australian pigs, confirming the responsible and sustainable approach taken by pig veterinarians. A key issue in helping these intensive animal industries is to have validated testing systems available for diagnostic laboratories to guide field veterinarians with antimicrobial sensitivity test results. Our research has provided the first validated antimicrobial testing methodology for a key pig pathogen – *Glaesserella parasuis*. Currently, we are providing the data that will allow the recognition of sensitivity or resistance to ampicillin for treating infections due to a major emerging pathogen of free range and organic chicken meat and layer flocks – *Pasteurella multocida*. Currently Australian laboratories cannot interpret and thus guide the use of this key agent for disease control in poultry. In the final example, we have been working at the interface between wildlife and humans. In this work, we are collaborating with clinicians, clinical microbiologists, veterinarians, and diagnostic laboratories (veterinary and clinical) looking at the impact of a poorly understood bacterium (*Lonepinella koalarum*) on koala gut health, koala wounds and human infections following koala bites. One Health is key multidisciplinary research area for QAAFI, now and into the future.

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## Knowledge on Antibiotic Use and Resistance Among Poultry Farmers in Fiji

**Miss Shivani Singh**<sup>1</sup>, Mrs Sharon Gaundan<sup>1</sup>, Mr Walter Okello<sup>2</sup>, Mr Anthony Keyburn<sup>2</sup>, Mr Royford Magiri<sup>1</sup>  
<sup>1</sup>Fiji National University, Suva, Fiji, <sup>2</sup>Commonwealth Scientific and Industrial Research Organization, Canebara, Australia

Antibiotic resistance is an emerging global health threat which is linked to the overuse and misuse of antibiotics. This study was conducted to understand the knowledge and practices of smallholder poultry farmers on antibiotic use and resistance in Fiji. A cross-sectional study using a structured face-to-face interview was conducted in Viti levu Fiji Island. This study found that knowledge of antibiotics was very poor. None of the farmers knew about antibiotic resistance and were able to explain the concept correctly. After the definition of antibiotic was explained to the farmer, only few reported that their chickens had ever received antibiotics, and the majority of farmers whose poultry had not received antibiotics reported the lack of access to veterinary services. When used, antibiotics were only used for treatment with no reported use for disease prevention or growth promotion. None of the commonly used antibiotics were critically important antimicrobials. Compliance with withdrawal periods was not routinely followed. There is a need to improve access to government veterinary services for farmers in Fiji, while addressing identified knowledge gaps on antibiotics and promoting prudent use practices. The findings from this study serve as baseline information to inform future interventions.

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## Imposter fish: Uncovering fraud and obscure trade in global seafood supply chains

**Dr Donna Cawthorn**<sup>1</sup>, Professor Louwrens C. Hoffman<sup>2</sup>, Professor Stefano Mariani<sup>3</sup>

<sup>1</sup>Department of Agriculture and Fisheries, Queensland Government, Brisbane, Australia, <sup>2</sup>Queensland Alliance for Agriculture and Food Innovation, University of Queensland, Gatton, Australia, <sup>3</sup>School of Biological and Environmental Sciences, Liverpool John Moores University, Liverpool, UK

The deceptive marketing of seafood products is a pervasive worldwide problem that not only poses environmental, economic and health impacts, but also offers avenues for laundering illegally harvested products into legitimate markets. Here, we systematically unpack over a decade of research employing advanced genetic techniques and trade data analyses to map levels of seafood fraud and dubious activities across global supply chains, and to pinpoint variables responsible for these patterns. By DNA barcoding >800 seafood samples collected from retail and restaurant outlets in eight countries (South Africa, Canada, US, UK, Singapore, Australia, New Zealand, Turks and Caicos Islands), we show that species mislabelling rates approach 30% on average; but that these rates differ by country, outlet type and particularly by taxonomic group. In fact, for iconic fish families like snapper (family Lutjanidae), our results indicate that the lax application of generic 'umbrella' terms and widespread mislabelling (40%) conceals the identity of at least 67 species from 16 families across world markets, grouping species for sale that derive from numerous disparately managed fisheries and with markedly different conservation concerns. Moreover, by comparing production, import and export statistics for various groups of valuable fishes (snappers, groupers, seabreams), we demonstrate that widely used Harmonised System (HS) codes and accompanying official trade records lack sufficient granularity to track the true biodiversity exploited by fisheries, leaving trade permeable to illegal practices and perpetuating this lack of transparency onward to consumers. Illuminating these loopholes should compel improvements in international trade classifications, seafood labelling and traceability frameworks.

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## Provenance of food proteins

**Prof Louwrens Hoffman**<sup>1</sup>, Prof Daniel Cozzolino<sup>1</sup>, Dr Donna-Mareè Cawthorn<sup>2</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Bellbowrie, Australia,

<sup>2</sup>Department of Agriculture and Fisheries, Australia

The modern consumer has become a discerning food customer where provenance of the food is becoming an important determinant of purchasing intent. Provenance can be defined as a term that describes the origins/history of food such as where it has been grown, raised, or caught. With global warming, additional descriptors such as carbon-, and water- footprint, green house gas emissions, naturally grown/reared, have also become important factors. A typical example of provenance is the commonly used label of 'organic'. Provenance is frequently associated with the flavour of food – think wine. Food proteins that can be marked with a provenance label, typically have higher economic value; any food product with a competitive marketing edge that provides for a higher value is exposed to fraud. The food industry is challenged to find quick, reliable, non-invasive technologies to prove provenance. A procedure that is showing potential in this arena is the use of light-based (spectroscopic) technology such as hand-held NIRS (Near Infra-Red Spectrometers) to provide spectra that is then analysed by machine learning algorithms to detect what differentiates specific food protein samples.

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## Honey authenticity and provenance

**Dr Natasha Hungerford<sup>1</sup>**

<sup>1</sup>Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Health and Food Sciences Precinct, Cooper's Plains, Australia

Honey is a natural product produced by bees with its diverse composition affected by assorted factors including botanical and geographical origin, nectar flows, climate and beekeeping and handling practices. Defined by the Codex Alimentarius International Food Standard CXS 12-1981 (amended 2019) as “Honey is the natural sweet substance produced by honey bees from the nectar of plants or from secretions of living parts of plants or excretions of plant sucking insects which bees collect, transform and leave in the honey comb to ripen and mature.” Hence honey produced by bees other than honeybees (*Apis mellifera*) are not provided for in this definition. In particular, stingless bees (Meliponini) also produce ‘honey’ and are important pollinators in subtropical and tropical regions. Worldwide there are more than 500 species. Stingless bee honey is valued for its distinct flavour and purported beneficial properties. Recent research has provided valuable insights into stingless bee honey properties and presents future challenges for honey regulation.

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## Open challenges in agriculture remote auditing and cyber security

Prof Ryan Ko<sup>1</sup>, Mr Joshua Scarsbrook<sup>1</sup>

<sup>1</sup>The University of Queensland, School of Information Technology and Electrical Engineering, Brisbane, Australia

Remote auditing and inspection technologies create vast opportunities for the meat and food processing industries to increase their efficiencies and effectiveness. With remote auditing, a meat processor can be remotely inspected for food safety by auditors and regulators located in other states or countries. Processers may also be inspected against Halal certification requirements without requiring the auditors to travel to each specific site. To facilitate trusted, high-integrity inspections, many open challenges in data integrity and cyber security remain. How do we ensure that the video feeds from meat processors do not get leaked out into the public domain, and how do we ensure that the videos are not fake or tampered with? Leveraging a combination of approaches from trusted computing, video conferencing and smart glasses, the team from the University of Queensland and Bondi Labs were able to overcome some of these challenges and provide high-integrity inspections to a group of pilot customers of Bondi Labs and the AMPC. This talk introduces the research and technological breakthroughs from this collaboration.

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## What is the next level sensing provenance?

Assoc Prof Daniel Cozzolino<sup>1</sup>, Professor Louw Hoffman<sup>1</sup>

<sup>1</sup>The University of Queensland - Saint Lucia Campus, Brisbane, Australia

The definition of provenance is of primary importance for the Australian food industry to gain access into international markets. The definition, evaluation and understanding of provenance also provide with several economic advantages to the producers and farmers. The digitalisation of supply and value chains provide with unique opportunities to verify and map the production attributes of products sold on the Australian market or to be exported. The ability to trace food ingredients and foods throughout the supply and value chains can improve transparency and enforce provenance standards, adding value to the foods produced. The longer the journey from origin to shelves and the greater the number of parties involved; the more opportunity exists to commit fraud. Modern, portable, and easy to use sensing technologies provide with a myriad of possibilities to evaluate and trace the composition and safety of food ingredients and foods.



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## Tracing tropical plant domestication using microfossils

Assoc Prof Alison Crowther<sup>1</sup>

<sup>1</sup>*School of Social Science, The University of Queensland, St Lucia, Australia*

Tracing the domestication of plants presents unique challenges for archaeologists working in the tropics. Here, the variety of taxa brought under human control are often vegetatively propagated and therefore cannot be studied using the same approaches as applied to sexually reproduced crops. Archaeologists are hindered further by the generally poor preservation of remains of these plants in the archaeological record. As a result, major gaps remain in our understanding of the domestication trajectories of some of the world's most important food crops, including bananas and plantains (*Musa cvs*), sweet potato (*Ipomoea batatas*), yams (*Dioscorea* spp.) and taro (*Colocasia esculenta*), among others. Plant microremains, including starch granules and phytoliths, have been championed by tropical archaeobotanists for the last three decades as holding the key to unlocking the domestication histories of tropical crops. This paper will provide an overview of recent efforts to mature this approach and identify areas where future attention should be focused.

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## Establishing a virtual, on-line database of archaeological parenchyma for IndoPacific root crops

**Ms Aleese Barron<sup>1</sup>**

<sup>1</sup>*School of Archaeology and Anthropology, Australian National University, Canberra, Australia*

Archaeobotanical evidence for the exploitation of vegetatively-propagated root crops and vegetables in the Indo-Pacific region is currently limited. Systematic application of identification methods for vegetatively-propagated crop species utilising charred, desiccated or waterlogged remains of parenchymatous tissue is not currently undertaken on a regular basis due to a lack of expertise, the complexity in achieving species-level identifications as well as limited access to comprehensive reference collections. To address these issues, microCT imaging technology at the ANU CTLab has been used to compile a three-dimensional virtual reference collection of parenchymatous tissues for key plant species known to have been extensively cultivated by people in the region. The reference collection seeks to capture not only inter-species differentiation but also the intra-species morphological plasticity characteristic of many tuberous root crops. This collection is intended to substantially increase the rate of taxonomic determinations for parenchymatous fragments extracted from archaeological contexts in the Indo-Pacific region.

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## The identification of tropical arboriculture in Oceania using wood charcoal

**Ms Alexandra Ribeny**<sup>1</sup>, Dr. Emilie Dotte-Sarout<sup>2</sup>

<sup>1</sup>*School of Archaeology and Anthropology, Australian National University, Canberra, Australia,* <sup>2</sup>*School of Social Science, University of Western Australia, Crawley, Australia*

A growing body of research acknowledges the central role of arboriculture in prehistoric tropical subsistence practices, especially in the Indo-Pacific region. Within Mainland Southeast Asia, where the retrieval and analysis of archaeological plant macro-remains has remained relatively constrained around cereal-based agricultural signatures, a commensurate archaeobotanical record is still in development. Anthracology, the study of wood charcoal macro-remains, has significant potential to reconstruct historical anthropogenic vegetation change, including tree crops management. However, owing to issues of taxonomic diversity and the limited availability of reference material in the tropics, it remains significantly underutilised in Mainland Southeast Asia. This talk will use recent examples of the application of anthracology in Island Southeast Asia and the Pacific, to demonstrate the potential of wood charcoal analysis to investigate historical arboricultural practices. It will be argued that this demonstrates anthracology's potential to investigate the history of arboriculture within the context of Mainland Southeast Asian archaeology.

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## Tracking the domestication and dispersal of banana cultivars: New insights from phytoliths

**Dr Luc Vrydaghs<sup>1</sup>**, Prof Em Edmond De Langhe<sup>2</sup>, Dr Xavier Perrier<sup>3</sup>, Dr Christophe Jenny<sup>3</sup>, Dr Tim Denham<sup>4</sup>  
<sup>1</sup>Multidisciplinary Archaeological Research Institute (MARI) VUB, Brussels, Belgium, <sup>2</sup>Katholieke Universiteit Leuven (KUL), Leuven, Belgium, <sup>3</sup>CIRAD, UMR AGAP, Montpellier, France, <sup>4</sup>Tropical Archaeobotany Research Group, School of Archaeology and Anthropology, RSHA, ANU, Canberra, Australia

A reasonably coherent reconstruction has been achieved for the domestication of banana cultivar groups and its global spread in the tropics. This historical reconstruction is based on genetics, linguistics and botany (Perrier et al. 2001). It lacks grounding in chronological data which only archaeology can provide. Since the vegetative propagation of this seedless crop is linked to human dispersals, firm chronological information on the banana dispersal would deliver major contributions to the reconstruction of the relevant human history.

Phytoliths are primary archaeological traces of the *Musa* plant. Their very low presence in many archaeological records is striking, sometimes in seeming contradiction to other lines of evidence. The scarcity in identified fossil *Musa* phytoliths is nearly global, but particularly pronounced in Africa.

The relatively low frequencies of banana phytoliths in archaeological contexts and even in samples from recently cultivated plots needs to be investigated before one can firmly conclude on the presence or absence of *Musa* in a given place at a given time.

Foremost, there is not enough effort to recover phytoliths from archaeological contexts. There is an urgent need to raise awareness among archaeologists and to provide them with suitable investigation protocols.

Secondly, we hypothesize that *Musa* phytoliths may be significantly more prone to deterioration than other phytoliths and/or lost while extracting them from sediments. Little is known about their generation mechanism, the cause and consequences of their unique form, and of their postdepositional taphonomy. Such investigations are essential to understand deficiencies in the archaeobotanical record for bananas, thereby providing the chronological framework for the past geodomestication pathways of banana cultivar groups.

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## Historical dynamics of enset diversity in Ethiopian, integrating archaeobotany, ethnobotany and genomics

Dr Philippa Ryan<sup>1</sup>, Prof Dorian Fuller<sup>2</sup>, Dr James Borrell<sup>1</sup>, Dr Paul Wilkins<sup>1</sup>, Ms Benedetta Gori<sup>1</sup>, Dr Harriet Hunt<sup>1</sup>, Dr Cristina Castillo<sup>2</sup>, Ass. Prof Ermias Lulekal<sup>3</sup>, Ass. Prof Alem Beldados<sup>3</sup>

<sup>1</sup>RBG Kew, London, United Kingdom, <sup>2</sup>UCL, London, United Kingdom, <sup>3</sup>AAU, Addis Ababa, Ethiopia

Ethiopia is potentially Africa's most important centre of crop diversity, characterised by the evolution and domestication of multiple vegetative species. Our project focuses on the major food security crop enset, or "Ethiopian false banana" (*Ensete ventricosum*), a tree-like perennial banana relative. Enset supports some of the densest populations in sub-Saharan Africa and is the staple for 20 million people. It is cultivated over a wide elevational range and ecological gradients, exists at high biomass densities and has a deep cultural association with multiple ethnic groups. A key aim is to address fundamental questions on how the evolutionary history of vegetative agriculture has given rise to contemporary agrobiodiversity patterns, and its relationship to ecological and sociocultural history. This builds on extensive recent research on enset biogeography and genomics at Kew, which has included documenting hundreds of landraces across the southern Ethiopian highlands. Here, we will summarise key current data on diversity patterns. Then, we will outline our interdisciplinary approach, which integrates archaeobotany, ethnobotany and historical approaches, genomics and biogeography to better understand the long-term development and diversification of vegetative agriculture in Ethiopia. A key component is to bring together evidence from multiple time depths – including modern, represented by current genetic diversity; the recent past, through investigating changes in landrace uses and diversity since the mid-twentieth century; and pre-modern to ancient based on (i) molecular dating techniques (ii) archaeobotanical evidence, through working with partners who are excavating and analysing materials, and by concurrently developing methods for refining identification of enset phytoliths.

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## The archaeobotany of vegetative domestication in the tropics

Prof Tim Denham<sup>1</sup>

<sup>1</sup>*Australian National University, Canberra, Australia*

The early domestication of most vegetatively-propagated plants in wet tropical regions of the world is poorly understood. Here, I outline some conceptual frameworks for comparing the processes of domestication for vegetatively propagated crops with those of better-documented crops, such as cereals and legumes. These frameworks focus on domestication pathways and rates, yet highlight a range of uncertainties, including: conceptual ambiguities of definition, domestication gradients, decentred loci of 'domestication', and temporal imprecision.

In looking to the future, I sketch research strategies for inferring cultivation and vegetative domestication from an oft-elusive archaeobotanical record. This necessitates a somewhat critical evaluation of the lines of evidence that have previously been employed to infer vegetative domestication in the past and how such methodologies can be improved. I conclude by exploring the need for better inter-regional engagement among researchers working in the Amazon, Central Africa and the Indo-Pacific.

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## Banana gene editing technology

Dr Leena Tripathi<sup>1</sup>

<sup>1</sup>*International Institute of Tropical Agriculture (IITA), Dar es Salaam, Tanzania, United Republic of*

Banana is one of the major staple food crops grown in over 136 countries in the tropics and subtropics, with annual global production of around 163 million metric tons, feeding over 400 million people. Several diseases and pests constrain its production in addition to other factors like declining soil fertility and inadequate availability of clean planting material. The use of disease-resistant banana varieties is one of the most effective options to mitigate the negative impacts of pathogens and pests in banana production. Applying precision genetic technologies, including gene editing, can expedite the development of improved banana varieties resistant to diseases and pests by complementing conventional breeding, benefiting small-scale farmers and consumers. CRISPR/Cas9-based gene editing has emerged as the most powerful tool for crop improvement due to its capability of creating precise alterations in plant genomes and trait stacking through multiplexing. The availability of a well-annotated, whole-genome sequence of bananas coupled with robust genetic transformation regeneration protocols makes the banana a strong candidate for gene editing. Recently, the robust CRISPR/Cas9-based gene editing of banana has been established using *phytoene desaturase (PDS)* as a visual marker. The establishment of the CRISPR/Cas9 tool has paved the way for the gene editing application to improve banana for essential traits such as disease-resistant. A synopsis of recent advancements and perspective on the application of gene editing for the improvement of banana will be presented during this symposium. The current status of regulatory requirements for releasing gene-edited crops among different countries will also be briefly described.

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## The potential of commercialization in coconut cloning

**Prof Steve Adkins**<sup>1</sup>, Dr Quang Nguyen<sup>1</sup>, Professor Gabrielle Persley<sup>1</sup>, Dr Sundar Kalaipandian<sup>1</sup>, Mr Glen Boyle<sup>2</sup>, Mr Greg Kennish<sup>2</sup>

<sup>1</sup>The University of Queensland, School of Agriculture and Food Sciences (SAFS), Brisbane, Australia, <sup>2</sup>KokoNiu Group, Toowong, Australia.

Coconut (*Cocos nucifera* L.) is often referred to as “the tree of life” because of its many uses in the food, beverage, medicinal and cosmetic industries. Currently, more than 50% of the world’s palms are senile and need to be replaced immediately to ensure production levels meet the present and increasing demand for these coconut products. Replanting will not be possible using traditional seed propagation methods alone. Recent studies have indicated that *in-vitro* micropropagation *via* somatic embryogenesis is one of the most promising approaches for the large-scale production of new coconut plantlets. This paper describes a process in which the steps of selecting coconut varieties for clonal propagation, the rudiments of the cloning and acclimatization procedures, and the role of the public-private sector in developing process for creating, then delivering clones to farmers. The paper will evaluate the expected potency of such a pathway and discuss the challenges of delivering appropriately selected micro-propagated plantlets to farmers



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## The frozen orchard – securing avocado genetic diversity via cryopreservation

Dr Chris O'Brien<sup>1</sup>, Dr Jayeni Hiti Bandaralage<sup>1</sup>, Dr Raquel Folgado<sup>2</sup>, Dr Alice Hayward<sup>1</sup>, Mr Sean Lahmeyer<sup>2</sup>, Prof Neena Mitter<sup>1</sup>

<sup>1</sup>Centre for Horticultural Science (QAFPI), Australia, <sup>2</sup>The Huntington Library, Art Collections and Botanical Gardens, USA

Recent development and implementation of crop cryopreservation protocols has increased the capacity to maintain recalcitrant seeded germplasm collections via cryopreserved in vitro material. To preserve the greatest possible plant genetic resources globally for future food security and breeding programs, it is essential to integrate in situ and ex situ conservation methods into a cohesive conservation plan. In vitro storage using tissue culture and cryopreservation techniques offers promising complementary tools that can be used to promote this approach. These techniques can be employed for crops difficult or impossible to maintain in seed banks for long-term conservation. This includes woody perennial plants, recalcitrant seed crops or crops with no seeds at all and vegetatively or clonally propagated crops where seeds are not true-to-type. Many of the world's most important crops for food, nutrition, and livelihoods, are vegetatively propagated or have recalcitrant seeds. This review will look at ex situ conservation, namely field repositories, and in vitro storage for some of these economically important crops, focusing on conservation strategies for avocado. To date, cultivar-specific multiplication protocols have been established for maintaining multiple avocado cultivars in tissue culture. Cryopreservation of avocado somatic embryos and somatic embryogenesis have been successful. In addition, a shoot-tip cryopreservation protocol has been developed for cryo-storage and regeneration of true-to-type clonal avocado plants.

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## Let's toast – avocado tissue culture goes commercial

**Dr Jayeni Hiti Bandaralage**<sup>1</sup>, Dr Chris O'Brien<sup>1</sup>, Mr Graham Anderson Jr<sup>2</sup>, Mr Graham Anderson Sr<sup>3</sup>, Dr Alice Hayward<sup>1</sup>, Dr Madeleine Gleeson<sup>1</sup>, Prof Neena Mitter<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Indooroopilly, Australia, <sup>2</sup>Anderson Agriculture Engineering & Consultancy, Duranbah, Australia, <sup>3</sup>Anderson Horticulture Pty Ltd, Duranbah, Australia

'Avocado boom' is sweeping across the world with an exponential increase in demand for 'Green gold'. Over the last decade the world's production has more than doubled by nearly doubling avocado cultivated area. The conventional orchards practices are shifting towards high-density or ultra-high-density orchard systems aiming to maximise production capacity. This means increased demand for plants and increasing pressure on traditional propagation capability.

Avocado is a grafted orchard tree composed of an elite rootstock and a compatible scion to obtain the most productive, pest and disease tolerant and climate fit trees that can produce quality fruits of consumer preference. Clonal rootstock propagation is the rate limiting and the most critical step to obtain true-to-type plants from elite rootstocks. The conventional rootstock propagation adopts a 50-year-old method, which is now challenged by the high demand for planting material around the globe.

Exploiting the totipotency of plant cells, for the first time a high throughput tissue culture-based propagation system has been developed to efficiently propagate avocado rootstock. This technology eliminates many challenges in conventional clonal propagation system; dependency of seedlings and large volumes of budwood, grafting of rootstock budwood and etiolation conditions. The technology permits year-round propagation of disease-free rootstocks in comparatively small area. Field evaluation of grafted and ungrafted rootstocks have proven the genetic fidelity and superior fruit production compared to seedling and conventional clonal rootstocks. The technology has now been commercialised for faster and efficient rootstock production impacting the whole supply chain of this industry.

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## Regeneration of naked cells: a reliable protoplast regeneration platform for *Duboisia* species

**Mr Yuxin Xue**<sup>1</sup>, Dr. Jayeni Hiti Bandaralage<sup>1</sup>, Prof. Neena Mitter<sup>1</sup>

<sup>1</sup>Centre for Horticultural Science, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Brisbane, Australia

*Duboisia* is an Australian native in the family Solanaceae. It is the best leaf source for commercial scopolamine extraction, an active ingredient vital for pharmaceutical industry. Australia leads the global supply of *Duboisia* leaves with a value of AU\$100 million. Today's commercial breeds record 6% scopolamine by dry weight, but the scope for development is massive considering the increasing global demand for scopolamine and other important alkaloids produced naturally in this species.

Protoplast technology in the pace of *in vitro* culture has been deemed a significant and valuable technique. Its applications include mixoploid/polyploid development, conventional genetic engineering as well as the most novel gene editing technology. A reliable protoplast isolation and regeneration system require careful optimisation of various factors to maintain the viability and renderability of cells. Previous work on *Duboisia* protoplasts is only confined to cells from suspension culture, where there is a high risk of induced somaclonal variation due to rapid cell division under high hormone regimes.

Mesophyll cells for protoplast preparation will eliminate the above problems, but regeneration of plants from mesophyll derived protoplast is well known to be a great challenge. This study aimed to establish an efficient protoplast system using leaf tissues to avoid the high risk of mutation with greater efficiency. For the first time a reliable protoplast isolation and regeneration system was developed using mesophyll cells of *Duboisia* spp. High viability, successful micro callus formation and intact plant regeneration was achieved. This innovation will contribute toward the advancement of this valuable industry.

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## Plant tissue culture: An under-estimated tool in plant production systems

Mrs Sharon Hamill<sup>1</sup>

<sup>1</sup>*Department of Agriculture and Fisheries, Coes Creek, Australia*

Plant tissue culture plays multiple roles in ensuring sustainable and reliable production systems in both established and emerging plant industries. Plant tissue culture is an important tool used in all aspects of the plant production cycle.

Plant tissue culture systems play an important role in breaking disease cycles in industries with established or emerging pathogens by providing clean planting material. Virus indexed tissue cultured plants allow for safe global movement and access to germplasm for improved and disease resistant cultivars.

Although tissue culture plants are grown in sterile media consideration must be made to indexing tissue culture plants to ensure they are free from pathogens such as viruses, phytoplasma and bacteria. Indexing is also important to identify non-pathogens to improve tissue culture production efficiency and for research applications such as cryopreservation and germplasm collections. Tissue culture is also used to eliminate pests and pathogens. Plant tissue culture is important in plant improvement and development of new cultivars, both directly (mutation breeding, inducing polyploidy, virus elimination) and indirectly (polyploid parents from improved diploids in breeding programs, embryo rescue, rapid multiplication of breeding selections, molecular biology to improve cultivars).

Moving forward plant tissue culture will play an increasingly important role in a wider range of applications such as bioreactor production systems to produce valuable food, industry and health products. Some relevant examples used in horticultural crops will be briefly discussed.

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## Molecular work on developing citrus varieties with preferred flavonoids profiles

**Prof/Dr Juan Xu<sup>1</sup>**, Dr. Jiajing Chen<sup>1</sup>, Dr. Zhaoxin Peng<sup>1</sup>, Mr. Ziyu Yuan<sup>1</sup>

<sup>1</sup>Key Laboratory of Horticultural Plant Biology (Ministry of Education); Huazhong Agricultural University, Wuhan, China

Flavonoids as functional components, have significant impacts on sensory qualities, consumer health, and play important roles in resisting various stresses. Citrus fruits are rich in flavonoids, especially the branch products of flavanones and polymethoxyflavones (PMFs), which are the main effective components of traditional citrus medicines. Citrus flavanones include bitterness neohesperidoside and non-bitterness rutosides, while PMFs are normally with bitter taste. However, the molecular mechanisms and branch biosynthetic pathways of citrus flavonoids have not yet been systematically elucidated. Therefore, this study combined forward and reverse genetics, molecular biology, bioinformatics, metabolomics with transcriptomic analysis to mine and locate flavanones and PMFs biosynthesis-related candidate glycosidase genes and *O*-methyltransferase genes (*OMTs*). The main results are as follows:

1. Comparative profiling and natural variation of flavonoids in various citrus germplasms revealed that citrus could be divided into 4 groups based on flavanones profiles, while PMFs' accumulation is a phenotype inherited from mandarin ancestors which might be a dominant trait in the natural citrus germplasms.
2. Mining and functional characterization of PMFs biosynthesis-related genes by using *Saccharomyces cerevisiae*, *Escherichia coli* and citrus calli over-expression systems, helped to preliminarily constructed the metabolic pathway of *de novo* synthesis of PMFs from apigenin in 'Red tangerine'. Meanwhile, we also screened transcription factors correlated with PMFs biosynthesis.
3. Bulk Segregation Analysis was successfully applied to locate the key genes involved in citrus flavanones and PMFs biosynthesis.

The study will help to formulate future citrus breeding strategies to produce new germplasm with predictable fruit qualities related with flavonoids.

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## The importance of fruit sensory quality – an industry perspective

### **Mr Michael Tatlock<sup>1</sup>**

<sup>1</sup>Perfection Fresh Australia Pty Ltd, Australia

Why is sensory fruit quality so important?

From a commercial perspective, the key to creating a category defining product, is to not only develop good looking, tasty fresh produce, but ensure it tastes **great** consistently.

Developing a product that exceeds expectations and reliably delivers exceptional 'taste' is the key to unlocking the repeat purchase – “the holy grail” for food and beverage marketers.

Building consistency takes a whole of business approach. Its starts with listening closely to consumers and defining the market. Once understood, Perfection Fresh partner with passionate growers that take pride in striving for excellence.

To supply produce that consistently delights the taste buds requires:

- Utilising fundamental agronomic principles to nourishing the perfect crop
- employing pre- and post-harvest technology to enhance its sensory attributes
- rigorously measuring and monitoring to ensure optimal handling during every step in the supply chain
- development of a dedicated team that “Lives and Breathes” successful delivery to market
- building strong relationships with customers to ensure the product reaches the consumer at its best
- analysing consumer insights to continuously improve the consistency and predictability of the sensory experience
- deliver a strong marketing campaign to entice new consumers to try Calypso

The reward for understanding your consumer and delivering on that promise to reliably exceed sensory expectations last season made Calypso the leading mango variety gaining 730, 000 new households.

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## Profiling the flavour of Australian papaya (*Carica papaya* L.) varieties

**Ms ZiWei Zhou<sup>1</sup>**, Professor Rebecca Ford<sup>1</sup>, Dr Ido Bar<sup>1</sup>, Dr Chutchamas Kanchana-udomkan<sup>1</sup>

<sup>1</sup>Griffith University, Brisbane, Australia

One of the major challenges to expanding the Australian papaya industry is inconsistency in fruit flavour. Commercial papaya varieties grown in Australia vary greatly in taste and aroma. The industry to date has not purposefully incorporated consumer preferences. Meanwhile, through prior profiling, there are several 'off tastes' present in current varieties that exclude a proportion of the population as papaya consumers. Therefore, to drive preferred flavour as a key breeding objective, a better understanding of the genetic mechanisms and biosynthesis pathways underpinning preferred flavours was undertaken. Specifically, this study included the identification of preferred papaya flavour profiles using a trained sensory panel, and the expression levels and patterns of related sweetness and volatile compounds. To uncover a suit of genes related to the consumer preferred flavours, whole RNA sequencing followed by *de novo* genome assembly was performed on extreme flavoured papaya varieties RB1 (preferred with sweet flavour and floral aroma) and 1B (non-preferred with bitter flavour and musty aroma) fruit at ripe and unripe stages. In total, 180,368 transcripts were annotated, and 5,191 genes were differentially expressed between the two varieties at the ripe stage. Eight candidate genes related to sugar (*cpBGLU42*, *cpBGLU31*, *cpBGH3B*, *cpPFP* and *cpSUS*) and volatile (*cpGES*, *cpLIS* and *cpBAO*) metabolism pathways were validated through qPCR. These genes are proposed as major metabolic switches in sugar transport, sucrose metabolism and aromatic compound production pathways and will be further investigated for use in future selective breeding strategies through assessment in broader germplasm and growth environments.

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## Tropical fruit - using key aroma components as predictors of sensory quality

Mr Jenson George<sup>2,1</sup>

<sup>1</sup>DAF, Brisbane, Australia, <sup>2</sup>QAAFI, Brisbane, Australia

Pineapple (*Ananas comosus*) is one of the most popular tropical fruits consumed worldwide. The flavourful fruit is known to contain a large number of aroma volatile compounds in varying levels. Though, hundreds of volatile compounds have been identified so far, only several of them (known as key aroma compounds) are reported to contribute to the unique flavour of pineapple. Huge attention has been applied to the deeper and specific understanding of the aroma profile of pineapples that play a significant role in the sensory notes of the fruit. The Queensland Alliance for Agriculture and Food Innovation (QAAFI) - Queensland Department of Agriculture and Fisheries (QDAF) joint research project, funded by the Hort Innovation Australia, titled as Genetics of fruit sensory preferences, aims to identify and characterise key quality-determining flavour compounds in Queensland grown pineapple from the DAF breeding program, and to develop high-throughput analytical methods [based on stable isotope dilution assay (SIDA) – headspace (HS) - Solid phase microextraction (SPME) - gas chromatography - mass spectrometry (GCMS)] to measure those key components accurately and precisely. This knowledge will be applied to profile key parent and progeny lines to support identification of molecular markers and support marker-assisted breeding. Results of the work are essential for the improvements in genetic studies, plant breeding, resistance research, nutritional science to develop superior fruit varieties with high consumer appeal and improved characteristics for producers. The presentation aims to discuss the available published information of the aroma of pineapple, analytical methods, associated challenges, and strategies.



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## Fruit quality: Do we know what consumers want?

Assoc Prof Heather Smyth<sup>1</sup>

<sup>1</sup>The University of Queensland, Indooroopilly, Australia

While production traits of horticultural produce are generally easy to define, consumer quality traits are typically more challenging to characterise, and are often overlooked when breeding new commercial cultivars. Typically, consumer quality is described in relatively coarse terms – sugar and acid levels, skin characteristics, flesh colour, and texture or firmness. Overall flavour may or may not be considered, regardless this is often evaluated by field-staff rather than by consumers under controlled tasting conditions. While these may broadly describe fundamental aspects of fruit characteristics, each is made up of a unique balance of flavour and aroma compounds, colour pigments and internal structures that together define the consumer experience. Further, not all consumers value the same fruit quality parameters equally, and the complexity of market segmentation is an aspect usually ignored during plant breeding efforts. Clearly there is room for improvement. This presentation will provide an overview of what we know about consumer preferences for fruit quality parameters and outline a pathway to bridge the gap between plant breeding efforts and meeting consumer expectations.

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## The role of inclusivity in technologically-driven innovation processes in Australia

Dr Simon Fielke<sup>1</sup>

*Commonwealth Scientific and Industrial Research Organisation (CSIRO), Queensland, Australia*

Traditionally, innovation processes have been rather secretive, protected by patents, intellectual property legislation and caution over sharing private information that may create value for private organizations. Increasingly, such innovation processes are inadequate to address grand challenges (climate change, pandemics, etc.) facing modern societies. As such inclusivity of broad and diverse stakeholders within innovation processes has been argued to address the temporal and equitability issues of a traditional approach to innovation. Fostering and contributing to innovation (eco)systems has become central to public and private organizations quests to attract global talent, capital, and prestige.

*What is the role of diverse stakeholders in such innovation processes?*

In short, this depends. National, sectoral, and organizational stakeholders and their shared cultures are dealing with a transition from innovation processes and responsibilities of the past as they evolve into current and future innovation systems.

*Digitalisation as an opportunity to build more inclusive innovation processes - examples from Australia*

This presentation will provide multiple examples of digital technological innovation processes (ie apps, web interfaces, internet of things sensors, etc.) involving Australian research and development organizations and diverse networks of stakeholders that invest in, develop, deploy, use, and obtain value from such development processes.

*Accessibility and literacy considerations of digital divides*

Finally, the presentation will conclude with notes of caution to consider when investing in such collaborative innovation, with reference to digitally enabled technologies and processes that require ongoing 'capacity building' as part of innovation systems of the future.

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## View from the field: Co-innovation with small-scale Farmers

Dr Bruno Condori Ali

*<sup>1</sup>Inter-American Institute for Cooperation on Agriculture, Bolivia, Plurinational State of*

Farmers' knowledge is a crucial component of local research and continuum applied innovation in global agriculture. Where research is developed by the scientific community, it should complement and strengthen this knowledge. This is much more preponderant and dynamic in environments of mega diversity of species, environments and cultures coexisting in a territory and with continuous adaptation over time. Farmers and indigenous populations have mostly practiced a holistic vision of the way to improve their productive conditions, respecting nature through the use and recognition of natural resources, which could be legally institutionalized. For example, as a result of these local efforts, Bolivia has led the recognition of mother earth rights (071 National Law) and promoted the sovereignty of knowledge through the rescue of ancestral knowledge to meet demands of the peoples in harmony with their environment. As such, Bolivia is one of the promoting countries for international acknowledgement of this vision through the UN, admitted after April 22 as the international day of mother earth. This thrust towards public advocacy from a bottom-up perspective or from the local to the national is effective for including multi-actor and multi-sector inclusive development in innovation plans and programs. However, despite the progress in demand from farmers, including national and international declarations, there is still a need to reduce gaps regarding access to locally and timely adapted technology, information, knowledge, and intergenerational dialogue, which can strengthen effective inclusion in social, economic and cultural terms. In practice, participatory research promoted by various institutions has shown progress in innovation development by combining local and modern knowledge. This effective dialogue of visions of development can reduce innovation generation periods in conditions of social, economic, and environmental pressures, strengthening the productivity and sustainability of local production systems. Some final reflections are: recognition of farmers' knowledge and practices; dissemination of farmer innovations; facilitating the dialogue among all actors involved in agricultural innovations; and incorporating agricultural technology with local knowledge, would improve the odds to success of joint efforts and actions.

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## Co-creating sustainability: Innovation in Sustainable Agrifood Systems

Dr Alyssa Jade McDonald-Baert<sup>1</sup>

<sup>1</sup>*Consultative Group on International Agricultural Research (CGIAR), Germany*

UN FAO and WEF have called for 1% of food-related GDP to be invested in innovation. What are the institutional perspectives to ensure it is inclusive, socially responsible and sustainable?

While agri-food systems have delivered staple crop yield increases over the last decades, it has not reduced global nutritional deficits or environmental degradation, nor improved farmer livelihoods. While 30% of greenhouse gases, 70% of freshwater and 80% of tropical deforestation are attributed to global ag, it may be the only sector which can genuinely produce its own environmental and social improvement. Opportunity exists for ag-science to co-create new ideas, products, services, and solutions; introduced and scaled by an interlinked set of individuals, processes, assets, and institutions. Fostered systems transformation, inclusive by nature, stimulates goal-driven action, and addresses emerging trends and power (and imbalances). Siloed research organizations tended to 'push' endeavors, rather than 'pull together' the ecosystem. Good practices exist which combine (g)locally scaled practices and co-created socio-technical innovation bundles which can reduce negative tradeoffs. Multi-stakeholder platforms can interact with innovation platforms via Farmer Research Networks and facilitate Participatory Innovation Development.

Evidence suggests that a high degree of diversity among contributor can nourish a fertile environment for new ideas. Beyond gender, ethnicity, (dis)ability and neurodiversity, what role does non-human diversity have? Eg. Animal rights, environmental justice and AI rights of technology.

Our institutional capacity, (i.e., value-driven, authentic leadership) to overcome the current challenges and future scenarios will depend on our capacity to grapple with 'do no harm' principles, agile programming and iterative design to redesign interventions.

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## The efficiency of inclusive partnerships for agriculture international development innovation in limited-resource

Dr. Melinda R.S. Moata<sup>1</sup>

<sup>1</sup>*State Agricultural Polytechnic of Kupang, Kupang, Indonesia*

As the second Sustainable Development Goal (SDG), End hunger, achieve food security and improved nutrition, and promote sustainable agriculture must be achieved in all countries, including those with limited resources. The Hexahelix collaboration (including academics, the government, the private sector, farmers, non-governmental organizations, and the media) has acted as an example of inclusive cooperation in Indonesia's resource-constrained region. This model will facilitate product innovation for sustainable agriculture: the needs and problems of the community will be studied by academics in collaboration with the private and public sectors, implemented and supervised by non-governmental organizations and graduates, and promoted through the media. A strategy for inclusive innovation is a research cooperation between academia and industry or government to solve an issue in the community or industry, including the sharing of resources. The research must develop a business model and result in a teaching factory or product sold by micro-enterprises and smallholder farmers to the community. In addition to research, tailor-made training collaboration across stakeholders is a strategic initiative to increase agricultural extension capacity building prior to training for front-line farmers. Moreover, inclusive social partnership (social capitals) has demonstrated positive effects for women in building a food resilience system, particularly during crises, in order to achieve food security and nutrition needs.

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## Inclusive Partnerships for One CGIAR

**Dr Nompumelelo Obokoh<sup>1</sup>**, Prof Fetien Abay Abera<sup>2</sup>, Prof Magali Garcia<sup>3</sup>, Prof Holger Meinke<sup>4</sup>, Dr Christine Negra<sup>5</sup>, Ms Allison Grove Smith<sup>6</sup>

<sup>1</sup>Board of the National Research Foundation (NRF); CGIAR Independent Science for Development Council, Pretoria, South Africa, <sup>2</sup>Mekelle University, Ethiopia, <sup>3</sup>Faculty of Engineering, Universidad Mayor de San Andres, Bolivian Plurinational State of, <sup>4</sup>University of Tasmania, Australia, <sup>5</sup>Versant Vision LLC, New York, United States, <sup>6</sup>CGIAR Advisory Services (CAS) Secretariat, Italy

The Independent Science for Development Council (ISDC) is a standing panel of impartial, world-class scientific experts providing rigorous, independent advice to the CGIAR System Council and stakeholders. Building on earlier work, ISDC embarked on a literature review and expert consultations (N = 13) to examine existing inclusive innovation systems; validated strategies for navigating trade-offs, advancing inclusivity through partnerships, and fostering mindset and behavioral shifts through institutional changes; and mechanisms for measuring the practice and impact of inclusive innovation. As CGIAR implements its new Engagement Framework for Partnerships and Advocacy, internal and external research leaders must be more complexity-aware and integrated within wider development and systems change agendas. For One CGIAR partners, this includes balanced emphasis on partners across agricultural communities, multi-scale value chains, and public-private R&D networks. The review and consultations identified the following five key partnership strategies.

1. Analyze the functioning of network-based partnerships including knowledge creation and exchange, institutional collaboration and capacity for local differentiation
2. Assess the operations of public-private partnerships including their influence on innovation system
3. Invest in higher-quality partnerships including effective facilitation, dedicated support, linkage to broader development efforts and performance assessment
4. Increase the duration and scope of partnerships to accelerate the likelihood of innovations scaling beyond a niche level
5. Steer partnership strategies informed by more robust assessment of their functions and performance.

Although the literature review and consultation outcomes provided broad recommendations for inclusive partnerships, what is missing is how can these recommendations be strengthened for research for development organizations similar to CGIAR.

Keywords: research 4 development; technology; leadership; agricultural innovation; partnerships

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## Surveillance of emerging animal diseases in lower income countries - USAID's role

Dr Robert Bertram<sup>1</sup>, Dr. Angela Records<sup>1</sup>, Dr. Tyrell Kahan<sup>1</sup>

<sup>1</sup>United States Agency for International Development (USAID), Washington, USA

**The Disease Sentinels** symposium aims to identify how animals (and other indicators) can be better used as “disease sentinels”, to enable the early detection and rapid response to outbreaks of emerging infectious diseases in animals, to help minimize economic impacts that threaten livelihoods and food security. These sentinels also provide opportunity for early prevention of spread to other species, including humans. Identifying and managing these risks are integral to “One Health” concept.

*What are “disease sentinels”?* These include monitoring for signals in wildlife and farm animals that can act as carriers of emerging infectious (zoonotic) diseases, which can then be transferred from wildlife or livestock to people; disease vectors including insects and birds; E-Signals indicating changing (human) behaviour (e.g. social media); environmental signals (e.g. excessive rainfall); sensors on animals to detect temperature changes as a sign of infection. USAID is also leveraging the “One Health” approach to integrate sentinel and early warning systems for plant disease and pests; the architecture can in some cases be shared in ways that offer additional input to sentinels related to animal health.

The aim is to provide timely information on pathogen prevalence and disease outbreaks in animals that will alert biosecurity, veterinary and public health authorities to potential outbreaks of human infectious diseases. More effective ways to *predict, detect* and *respond* to signals of early disease incidence in animals would be more efficient for disease control thus and more effective in reducing the risks and the social and economic costs of human disease epidemics.

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## African Swine fever (ASF) - Unintended consequences of the disease

Professor Claire Turker, Dr Anna Fagre, Dr George Wittemyer, Dr Tracy Webb, Dr Edward Okoth, Professor Sue VandeWoude

<sup>1</sup>*International Livestock Research Institute Nairobi, Nairobi, Kenya*

African Swine Fever (ASF) was reported in domestic pigs in China in 2018. This highly contagious viral infection with no effective vaccine reached pandemic proportions by 2019, substantially impacting protein availability in the same region where the COVID-19 pandemic subsequently emerged. We discuss the genesis, spread, and wide-reaching impacts of this epidemic in a vital livestock species, noting parallels and potential contributions to ignition of COVID-19. We speculate about impacts of these pandemics on global public health infrastructure and suggest intervention strategies using a cost: benefit approach for low-risk, massive-impact events. We note that substantive changes in how the world reacts to potential threats will be required to overcome catastrophes driven by climate change, food insecurity, lack of surveillance infrastructure, and other gaps. A One Health approach creating collaborative processes connecting expertise in human, animal, and environmental health is essential for combating future global health crises.



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## Diagnostic assay use in detecting emerging infectious diseases in sentinel animals

Dr Philip Teye<sup>1</sup>

<sup>1</sup>International Livestock Research Institute, Nairobi, Kenya

A key issue in the use of livestock and wildlife to act as sentinels for emerging infectious diseases (EIDs) is the availability and use of diagnostic assays. Timely use of such assays can confirm the presence and nature of pathogens in suspected outbreaks or in ongoing surveillance, allowing a more rapid and targeted response to reduce the risk of outbreaks developing into major epidemics. Such assays are also essential to determine the spread of disease, to guide interventions options and to confirm disease elimination. To be optimally deployed, assays need to be accurate, accessible, affordable and amenable for use on relevant samples from livestock, wildlife and pathogen vectors.

This presentation will review the role of the 'traditional' diagnostic platforms (including advantages and disadvantages) with emphasis on:

- Laboratory-based assays (e.g. PCR tests and ELISA)
- Point of care/pen-side tests for rapid results (e.g. antigen tests for large scale screening)

In addition, the use of diagnostic assays based on recent technological advances will be discussed, These include:

- Rapid, *in situ* genomic assays for more accurate typing at the sub-species level (e.g. nanopore sequencing technology)
- Mass surveillance with easy-to-use, affordable, home-based kits
- The integration of diagnostic assay technology with wireless communication technology
- Novel sampling methods especially in wildlife, e.g. faecal sampling for haemopathogens
- Remote sensing devices on animals to monitor clinical signs such as temperature rises.

Finally, the potential use of rapidly deployed, mobile laboratories for areas of limited infrastructure will be discussed.

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## How science can drive policy in the management of epidemics

Prof Martyn Jeggo<sup>1</sup>

<sup>1</sup>Geelong Centre for Emerging Infectious Disease, Deakin University, Corlette, Australia

This presentation will examine how science has been used to develop policies in the management of epidemics. It will also examine why this did not always occur with the response to the Covid pandemic. It will highlight the crucial link between sound science and policy setting as a basis for effective operational activities. As an example, an examination of rinderpest global eradication demonstrates that getting the science right was crucial to developing the OIE rinderpest pathway. This document guided national and international policies that led to successful global eradication. In Australia to better manage the risks to livestock from an epidemic disease incursion, a series of science-based emergency response plans have been developed that not only describe the disease and its diagnosis but guide the response. This has enabled key policies to be developed, including crucially a cost sharing arrangement. These pre-emptive processes did not characterize the response either national or globally, to the recent Covid pandemic. Several factors contribute to this but included a failure to ensure that good science always underpinned the policies that were developed during the pandemic. A compounding factor has been a failure to effectively adopt a One Health approach to managing zoonotic events, including Covid. Merging science from many different disciplines, including both social and climate science will be crucial in developing policies to effectively manage the risks from future pandemics, whether in animals or humans. A process for adopting this One Health approach will be described.

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## AMR in Pacific Island Countries: current status, challenges and strategic solutions.

**Dr Royford Magiri<sup>1</sup>**, Ms Sharon Gaundan<sup>1</sup>, Ms Shivani Singh<sup>1</sup>, Dr Walter Okello<sup>2</sup>, Prof Paul A. Iji<sup>1</sup>  
<sup>1</sup>Fiji National University, Suva, Fiji, <sup>2</sup>Commonwealth Scientific and Industrial Research Organization, Canberra, Australia

Antimicrobial resistance (AMR) is currently recognized as a major emerging threat to human and animal health. Globally, there is rapid rise in AMR on both human and veterinary medicine. In Fiji, AMR profiles are poorly documented and limited data is accessible. Fiji currently has no national veterinary antibiotics resistance surveillance network or regulations and guidelines on veterinary drug use. However, information from available literature indicates that although human drugs are better managed than the veterinary drugs, the knowledge is still limited and dispersed. The current Australia Centre for International Agricultural Research (ACIAR) funded AMR project is aimed at addressing some of the gaps in managing AMR in the region. The project is the first to adopt the One-Health approach to research into AMR in humans, animals and the environment in the Pacific region.

Combating AMR requires that human health and veterinary personnel work with all other stakeholders. Therefore, there is a need to educate farmers, human patients and the general public on the fight against AMR. Further, AMR data are necessary to aid in development of effective AMR control strategies.

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## Investigation of foodborne illness outbreaks linked to fresh produce

Dr Craig Shadbolt<sup>1</sup>

<sup>1</sup>*NSW Food Authority, Newington, Australia*

Within the last 10 years, Australia has experienced five significant foodborne disease outbreaks linked to fresh produce. Internationally there have also been large incidents attributed to horticultural commodities. New food safety regulations to be introduced for the melon, leafy greens, and berry sectors in Australia will help to address food safety on farm. However, significant challenges still exist in outbreak mitigation and investigation. Severe weather events (floods, droughts, fires) linked to a changing climate increase the likelihood of significant contamination and pressure on supply chains. Outbreaks linked to fresh produce may also take several days to be detected and linked to a food commodity, even with major advances in microbiological diagnostics and analysis, such as genomic sequencing. Traceability is improving thanks to the introduction of 2D barcoding, but this will take some time for adoption across supply chains, leading to gaps in rapid tracing of an outbreak to a potential source. Finally, there are major benefits to be realised from adoption of digitised incident response platforms in food safety, and established information sharing agreements between government and industry bodies to improve coordination and trust during an outbreak.

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## Primary production and processing standards for horticulture

Mr Brian Witherspoon<sup>1</sup>

<sup>1</sup>*Safe Food Production Queensland, Greenslopes, Australia*

With three new horticulture standards recently gazetted for inclusion in the Food Standards Code, this presentation will (a) provide an overview of the new standards, (b) outline how States and Territories are working together to implement the standards in a consistent and cost effective manner, and (c) how Safe Food Production Queensland plans to ensure the standards are implemented in Queensland in a way that supports best practice food safety management through the supply chain for the benefit of both consumers and industry while maximising the use of existing data/information gather by industry monitoring schemes.

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## Enabling food safety compliance in the fresh produce industry

Dr Sukhvinder Pal (SP) Singh<sup>1</sup>

<sup>1</sup>*NSW Department of Primary Industries, Ourimbah, Australia*

Supplying 'safe' fresh produce to consumers is fundamental for the sustainability and profitability of the horticulture sector. The foodborne illness outbreaks linked to fresh produce cause substantial economic losses to the industry and undermine the confidence of consumers and regulators in the affected produce category. Currently, the Australian produce industry is non-regulated and dependent upon volunteer food safety schemes. However, there is increasing pressure to regulate the fresh produce industry to mitigate food safety risks. As a result, some regulatory measures for the selected produce (berries, melons and leafy vegetables) are imminent in Australia. This presentation will provide an overview and insights into the research and adoption strategies that are currently being implemented to improve food safety systems in the industry. The opportunities and challenges in enhancing the compliance of the industry to food safety schemes and forthcoming regulatory measures will be discussed from the growers' and packers' perspectives. The role of food safety surveillance, industry practice monitoring and outreach to minimise food safety microbial hazards will also be elaborated. The presentation will highlight the importance of proactive and multipronged approaches in enabling food safety compliance and nurturing a strong food safety culture in the horticulture sector.

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## Improving food safety through enhanced digital traceability in the horticulture sector

**Mr Greg Calvert<sup>1</sup>**

<sup>1</sup>*FreshChain Systems, North Sydney, Australia*

FreshChain Systems is an Australian company that has developed a blockchain enabled end to end traceability, assurance and proof of provenance platform for food and beverage.

Using unique, serialized and encrypted 2D QR codes on labeling we link all levels of packaging to provide instant visibility through the supply chain to identify, capture and share critical information in the event of a biosecurity threat or critical food incident.

Consumers are invited to scan a FreshChain code, leading to rich engagement that educates and builds curiosity around the importance of healthy eating, storage and product use.

Increased trade access, reduced compliance costs and improved data accuracy are delivered through digital transformation including enhanced upstream and downstream traceability and approvals digitisation.

We help share growers sustainability targets, investments and progress with consumers and gain deep insights through on-pack engagement from which decisions can be made to improve the quality offering.

Using bespoke environmental and location sensors linked to serialized shipments, we track and alert on a product's journey against agreed specifications. FreshChain makes visible the chain of custody ownership in real time to mitigate food waste through diversion to inputs if rejection of goods is considered likely.

FreshChains anti-counterfeit measures embedded in the codes protects brands in export markets against food fraud and counterfeit products.

Using ML, FreshChain analytics include quality ratings and comments, freshness index, location scans and repeat purchase, conversion rate, in-app usage and time spent, chain-of-custody movement and comparison of varieties based on location, growing methods and weather patterns.

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## Fresh produce production and supply chain ecosystems

Mr Terry O'Leary<sup>1</sup>

<sup>1</sup>Melons Australia, Chinchilla, Australia

The fresh produce production and supply chain ecosystems are complex, with several risk factors beyond the growers' control. Therefore, it requires a whole-of-the-chain approach to address food safety challenges by adopting best practice across the supply chain and digital traceability to identify and recall the produce rapidly and accurately. Consumers' expectations and regulatory standards for food safety are rapidly evolving to meet emerging challenges. Currently, the Australian produce industry is non-regulated and dependent upon volunteer food safety schemes. However, some regulatory measures for the selected produce (melons, leafy vegetables and berries) are imminent in the future. The upcoming regulatory measures would require increased investments to implement changes in industry practices and manage food safety risks to achieve compliance. Small to medium scale growers would feel additional burden of compliance fatigue, both financially and procedurally. In this presentation, the industry's perspective on how to successfully navigate through the food safety landscape will be presented.



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## Postharvest Sanitiser and Fungicide Interactions and Their Implications on Food Safety

**Miss Joanna Rothwell<sup>1</sup>**, Professor Robyn McConchie<sup>1</sup>, Associate Professor Tina Bell<sup>1</sup>, Professor Dee Carter<sup>1</sup>, Dr Mark Bradbury<sup>1</sup>

<sup>1</sup>ARC Training Centre for Food Safety in the Fresh Produce Industry, School of Life and Environmental Sciences, Sydney Institute of Agriculture, Faculty of Science, The University of Sydney, Camperdown, Australia

Fresh fruit and vegetables are frequently treated with sanitisers and fungicides after harvest to increase shelf life and safety. Sanitisers are used to reduce levels of foodborne human pathogens and to prevent their dispersion in wash water, while fungicide application is used to reduce postharvest spoilage by fungal pathogens. Direct or indirect mixing of fungicides and sanitisers can occur during postharvest treatment, however their compatibility in terms of continued efficacy against relevant microorganisms is not well understood. In the current study, industrial formulations of guazatine- and imazalil-based fungicides used in the postharvest treatment of rockmelons were mixed with peroxyacetic acid- and chlorine-based sanitisers. The physicochemical properties of solutions were assessed, and the antimicrobial efficacy of these combinations were tested against relevant foodborne pathogens; *Listeria monocytogenes*, *Salmonella enterica* and *Escherichia coli* as well as common rockmelon spoilage moulds; *Geotrichum candidum*, *Trichothecium roseum* and *Rhizopus stolonifer*. The addition of fungicides rapidly reduced the concentrations of active components of sanitisers to less than half or to below detectible levels. Most fungicide-sanitiser mixes remained effective against pathogenic bacteria, however the addition of the guazatine fungicide to the chlorine sanitiser led to significantly lowered effectiveness against *S. enterica*. Sanitiser-fungicide interactions for fungal spoilage organisms were unpredictable as antagonistic, indifferent, and synergistic interactions were all observed. Mixing these chemicals compromised fungicidal and antibacterial activity in several instances highlighting the critical need for appropriate agrichemical management in postharvest treatment of fresh produce to maximise food safety and quality.

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## Tree translocation in Aboriginal Australia

Dr Jennifer Silcock<sup>1</sup>

<sup>1</sup>*The University of Queensland /Queensland Herbarium, Charleville, Australia*

While it is well-documented that Australian Aboriginal people altered the composition and structure of vegetation communities through regular burning and engaged in complex food harvesting, processing and storage, the extent to which they intentionally dispersed and propagated plants remains unclear. A review of the ethnographic, archaeological, biogeographic and phylogenetic record reveals sparse but detailed accounts of movement, planting and nurture of important plant species, often involving ceremonial elements. Of the >50 species involved, 20 are trees including the iconic and geographically restricted Central Australian Cabbage Palm, Boab, Bunya Pine and Black Bean. Others are widespread across numerous vegetation types, including Kurrajong, Wirra/Sally Wattle, Quandong and Batswing Coral Tree. Post-contact translocations have also occurred, whereby Aboriginal people have propagated trees in their gardens to maintain connection to important sites and species. In a small area of semi-arid New South Wales, >600 examples of trees and shrubs growing in eucalypt hollows have been documented. While some are the result of bird or wind dispersal, their strong association with Culturally Modified Trees and important camp sites and travel routes suggests that Aboriginal people may have played a direct role in creating this unique epiphyte-rich landscape. It is unlikely that we will ever know the full extent and nature of plant translocations in Aboriginal Australia. However, interdisciplinary approaches combining traditional knowledge, linguistics, ethnography, genetics, archaeobotany, palynology and biogeography hold great promise for understanding human-tree interactions and examining the presumed 'natural' distribution of some of our most iconic trees.

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## Genomic data reveals dispersal of edible rainforest trees by First Nations peoples.

**Mx Monica Fahey**<sup>1,2</sup>, Dr Emilie Ens<sup>1</sup>, Dr Maurizio Rossetto<sup>2</sup>

<sup>1</sup>*Cross Cultural Ecology Lab, Macquarie University, North Ryde, Australia,* <sup>2</sup>*Research Center for Ecosystem Resilience, Royal Botanic Gardens Sydney, Sydney, Australia*

Over millennia, Indigenous peoples have dispersed the propagules of non-crop plants through trade, seasonal migration or attending ceremonies. This has potentially increased the geographic range or abundance of many “wild” edible plant species around the world. Retracing the historical propagule dispersal by Indigenous peoples can yield insights to the long-term demographic and evolutionary impacts of plant translocations and has implications for the plant restoration industry and cultural resource management. In this study, we employed coalescent models with genotyping-by-sequencing (DArTseq) and long-read sequence data to retrace the Indigenous-mediated dispersal of culturally significant rainforest food trees in eastern Australia. We focused on the large-fruited Bunya Pine (*Araucaria bidwillii*) and Black Bean (*Castanospermum australe*), that lack the capacity for long-distance dispersal. The genomic signals in our study species revealed regional variation in human-plant interactions that appear to have shifted under settler-colonialism. With reference to our findings, we consider how “assisted migration” (the movement of a species outside its natural range) and “introductions” (the establishment of new populations within a species’ existing range) may impact the genetic diversity and adaptive potential of dispersal-limited species.

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## Domesticating treescapes – archaeobotanical analyses of macroremains, case-studies from Australia and Pacific

**Ms Chae Byrne**<sup>1</sup>, Dr India Dilkes-Hall<sup>2</sup>, Dr Emilie Dotte-Sarout<sup>3</sup>

<sup>1</sup>University of Western Australia, Perth, Australia, <sup>2</sup>University of Western Australia, Perth, Australia, <sup>3</sup>University of Western Australia, Perth, Australia

Application of archaeobotanical analysis throughout Australia and the Pacific have provided intimate insights into the relationships between past people and the landscape throughout deep time. Three case studies will be presented which explore paleoenvironmental reconstructions of ancient treescapes through the recovery and analysis of archaeological botanic macro remains including fruits, seeds, nuts, and wood charcoal. These studies allow us to discuss how archaeobotanical analyses, especially from macroremains, can be used to reconstruct treescapes dynamics and how past people managed them to flourish in highly diverse regions, even during the most climatically volatile periods of human history.

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## A 20,000 year history of *Canarium* (galip) exploitation from Papua New Guinea

Prof Andrew Fairbairn<sup>1</sup>

<sup>1</sup>The University of Queensland, St Lucia, Australia

*Canarium* is a genus of long-lived rainforest trees that produce oil and protein rich kernels utilised as foods throughout the Old World tropics. Its nuts are protected by a durable endocarp ('nutshell'), particularly well preserved in an identifiable form in charred archaeological deposits, and it is one of the few plants to have a widespread archaeological record in Sahul (the Pleistocene continent of Australia and New Guinea). *Canarium indicum* is widely cultivated across the northern coast of New Guinea and into the adjacent islands, some of which are heavily dependent on it and other tree species for food. It has long been the focus of speculation on its origins and domestication history, with claims of Pleistocene translocation to the islands from New Guinea's mainland. Archaeological evidence now identifies *Canarium* nuts as a key part of the plant foods used by Sahul's tropical residents from its earliest occupation, small fruited *C. australianum* found at Madjedbebe from 65-52,000 BP. The genus is first known in PNG from Manus at 20-21,000 BP, larger fruited forms distinguishable after 12,000 BP, with finds on nearby islands and coast showing it to be present widely after that time. Cultivation and translocation remain difficult to identify, in great part due to the limitations of identifying macrofossil remains. While Pleistocene translocation remains possible, is remains archaeologically unproven and better evidence for lowland coastal translocation and cultivation comes in the early to mid-Holocene when *Canarium* is routinely recovered in association with a range of other well known tree crops.

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## Morphological characterisation of coconut in conserved ex-situ germplasm in Papua New Guinea

**Mr Julius Maot<sup>1</sup>**, Ms Doralie Kadora<sup>1</sup>, Mr Ben Ovenaka<sup>1</sup>, Ms Adolphia Mandem<sup>1</sup>

<sup>1</sup>*Kokonas Industri Koporesen of Papua New Guinea, Madang, Papua New Guinea*

Assessment of genetic diversity is an essential component in germplasm characterization and utilization. In this study, we determined genetic diversity of 39 tall and 12 dwarf coconut (*Cocos nucifera* L.) accessions conserved *ex-situ* from the genebank in Madang Province, Papua New Guinea by using morphometric methods to assess variations in diversity on nut characters. From the sixteen different data-sets, the morphological characteristics assessed was based on fruit component analysis (FCA) over a period of four years (2018-2021). Data was analysed using R-statistics and SPSS statistical package. Phylogenetic tree construction, using Mahalanobis genetic distance revealed that the germplasm fell into five major clusters comprising of 1, 10, 3, 21 and 4 for the tall genotypes, and 3 major clusters comprising of 6, 2, and 4 for the dwarf genotypes. The value of Wilks statistics,  $p=0.03$  ( $p<0.05$ ) showed significant difference between the tall cultivars and for the dwarf cultivars  $p=0.009$  ( $p<0.05$ ) showed significant difference between the dwarf cultivars. The results from this study observed nut characters from the same cluster group has similar relationship to copra and virgin coconut oil (VCO) yields in both tall and dwarf cultivars. Cultivars with bigger nut sizes in the same cluster group indicate high yields of copra and VCO compared to the smaller sizes. Coconut palms genetic diversity assessment based on nut characters quantitatively and qualitatively did show variations amongst the tall and dwarf cultivars respectively.

Key words: Morphological characterization, *Cocos nucifera* L., genetic diversity, cluster analysis, tall and dwarf accessions, FCA.

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## Breeding for flavour and yield in *Theobroma cacao* L

Prof Pathmanathan Umaharan<sup>1</sup>

<sup>1</sup>The University of the West Indies, Cocoa Research Centre, St. Augustine, Trinidad and Tobago

*Theobroma cacao* L., the basis of the rapidly growing global chocolate and confectionary industry, is a tropical tree species originating in the Amazon basin in South America but widely cultivated throughout the tropics and parts of the subtropics. As the growing regions and production systems broaden, and the cocoa market diversifies out into speciality market segments, cocoa faces new challenges both in cultivation as well as in meeting new market demands. Increasing productivity and quality in the face of new challenges and demands, further aggravated by climate change, has been testing cocoa breeders, globally. While the genebanks contain considerable genetic variability for important traits, the breeding programmes have not adequately captured the diversity to develop products to meet various growing niches and markets. Neither have propagation and distribution programmes, ensured deployment of diversity in farmer fields. As the custodian of the largest international cocoa genebank, the Cocoa Research Centre of the University of the West Indies in collaboration with partners has developed an ambitious programme to support breeding, programmes, internationally. The aim is to produce a range of technologies, services and breeding populations to accelerate cocoa breeding to meet the needs of countries and markets that face novel challenges. A case study in identifying genetic variability, genes controlling the traits, building populations and sharing genetic resources globally is discussed. Best practices that have emerged as well as the need for coordinated breeding networks is emphasised.

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## Deconstructing elements of “Terroir” in cocoa (*Theobroma cacao* L.) for niche marketing

Dr Darin Sukha<sup>1</sup>, Dr Naailah Ali<sup>1</sup>, Prof Pathmanathan Umaharan<sup>1</sup>

<sup>1</sup>Cocoa Research Centre, The University of the West Indies, St. Augustine, Trinidad and Tobago

Cocoa (*Theobroma cacao* L.) is increasingly being used to produce a wide range of consumer products, confectionaries, pharmaceuticals, cosmeceuticals, and nutraceuticals, in an expanding speciality market segment. Most of the world’s cocoa production is carried out by smallholder farmers who endure mounting pressures to sustain their livelihoods. Niche marketing presents an opportunity to realise better incomes for small holder farmers producing cocoa bean micro-lots. In this context, understanding the contribution of cocoa genetic diversity, biotic and abiotic elements of the growing and the processing environment on unique flavour attributes coupled with origin story are important. Just like with wine and coffee, a holistic appreciation of quality is needed in cocoa and must be leveraged in developing and marketing origin cocoa and resulting chocolate brands. The Cocoa Research Centre has spent the last two decades deconstructing the various components that make up “Terroir” or the sense of place where cocoa is grown and processed. This presentation summarises the complex interplay of the elements that define “Terroir”. It starts with a macro view at the inter- and intra- country level, then takes a closer look at the role of genetic diversity, wet bean attributes, and fermentation dynamics in unlocking cocoa genetic flavour potentials. Our research has produced a science-based technology toolkit that considers wet bean attributes, optimal fermentation dynamics, the nuanced nature of sensory quality, quality control, certification and traceability towards geographical based branding for niche marketing of cocoa origins at the country, regional, estate and even varietal levels.



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## Sesame ideotype for Australian tropics

Dr Surya Bhattarai<sup>1</sup>, Mr Nimrod Bardanov, Mr Andrew McDonald

<sup>1</sup>Central Queensland University, Rockhampton, Australia, <sup>2</sup>Equinom Ltd, Indianapolis, United States of America,

<sup>3</sup>Agriventis Technologies Ltd, Sydney, Australia

Sesame (*Sesamum indicum* L.) is highly drought tolerant crop. However, rainfed sesame crops in QLD Australia often experience drought effect particularly during the reproductive phase of the crop, resembling the terminal drought effects. Yield loss as much as 75% due to drought effects has been reported. Previous studies suggested maximum sesame seed and oil yield with 600-800 mm of irrigation. Typical rainfall in central QLD during the summer months (January-May) coinciding with sesame growing season sums to ~465 mm (63 years average), which is only about the half of the crop water requirement. Therefore, successful sesame production in this region requires drought tolerance sesame genotypes. Failure of rainfed sesame crop is generally associated with the longer crop duration of 140-150 days, often exposing the crop to terminal drought. Breeding for short season (<100 days for maturity) varieties for summer planting could offer drought avoidance by sesame crop in central Queensland. Sesame ideotype design with the focus on physiological and phenological traits associated with enhanced water use efficiency is suggested. This involves sesame ideotype design following the sesame crop growth model of APSIM, target WUE and drought tolerant traits such as earliness, fewer smaller and thicker leaves, light reflective leaf cuticle, compact short stature, and semi-determinate habit, medium to large capsule size, large seed size, synchronous capsules, higher response to nutrient and resistance to insects/pests and diseases. Utilization of different agroclimatic zones that offer sesame production all year round, will accelerate the drought tolerant sesame speed breeding.

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## Tomorrow's vanilla: Genomics, plant breeding, and conservation of the world's favorite flavor

Dr Alan Chambers<sup>1</sup>, [Dr Muhammad Sohail Mazhar](#)<sup>2</sup>

<sup>1</sup>Tropical Research and Education Center, University of Florida, Homestead, United States, <sup>2</sup>Department of Industry, Tourism and Trade of the Northern Territory Government, Darwin, Australia

Vanilla has potential to be among the highest grossing agricultural commodities. Spices like vanilla comprise a small portion of our diet, but have major impacts on the sensory quality of our food. Vanilla extract comes from the cured beans of either *Vanilla planifolia* or *V. x tahitensis* as legally defined by regulatory agencies in the largest markets. *V. planifolia* is native to North and Central America, but Madagascar is today's leading vanilla grower. Domestic vanilla production is becoming increasingly attractive as international supplies are perennially strained and demand for vanilla extract increases as global food companies pledge to remove artificial ingredients from their products. Most vanillin, the primary flavor component of vanilla extract, is chemically synthesized, but vanilla extract has the potential to support growers that are striving to meet an evolving consumer base favoring local, organic, and natural products. Vanilla is somewhat unique in that the species not been domesticated through plant improvement, and today's industry relies on cultivated, wild clones. A renewed interest in vanilla genomics and plant breeding is providing new opportunities to solve many of the challenges facing the vanilla industry including uncovering diversity within *V. planifolia*, identifying candidate genes in important biochemical pathways, and resolving differences among vanilla species supporting conservation efforts. Judicious varietal screening and industry transformation are the potential areas for establishing profitable Australian vanilla industry.

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## Shaping the Future of Agriculture with Genomics

Dr Xin Liu<sup>1</sup>

<sup>1</sup>BGI Australia, Herston, Australia, <sup>2</sup>BGI Group, China

*Panax notoginseng*, also known as Sanqi, was a plant species, recently to have been cultivated as herb medicine locally in two southern provinces of China and nearby regions of Vietnam. One of its metabolites, ginsenosides, has been believed to be effective for some blood disorders. Thus, cultivation of *P. notoginseng* has become an important source of local farmers' income, despite there are notable problems including low production, serious diseases, and difficulties in continuous cultivation. It was challenging to solve these problems because there were limited research and improving efforts on this economical plant. Here, we applied sequencing technologies to establish genetic resources of *P. notoginseng*, making it feasible for resolving its cultivation problems. We first sequenced and assembled its genome, which was 2.5 Gb with high repeat content, and improved in the assembly continuity and quality comparing to previous genome assemblies. We then anchored the assembled sequences to chromosomes using HiC sequencing data, resulting in a chromosome level genome assembly. Within this genome, we identified contracted disease resistant gene families (for example, 129 NBS-LRR genes) compared to other related species, indicating possible reason for its disease susceptibility and future improving directions. Through transcriptome sequencing of roots, leaves, and flowers, we identified expression level changes and predicted transcription factor binding sites (TFBS) of genes probably involved in the ginsenoside biosynthesis, providing clues for future production improvement. Finally, we carried out resequencing on 240 representative individuals, with major phenotypes including stem thickness, root weight, and disease resistance to be measured. Through resequencing, we depicted genetic diversity and population structure of *P. notoginseng*, and more importantly, we were able to associate genotypes with phenotypes, generating genetic markers. These markers were successfully used to improve the production and cultivation efficiency. Our study on *P. notoginseng*, sets up an example for effectively improve local crops based on sequencing data.

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## Breeding papaya to suit every household: Genetic gains and trait stability

**Prof Rebecca Ford**<sup>1</sup>, Dr Chat Kanchana-udomkan<sup>2</sup>, Dr Fawad Ali<sup>1</sup>

<sup>1</sup>Griffith University, Brisbane, Australia, <sup>2</sup>Kasetsart University, Kamphaeng Saen, Thailand

Traditional selective breeding approaches offer significant potential to develop new red papaya (*Carica papaya* L.) varieties to match household consumer preferences. For this, knowledge of the heritability and stability of key agronomic and fruit quality traits is required. Accordingly, these were assessed in ten F5 single seed descended populations, derived from a cv. 'Solo' x cv. 'Holland' parental cross. To assess for environmental effects on trait stability, the F5 trees were grown in replicate at four field sites, two each within two distinct agroecological Tablelands or Coastal climates in Tropical North Queensland, Australia and alongside the current industry standard, RB1. Following seedling transplantation to the field, the traits were assessed at five and 10 months and broad-sense trait heritability and genetic gains were determined. Consequently, height to first fruit, trunk circumference, fruit weight and soluble solid contents (<sup>0</sup>Brix) were highly heritable and stable at all field sites ( $h^2_{b.s}$ , 0.7-0.9) with genetic gains of ~18% for height to first fruit and fruit weight. Conversely, heritability of fruit length, fruit width, cavity length and width, and flesh thickness ranged greatly among sites ( $h^2_{b.s}$  0.04-0.9). Across all sites, the trunks of the F5 trees were 37% wider, set fruit 47% closer to the ground and had 20% more marketable fruit with 33% smaller fruit cavity widths, and 11% heavier and 12% sweeter fruit than RB1. These gains will improve tree standing, reduce mechanical picking and packing costs, and increase return to red papaya growers through production and marketability of consumer desirable fruit.

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## Digitally aided rangeland management

**Prof Derek Bailey**<sup>1</sup>, Prof Mark Trotter<sup>2</sup>, Prof Colin Tobin<sup>3</sup>, Kelsey Nelson<sup>1</sup>, Caroline Wade<sup>1</sup>, Cory Oltjen<sup>1</sup>, Ly Trieu<sup>4</sup>, Jiefei Liu<sup>4</sup>, Prof Huiping Cao<sup>4</sup>, Prof Son Tran<sup>4</sup>

<sup>1</sup>Animal and Range Sciences Department, New Mexico State University, Las Cruces, United States, <sup>2</sup>CQ University, Rockhampton, Australia, <sup>3</sup>North Dakota State University, Carrington, United States, <sup>4</sup>Computer Science Department, New Mexico State University, Las Cruces, United States

Monitoring livestock and forage conditions on extensive rangelands is labor intensive and expensive. Technological advancements have made real-time remote monitoring of livestock using on-animal sensors more feasible and less costly. Global positioning system (GPS) tracking data can be transferred from livestock to the internet using cellular phone technologies, low range wide area networks (LoRaWan) and satellite transmissions. Accelerometers can be used to monitor animal activity, but the data must be summarized on the device for efficient transmission to the internet. Digital technologies can help with decision making associated with at least 3 of the 4 principles of grazing management (stocking rate, season of grazing and distribution). Accelerometers and GPS tracking can be used to remotely monitor livestock behavior. As available forage declines cattle grazing time typically increase as animals search for forage. Social interactions among individual animals also change as forage availability declines. Cattle disperse and distance between animals increase as forage abundance decreases. Tracking also has potential to notify managers where livestock are congregating and potentially overgrazing, but prediction of forage utilization at light levels is not exact. Measuring forage defoliation over extensive and diverse landscapes and monitoring spatial movements and activity of large herds is usually impractical, which results in sampling issues and imprecise prediction of forage use patterns from tracking data. Improvements in technology and associated cost reductions of sensors as well as development of algorithms and software potentially gives ranchers and pastoralists tools to remotely monitor livestock and rangeland conditions, which can facilitate prompt managerial responses.

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## The intertwine of technologies for sustainable landscapes

Mr Phil Tickle<sup>1</sup>, Dr Peter Scarth

<sup>1</sup>*Cibolabs, Toowoomba, Australia*

Managing a profitable and sustainable livestock grazing enterprise within highly variable landscapes, climate and market conditions is inherently complex. Issues such as operating costs, significant labour shortages, increasing compliance, emerging natural capital markets and maintaining industries' social licence to operate are driving producers to adopt new technologies to make more informed, objective and transparent decisions.

Over the past 5 years, Cibolabs have developed new approaches to forage budgeting and monitoring which combine the latest satellite and data science technologies and traditional pasture assessment methods.

The service is underpinned by a network of over 6000 pasture sites, and currently provides 5-day, 10m resolution Sentinel satellite imagery predictions of pasture biomass using high-performance computing and new machine learning methods to over 60 million hectares per week. Integrations with Agriwebb, Ceres Tags, PairTree, FlintPro and other platforms also make objective forage budgeting easier and provide new insights into animal behaviour and pasture utilisation. Most importantly, business-to-business collaboration within the rapidly growing AgTech sector is facilitating adoption and leveraging benefits for users.

The presentation will provide insights into how producers can get the most out of these exciting new capabilities, and opportunities for future development, and collaboration with the launch of the Australian Feedbase Monitor. This world-leading service, planned for launch in late 2022, will provide every farm in Australia with access to 1ha resolution rolling monthly pasture biomass estimates updated on a weekly basis to support strategic decision making, emerging natural capital markets, supply chains and industry reporting.

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## Lambing event detection as an example of autonomous sensing

Dr Sabine Schmoelzl<sup>1</sup>, Dr Daniel Smith<sup>1</sup>, Ms Jody McNally<sup>1</sup>, Dr Aaron Ingham<sup>1</sup>

<sup>1</sup>Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Birth events are key events in livestock production. Reproductive efficiency plays a pivotal role in farm profitability and the environmental footprint of the products (meat, wool, animals). In Australian livestock production systems, the date of the lambing birth event is only routinely recorded for stud flock animals, but not for those in commercial flocks. Accurate birth dates are required to determine an animal's age and accurate age is required to calculate important production traits such as weaning weight, an important trait for genetic selection. Current methods to estimate birth dates contribute to artificially high levels of variation in age dependant traits and lead to reductions in genetic prediction accuracy. Accurate attribution of birth date based on data collected from on-animal sensor data may provide an opportunity to reduce variation and ensure reliability of weight for age traits. As part of a larger study characterising lambing behaviours, we collected day-and-night video-based footage from multiple groups of ewes and annotated start and end points of the birthing event (n=73). The data from a tri-axial accelerometer fitted to the ewe's neck was used as an input to an algorithm developed to detect the date of lambing events. The algorithm used a non-parametric distribution distance to identify salient changes in ewe activity associated with lambing. The opportunity now exists to validate the reliability and accuracy of these algorithms.

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## Evaluating and enhancing technologies to detect parturition events in cattle

Dr Christie Pearson<sup>1</sup>

<sup>1</sup>Northern Territory Department of Industry Tourism and Trade, Australia

Extensive grazing systems of northern Australia are characterised by large herd and paddock sizes making monitoring of animals around calving time difficult. The utilisation of remote monitoring technologies such as Global Navigation Satellite System (GNSS) devices and Vaginal Implant Transmitters (VIT) offer ways to monitor cows and calves around calving to better understand risk factors that may contribute to calf loss. Two separate trials occurred between 2018 and 2021, one in the Victoria River District of the NT and the second near Katherine in the NT. Both trials' objectives were to test different birth alert systems for their ability to provide timely birth notifications under commercial conditions. In the first trial, 30 cows were fitted with GNSS collars with paired VIT and direct satellite communication. These devices only gave true birth alerts in 27.6% of cases. The alerts were received  $213 \pm 430$  and  $235 \pm 3$  minutes after the VIT was expelled for year 1 and 2, respectively. In the second trial, GNSS collars and VIT's were fitted to 200 cows per year for two years. In the first year 85% of VIT's gave timely calving alerts, but only 51% of reused VIT's in the second year gave timely alerts. The first trial concluded that these devices were not suitable for use under these conditions in their current state, and the second trial concluded that the remote monitoring system worked when the GNSS device was working, and enabled cows to be found and calving observations to be recorded.



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## Capturing reproductively associated behaviours in cattle using agricultural technologies

Dr Anita Chang<sup>1</sup>, Mr Justin Macor<sup>1</sup>, Mr Caleb Rykaczewski<sup>2</sup>, Mr Jonathan Reid<sup>1</sup>, Professor Mark Trotter<sup>1</sup>

<sup>1</sup>Central Queensland University, Rockhampton, Australia, <sup>2</sup>The Ohio State University, Columbus, United States

Reproductive efficiency is a key factor impacting on productivity and profitability in cattle production systems. In extensive grazing systems, close animal monitoring is often not economically or physically feasible due to the expansive paddock sizes. The development of sensor technologies has provided the opportunity to remotely monitor animal behaviour and location in these extensive environments, bypassing the challenges associated with traditional monitoring methods. This presentation will report on reproduction research being conducted utilising sensor systems and will propose and evaluate technologies for detecting the key behaviours associated with reproductive events.

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## Technobeefuction: Tools available for a new era of northern beef production

Dr Kieren McCosker<sup>1</sup>

<sup>1</sup>*The University of Queensland, Gatton, Australia*

Technologies supporting the remote monitoring of livestock are constantly emerging. These evolving agricultural technologies offer substantial opportunity to improve reproductive performance of females within northern beef production systems, which are potentially on the cusp of transformational change.

The ability to remotely monitor how animals behave and interact with the grazing resource will greatly expand the amount of information that can be collected on animals under commercial situations. While exciting developments are constantly occurring, these technologies are equipping industry stakeholders with the required tools to tackle well-known and long-standing inefficiencies within the northern beef production system as well as equipping them for future techno-based genetic advances, supporting long-term sustainability and durability.

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## The sustainability of the Australian Agri-food System

Mr John Smith<sup>1</sup>, Mr Michael Beer<sup>1</sup>

<sup>1</sup>*AgriFutures, Australia*

In 2015, leaders from around the world gathered to create and adopt a set of goals to “end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda.” These targets, set by the United Nations—known as the Sustainable Development Goals (SDGs)—set a vision for governments, organisations, businesses, and citizens to make our world a prosperous, equitable and sustainable place for all people.

The SDGs are a global benchmark and there is a risk that Australia’s rural industries may compromise market access if we do not pay closer attention to world trends in implementing them. Currently Australia is ranked 59th in the world (CCPI index) and behind many other developed countries including New Zealand, Canada, the United States and the United Kingdom. While the SDGs are just one measure of sustainability, these goals are increasingly viewed as the internationally accepted language for measuring and reporting business, industry and country-level sustainability credentials. Individually, we know that Australia’s rural industries are working hard and making significant investments to advance their sustainability outcomes. However, the level of maturity in SDG alignment and reporting varies considerably across industries.

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## The sustainability of Australian pork production

Ms Margo Andrae<sup>1</sup>

<sup>1</sup>Australian Pork Ltd, Canberra, Australia

Australian Pork Limited (APL) is the services body providing research, development, marketing, extension, policy advice, and advocacy to the Australian Pork Industry.

The global animal protein sector often talks about “social licence” to operate, however for the wider Australian pork industry the goal is “societal celebration”. We believe Australian pork has a great story to tell so the aim is to be celebrated rather than simply accepted. This is no easy goal. Community research undertaken by APL in early 2021 showed that Australians don’t think, talk, understand, or engage with the pork industry. In fact, the research with over 2000 Australians told us that only 1 in 5 Australians felt they understand or are knowledgeable about the pork industry at all. The story we need to tell is that in fact, the pork industry in Australia intends to be leaders globally in both climate solutions and animal welfare best practice. This is done by driving impactful research, and through close consultation with producers on the ground, as well as the broader community. Australian pork producers are building upon a great history of environmental improvement. Since 1980, they have reduced their carbon footprint by more than 60 percent and water use by 80 percent. The Australian pork industry is currently focused on finding new approaches for climate friendly farming, with a goal for zero waste by 2025.

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## Australian chicken meat industry's sustainability roadmap

**Dr Kylie Hewson<sup>1</sup>**

<sup>1</sup>*Australian Chicken Meat Federation, North Sydney, Australia*

The Australian chicken meat industry recognises the need to reduce emissions, globally, and collaborates with industry and government stakeholders, scientists and customers to progress initiatives that create real impact. The chicken industry has an enviable record when it comes to setting and achieving goals for significant improvements across a range of sustainability criteria, and industry members continue to demonstrate their commitment to continuous improvement in environmental sustainability in their own operations. Chickens are the most efficient converters of feed to animal protein, which results in low supply chain impacts via feed use compared to other sectors. In addition, the industry generates comparatively low direct impacts associated with land because of the small direct land footprint. The industry also has a strong track record of rapid uptake of new technologies, including adoption of renewable energy options, such as solar. The stages in the chicken meat supply chain that have the greatest environmental impact arise from dietary inputs (including source regions for grain and particularly imported feed inputs such as soymeal), fertilisation and processes used in the production of grains used in chicken feed, feed conversion ratio, and water and energy consumption on grow-out farms (especially for heating & cooling) and in meat processing. Note that several of these stages are outside the direct control of the chicken industry, particularly the impacts from grain production. This highlights further that supply chains as a whole need to work together to reach Australian and global goals of net zero carbon emissions.

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## The problem with 'net' in net zero

Dr Tony Peacock<sup>1</sup>

<sup>1</sup>*Australasian Pork Research Institute, Roseworthy, Australia*

Adopting a 'carbon neutral' or 'net zero' target is easy. Fulfilling the obligation that follows is hard. 'Carbon Neutral' requires finding a balance of greenhouse gas emissions by offsetting or removing an equivalent amount of those produced. For a business, being carbon neutral would mean investing in carbon credits/offsets to balance out the carbon emitted from operations. Technically, a business can increase the emissions it produces, so long as it 'offsets' the same greenhouse gas emissions. 'Net Zero' requires a reduction in greenhouse gas emissions. This is a benchmark standard for decarbonisation (without a recognised standard) and often a goal towards tackling climate change. It means companies must reduce emission across their value chain. Only what is unfeasible to be eliminated must be neutralised.

Recently, eminent scientists have begun to seriously question the concept of 'net zero'. They argue that it is a good idea in concept but that it 'helps perpetuate a belief in technological salvation and diminishes the sense of urgency surrounding the need to curb emissions now'. In Australian agriculture, there is a lot of variation in how entities are dealing with carbon emission footprint and likewise some good and bad methods for industry to generate Australian Carbon Credit Units.

For any realistic chance of avoiding climate change beyond 1.5 degrees, the emphasis must be on immediate and serious decarbonisation of businesses. Methods and standards should be adopted to avoid loss of public confidence and climate 'action' that has no real impact.

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## Pathways to net zero for Australian pork and poultry production

Dr Zhong Xiang Cheah<sup>1,2</sup>, [Miss Mary-Frances Copley](#)<sup>1</sup>

<sup>1</sup>Integrity Ag & Environment, Toowoomba City, Australia, <sup>2</sup>The University of Queensland, Gatton, Australia

Climate change action is a global priority for governments, business, lenders, and industries. Pork and poultry farming is highly efficient and produces high-quality food products with a relatively low carbon footprint but, along with every sector, there is an imperative to reduce impacts over time.

A review was completed of mitigation options that could be suitable for the pork and poultry industries based on the emission profile of chicken meat, eggs, and pork. Strategies deemed prospective were grouped into 'modules', implemented consecutively between 2020-2035, leading to the delivery of low carbon and carbon neutral products. The pathways included the incremental, ongoing emissions reduction brought about by the decarbonisation of the electricity grid.

Reductions of 47 – 51% of emissions were observed in the poultry pathways. Through a reduction in on-farm emissions of 48%, this came close to achieving net zero emissions within the farm boundary for poultry (i.e., not including emissions from purchased inputs). Case-study piggeries also experienced substantial reductions in on-farm emissions.

Although emissions reduction is not simple and, at this stage, reaching net zero will require considerable investment and purchased offsets, there are several economically viable, readily available strategies with proven application in the Australian pork and poultry industries. Whilst net zero production will likely increase cost-of-production, the strong environmental credentials of Australian pork and poultry and demonstrated responsiveness to consumer preferences mean the industries are well-positioned to initiate a dialogue with customers and lenders around the potential for cost-sharing in the supply chain to deliver net zero production.

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## Nourishing Australia: The Decadal plan for the science of nutrition

Prof Helen Truby<sup>1</sup>

<sup>1</sup>*The University of Queensland, School of Human Movement and Nutrition Science, Australia*

The Australian Academy of Science is currently implementing the 'Decadal Plan for the science of nutrition. This 10 year plan provides a road map as to how Australia will rise to the challenge of improving the nutritional health of the population. Population-level dietary recommendations for optimal health were developed first on the basis of nutrient requirements, and more recently on the basis of food groups and now use a more holistic approach using dietary patterns.

Poor diet is the second largest cause of morbidity in the world. The obesity epidemic plus the increasing incidence of Type 2 diabetes requires a focus of prevention. It is clear that the old style of dietary recommendations are not effective and that more subtle tailored messages are critical to develop if we are to achieve dietary patterns conducive to improved health for all Australians. A challenge for the science of nutrition is to be able to unravel the complex mechanisms by which diet influences biology and health at an individual level, so that food systems and dietary guidelines can be optimised for both health outcomes as well as environmental sustainability. The Decadal Plan for the science of nutrition aims to deliver on these critical goals by bringing the nutrition community together with many other disciplines in order to deliver solutions that will enable all Australians to have access to a safe and nutritious food supply.



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## Environmental impacts of dietary patterns--methods and global perspectives

Assoc Prof Jolieke C. van der Pols<sup>1</sup>

<sup>1</sup>*QUT Centre for Agriculture and the Bioeconomy & School of Exercise & Nutrition Sciences, Faculty of Health, Kelvin Grove, Australia*

For the purpose of assessing the impacts on health of what people eat, there has been a shift in focus away from individual nutrients or foods towards evaluating whole diets (the total of all foods habitually consumed by a person within a day). With the need to increase sustainability of food systems, methods have been developed to evaluate both the health effects and environmental impacts of diets concurrently to help inform decision making and trade-offs for specific contexts and settings globally. Life cycle assessment (LCA) methods are commonly used for this purpose.

This presentation will illustrate different approaches used to evaluate health and environmental impacts of whole diets, in particular those using LCA methodology. Strengths and limitations will be discussed from a global perspective.

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## Dietary patterns, food security and food choice in the Pacific Islands

**Dr Sarah Burkhardt**<sup>1</sup>, Prof Steven Underhill<sup>1</sup>, Ms Jessica Raneri<sup>2</sup>

<sup>1</sup>Australian Centre for Pacific Islands Research, University of the Sunshine Coast, Maroochydore DC, Australia,

<sup>2</sup>Australian Centre for International Agricultural Research and Department of Foreign Affairs and Trade, Canberra, Australia

Rapid food system transformation is underway in Pacific Island countries. As a result, dietary patterns that have historically relied on traditional, local foods are being replaced with those that are increasingly reliant on imported and highly processed foods. This change limits dietary diversity and has contributed to high rates of overweight/obesity, undernutrition, micronutrient deficiency, and diet-related non-communicable diseases. Local, traditional foods of the region, for example fruits and vegetables, are highly nutritious and often adapted to local climatic conditions. Dietary patterns high in fruits/vegetables can be protective against poor health outcomes, however, literature suggests that many Pacific Islanders do not consume recommended amounts. Supporting consumption of local, traditional fruits/vegetables could increase consumption of micronutrients, particularly vitamin A and Iron, fibre and phytonutrients. Besides health benefits, promoting and using locally produced foods can increase food sovereignty, promote food security and positively impact livelihoods and communities through increased domestic production. Despite these benefits, multiple barriers exist across the food system, including constrained access to quality seeds and planting material, high prices in local markets, limited capacity for food preparation and preferences for other foods, resulting in limited consumption. This presentation outlines the scope for local, traditional foods, with a focus on fruits/vegetables, to enhance dietary patterns and health, and opportunities to increase consumption. Key nutritional characteristics of selected fruits/vegetables will be highlighted to demonstrate potential health benefits. Drivers of food choice impacting fruit/vegetable consumption, including cost, access and availability, will also be examined in the context of modern and traditional dietary patterns.

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## Seeking sweetness – a systematic scoping review of factors influencing sugar-sweetened beverage consumption

**Ms Jessica Cartwright<sup>1,2,3</sup>**, Dr Olivia Wright<sup>1,2,3</sup>, Dr Michael Netzel<sup>1,2</sup>, Professor Yasmina Sultanbawa<sup>1,2</sup>  
<sup>1</sup>ARC Industrial Transformation Training Centre for Uniquely Australian Foods; The University of Queensland, Brisbane, Australia, <sup>2</sup>The Queensland Alliance for Agriculture and Food Innovation; The University of Queensland, Brisbane, Australia, <sup>3</sup>School of Human Movement and Nutrition Sciences; The University of Queensland, Brisbane, Australia

Despite some improvements in recent decades, there is still a profound health gap between Indigenous and non-Indigenous populations, which is partly attributed to dietary factors. It is internationally recognised that Indigenous communities have higher consumption rates of sugar-sweetened beverages (SSB) than their non-Indigenous counterparts, and there is a well-established association between these consumption rates and chronic disease prevalence. If this problem remains unaddressed, trends will continue along their current trajectory, meaning perpetual increases in SSB consumption and an increased burden of disease. This poses significant health risks to these communities and may have dire consequences on further attempts to close the gap. The focal point of many studies in this area is very intervention-based, and there has been little investigation into why remote Indigenous communities have such high rates of SSB consumption. Therefore, the aim of this literature review was to understand the underpinning factors that contribute to SSB consumption in remote Indigenous communities and categorise them according to a framework based on the socio-ecological model. The implications of this literature review are far-reaching as the determinants for SSB consumption can form the basis of future interventions in remote communities and may ultimately be the missing puzzle piece in closing the gap.

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## Alternative options for salt in dietary patterns: Underutilised plant species

**Ms Sukirtha Srivarathan<sup>1,2</sup>**, Dr Anh DT. Phan<sup>1,4</sup>, Dr Sandra M. Olarte Mantilla<sup>4</sup>, Dr Olivia R.L Wright<sup>3</sup>, Prof Yasmina Sultanbawa<sup>1,4</sup>, Dr Michael E. Netzel<sup>1,4</sup>

<sup>1</sup>ARC Industrial Transformation Training Centre for Uniquely Australian Foods, Brisbane, Australia, <sup>2</sup>Department of Biosystems Technology, Faculty of Technology, University of Jaffna, Ariviyal Nagar, Sri Lanka, <sup>3</sup>School of Human Movement and Nutrition Sciences, The University of Queensland, St. Lucia, Australia, <sup>4</sup>Centre for Nutrition and Food Sciences, The University of Queensland, St. Lucia, Australia

In recent years, underutilised plant species such as edible halophytes have received significant interest due to their high salinity tolerance, a crucial trait in times of climate change, increasing world population and loss of crop land. Although edible halophytes are widely distributed and “popular” for their diverse applications among Indigenous Communities in Australia, studies on their nutritional profile and bioactivity are very limited. However, there is growing interest in finding natural salt substitutes with favourable sensory attributes, since high intake of table salt/sodium is a main contributing factor for high blood pressure and subsequently increased risk of cardiovascular diseases, one of the main health risks worldwide. Interestingly, some edible halophyte species were found to be promising natural salt substitutes, but studies in this area are very basic and limited. Therefore, the nutritional composition, sensory properties and *in vitro* bioactivity of four important Australian indigenous edible halophytes (AIEH), Saltbush (*Atriplex* sp.), Samphire (*Tecticornia* sp.), Seablite (*Suaeda* sp.) and Seapurslane (*Sesuvium* sp.), were determined and will be presented in my talk.

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## Strawberry – an overlooked source of natural folate?

**Dr Michael Netzel**<sup>1</sup>, Dr Olivia Wright<sup>2</sup>, Dr Hung Trieu Hong<sup>1</sup>, Dr Gabriele Netzel<sup>1</sup>, Professor Michael Rychlik<sup>4</sup>, Associate Professor Tim O'Hare<sup>3</sup>

<sup>1</sup>ARC Training Centre for Uniquely Australian Foods, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Coopers Plains, Australia, <sup>2</sup>School of Human Movement and Nutrition Sciences, The University of Queensland, St. Lucia, Australia, <sup>3</sup>Centre for Nutrition and Food Sciences, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Gatton, Australia, <sup>4</sup>Chair of Analytical Food Chemistry, Technical University of Munich, Munich, Germany

Folate is critical for a range of biological functions in adults and children, including DNA, protein and neurotransmitter synthesis. It is also essential for the healthy development of the foetus in early pregnancy and for the prevention of neural tube defects, such as spina bifida. Strawberries are considered a tasty and healthy fruit snack consumed all over the world and may potentially be an important dietary source of natural folate. However, the relative importance of strawberry as a dietary source will depend on the total folate content, vitamer profile, storage stability and bioavailability to humans. As part of the Horticulture Innovation 'Naturally Nutritious' project, a broad range of commercial strawberry cultivars and experimental breeding lines were screened for total folate content and their vitamer profile. Furthermore, stability of folate in commercial strawberry cultivars stored under common domestic storage conditions was assessed and finally, the bioavailability of folate in strawberries was compared with a commercial folate-supplement in healthy human subjects. Results and highlights of this study will be presented at the conference.

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## Robotti—the first robotic autonomous implement-carrier to Australian farmers

Mr Braden Hellmuth<sup>1</sup>

<sup>1</sup>*Corematic, Bundaberg, Australia*

The integration of technology and automation into Australia's agricultural industry is an integral part of the sustained growth required to meet the demands of an ever-growing population. As the next step in the evolution of agricultural machinery, an autonomous implement carrier could utilise products currently available on the market and provide a solution to the farmer in the present day.

Robotti from Agointelli is a commercially available implement carrier providing a highly accurate and versatile solution for the Australian horticultural industry. Able to work autonomously for up to 60 hours, time-consuming tractor operations can be rethought and completed by Robotti. With a traditional diesel hydraulic system and a standard 3-point linkage, Robotti provides familiar features to the farmer whilst allowing them to automate their activities.

Automation in farming brings with it a broad range of benefits, such as reducing the reliance on labour, decreasing soil compaction, and allowing the farmer to scale operations and undertake multiple tasks at once. Robotti is a solution that is here now and ready to work.

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## DigiHort: Digital Twins for Innovation of Future Orchard Systems

Liqi Han<sup>1</sup>, Jian Cao<sup>1</sup>, Paula Ibell<sup>2</sup>, Yan Diczbalis<sup>3</sup>

<sup>1</sup>The University of Queensland, Brisbane, Australia, <sup>2</sup>The New Zealand Institute for Plant and Food Research Limited, Motueka, New Zealand, <sup>3</sup>Queensland Department of Agriculture and Fisheries, South Johnstone, Australia

New orchard systems of the future feature unconventional layouts and narrow canopies with fruit walls under intensive pruning and training practices. The development of such systems is not only time- and labour consuming, but also faces other challenges in potential overuse of chemicals, in maintenance of fruit/nut quality and in response to climate change. Our DigiHort solution is to address those challenges via development of Digital Twins powered by High Performance Computing and Artificial Intelligence. It includes two components: LIGHT and SPRAY.

The LIGHT component allows its users to have 3D digital twins of their orchard designs and pre-evaluate how different factors such as row orientation, tree spacing, canopy size and terrain could affect the potential orchard light environment. This can help decision makers optimise their orchard designs *in silico* before creating/reconfiguring real orchards *in situ*.

Using the SPRAY component, the growers can operate their sprayer digital twin within their orchard digital twin, configure the virtual sprayer with different nozzle types and directions, adjust vehicle speed and/or flight height, simulate spray operations with explicit droplets, evaluate wastage and coverage, and then figure out the optimal instructions to guide their real-world practices.

The ultimate purpose is to develop these two technologies into adoptable, affordable and easy-to-use decision-support tools for tree crop growers and horticulturalists to optimise orchard light quality, minimise spray wastage, narrow the range of investigations, and accelerate the innovation of future horticultural systems with better yield, lower cost and less pollution.

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## Innovation in action

**Ms Reeanjou Ram<sup>1</sup>**

<sup>1</sup>*iTrazo, Australia*

**Innovation in action.** Traceability Technology Adoption in Ag

### **More information:**

1. What is driving traceability – Compliance, Regulations and Consumers
  - The importance of implementing traceability in your supply chain.
  - Understanding the drivers
  - Collaboration across the eco-system
  - the commercialisation side of the story
  - Adoption of the tech, barriers and challenges

**Innovation in action.** Traceability Technology Adoption in Agriculture

Before the COVID-19 pandemic, many people took the supply chain for granted. In fact, many people didn't think of the supply much at all. Today, producers, manufacturers, warehouses, logistics providers, distribution centres, and retailers are all topics of mainstream media. Times are changing—so is supply chain traceability.

The importance of implementing traceability in your supply chain:

In our post-COVID world consumers increasingly want to know where a product is coming from, the ingredients involved in its production, and whether it was grown, raised, or produced using the most ethical and sustainable practices possible. Australian Agriculture has great ambitions ... it won't be achieved without traceability.

What is driving adoption of traceability:

Increased food safety and addressing bio security by identifying hazards before affected products make it to end consumer markets. Quick, efficient, and less costly product recall and brand damage. Regulatory and compliance bodies seeking greater supplier accountability translating to consumer trust and improved quality control.

Greater inventory visibility, tracking, financial risk mitigation, including environmental sustainability claims, increased operational efficiency and reduced wastage and data sharing and interoperability are all



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## DivSeek International Network and the Australasian Hub—extending the community of practice for open dissemination of information about plant genetic resources

**Prof Graham King<sup>1</sup>**, Prof Andy Lowe<sup>1</sup>,

<sup>1</sup>*DivSeek International Network and the Australasian regional Hub*

DivSeek International Network ([www.divseekintl.org](http://www.divseekintl.org)) is a global community of practice that connects, combines and communicates expertise among stakeholders engaged in the management and characterization of Plant Genetic Resources (PGR). DivSeek comprises leading researchers and practitioners across a broad base of academic and research institutions, government agencies, and inter-governmental organizations. A key role is to facilitate and encourage open dissemination of information about PGR in the context of benefit-sharing and respect for indigenous knowledge, international treaties and conventions established to protect them. An initial set of regional and thematic hubs and working groups have been established.

*DivSeek Commons* has been established as an ‘Ecosystem of Standards, Open Data Resources, Analysis Tools and Best Practices’ for PGR. This includes developing and maintaining a comprehensive inventory of available tools, resources, standards and training materials for PGR and downstream characterization.

The *DivSeek International Regional Hub for Australasia* aims to bring together researchers across Australia and New Zealand to develop tools, data infrastructure and best practices for characterising minor, new and emerging crops. This provides a special focus for novel or recently domesticated crops from indigenous flora and locally adapted germplasm, as well as medicinal and therapeutic plants. We aim to provide new insights into the implementation of the Nagoya Protocol including best practices for incorporating indigenous knowledges into plant genetics research. With almost 50 members and supporters across 23 institutions, the Hub spans a range of world-leading expertise. Amongst major activities underway in 2022, includes our comprehensive survey of genetic resource collections.

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## CePaCT: conservation and use of Pacific plant diversity for food and health

**Ms Logotonu Meleisea Waqainabete<sup>1</sup>**

<sup>1</sup>*Pacific Community (SPC), Centre for Pacific Crops and Trees (CePACT), Suva, Fiji*

The Centre for Pacific Crops and Trees (CePaCT) is the Pacific's main regional gene bank conserving and making available crop and tree diversity of the Pacific. Established in 1998 by the Pacific Community (SPC) in response to regional recommendations, CePaCT is based in Suva, Fiji and is owned by the Pacific member countries. CePaCT is internationally recognized by key partners such as the Global Crop Diversity Trust, the Consortium of International Research Centres and the International Treaty on Plant Genetic Resources for Food and Agriculture as the focal point for Plant Genetic Resources for Food and Agriculture in the region. CePaCT's main aim is to advance regional, national and community capacity in the conservation, development, distribution, and utilisation of plant genetic resources in the Pacific including supporting seed and planting material supply networks to facilitate access to and availability of plant materials thus contributing to food security, improved health, and livelihoods of Pacific people as well as strengthening resilient agricultural production systems.

Currently, CePaCT conserves >2,200 accessions of 18 crops and 33 tree species, 67% of which originate from the Pacific. The Centre has distributed >100,000 tissue culture plants and >1,000 kg seeds to >50 countries in the Pacific and globally for research and training, disaster rehabilitation and direct use. CePaCT's main activities include the conservation of *ex situ* (*in vitro*, seeds, field) collections, health testing of accessions, distribution of germplasm, research, training and capacity building and the provision of scientific and technical advisory support on plant genetic resources management.

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## Coordination of information platforms to support use of Plant Genetic Resources

**Prof Pankaj Jaiswal<sup>1</sup>**

<sup>1</sup>*Oregon State University, Corvallis, Oregon, United States*

Various global challenges including those on climate change, population growth, reduced acreage of arable land, and increased cost of inputs need new strategies to unlock the growth and yield potential of our food crops. Improvements need to happen both in increasing yield from the farm produce through genetic gains and better agronomic practices as well as by rescuing the post-harvest produce. Researchers are making all-out efforts to unravel the genomes of many crops and extending the discovery to include pan-genomes and genetic diversity to find novel alleles, genes, and genetic elements associated with desired improvements in traits like abiotic and biotic stress tolerance, grain, fruit, and tuber yield, improved nutrition and quality besides biomass and photosynthetic gains. I will present an overview of the coordination happening between global plant genomics resources including Gramene, Plant Reactome, Ensembl Plants, Gene Expression Atlas, Planteome ontologies, and how we can extend the application of global conventions to digital sequence information (DSI) sourced from plant genetic resources for developing future crops.

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## Genebank perspectives on improving efficiencies through using omic technologies

**Dr Sally Norton<sup>1</sup>**

<sup>1</sup>*Australian Grains Genebank, AgVic, Horsham, Australia*

The Australian Grains Genebank (AGG) mandate is to acquire, conserve and distribute plant genetic resources to support the Australian grains industry. The AGG has c. 200,000 accessions of temperate and tropical cereals, oilseeds and legumes species covering varieties, landraces, progenitors and wild relatives. These genetic resources are used as sources of new and novel traits for grain crop improvement as they contain genetic diversity that has been lost through bottlenecks imposed by domestication and breeding. Traditionally, genebanks have managed and prioritised the maintenance of their germplasm based on passport and seed inventory data to. Generally, there can be a lack of detailed passport and characterisation data available, and what is available may not enable the effective management of a genebank, or meet the information needed to effectively support today's research and breeding programs. This is a major impediment and cost for germplasm utilisation by researchers and breeders. To address this, the AGG is using genotyping and next-generation phenotyping (seed, plant, canopy) technologies to accurately assess genetic diversity, facilitate trait identification, and the capture of quantitative phenotypic/physiological data. These technologies will enable the AGG to increase curation accuracy and efficiency and provide genebank users with enriched passport information that will improve breeding efficiencies within Australia, and potentially accelerate the production of more resilient grain crop varieties for Australia. This presentation introduces the program of works underway to future orientate the AGG to facilitate the development of new grain crop varieties, and to improve the accuracy and efficiency of genebank operations.

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## Collection genomics: Rapid assessment of wild diversity and advances with target capture

Dr Katharina Nargar<sup>1,2</sup>, Dr Alicia Greal<sup>1</sup>, Dr Alexander Schmidt-Lebuhn<sup>1</sup>, Prof Darren Crayn<sup>2</sup>

<sup>1</sup>Commonwealth Scientific and Industrial Research Organisation (CSIRO), Cairns, Australia, <sup>2</sup>Australian Tropical Herbarium, Cairns, Australia

Biological collections are rich repositories of phenotypic and genetic information on wild diversity built over centuries of collection and curatorial effort. Global herbaria house over 350 million specimens facilitating assessment of phenotypic and genetic changes over time and space including from extinct species, varieties and populations. Advances in digitisation, high-throughput sequencing and bioinformatic analysis now provide unparalleled opportunities to rapidly assess past and extant diversity in wild crop relatives at broader scale. Collections material poses unique challenges to genetic studies, such as DNA damage and degradation, contamination from microbial DNA, inhibiting secondary compounds, and small DNA quantities. Target sequence capture has revolutionised our ability to sequence hundreds to thousands of specific DNA regions from collections materials using hybridisation probes that enrich DNA regions of interest for high-throughput sequencing, thus facilitating rapid screening of genomic diversity at reduced cost compared to genome skimming. This talk will highlight national and international initiatives that exploit the versatility of target capture for building genomic reference datasets at different taxonomic scales—from phylogenomics to population genomics, facilitating the rapid characterisation of wild diversity. These initiatives, specifically Genomics for Australian Plants (GAP), Environomics Future Science Platform (CSIRO), and Plant and Fungal Tree of Life (PAFTOL), have significantly advanced the use of target capture in collection genomics and are increasing the accessibility of wild genomic resources to researchers world-wide.

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## Indian National Seed Genebank - Goldmine for future trait-specific genetic resources

Dr Veena Gupta<sup>1</sup>, Dr Anjali Kak<sup>1</sup>, Dr Chithra Devi Pandey<sup>1</sup>, Dr Sherry R Jacob<sup>1</sup>, Dr Sushil Pandey<sup>1</sup>, Dr Badal Singh<sup>1</sup>, Dr Harish GD<sup>1</sup>, Dr Padmavati Gore<sup>1</sup>

<sup>1</sup>Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources, New Delhi, India

India's National Genebank (NGB) at ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi, currently conserves ~ 0.46 million accessions of >2014 species, maintained round the year predominantly (97%) in Seed Genebank (-18°C). To confront the challenges of population expansion/climate change/ habitat destruction/malnutrition, plant genetic resources (PGR) are of strategic importance to ensure sustainable crop production, food and nutritional security and also to enhance economic prosperity of the present and future generations. Comprising the sum of genes, gene combinations or genotypes, PGR serve as a reservoir and toolkit for adaptation to climate change. The NGB conserves seeds of landraces/primitive varieties (13340 accessions), traditional/folk varieties (81254 accessions), released cultivars/varieties (6941 accessions), wild relatives of crop species (13807 accessions) and trait specific registered germplasm (1948 accessions) having resistance/tolerance to biotic and abiotic stresses, and novel, unique and distinct traits with academic, scientific and applied value or of commercial importance. To name a few, in wheat a high zinc content line (IC 296727) and heat tolerant line (IC 0336818); *Hordeum vulgare*, IC 0635023 accession resistant to all pathotypes of yellow rust; in *Ocimum sanctum* IC 0627270 with 81% methyl eugenol content and several *Musa* landraces for resistance to *Fusarium* race1. Extensive characterization programme for genebank accessions is in progress to unravel the new sources of genes for future improvement programmes.

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## Trajectory of the gourmet mushroom industry

### Mr Mickey Pascoe<sup>1</sup>

<sup>1</sup>*Little Acre Gourmet Mushrooms, Geebung, Australia*

Gourmet mushrooms is a catch all term for the diverse range of exotic fungi coming in many shapes, flavours and colours. Considered a sustainable and ethical food choice, gourmet mushrooms tick all the boxes of nutritional security, yet they are a product that you can rarely find on many supermarket shelves.

Mushrooms are the sixth most valuable horticultural crop in Australia with 80% of households regularly purchasing fresh mushrooms, the majority of these are Agaricus mushrooms, commonly known as buttons or field mushrooms. Gourmet mushrooms, which are grown in a different production system, have a lot to offer consumers with actions needed to be taken to increase their domestic supply. Currently an increase in consumer demand is being met at a grassroots level. A primary driver for this is the relative ease of production with low energy and water consumption, and the ability for gourmet mushrooms to grow on agricultural waste products. Couple this with a high sale price and its likely you will find a micro gourmet mushroom farmer at most farmer's markets across the country.

As a spotlight is being placed on this emerging industry, the current direction of the Australian gourmet mushroom scene will be presented. Looking at why this crop has the ability to become one of Australia's most sustainable food sources and a key crop in building a reliable food production system for the 21st century.

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## Fable Food Co – ending industrial animal agriculture with mushrooms

**Katrine Fox**<sup>1</sup>

<sup>1</sup>*Fable Food Co, Sunshine Coast, Australia*

At Fable our mission is to help end industrial animal agriculture and we do this by making delicious meaty food from mushrooms.

The meat industry is one of the world's largest industries. It's 2.5% of global GDP and worth US\$2T annually. It's also horrific from an environmental, health and ethical perspective. It's responsible for 14.5% of global greenhouse gas emissions, the ill treatment and slaughter of billions of animals annually and major killers like heart disease and bowel cancer are highly correlated with meat consumption and at 110kg of land animals per person per year in Australia, we eat far too much meat.

So rather than making meat from animals, we make it from shiitake and agaricus mushrooms together with a short list of all natural plant based ingredients. Our products are delicious, as British 3 Michelin Star Chef Heston Blumenthal says, "it doesn't do them justice to be compared with meat, they're an amazing ingredient in their own right."

After launching in December 2019, we're now on the menu in over 750 cafes and restaurants and our products are ranged in over 1,000 retail stores in Australia. We're also available through the meal kit companies Marley Spoon in Australia and Gousto in the UK.

Our goal is for our meat products to taste better than animal meat and be cheaper than animal meat, then there's no reason for people to eat meat from animals anymore.



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## Production of psilocybin mushrooms in Australia

Mr Shaun Duffy<sup>1</sup>

<sup>1</sup>*Reset Mind Sciences Ltd, West Perth, Australia*

West Australian company Reset Mind Sciences (**Reset**) is at the forefront of the emerging industry using psychedelic drugs to treat mental health. The last decade has seen a global resurgence of research into the use of substances such as psilocybin and MDMA to treat conditions including depression, anxiety and PTSD. The current “psychedelic renaissance” as it’s widely known, builds on an extensive body of research conducted during the 1950s and 1960s into these substances.

Reset Mind Sciences CEO Shaun Duffy will provide an overview of their work to cultivate mushrooms containing the psychoactive ingredient psilocybin. Reset is a subsidiary of ASX listed medicinal cannabis company Little Green Pharma (**LGP**) and is drawing on their experience producing GMP compliant pharmaceutical grade medicines from botanicals.

Reset has custom designed a dedicated mushroom grow chamber to be co-located at LGP’s cannabis cultivation facility and has assembled a highly qualified and experienced team to undertake its cultivation efforts. At present psilocybin is classified as a Schedule 9 Prohibited Substance by the Therapeutics Goods Administration meaning its production and supply is extremely tightly controlled. Reset is one of the few companies to successfully obtain the necessary licenses and approvals that are required to cultivate, hold and supply psilocybin.

In addition to its cultivation activities, Reset is undertaking the first clinical trial in Western Australia using psilocybin. Shaun will provide an overview of Reset’s clinical trial and the manner in which psilocybin is being researched to treat mental health.

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## Multi-Omic characterisation and therapeutic potential of a native Australian mushroom, *Hericium coralloides*

Dr Kylie Agnew-Francis<sup>1</sup>, Dr Alistair McTaggart<sup>2</sup>, Ms Isabeau Lawer<sup>1</sup>, Mr Mickey Pascoe<sup>3</sup>, Dr Edward Kerr<sup>1</sup>, Mr Daniel Ellis<sup>1</sup>, A/Prof Benjamin Schulz<sup>1</sup>, Prof Avril Robertson<sup>1</sup>

<sup>1</sup>The University of Queensland, School of Chemistry and Molecular Biosciences, St Lucia, Australia, <sup>2</sup>Centre for Horticultural Science, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Ecosciences Precinct, Dutton Park, Australia, <sup>3</sup>Future Farms Australia PTY LTD (T/A Little Acre Gourmet Mushrooms), Geebung, Australia

Mushrooms have outstanding therapeutic and nutritional benefits along with high commercial and biocultural significance. Australia is believed to be home to thousands of native mushroom species, the majority of which are undescribed and unexplored, despite significant commercial and community interest in their use. Very few have ever been surveyed for their medicinal properties, nutritional content, chemical composition, or phylogenetic relationships.

This presentation will summarise preliminary findings of our current research into an edible native mushroom, *Hericium coralloides* (coral tooth). This research aims to establish the metabolomic, proteomic and genomic profiles of this species compared to other native and non-native *Hericium* mushrooms, as well as the activity of extracts against a range of clinically relevant disease models. Ongoing research in this space will provide valuable opportunities for the commercialisation of new species as a gourmet food or herbal supplement and stimulate wider interest in existing commercial cultivars.

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## Innovation of Australian native magic mushrooms for the psilocybin industry

Dr Alistair McTaggart<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Dutton Park, Australia

Psilocybin, a psychoactive compound produced by fungi (magic mushrooms), is a breakthrough therapy for anxiety, depression, addiction, and patients in palliative care. Most magic mushrooms are species of *Psilocybe*, which nearly all share a cluster of genes that metabolise tryptophan into psilocybin. Two species are widespread in Australia, *Psilocybe cubensis*, the gold top mushroom, and *P. subaeruginosa*, colloquially called 'flying saucer mushrooms'. *Psilocybe cubensis* is likely naturalised in Australia and its centre of origin is unknown. It is the stalwart species cultivated by recreational growers, who have potentially impacted its genetics by propagating from limited founding genetic diversity and inbreeding over time. The Oregon Psilocybin Advisory Board recommended that *P. cubensis* should be the sole taxon grown to commercially produce psilocybin. *Psilocybe subaeruginosa* is native to Australia but is not a commercial option, as in a low percentage of mushrooms, a compound is produced that temporarily paralyses users. This talk will cover new knowledge on the diversity of magic mushrooms in Australia, the bottlenecks to cultivation, and the solutions so far to innovating an Australian native magic mushroom for the psilocybin industry.

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## Increasing the production yield of mushrooms with pulsed electric field technology

**Mr Farzan Zare**<sup>1</sup>, Dr. Negareh Ghasemi<sup>1</sup>, Dr. Nidhi Bansal<sup>2</sup>, Mr Abhishek Garg<sup>2</sup>, Dr. Hamid Hosano<sup>3</sup>

<sup>1</sup>School of Information Technology and Electrical Engineering, The University of Queensland (UQ), St Lucia, Australia,

<sup>2</sup>School of Agriculture and Food Sciences, The University of Queensland (UQ), St Lucia, Australia, <sup>3</sup>Biomaterials Department, Institute of Industrial Nanomaterials, Kumamoto University, Kumamoto, Japan

Pulsed electric field (PEF) technology is capable of increasing the growth rate, total yield, and altering the nutritional and organoleptic properties of agricultural and horticultural crops such as filamentous fungi or mushrooms. We investigated the role of PEF technology on *Pleurotus Ostreatus* white oyster mushroom species. A rod-to-plate electrode geometry was utilised to stimulate mushroom substrates in buckets with an electric field strength ranging between 1-10kV.cm<sup>-1</sup>, a pulse repetition rate between 1-20Hz, and a total electrical energy of 62.3kJ delivered over 30 days of excitation. Three types of pulses were applied to each mushroom bucket, (1) bipolar square waves with a pulse width of approximately 4μs for each polarity with an interphase delay time of approximately 3μs, (2) unipolar square wave with a pulse width of 500ns, and (3) a unipolar exponentially decaying waveform with an effective pulse width of 2μs. The total electricity cost to excite each bucket was less than AUD\$0.06 over the 30 days of excitation. The total yield of the PEF-treated oyster mushrooms was increased by 34.0-45.5%, irrespective of the environmental and humidity conditions which varied between the repeated experiments. A proximate analysis of the mushroom fruiting bodies was conducted post-excitation for the moisture, fat, protein, and mineral content and compared with a negative control (no PEF excitation). The stimulated group showed a slight increase in mean crude fat and protein content compared with the control group. Bioaccumulation from the electrode surface was also reported to contribute to approximately 10% higher mineral content in the mushrooms.

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## Trait networks enhance understanding of growth and water use in contrasting environments

Dr Sean Gleason<sup>1</sup>

<sup>1</sup>*United States Department of Agriculture, Fort Collins, United States*

Plant growth and yield is the distant and final outcome of a complex network of coordinated physiological processes – an outcome that first begins with the exchange of water for atmospheric CO<sub>2</sub>. However, this simplistic view of plant growth gives short shrift to the infinite combinations of physiological and structural traits (trait networks), soil characteristics, and climates that engender plant performance. Given that experimental methods are not able to evaluate all of these plant-soil-climate combinations, process-based physiological modeling offers a ready alternative for gaining insight into beneficial plant trait networks. Here, using this framework, I take a step back from single trait performance outcomes and ask, what specific traits and trait connections would confer improved performance in a given soil and climate context? I focus on carbon-water relationships, specifically water uptake, water transport to the stomata and sites of evaporation in the leaves, and the exchange of water for CO<sub>2</sub>.

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## Designing wheat crops for changing environments

Assoc Prof Karine Chenu<sup>1</sup>, Dr Brian Collins<sup>1</sup>, Dr Najeeb Ullah<sup>1</sup>, Dr Jack Christopher<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Toowoomba, Australia

Abiotic stresses limit wheat production in major production regions worldwide. With climate change, increases in CO<sub>2</sub> concentration, temperature, evaporative demand and rainfall variability are projected to impact different crop processes and their interactions. A modelling approach was used to characterise the type of abiotic stresses that wheat crops are currently, and will be, experiencing in projected climate scenarios across the Australian wheatbelt. Over the last 30 years, without considering adaptation (i.e. with the same genotype and management practices), wheat crops have been increasingly affected by post-flowering heat stress, drought and frost. To best tune crop development with environmental variability, genotype and management adaptations were assessed in terms of crop maturity type and sowing date for current and future climate scenarios. Overall, for the future climate scenarios tested, results highlighted a shift towards earlier optimum sowing windows or earlier maturing genotypes by 2050. Heat and its interaction with drought appeared as the dominant sources of yield loss across the Australian wheatbelt in the future climate scenarios. The results, as well as advances in physiological and genetic adaptations will be discussed with a view to promoting increased grain yield across the Australian wheatbelt.

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## Designing photosynthesis for improving crop yield in contrasting environments

**Dr Alex Wu**<sup>1</sup>, Mr Jason Brider<sup>1</sup>, Dr Florian Busch<sup>2,3,4</sup>, Professor Min Chen<sup>5</sup>, Professor Karine Chenu<sup>1</sup>, Dr Victoria Clarke<sup>2</sup>, Dr Brian Collins<sup>6</sup>, Dr Maria Ermakova<sup>2</sup>, Professor John Evans<sup>2</sup>, Professor Graham Farquhar<sup>2</sup>, Dr Britta Forster<sup>2</sup>, Professor Robert Furbank<sup>2</sup>, Dr Michael Gorszmann<sup>2</sup>, Dr Miguel Hernandez<sup>5</sup>, Dr Benedict Long<sup>2</sup>, Mr Greg Mclean<sup>1</sup>, Professor Andries Potgieter<sup>1</sup>, Professor Dean Price<sup>2</sup>, Dr Robert Sharwood<sup>7</sup>, Mr Michael Stower<sup>1</sup>, Dr Erik van Oosterom<sup>1</sup>, Professor Susanne von Caemmerer<sup>2</sup>, Professor Spencer Whitney<sup>2</sup>, Professor Graeme Hammer<sup>1</sup>

<sup>1</sup>ARC Centre of Excellence for Translational Photosynthesis, Centre for Crop Science, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Brisbane, Australia, <sup>2</sup>ARC Centre of Excellence for Translational Photosynthesis, Division of Plant Science, Research School of Biology, The Australian National University, Acton, Australia, <sup>3</sup>School of Biosciences, University of Birmingham, Birmingham, UK, <sup>4</sup>Birmingham Institute of Forest Research, University of Birmingham, Birmingham, UK, <sup>5</sup>ARC Centre of Excellence for Translational Photosynthesis, School of Life and Environmental Science, Faculty of Science, University of Sydney, Sydney, Australia, <sup>6</sup>College of Science and Engineering, James Cook University, Townsville, Australia, <sup>7</sup>Hawkesbury Institute for the Environment, Western Sydney University, Richmond, Australia

Photosynthetic manipulation provides new opportunities for enhancing crop yield. However, understanding and quantifying importance of individual and multiple manipulations on the seasonal biomass growth and yield performance of target crops across variable production environments is limited. Using a state-of-the-art cross-scale model in the Agricultural Production System Simulation (APSIM) platform we predicted the impact of altering photosynthesis on the enzyme-limited ( $A_c$ ) and electron transport-limited ( $A_j$ ) rates, seasonal dynamics in canopy photosynthesis, biomass growth, and yield formation via large multiyear-by-location crop growth simulations for  $C_3$  wheat and  $C_4$  sorghum. In the top decile of seasonal outcomes, yield gains were predicted to be modest, ranging between 0 and 8%, depending on the manipulation and crop type. However, photosynthetic enhancement can affect crop growth, timing and severity of water and nitrogen stress on the growing crop, resulting in non-intuitive seasonal crop dynamics and yield outcomes. We predicted that strategies enhancing  $A_c$  alone generate more consistent but smaller yield gains across all water and nitrogen environments,  $A_j$  enhancement alone generates larger gains but undesirable in more marginal environments. Large increases in both  $A_c$  and  $A_j$  generate highest gains across all environments. This study uniquely unpacks complex cross-scale interactions between photosynthesis and seasonal crop dynamics, improves understanding and quantification of the potential impact of photosynthesis traits (or lack of it) for crop improvement research.

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## Manipulating sorghum leaf angle for improved growth

Dr Karen Massel<sup>1</sup>

<sup>1</sup>*The University of Queensland, St Lucia, Australia*

Changing the developmental patterns of crops can have enormous impacts to the water and carbon demands of the plant, and by altering the canopy architecture through targeted genetic manipulation we can greatly improve yield and yield stability of crop species. In sorghum, we used gene editing to target numerous auxin transporters have led to varied impacts on numerous canopy traits such as plant height, tiller number, and leaf size, along with the surprising finding of altering leaf angle and erectness. Leaf angle and erectness are a key components of canopy architecture and have been identified as key components for the development of high-yielding varieties. Although hormones are known to impact leaf angle, often gibberellins are implicated in QTL studies whereas auxins are believed to have a smaller role. This may be attributable to the redundancies found in the PIN genes of auxin transport, where our findings suggest we can modify the leaf angle by approximately 15° in either direction through knocking out just one or two genes. The traits discovered throughout this work have undergone predictive modelling for their potential impact in diverse environment and management scenarios. Although these outcomes are not the ideal 'smart canopy' with a gradual decline in leaf angle down the stem, these findings reveal auxins role in numerous aspects of canopy development and showcase how simple genetic manipulations can have dramatic phenotypic trait outcomes, which is a step toward developing superior crop varieties.



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## Understanding physiological changes associated to yield gain in US commercial sorghum

**Ms Paula Demarco<sup>1,6</sup>**, Laura Mayor<sup>2</sup>, José L. Rotundo<sup>3</sup>, P.V. Vara Prasad<sup>1</sup>, Geoffrey P. Morris<sup>4</sup>, Javier A. Fernandez<sup>1</sup>, Santiago Tamagno<sup>5</sup>, Prof Graeme Hammer<sup>6</sup>, Carlos D. Messina<sup>3</sup>, Ignacio A. Ciampitti<sup>1</sup>

<sup>1</sup>Department of Agronomy, Kansas State University, Manhattan, United States, <sup>2</sup>Corteva Agriscience, Wamego, United States, <sup>3</sup>Corteva Agriscience, Johnston, United States, <sup>4</sup>Corteva Agriscience, 7250 NW 62nd Ave., Johnston, IA 50310, USA <sup>4</sup> Department of Soil and Crop Sciences, Colorado State University, Fort Collins, United States, <sup>5</sup>University of California, Davis, United States, <sup>6</sup>Centre of Crop Science, University of Queensland, Brisbane, Australia

Understanding physiological changes in response to long-term selection for yield can inform breeding decisions and hasten genetic gain. The objective of this study was to characterize changes over time in yield-relevant physiological traits for hybrids with different years of release for grain sorghum (*Sorghum bicolor* L. Moench). Field trials were conducted during the 2018 and 2019 seasons in eight site-years across the states of Kansas and Texas (US) including 20 commercially-available grain sorghum hybrids released by Pioneer between 1963 and 2017. Detailed yield-related physiological traits were determined in two site-years including grain yield and its components, grain filling, plant biomass, panicle length, and water-soluble carbohydrates (WSC) during the reproductive period. Consistent with estimates using historical yield data, sorghum yield improvement was 27 kg ha<sup>-1</sup> yr<sup>-1</sup>. For the two site-years with detailed yield-related physiological traits, no changes in final grain weight, grain filling duration and rate over time were documented. In contrast, grain number increased at a rate of 100 grains m<sup>-2</sup> yr<sup>-1</sup>. Modern hybrids had larger panicle size and showed greater accumulation of WSC during vegetative period (as measured at start of flowering) and greater remobilization of WSC during the reproductive period (after flowering) to grain, thus, maintaining grain size on the increased grain number per unit area and harvest index. These findings suggest that WSC dynamics play a critical role on past genetic yield gain in sorghum and its potential for future improvements should be considered.

Keywords: sorghum, yield gain, physiological traits.

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## Why climate resilient dryland cropping systems?

**Ms Verity Morgan-Schmidt<sup>1</sup>**

<sup>1</sup>*Gheerulla Creek Consulting, Kenilworth, Australia*

Australian agriculture is constantly heralded for its resilience. The land of drought and flooding rains demands adaptation, innovation and the relentless pursuit of efficiency as precursors to surviving and thriving in an ever changing landscape.

But beyond the motherhood statements, what does climate resilient dryland cropping look like from a grassroots perspective? Why is it so important for individual farmers, communities, Australian agriculture and global food security? What does climate resilience mean in an export focussed industry? Applying the triple prism of “people, profit, planet” to the realities of dryland cropping - this presentation will explore how Australian dryland cropping farmers have adapted to climate change and improved their resilience to date and what they need from research and development into the future.

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## What is the climate productivity frontier for 2050 cropping likely to be?

Dr Steven Crimp<sup>1</sup>

<sup>1</sup>ANU Institute for Climate, Energy and Disaster Solutions, Canberra, Australia

At a global scale, dryland cropping occurs in an area approximately 40% of the total terrestrial land surface, hosting a similar proportion of the global population and spanning hyper-arid to sub-humid climates. These areas are characterised by considerable seasonal and inter-annual variations in both temperature and precipitation.

Cereal yields in dryland regions, particularly when produced without irrigation, are low due to water limitations and without water the benefits of innovative technologies like high-yielding varieties, fertilizers, pest management, are largely muted. This is evident in recent estimates of agricultural productivity, for crops like sorghum and millet (grown almost exclusively in arid and hyper-arid dryland environments) versus crops like wheat and maize that are grown in dryland regions that less water limited. Worldwide average yields for wheat have increased 2.5 times and for maize have increased 2.2 times, during the past four decades, and maize yield. In contrast worldwide yields of sorghum have increased only 1.6 times and millet 1.26 times during the past four decades.

The challenges to achieving sustainable food security in the coming decades are considerable, with multiple converging stressors e.g. a growing global population, increasing frequency of disruptive extreme, increasing input costs and volatility in commodity prices.

Identifying common and unique challenges and adaptation options requires an understanding of the interactions across all dimensions of the food systems. These include genetics, environment, management, social and legislative dimensions and their interactions (G × E × M × S × L).

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## Northern Australia Climate Program: Improving climate forecasting in northern Australian grazing systems

Dr Chelsea Jarvis<sup>1</sup>, Mr David Cobon<sup>1</sup>

<sup>1</sup>University of Southern Queensland, Toowoomba, Australia

Much of northern Australia has highly variable rainfall and is prone to both droughts and floods, which can seriously impact primary production. The Northern Australia Climate Program (NACP) is tasked with furthering and communicating climate science for the grazing industry in northern Australia. To accomplish this, NACP is composed of three components: Research, led by the Bureau of Meteorology (BOM); Development, led by the University of Southern Queensland (UniSQ); and Extension, also led by UniSQ.

The research component focusses on improving the seasonal climate model and optimising it for northern Australia. Long-term, this leads to improved forecast accuracy. The development component seeks to create new forecasting tools that specifically meet end-user needs. Both research and development benefit from a two-way flow of information between researchers and producers that is facilitated by NACP regional extension officers called Climate Mates.

The Climate Mates were hired based on connections to their community, knowledge about the local grazing industry, and communications skills. Training was provided for the Climate Mates by experts in climate and extension fields, including NACP research partners. The Climate Mates perform extension activities, such as speaking at workshops and 'Kitchen Table Talks' to communicate NACP findings and NACP-developed climate tools.

The NACP model is easily applicable to other regions and industries. Linking research and development to end user needs via extension assures that user needs are being met and research is meaningful in an applied context. Lessons learned from experiences with the NACP should be considered when implementing this model elsewhere.

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## Breeding crops for changing climates: where and when to start?

Dr Fernanda Dreccer<sup>1</sup>

<sup>1</sup>*Commonwealth Scientific and Industrial Research Organisation (CSIRO), Queensland, Australia*

Climate change with associated warming, unreliable rainfall and extreme climate variability challenges future agricultural productivity and food security. To address this challenge, breeding efforts need to focus on appropriate solutions to produce crop varieties for future environments and systems in which they will be grown. Part of that effort needs to recognise differences in the climate signals, e.g. impact of general warming vs. intrinsic heat stress, identifying traits and combinations of traits with potential for tolerance, and deploying breeding methods appropriate for the genetic complexity of the networks of traits involved in crop adaptation to the variable rates of a continually changing target population of environments.

Breeding for adaptation relies on understanding the rates of the environmental changes and a strong and systematic signal (highly correlated) for traits contributing to adaptation to enable identification of important alleles and permit their selection to generate new varieties. For environmental extremes typical of climate change, assessing value will be challenging due to their variable frequency. The need for new breeding approaches requires attention. As forecasts improve and farming systems evolve in response to greater heat, drought, and/or extremely wet seasons, tailoring germplasm with a specific fit to these conditions may represent a valuable proposition for growers. From the perspective of wheat breeding for Australian conditions, we discuss the need for a gamut of germplasm both in terms of adaptation for specific conditions and longer-term breeding efforts to improve intrinsic tolerance, and report on studies targeting constitutively expressed ideotypes (e.g. high biomass wheats for later sowing, increased rates of grain-filling, increased coleoptile length and reduced lodging).

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## Assessing the benefits of genomic tools for herd management decisions in drought

Dr Sabine Schmoelzl, Dr Adam Liedloff, Mr Yacob Beletse, Dr Antonio Reverter, Dr Brad Hine

<sup>1</sup>*Commonwealth Scientific and Industrial Research Organisation (CSIRO), Armidale, Australia*

Loss of improved genetics when de-stocking in response to drought is a major fear of producers and can prevent the timeliness of reducing stocking numbers. In drought conditions, or in response to other disruptions, producers face the need to reduce overall animal numbers to fit feed availability, including the need to substantially reduce the breeder herd within a limited timeframe. Delayed or insufficiently scaled destocking decisions can lead to resource degradation and can threaten financial viability of the business operation. Reduction of the breeder population affects the ability to generate income at the end of a drought period but also can affect the overall genetic value of the herd.

Genomic selection tools with indices directed at producers are emerging which provide commercial beef producers with the opportunity to base destocking strategies on genetic merit. Estimates of the long-term economic costs/benefits of destocking based on pregnancy status/age versus genetic merit of individual animals are not currently available.

In a proof-of-concept study, we used the Crop Livestock Enterprise Model (CLEM) to consider the different destocking strategies and their impact on the genetic value of the herd in a range of industry-relevant scenarios. The individual-based herd sub-model in CLEM was enhanced to track genetic index values of individuals and to consider these in herd management functionality in the model. In future work, the simulations will support informed decision making to meet the challenges imposed by an increasingly variable production environment.

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## Gender-specific perceptions on climate risks and farm level adaptation in coastal Bangladesh

**Dr Mst. Esmat Ara Begum<sup>1</sup>**, Dr. Md. Abdur Rashid, Dr. Md. Harunor Rashid, Dr. Mohammed Mainuddin

<sup>1</sup>*Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh*

The saline coastal areas of Bangladesh is one of the most climate vulnerable regions in the world due to low adaptive capacity and direct exposure to multiple climate risk. This study examines gender specific perceptions of major climate risks, and farmers' adaptation strategies in Dacope Upazila of Khulna district. Cross-sectional data collected from 100 households producing watermelon in Rabi season were employed. Perception of women in adaptation strategies to climate change is significantly lower than their counterparts. Results of the binary logit regression model revealed that membership of a farmers' association and perception of decreasing rainfall influenced farmers' adoption of intercropping as an adaptation strategy while experience in watermelon farming and perception of an increase in soil salinity influenced the adoption of mulching. Group membership, and perception of decrease in rainfall had a positive influence on farmers' adoption of use of mini pond for irrigation. Household size and access to training influenced farmers' adoption of changing sowing time and farming experience had a positive influence on changing cropping patterns. The findings from the Propensity Score Matching suggested that using these adaptation strategies exert positive effects on crop yield and income of the farmers. Policy further focuses on more investment in research institutes to strengthen the provision of agricultural services by improving support for irrigation and training to the farmers for enhancing their holistic adaptation to the effect of climate change. National Agriculture Policy in Bangladesh should also promote the formation of farmer associations to strengthen the adaptive capacity.

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## Precision pest management: A key to support healthy agriculture and food systems

Dr Nancy Schellhorn<sup>1</sup>

<sup>1</sup>RapidAim, Queensland, Australia

Technological advances in automated pest detection are enabling high quality pest information and in turn, precision pest management. RapidAIM digital crop protection that provides real-time detection for a range of pests, is one such example. Real-time pest detections are enabled by the fully integrated Internet of Things (IoT) insect sensors ([www.rapidaim.io](http://www.rapidaim.io)) deployed by customers.

Here we showcase the RapidAIM system of on-farm pest detections, and regional daily forecasts. The real-time data flowing from the sensors is aggregated and ingested into models for a broad range of pest analytics. Using machine learning, forecasts are generated across regions of 500km<sup>2</sup>. The high-quality, highly granular data flow from the IoT sensors results in a regression model that captures > 90% of the variability in field data.

The information from the regional forecast is used by crop advisors and growers to plan and prepare for the week, whereas the RapidAIM on-farm grid of sensors is used by growers to know when and where pests show up on their property and for them to validate whether control is working. Attachment to the RapidAIM service varies among end users and includes better workflow, 10x increase in fruit quality, greater confidence in managing pests, and improved efficiencies. Queensland fruit fly, *Bactrocera tryoni*, was the first pest for the commercial service provided by RapidAIM. The technology has expanded to include other key pests of horticulture including nut and fruit borers, and grain pests with focus on bollworms and armyworms.



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## Beneficial insects to deliver non-toxic solutions for pest management

Mr Dan Papacek<sup>1</sup>

<sup>1</sup>*Bugs for Bugs, Australia*

Following the widespread production and adoption of DDT and other organochlorine pesticides into agricultural systems more than 75 years ago, alternative pest management strategies were largely forgotten. Integrated Pest Management (IPM) has long been promoted as an environmentally sustainable alternative to an unthinking reliance on chemical pesticides.

Biological control of pests using both naturally occurring and mass-reared beneficial insects and mites is a key element in the IPM philosophy. This presentation provides an overview of the commercially available biocontrol agents in Australia with emphasis on the principles of conservation biocontrol.

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## Bioreporters and microbial omics approaches for discovery and deployment of biocontrols

Dr Louise Thatcher<sup>1</sup>, Dr Marta Gallart<sup>1</sup>, Dr Lachlan Dow<sup>1</sup>, Dr Katharina Belt<sup>2</sup>, Dr Cathryn O'Sullivan<sup>3</sup>, Dr Margaret Roper<sup>2</sup>

<sup>1</sup>Commonwealth Scientific and Industrial Research Organisation (CSIRO), Canberra, Australia, <sup>2</sup>Commonwealth Scientific and Industrial Research Organisation (CSIRO), Floreat, Australia, <sup>3</sup>Commonwealth Scientific and Industrial Research Organisation (CSIRO), St Lucia, Australia

Actinobacteria play important roles in soil ecology and members of this phylum are known for their ability to produce bioactive compounds with applications across multiple industries. For example, in agriculture this includes plant pathogen inhibiting compounds, inducers of immunity priming, or plant growth promotion. Genome sequencing has revealed these bacteria have far greater potential to produce bioactive compounds than was previously thought with up to 90% of chemical potential yet to be characterised. This vast hidden potential can be tapped for the discovery of new biopesticides to supplement existing or no longer viable crop protection tools. We curated a collection of beneficial soil and plant endophyte Actinobacteria isolated from the biodiversity hotspot of south-west Australia and developed and initiated screening via three platforms. 1) Genome sequencing and predictive comparative genomics approaches to determine chemical potential and facilitate the discovery of new compound leads and limit the rediscovery of known compounds. 2) Combined omics approaches with traditional microbial fermentation processes and *in vitro* and *in planta* screening across fungal pathogen diversity panels for selection of potent pathogen suppressive isolates and/or their bioactive compounds. 3) Using plant immune-biosensors (gene-based reporter systems) to screen Actinobacteria in real-time for their ability to potentiate plant immunity or manipulate plant defence signalling responses. This way, plant-microbe interactions can be monitored through non-destructive imaging. Combined, these platforms which can be adapted and deployed across microorganisms beyond Actinobacteria, are facilitating the discovery of biocontrols with powerful disease suppressive properties and the development of new biofungicide products.

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## Biological control of parasites and disease vectors associated with domestic livestock species

Dr Peter James<sup>1</sup>

<sup>1</sup>*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Australia*

There is increasing consumer demand for food and fibre produced in ethical, low residue and environmentally benign animal systems. In addition, the effectiveness of many key pesticides has been reduced by the development of chemical resistance and the high costs of registering new compounds has reduced the flow of novel and cost-effective replacement chemistries. This has increased focus on biological and other non-chemical methods as alternative or complementary controls. However, the particular characteristics of Australian animal production systems often present challenges for the implementation of non-chemical pest and parasite controls. This presentation will focus on some of the factors that impact on the feasibility and cost effectiveness of biological pest controls in livestock systems and describe research towards development of efficient and sustainable non-chemical methods.

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## Biological control of invasive woody weeds in natural ecosystems

Prof Victor Galea<sup>1</sup>

<sup>1</sup>The University of Queensland, School of Agriculture and Food Sciences (SAFS), Gatton, Australia

A stem implanted capsule technology developed by BioHerbicides Australia and the University of Queensland has resulted in improved and more sustainable outcomes for woody weed management. The technology utilises either biological material (fungal bioherbicides) or dry formulated chemical (synthetic) herbicides in size 0 hypromellose pharmaceutical capsules. Capsules are introduced to the target using a specifically engineered device, the Injecta<sup>®</sup>, that drills a hole into the stem allowing for rapid implantation of the capsule and its sealing in place with a wooden plug. The Injecta unit is powered by a cordless drill, is portable and easy to use with a removable magazine that holds 30 doses.

A fungal bioherbicide (Di-Bak Parkinsonia) for the treatment of invasive parkinsonia (*Parkinsonia aculeata*) has been registered for use, and available for sale since December 2018 giving excellent control of this weed under rangeland situations across northern Australia. Treatment of the target with the bioherbicide requires a single dose for a tree of any size. Treated trees rapidly display disease symptoms leading to mortality. The resulting dieback disorder leads to progressive spread through the treatment site leading to massive reduction in the adult and juvenile parkinsonia population. Colonisation of the soil by the fungal agents leads to pre and post-emergent control to deplete the soil seed bank. This product has also shown efficacy against Mesquite (*Prosopis* spp.). Bioherbicide candidates for other woody weed species are currently under development.

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## Antifungal photodynamic inactivation with curcumin

**Ms Maral Seididamyeh<sup>1,2</sup>**, Dr Michael Netzel<sup>1,2</sup>, Dr Ram Mereddy<sup>3</sup>, Prof Yasmina Sultanbawa<sup>1,2</sup>

<sup>1</sup>Centre for Nutrition and Food Sciences, Queensland Alliance for Agriculture and Food Innovations, The University of Queensland, St Lucia, Australia, <sup>2</sup>ARC Industrial Transformation Training Centre for Uniquely Australian Foods, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Indooroopilly, Australia,

<sup>3</sup>Department of Agriculture and Fisheries, Queensland Government, Coopers Plains, Australia

Food-borne diseases caused by contaminated food products continue to pose a threat to public health, as well as causing major economic losses and a negative impact on companies' reputation among consumers. Conventionally, various synthetic fungicides are used in the horticulture industry to reduce and inhibit the postharvest fungal contamination and decay in fruits and vegetables. Photodynamic treatment has been recently introduced to food industry as a promising green and cost-effective decontamination technique with no reports on toxic residues and microbial resistance. There are various natural photosensitizers that have been studied, among which curcumin showed to be effective against a wide spectrum of pathogenic and spoilage microorganisms including fungal spores. The antimicrobial activity is an effect of reactive oxygen species generated via photoexcitation of photosensitizer that is exposed to light. The application and efficiency of photodynamic treatment in various food matrices against a broad range of microorganisms demonstrates the potential of using this technology in food industry.

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## Carbon dots: A toolbox for managing biotic and abiotic stresses in plants

**Prof Qin Li**<sup>1</sup>, Mr. Muhammad Zia<sup>1</sup>, Dr. Prabhakaran (Sam) Thanjavur Sambasivam<sup>1</sup>, Prof. Rebecca Ford<sup>1</sup>, Dr. Shamsul Bhuiyan<sup>2</sup>

<sup>1</sup>Griffith University, Nathan, Australia, <sup>2</sup>Sugar Research Australia Pty. Ltd., Woodford, Australia

Climate change coupled with a rapid population growth has resulted in a plethora of new challenges to the agricultural industry. Rising temperatures, altered precipitation patterns and reduced water availability are having a huge impact on global food security. [1] Moreover, plant diseases and pests are responsible for 20-40% of global crop losses with an estimated value of USD 220 billion. [2] The challenges are beyond what the conventional agrochemicals can offer, and the industry is calling for more environmental-friendly technologies to enable sustainable and productive farming. Nanomaterials have emerged over the last few decades as one of the key contenders in offering such solutions. Carbon nanodots, a new member of the nanocarbon family, are the rising star in offering a versatile toolbox for managing a diverse biotic and abiotic stresses faced by crop plants. [3] Carbon dots are carbon-based nanoparticles, typically of a size smaller than 50 nm, exhibiting unique opto- and electro-properties. By tuning the precursors and synthesis method, carbon dots can be made as graphene quantum dots, or amorphous carbon nanoparticles, or carbon quantum dots, or even polymeric 'carbon' dots. [4] Moreover, their surface functionalities can be easily tuned owing to the versatile carbon chemistry. In this talk, we will provide a review based on literature and our own work on how to use carbon dots for enhancing photosynthesis efficiency, promoting growth, improving the heat and drought tolerance of plants, and providing disease resistance.

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## Plant nanobionics for enhanced photosynthesis in *Arabidopsis*

Dr Yichao Wang<sup>1</sup>

<sup>1</sup>Deakin University, Waurn Ponds, Australia

Increasing plant photosynthetic efficiency plays a critical role in food security and sustainable agriculture. Chloroplasts, the organelles in plants, convert solar energy into sugars that the cells can use. However, chloroplasts are only activated by wavelengths between 400 and 700 nm, which represent less than 45% of the solar spectrum. Therefore, extending the light spectrum and utilising the infrared (IR) or near UV lights for plant growth are essential to improve photosynthesis. In this study, we developed metal oxides-based upconversion nanoparticles that can be delivered *in vivo* to the chloroplasts of the model plant *Arabidopsis* by using plant nanobionics. In comparison to the control plants, *Arabidopsis* with nanomaterials exhibit a significant increase in root and stem lengths and wet/dry weights. Compared to plants without nanomaterials, *Arabidopsis* with nanomaterials enhances its photosynthetic rates by 2.5 times and its electron transport rate by 20%. Such an improved photosynthetic efficiency results from localised nanoparticles which absorb near-infrared (NIR) light and convert it to visible light via multiple-photon absorption, enhancing the solar lights coverage for plant growth. This work provides a feasible solution for improving photosynthesis using a plant nanobionics strategy.

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## Silica nanoparticle-based nanobiopesticides for sustainable agricultural applications

Dr Jun Zhang<sup>1</sup>, Prof Chengzhong Yu<sup>1</sup>

<sup>1</sup>The University of Queensland, Australian Institute for Bioengineering and Nanotechnology (AIBN), St Lucia, Australia

Biopesticides derived from natural materials are a new generation of eco-friendly pesticides for organic farming, crop protection and the livestock industry. However, most of biopesticide actives suffer from short duration of effectiveness and low potency in field conditions. Based on an advantageous nanoparticle technology, new nano-biopesticide designs with dual adhesion and protection functions were developed. Silica nanoparticles with spiky nanotopography were used as the nano-carrier. The nano-biopesticide formulations fabricated maintained the rough surfaces. When applied topically, this nano-biopesticide formulation exhibit enhanced adhesion to both agricultural substrates (e.g. animal hair) and pest surface. The dual adhesion property from the rough surface leads to significantly higher pest mortality and resistance to weathering effect towards benchmark commercial products. The solar radiation test revealed that the nano-biopesticide formulation exhibited >10 times higher photostability than the commercial product. This work provides important knowledge on the development of high-performance nano-biopesticides for sustainable agricultural applications.



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## Exposure assessment of nanopesticides

Assoc Prof Melanie Kah<sup>1</sup>

<sup>1</sup>*The University of Auckland, Auckland, New Zealand*

A variety of nano-delivery systems for pesticides, called nanopesticides, are being proposed and evaluated to improve current agricultural practices. Such delivery systems can be made of a range of materials, including inorganic (e.g. metals, metal oxides, clays), organic (e.g. polymers, lipids), and biological materials (e.g. inactive viruses). The potential applications and benefits are likely to be enormous. However, agroecosystems are incredibly diverse and complex, and designing viable and safe products for application in the field is challenging. A number of nanopesticides are already (or are close to) entering the market. Scientists and regulatory agencies have thus a high interest in evaluating implications for human and environmental health, and develop adequate regulatory tools that allow (i) the robust risk assessment of nanopesticides and (ii) an evaluation of their performances relative to currently used products. This presentation will summarize the findings of a series of investigations into the environmental fate of nanopesticides made of organic and inorganic materials. Results will be compared with those for unformulated active ingredients as well as commercially available formulations. These comparisons allow to discuss (i) the processes driving the fate of nanopesticides, (ii) how they can be evaluated under laboratory conditions, and (iii) the implications for exposure assessment in the regulatory context.

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## Interactions between nano formulations with plant leaves

Miss Shang Xu Jiang<sup>1</sup>, Dr Peng Li<sup>1</sup>, Dr Nasim Amiralian<sup>1</sup>, Professor Neena Mitter<sup>1,2</sup>, Professor Zhi Ping Xu<sup>1</sup>

<sup>1</sup>The University of Queensland, Australian Institute for Bioengineering and Nanotechnology, Brisbane/St Lucia, Australia,

<sup>2</sup>The University of Queensland, The Queensland Alliance for Agriculture and Food Innovation, Brisbane/St Lucia, Australia

Efficient topical spray of current agrochemical formulations and newly emerging particle-carried ones is one of the most direct and suitable approaches to sustainably enhancing the crop yield when facing the dramatical growth of the world population. However, the delivery efficiency of these agrochemical formulations is relatively low, resulting in the excessive usage of agrochemicals and subsequent eco-environmental issues.

The inefficiency of topical spray of agrochemical formulations is partly attributed to the runoff of spray drops from leaves to soil, which would be mitigated with continuous advances of nanotechnology. Nanotechnology is regarded as one enabling technology for developing sustainable agriculture. Specifically, nano-celluloses appear as an enhancer for topical spray of solutions and suspensions, which may largely reduce the droplet runoff from the leaves. Cellulose is the most abundant natural biopolymer with high industrial interests due to the low cost, good biodegradability, and no toxicity. The introduction of nano-cellulose into agrochemical formulations is hypothesised to enhance the deposition of formulation droplets on the leaf surfaces through various interactions. In this talk, I will report my group's recent findings regarding nano-cellulose formulations that enhance topical spray of soluble and particle-carried agrochemicals. My talk will focus on our nano-cellulose suspensions for enhanced water adhesion (water retention) on leaves. This work can be applied using the current spray facilities, and lead to huge economic and environment benefits to Australia and the world.

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## Development of Plant-Derived Nanovesicles for Anti-Fungal Strategies

Dr Angela Chen<sup>1</sup>, Mr Miguel Rito<sup>2</sup>, Ms Rachael Hamby<sup>1</sup>, Dr Hailing Jin<sup>1</sup>

<sup>1</sup>University Of California, Riverside, Riverside, United States, <sup>2</sup>University of Coimbra, Portugal

Fungal pathogens are a severe threat to food security, resulting in ~10% of global crop losses. Resistance to every major agricultural pesticide has also been noted, necessitating new anti-fungal strategies. One promising method is spray-induced gene silencing (SIGS), where double-stranded RNA (dsRNA) that targets fungal virulence genes is directly applied to plant material to control pathogen growth. The vulnerability of naked dsRNA to environmental conditions can result in degradation and a need for repeated application though, hampering SIGS application. To address this limitation, we examined the potential of plant-derived nanovesicles for dsRNA delivery and protection in SIGS application. Plant nanovesicles were isolated and characterized from various fruit and vegetable juices. Furthermore, although the plant nanovesicles exhibited differences in their material and functional characteristics based on juice source, all nanovesicles could be loaded with dsRNA. Finally, treatment of tomato fruits with dsRNA-loaded plant nanovesicles was effective against *Botrytis cinerea* infection. Overall, this study demonstrates how plant nanovesicles can be a new class of effective, economical, and eco-friendly nanocarriers for SIGS, providing an alternative to traditional chemical pesticides.

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## Navigating seed systems: pathways to climate-resilient development

Dr. Teshome Hunduma Mulesa<sup>1</sup>, Dr. Ola T. Westengen<sup>1</sup>

<sup>1</sup>*Department of International Environment and Development Studies(Noragric), Norwegian University of Life Sciences(NMBU), Ås, Norway*

Seed system development has received increased investments to enhance farmers' seed security in many developing countries for the last two decades. However, there is much disagreement on technical, institutional, and policy approaches to achieving this. This paper reviews the state of knowledge on seed system development, outlining the theoretical and empirical insights emerging from the literature that can help actors to navigate the way forward. We identify three key seed system functions — crop diversity management and varietal development, seed production, and seed dissemination — and two contextual factors affecting the operationalization of these functions— seed governance and food system drivers. For each of these functions and contexts, we synthesize evidence on the contributions and limitations of actors, activities, and institutions from both formal and informal seed systems and highlight ways forward to meet farmers' seed needs and demands. To improve farmers' seed security, technical and institutional interventions to enhance the functioning of seed systems must consider the strengths and weaknesses of all seed systems farmers use. Only such evidence-based interventions can meet the economic, agroecological, and socio-cultural needs and lead to the development of a resilient and socially inclusive seed system.

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## Rethinking the control and freedom of seed banks

Dr Kamalesh Adhikari<sup>1</sup>

<sup>1</sup>*School of Law, The University of Queensland*

Internationally, there is growing recognition that seed banks function as archives to make the historic and ongoing plant collections accessible for future use, including crop and food improvement research. This is because seed banks collect plants from wild and cultivated land (in situ) to conserve plant genetic diversity outside of natural surroundings (ex situ), and in so doing, make that diversity available for research, breeding, and food innovation. Unfortunately, following the enforcement of the Nagoya Protocol in 2014, ways by which seed banks collect, use, and circulate plants are increasingly becoming difficult and uncertain. The Nagoya Protocol extends to regulate seed banking practices based on the principles that plants are no longer part of the common heritage but are subject to control by State's sovereign rights, intellectual property rights, and other property rights, including the rights of plant providers and Indigenous people. Focusing on the difficulty and uncertainty created by the Nagoya Protocol, this paper will explore two critically important questions: How are seed banks impacted by the Nagoya Protocol? And, what legal space do seed banks have or need for continuing the access, use, and circulation of plant genetic diversity? In attempting to address these questions, the paper will also highlight the complexities and uncertainties associated with the access, use, and distribution of plants that seed banks collected long before the establishment of the Nagoya Protocol.

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## Strengthening farmers' seed systems in East Africa

Dr Gloria Otieno<sup>1</sup>

<sup>1</sup>*Alliance of Bioversity International and CIAT, Kisumu, Kenya*

Smallholders seed systems in the global south represent 80 percent of the seed and ultimately food systems. Yet, over the past few decades primary investments on seed systems have focused on the formal sector which accounts for only 20 percent of seeds farmers use. Moreover, climate change and biodiversity loss is leading to major challenges in availability of diverse seeds to farmers. Recent experiences in East Africa demonstrate that gene banks play an important role of providing diverse seeds to smallholders specifically to build their resilience to climate change and for breeding. However, since the “informal sector” remains crucial for seed acquisition, interventions in seed value chains and in policies, institutions and regulations are needed to improve seed systems and make them more responsive to smallholders' needs. As such, a number of interventions are crucial such as: creating linkages between national gene banks and community seedbanks to provide diversity needed by farmers; engaging with breeding programs in participatory varietal selection and breeding; and strengthening community-based seed production through supportive policies and regulations that incorporate provisions for alternative quality assurance mechanisms and the registration of farmer varieties.

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## National efforts to strengthen seed systems: Experiences from Bhutan

Dr Asta M Tamang<sup>1</sup>

<sup>1</sup>National Biodiversity Centre, Serbithang, Thimphu, Bhutan

Seed systems play a central role in food production and consumption sustainability by maintaining the diversity of crops and varieties and providing new, improved varieties with various traits that farmers need for crop production in Bhutan. This role can be bolstered by tapping into the strengths of both formal and farmers' seed systems and improving the coordination, linkages, policy, and legal frameworks to encourage the participation of all seed system actors and investment by public, private and community-based institutions. This paper examines seed system actors' efforts at various levels in Bhutan, i.e., their programs, activities, and strategies for strengthening national seed systems. In addition, the paper documents challenges and success stories related to stakeholder coordination and policy and legal frameworks governing Bhutanese seed systems. Despite some government, donors, and non-governmental efforts to strengthen national seed systems, approximately 98% of seed supply is from poorly supported local seed systems. Moreover, the formal seed system that supplies the remaining 2% of the seeds depends on seed imports from other countries. However, community-based seed production and distribution show promise in integrating formal and informal seed systems, improving timely and quality seed supply, and varietal turnover for farmers growing different crops in one of the most diverse agro-ecologies of the Himalayas. This paper concludes by highlighting the policy and program support required to strengthen the under-funded seed systems of Bhutan by policymakers, the government, and donors.

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## Developing seed law in Southeast Asia's Greater Mekong Subregion

**Mr Erik Delaquis<sup>1,2,3</sup>**, Dr Michael Halewood<sup>4</sup>, Ms Cheyenne Gerlach<sup>3</sup>, Dr Ir Conny J. M. Almekinders<sup>3</sup>, Dr Jonathan Newby<sup>1</sup>, Prof Dr Ir Paul C Struik<sup>2</sup>

<sup>1</sup>International Center for Tropical Agriculture (CIAT), Vientiane, Lao People's Democratic Republic, <sup>2</sup>Wageningen University & Research, Centre for Crop Systems Analysis, Wageningen, The Netherlands, <sup>3</sup>Wageningen University & Research, Knowledge, Technology and Innovation Group, Wageningen, The Netherlands, <sup>4</sup>Bioversity International, Rome, Italy

Seed use and exchange continue to come under ever increasing regulation. We investigate the development of regulations in Southeast Asia's Greater Mekong Subregion (GMS), a region undergoing a rapid period of legislative development. Despite shared borders and entangled economies, GMS countries are politically heterogeneous, and have responded to developments in the international environment with differing seed law development trajectories.

Utilizing systematic searches of five major databases of laws, regulations, and policies, we identified 137 items relating to the legislation of seed in Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam. We identified major periods of legal development and elements of the resultant legal frameworks encouraging or inhibiting diverse, pluralistic seed systems. In addition, we mapped participation in key international agreements, treaties, and trade blocs, and discuss the influence of these international scale organizations on regional seed law.

Our findings highlight the influences of international organizations on national legislators, including growing pressure imposed by the recent emergence of numerous mega trade areas both within and beyond East Asia to adhere to UPOV standards – even though most countries are not formal members. We show that the increasingly layered seed regime complex promotes the development of formal and commercial sectors, potentially at the expense of existing and future farmer and polycentric actor networks. The example of cassava, a major regional commodity crop, is used to highlight the discrepancies in applicability between new emerging legislation based largely on grains and cereals, and existing practice, particularly as applied to important economic vegetatively propagated crops.



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## Impacts of seed clubs in ensuring local seed systems in the Mekong Delta, Vietnam

**Nguyễn Hữu Lợi**<sup>1</sup>

<sup>1</sup>*Can Tho University, Vietnam*

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## Pangenomics for improving tropical legume crops

**Prof Rajeev Varshney<sup>1</sup>**

<sup>1</sup>Centre for Crop & Food Innovation, State Agricultural Biotechnology Centre, Food Futures Institute, Murdoch University, Murdoch, Australia

Innovative genomics and crop breeding approaches have shown promise in enhancing crop performance. However tropical legume crops such as chickpea, pigeonpea and peanut have remained lagging behind as compared to leading cereal crops and industrial legume crops like soybean in area of genomics-assisted breeding. To accelerate crop improvement in the tropical legume crops, we assembled reference genomes for these crops. As availability of genome of one individual is not enough for describing the genetic variation for a given crop species, we sequenced large number of individuals including 3000 genotypes in chickpea and 300 genotypes each in pigeonpea and peanut. Based on these whole genome re-sequencing data, pangenomes were developed for each legume crop. Such pangenome analyses describe genomic diversity across cultivated species and their wild progenitor accessions in each of these legume crops. Our analysis found chromosomal segments and genes that show signatures of selection during domestication, migration and improvement. Deleterious mutations responsible for limited genetic diversity and decreased fitness were also identified in elite germplasm in chickpea. Furthermore, in the case of chickpea after undertaking genome wide association study with whole genome sequencing data and phenotyping data collected at six locations for two years, we identified superior haplotypes for improvement-related traits in landraces that can be introgressed into elite breeding lines through haplotype-based breeding. Finally, by using genomics-assisted breeding approaches, more than a dozen high-yielding legume varieties with enhanced tolerance to biotic/abiotic stresses and higher nutrition have been developed and delivered to small-holder farmers in India, Ethiopia, and Kenya.

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## Genomics and phenomics assisted Mungbean breeding

Dr Ramakrishnan Madhavan Nair<sup>1</sup>, Dr AKMM Alam<sup>2</sup>, Dr Aditya Pratap<sup>3</sup>, Dr Rudy Soehendi<sup>4</sup>, Ms Rael Karimi<sup>5</sup>, Dr Mar Mar Win<sup>6</sup>, Dr Merrill Ryan<sup>7</sup>, Ms Shanice Van Haeften<sup>8</sup>, A/Prof Lee Hickey<sup>8</sup>, Dr Abhishek Gowda<sup>1</sup>, Dr Aparna Shivanna<sup>1</sup>, Dr Roland Schafleitner<sup>9</sup>, Dr Ya-ping Lin<sup>9</sup>, Dr Cheng-Ruei Lee<sup>10</sup>, Dr Eric Huttner<sup>11</sup>

<sup>1</sup>World Vegetable Center, South & Central Asia, Hyderabad, India, <sup>2</sup>Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, <sup>3</sup>ICAR- Indian Institute of Pulses Research (IIPR), Kanpur, India, <sup>4</sup>Indonesian Legumes and Tuber Crops Research Institute (ILETRI), Malang, Indonesia, <sup>5</sup>Kenya Agricultural and Livestock Research Organization (KALRO), Katumani, Kenya, <sup>6</sup>Myanmar Department of Agricultural Research (DAR), Yezin, Myanmar, <sup>7</sup>Queensland Department of Agriculture and Fisheries (DAF), Warwick, Australia, <sup>8</sup>The University of Queensland (UQ), Brisbane, Australia, <sup>9</sup>World Vegetable Center, Hq, Shanhua, Taiwan, <sup>10</sup>National Taiwan University (NTU), Da'an, Taiwan, <sup>11</sup>Australian Centre for International Agricultural Research (ACIAR), Canberra, Australia

Mungbean (*Vigna radiata* var. *radiata* (L.) Wilczek) is a nutritious legume crop adapted to tropical and subtropical conditions. Short duration (60 days), and tolerance to heat and drought makes mungbean a suitable crop for different cropping systems. The World Vegetable Center has established a Mungbean Mini-core Collection of 296 accessions that displays a large portion of the variation available in the World Vegetable Center mungbean genebank collection of around 8,000 accessions. A wide range of useful traits including resistance to Mungbean Yellow Mosaic Disease, anthracnose, halo blight, dry root rot, powdery mildew, cowpea aphids, thrips, salt tolerance, and synchronous maturation have been identified in the mini-core and have been used in mungbean breeding programs by the partners of the International Mungbean Improvement Network (IMIN). Genomics tools will support molecular breeding approaches in mungbean to introgress disease and pest resistance from landraces into high yielding elite varieties. A grant of the Agricultural Greater Good Program from Illumina allowed to resequence the whole genome of the mini-core collection lines plus important breeding materials. Multilocation field evaluation data of the mini-core collection and of breeding lines are available, and in parallel, high throughput phenotyping of the mungbean collection is ongoing to collect precise data on mungbean development and morphology. The project partners are actively engaged in the introgression of traits from donors identified during IMIN1 and are progressing testing of high performing lines.

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## Physiological insight to improve mungbean productivity

**Dr Millicent Smith<sup>1,2</sup>**, Shanice Van Haeften<sup>1</sup>, Caitlin Dudley<sup>1</sup>, Andries Potgieter<sup>1</sup>, Hannah Robinson<sup>1</sup>, Lee Hickey<sup>1</sup>  
<sup>1</sup>Centre for Crop Science, Queensland Alliance for Agriculture and Food Innovation, St Lucia, Australia, <sup>2</sup>School of Agriculture and Food Sciences, Gatton, Australia

Mungbean (*Vigna radiata* (L.) R. Wilzeck var. *radiata*) is a high-value summer crop rotation in Australia due to its short duration and low input requirement with growers receiving good returns for quality product. Despite high prices and demand, mungbean production can be viewed as a risk due to variable yield. Recent research has helped to establish the key physiological determinants of yield for current mungbean varieties. Opportunities are now available to build on this foundational knowledge to ensure that future mungbean varieties have optimal characteristics that ensure yield stability. Using detailed phenotyping protocols in the glasshouse and unmanned aerial vehicle platforms in multi-environment field trials, key traits such as canopy development, flowering time, flowering behaviour, canopy temperature and stomatal conductance have been measured on a diverse mungbean population. New physiological knowledge of traits and trait variation has been captured and will contribute to the advancement of crop improvement programs.

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## Proteomics for designer pulse protein

**Ms Arineh Tahmasian<sup>1,2</sup>**, Dr James Broadbent<sup>2</sup>, Dr Angéla Juhász<sup>1</sup>, Dr Mitchell Nye-Wood<sup>1</sup>, Dr Thao Le<sup>3</sup>, Prof Michelle Colgrave<sup>1,2</sup>

<sup>1</sup>Edith Cowan University, Joondalup, Australia, <sup>2</sup>CSIRO Agriculture and Food, St Lucia, Australia, <sup>3</sup>Auckland University of Technology, New Zealand

There is a growing demand for plant-based protein sources to complement the traditional protein sources and meet future global nutritional requirements. The grain legumes, one of the highest natural sources of protein and fibre, have the potential to provide a sustainable solution to ensure food and nutrition security. These nutrient-dense seeds are also an excellent source of bioactive components the consumption of which are known to have positive outcomes on controlling cardiovascular disease, diabetes and obesity. Despite the significant potential the insights on the proteome diversity and the molecular mechanisms controlling the phenology in pulses are still elusive.

Proteomic approaches can unravel the proteome diversity of existing germplasm of different pulse species, and hence result in identification of optimal varieties for further enhancement and development of varieties suited to different markets. Furthermore, proteome studies can inform precision genome engineering targets through discovery of marker proteins responsible for desired traits and provide an opportunity to manipulate the genes responsible for protein(s) of interest in order to yield a superior phenotype.

Herein, discovery and quantitative proteomic approaches will be described for in-depth profiling of legume grain proteins and screening genetically diverse varieties for their nutritional and antinutritional protein contents. In addition, the applications of bioinformatic tools to gain biological insights into the identified proteome and unravelling the potential candidate markers associated with particular traits will be described. The findings from combinational proteomic and bioinformatic approaches will have an important contribution in accelerating pulse improvement programs and addressing the challenges of maintaining a sustainable food system.

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## Application of artificial intelligence in tropical pulse breeding

**Prof Ben Hayes**<sup>1</sup>, Prof Kai Voss-Fels<sup>1,2</sup>, Dr Eric Dinglasan<sup>1</sup>, Associate Professor Lee Hickey<sup>1</sup>

<sup>1</sup>The University of Queensland, St Lucia, Australia, <sup>2</sup>Hochschule Geisenheim University, Geisenheim, Germany

In pulse breeding, lines with the highest *per se* performance (for disease resistance, yield, product quality) or best breeding values for these traits are selected as parents for crossing. This approach does not capture chromosome segments with desirable effects on these traits embedded in lines with overall low or average performance. The breeding challenge could be stated as identifying the best cross combinations that maximise stacks of chromosome segments (eg those containing desirable alleles). This is particularly challenging when a combination of traits (e.g. yield, disease resistance, quality) are considered simultaneously. This problem is well suited to evolutionary computation approaches (a form of AI), where algorithms inspired by biological evolution are employed to find solutions to complex problems.

We propose a new approach that uses evolutionary computing, genomic prediction, digital twin simulation and “speed breeding” to rapidly develop “ultimate stacks”. As a case study, we demonstrate the potential of this approach in chickpea, using elite lines and gene bank germplasm.

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## Novel breeding approach for faster cooking biofortified common beans in East Africa

**Dr Clare Tekla Mukankusi<sup>1</sup>**

<sup>1</sup>Alliance Of Bioversity International And International Centre For Tropical Agriculture (ciat), Kawanda, Uganda, <sup>2</sup>The UWA Institute of Agriculture, The University of Western Australia, Perth, Australia, <sup>3</sup>UWA School of Agriculture and Environment, The University of Western Australia, Perth, Australia, <sup>4</sup>Animal Genetics and Breeding Unit, University of New England, Armidale, Australia, <sup>5</sup>Australian Centre for International Agricultural Research, Canberra, Australia, <sup>6</sup>Tanzania Agricultural Research Institute, Maruku, Bukoba, Tanzania, <sup>7</sup>National Crops Resources Research Institute-National Agricultural Research Organisation, Namulonge, Uganda, <sup>8</sup>Rwanda Agricultural and Animal Resources Development Board, Huye, Rwanda, <sup>9</sup>Kenya Agricultural and Livestock Research Organization, Kakamega, Kenya, <sup>10</sup>Ethiopia Institute of Agricultural Research, Melkassa, Ethiopia, <sup>11</sup>Institut des Sciences Agronomiques du Burundi, Bujumbura, Burundi

Common bean (*Phaseolus vulgaris* L.) provides essential protein, iron (Fe) and zinc (Zn) for African women and children. Traditional varieties have long cooking time (CKT) which increases time, energy and health costs. A novel breeding approach "BRIO" based on accurate breeding values, rapid cycles, index selection for multiple traits and optimal contribution selection (OCS) was used to breed short CKT beans biofortified with Fe and Zn and high grain yield (GY). OCS based on economic index of weighted genomic estimated breeding values (GEBV) for each trait was used to design crossing within six market groups relevant to East Africa. Crosses for the second cycle were designed based on OCS in three groups: i) primary goal to reduce CKT and secondary goal to increase Fe and Zn, ii) primary goal to increase Fe and Zn and secondary goal to reduce CKT, and iii) primary goal to retain BCMNV bc3a resistance allele and secondary goal to reduce CKT time and increase Fe and Zn. Predicted changes in cycle 2 with OCS showed genetic improvements in all traits despite detrimental correlations between some traits. Selections were made in six partner countries in East Africa for advancement to advanced variety trials. A 30% reduction in the mean population CKT and 15% increase in Fe and 10% increase in Zn is expected after 5 cycles of annual recurrent selection.

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## Designing plant architecture for future climates

**Prof Andrew Borrell**<sup>1</sup>, Dr Albert Wong<sup>2</sup>, Dr Karen Massel<sup>2</sup>, Ms Yasmine Lam<sup>2</sup>, Mr Zac Aldiss<sup>2</sup>, Ms Jasmin Deo<sup>2</sup>, Prof Ian Godwin<sup>2</sup>, A/Prof Lee Hickey<sup>2</sup>, Prof Rod Snowdon<sup>3</sup>, Dr Ben Trevaskis<sup>4</sup>, Dr Barbara George-Jaeggli<sup>1,5</sup>, Dr Erik van Oosterom<sup>2</sup>, Prof Graeme Hammer<sup>2</sup>, A/Prof Emma Mace<sup>1,5</sup>, Dr Colleen Hunt<sup>5</sup>, Dr Guoquan Liu<sup>2</sup>, Prof David Jordan<sup>1</sup>

<sup>1</sup>The University of Queensland, Warwick, Australia, <sup>2</sup>The University of Queensland, Brisbane, Australia, <sup>3</sup>Justus-Liebig University, Giessen, Germany, <sup>4</sup>CSIRO, Canberra, Australia, <sup>5</sup>DAF, Warwick, Australia

Drought adapted crops will be required to ensure food security in the face of climate change. We explored how two gene families (*PIN* and *VRN*) modify canopy development and root architecture in two major crops (sorghum and barley) to enhance drought adaptation. Previous studies by our group identified that both gene families regulate plant architecture in cereals, highlighting the potential for manipulating root and shoot growth. We show that the *PIN* family of auxin efflux carriers induce some of the causal mechanisms driving the stay-green phenotype in sorghum. We found that 9 of 11 sorghum *PIN* genes aligned with known stay-green QTL. We demonstrated that *PIN* genes located within the *Stg1* (*SbPIN4*), *Stg2* (*SbPIN2*) and *Stg3b* (*SbPIN1*) QTL regions acted pleiotropically to modulate canopy development, leaf anatomy, photosynthesis, root architecture, root angle and panicle growth in sorghum. *SbPIN1*, *SbPIN2* and *SbPIN4* were differentially expressed in various organs relative to the non stay-green control. In subsequent studies, overexpression and knockout lines were developed for both gene families in both cereal crops. We show that *PIN* genes modify canopy, root and panicle architecture in sorghum and root architecture in barley. Furthermore, we demonstrate that *VRN* genes modify leaf length in barley and stem width and panicle length in sorghum. These findings show that manipulation of *PIN* and *VRN* genes can lead to phenotypes with altered canopy and root architectures, with the potential to create genotypes that are better adapted to future climates.



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## Crop hydraulic engineering using aquaporins

Assoc Prof Caitlin Byrt<sup>1</sup>

<sup>1</sup>*Australian National University, Canberra, Australia*

Crops use aquaporins to control cell and tissue water potential and flux. Aquaporins are pore-forming membrane proteins that can transport a range of solutes including water, gas, salt, nutrient, organic and signaling molecules. Aquaporins contribute to hydraulic conductivity through their roles in influencing solute uptake in roots, cell-to-cell solute flux, root-to-shoot solute transport, cellular osmolarity maintenance and stomatal regulation. The culmination of these roles significantly influences crop transpiration, water-use efficiency and productivity. The permeability of cell membranes to solutes can be adjusted by several orders of magnitude by altering aquaporin function. Aquaporins can be turned on and off, like a tap, and the membrane domains containing aquaporins can be connected and disconnected from the membrane locations that influence the flow of solutes by membrane remodeling. The interactions of aquaporins with other proteins and signals is important in determining the contribution of aquaporins to helping cells adapt to changes in the environment, such as changes in water availability. Aquaporin functions and interactions impact crop productivity when water is scarce. Resolving how different aquaporins contribute to different hydraulic features in crops and optimising their regulation through new and established breeding technologies is an important step towards adapting crops to environmental conditions where water availability is limited.

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## Quantifying physiological determinants of potential yield in mungbean

Dr Geetika Geetika<sup>1</sup>, Dr Douglas Brumley<sup>1</sup>, Prof Graeme Hammer<sup>1</sup>, Dr Millicent Smith<sup>1</sup>, Dr Vijaya Singh<sup>1</sup>, Dr Marisa Collins<sup>1</sup>, Dr Vincent Mellor<sup>1</sup>, Dr Kylie Wenham<sup>1</sup>, Assoc Prof RCN Rachaputi<sup>1</sup>

<sup>1</sup>The University of Queensland, Australia

Mungbean (*Vigna radiata* (L.) Wilczek) is a summer legume crop, grown under rain-fed conditions in the northern grain region (NGR) of Australia. Increased global demand and high market prices makes mungbean a profitable crop. Although, there is an increasing need to improve mungbean productivity, the current industry yield suffers from low and variable yield. NGR frequently experiences variable rainfall and extreme temperatures, exacerbating production risks. Despite this, improvements in yield and yield stability can be achieved through the use of crop simulation models to predict genotype performance under variable environments and management practices. However, detailed understanding of physiological determinants of yield is required to form the basis of crop models. Hence, there is a need to better understand the underlying drivers of yield in mungbean. The aim of this study was to quantify the effects of varying canopy density treatments on physiological determinants of potential yield in mungbean. Two experiments were conducted at The University of Queensland, Gatton, campus in the summer of 2019 and 2020, using three mungbean genotypes. Leaf area index (LAI) influenced by the canopy density treatments, was the key driver of differences in radiation interception, total dry matter, and grain yield. Radiation extinction coefficient,  $k$  was 0.68 and radiation use efficiency (RUE) was 1.3 g MJ<sup>-1</sup> PAR. A preliminary simulation of yield based on the physiological determinants predicted potential yield of 1.88-2.48 tonnes ha<sup>-1</sup> for the NE Australia. This predictive framework will provide opportunities to simulate crop adaptations for the present and future climate scenarios.

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## Designing sorghum crops for adaptation to future climates

**Prof Graeme Hammer**<sup>1</sup>, Mr Greg McLean, Dr Erik van Oosterom, Prof Scott Chapman, Dr Bangyou Zheng, Dr Alex Wu, Mr Al Doherty, Prof David Jordan

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Indooroopilly, Australia

Climate risks pervade agriculture. They generate major consequences on crop production. We do not know what the next season will be like, let alone the season 30 years hence. Yet farmers need to decide on **G**enotype and **M**anagement combinations in advance of the season and in the face of this risk on the production **E**nvironment. Beyond that, breeders must consider target adaptive traits for future genotypes up to 10 years ahead of their commercial release. Can we do more than continue the random walk of empirical and separate agronomic and breeding research that tells us more about consequences of seasons experienced than those yet to be experienced? Here we present the case for next generation thinking on design of G\*M\*E for advancing crop adaptation in future climates. We focus on adaptation to drought and heat in sorghum, but the concepts are generic. There exists considerable knowledge of climate, both past and future, from climate records and climate models. We know that CO<sub>2</sub> and temperature are increasing, and this alone influences drought and heat risks for crops. We also have considerable knowledge of crop growth and development responses to CO<sub>2</sub>, drought and heat, along with the physiology and genetics of underpinning mechanisms. This knowledge has been integrated into advanced crop simulation models that are now sufficiently credible to explore G\*M\*E scenarios via simulation of comprehensive “adaptation landscapes”. Here we combine this existing knowledge and modelling capability to explore the design of crops best suited to current and future environments.

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## Scalable modelling tools to assess G×E×M interactions at continental scales

Dr Jonathan Ojeda<sup>1</sup>

<sup>1</sup>Regrow Ag, Graceville, Australia

There is a gap in placing new maize varieties into the hands of farmers and a lack of crop modelling tools at regional scale in Sub-Saharan Africa. This project seeks to test the technical feasibility of using satellite imagery and crop modelling to predict success (based on crop growth and phenology) of a new maize cultivar (G) in a particular environment (E) and crop management (M). We are developing a decision support tool (Niche) to optimize allocation of on-farm trials using the regional fit of contrasting maize varietal types and identify the main sources of grain yield variability for each G×E×M combination. This project will allow end-users to identify i) where would experimental trials be best located and ii) with which cultivars per environment. By developing fine-scale agroecological zonation (1 km spatial resolution) through Technology Extrapolation Domains, the Niche tool can inform the on-farm trial planner how to representatively sample the Target Population of Environments. By understanding which cultivars may perform best in each agroecological zone and management, the Niche tool can support in developing the entry list per location. As such the Niche tool needn't provide a perfect allocation of cultivar to location but instead determine which set of cultivars might provide the best match. Empirical data from the executed on-farm trials can serve as validation and novel training data for the next iteration of predictive modelling. The approach generated in this project is reproducible to any crop and crop model and scalable to any region in the world.

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## BioClay™ - RNA based sustainable crop protection

Prof Neena Mitter<sup>1</sup>, Mr Mike Pointon<sup>2</sup>

<sup>1</sup>Queensland Alliance for Agriculture and Food Innovation, Australia, <sup>2</sup>Nufarm Australia Limited, Australia

Management of pests and diseases is a key cog in the Agrifood supply chain to ensure food and nutritional security. The ongoing usefulness of chemical pesticides suffers from issues such as residual toxicity, run-off, pest specificity and resistance. RNA based biopesticides or 'RNA sprays' for plants as a next generation crop protection platform without the need for genetic modification is gaining momentum globally. The BioClay™ technology to deliver double stranded RNA, the key trigger molecule of RNA interference as biological active using clay particles as carriers is being developed at the University of Queensland with Nufarm Australia Limited as the commercialisation partner. It presents a non-GM, residue free, specific, and environmentally sustainable crop protection alternative. RNAi effectors delivered as BioClay are stable, do not get washed off and provide protection to the sprayed and unsprayed leaves against the targeted virus for up to 20 days post spray. The clay degrades on the surface of the leaf alleviating concerns about residues. We have recently shown that BioClay can provide protection against multiple life cycle stages of whitefly, a pest with a very wide host range and *Botrytis cinerea*, a fungus that infects both horticultural and broad acre crops. BioClay platform is being progressed to target viruses, insect pests and fungi including pathogens such as *Verticillium*, *Fusarium* and *Phytophthora*. Real world application of RNA based biopesticides with sustainable credentials for the global consumer will be governed by factors such as cost-effective production of dsRNA, the regulatory landscape and public licensing.

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## Novel virus-like agent to deliver siRNAs into trees/vines for long-term pathogen control

**Prof Anne Simon<sup>1,2</sup>**

<sup>1</sup>Silvec Biologics, Gaithersburg, United States, <sup>2</sup>University of Maryland, College Park, United States

Pathogens that sequester in vascular tissue are extraordinary difficult to target with conventional eradicating agents applied by foliar sprays or trunk injections, which can be labor intensive and also require repeated applications for the life of the tree. RNA therapies that have been so beneficial for protection of humans from viral diseases can also be used for plants, as decades of research has shown that small RNAs can directly target bacteria, viruses, fungi, nematodes, and insects. The key to using this strategy for the protecting of seedlings and bearing trees is developing a robust delivery system that can generate copious amounts of small RNAs from a single application for the life of the tree. Five years ago, the chance discovery that a novel agent recovered from limequat trees in Southern California might have properties required for such a delivery system kicked off a race against time to determine its utility against citrus pathogens. We have determined that the vehicle, citrus yellow vein associated virus (CYVaV) has the capacity to deliver five to seven pathogen-targeting small RNAs, which in our laboratory hosts can completely shut down infection by viruses like citrus tristeza virus and fungi like *Botrytis cinerea*. CYVaV is symptomless and cannot move out of an infected tree without a specific helper virus, which can also be targeted to never infect the same tree as CYVaV. We have engineered the CYVaV delivery vehicle to be stable so one application should last for the life of the tree.

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## RNAi in integrated pest management

Dr Kristof De Schutter<sup>1</sup>

<sup>1</sup>*Department of Plants and Crops, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium*

The biodegradability and target-specificity of double-stranded RNA (dsRNA), puts RNA interference (RNAi) at the forefront of biosafe insecticide technology. RNAi-based applications are being developed to improve plants by modifying endogenous gene expression as well as to target pest and pathogen genes both within plants (i.e. host-induced gene silencing) and as topical applications (e.g. spray-induced gene silencing). Although these RNAi-based plant protection products show much potential, there remain critical knowledge gaps in each of these areas. Especially for the SIGS approach, RNAi efficacy needs to be improved by overcoming the barriers of RNAi. In addition, while there is an urgent need to develop appropriate science-based risk assessment procedures for topical RNAi applications. And particular emphasis must be placed on ensuring RNAi's compatibility with integrated pest management (IPM).

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## Protecting Australian crops from lepidopteran insect pests using RNAi

Dr Julia Bally<sup>1</sup>, Prof Peter Waterhouse<sup>1</sup>, Prof Kenneth Narva<sup>2</sup>

<sup>1</sup>Queensland University of Technology, Brisbane, Australia, <sup>2</sup>GreenLight Biosciences, Durham, USA

In the past 20 years, numerous invasive insect pest species have emerged and developed as a threat both worldwide and to Australia's natural environment and agriculture industries. More than 70% of all agricultural pests are insects belonging to the order Lepidoptera. Amongst them, insects such as *Helicoverpa armigera*, the cotton bollworm, and *Spodoptera frugiperda*, the fall armyworm, are responsible for severe yield losses in many cultivated crops and wild plants. Several approaches to control crop infestations by lepidopteran insects are commercially available with chemical pesticides remaining the most widely used. Unfortunately, the long-term use of these insecticides has led to the development of resistance and caused environmental concerns. Effective alternatives protection strategies that are healthier for the environment and for human health, must be continuously developed and improved to keep pace with the resistance development and global spread of invasive species. Other methods of control have been considered to this aim such as RNA interference (RNAi). RNAi can be used as an environmentally friendly pest management strategy. Over the last 5 years, plant expression of dsRNA that targets essential genes of Coleopteran pests has been shown to be an effective method of crop protection. However, the technology has been less effective against Lepidopterans until recently. We have achieved some success against this pest using dsRNA expressed in the chloroplasts or using chimeric insect/plant microRNAs. The challenge is to transfer this success into a sprayable form. We will describe new ways of dsRNA delivery for effective protection against devastating lepidopteran insect pests.



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## Organic nanovesicles are ideal RNA delivery carriers for spray-induced gene silencing

**Dr Angela Chen**<sup>1</sup>, Dr Lulu Qiao<sup>1,2</sup>, Dr Jonatan Nino Sanchez<sup>1,3</sup>, Rachael Hamby<sup>1</sup>, Luca Capriotti<sup>4</sup>, Miguel Rito<sup>5</sup>, Professor Bruno Mezzetti<sup>4</sup>, Professor Hailing Jin<sup>1</sup>

<sup>1</sup>University Of California, Riverside, Riverside, United States, <sup>2</sup>Nanjing Agricultural University, Nanjing, China, <sup>3</sup>University of Valladolid, Palencia, Spain, <sup>4</sup>Marche Polytechnic University, Ancona, Italy, <sup>5</sup>University of Coimbra, Coimbra, Portugal

Fungal pathogens are a severe threat to food security, resulting in ~10% of global crop losses. Resistance to every major agricultural pesticide has also been noted, necessitating new anti-fungal strategies. One promising strategy is spray-induced gene silencing (SIGS), where double-stranded RNA (dsRNA) that targets fungal virulence genes is directly applied to plant material to control pathogen growth. Naked dsRNA is highly susceptible to environmental conditions though, which can result in dsRNA degradation and a need for repeated application, hampering commercial SIGS efforts. To address this limitation, we examined the potential of artificial and plant-derived nanovesicles for dsRNA delivery and protection in SIGS approaches. Regardless of chemical composition or juice source, many of the nanovesicles possessed similar morphologies to plant extracellular vesicles and could be easily loaded with dsRNA. dsRNA was also protected from degradation after loading into the nanovesicles, which enhanced dsRNA stability on plant tissues. Finally, treatment of pre- and post-harvest plant materials with dsRNA-loaded nanovesicles was effective against *Botrytis cinerea* infection and extended protection compared to naked dsRNA. These findings demonstrate how naturally-derived and organic nanovesicles are effective, economical, and eco-friendly nanomaterials for SIGS, providing a potential alternative to traditional chemical pesticides.

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## Exogenous RNAi to control rust fungi

Ms Rebecca Degnan<sup>1</sup>, Dr Alistair McTaggart<sup>1</sup>, Dr Louise Shuey<sup>2</sup>, Mrs Leny Jane Pame<sup>1</sup>, Dr Grant Smith<sup>3</sup>, Dr Donald Gardiner<sup>1</sup>, Prof Bernard Carroll<sup>1</sup>, Prof Neena Mitter<sup>1</sup>, **Dr Anne Sawyer<sup>1</sup>**

<sup>1</sup>The University of Queensland, St Lucia, Australia, <sup>2</sup>Queensland Department of Agriculture and Fisheries, Dutton Park, Australia, <sup>3</sup>The New Zealand Institute for Plant and Food Research Limited, Lincoln, New Zealand

Exogenous RNA interference (RNAi) is an effective non-genetically modified (GM) control strategy for plant viruses, insect pests, fungal and oomycete pathogens. It involves the exogenous application of double-stranded RNA (dsRNA) to plants to trigger the silencing of targeted pest/pathogen genes. We have been exploring exogenous RNAi as a sustainable control for rust fungi, one of the largest groups of plant pathogens, across natural and agricultural systems. A particular focus has been on *Austropuccinia psidii*, the causal agent of myrtle rust, an aggressive disease of Myrtaceae plants. *A. psidii* arrived in Australia in 2010 and poses a serious threat to native plant biodiversity. The pathogen has a large host range of >350 species and serious species decline is already underway. Myrtle rust is not only destroying natural ecosystems but is also impacting native plant industries. We synthesised dsRNA molecules targeting rust fungi genes and tested their fungicidal effects *in vitro* and *in planta*. We found that urediniospores can take up dsRNA during the early stages of germination and that dsRNA targeting essential rust genes significantly reduced germination and development of infection structures such as appressoria and infection pegs. Exogenous RNAi was also effective *in planta*, significantly reducing myrtle rust symptoms on one-year-old trees. Our comparative genomics study showed that genes in the RNAi pathway are conserved across eight families of rust fungi, indicating that exogenous RNAi has potential for broad-scale management of rust fungi.

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## Performance of different N fertiliser technologies used in subtropical maize production

**Prof Michael Bell**<sup>1</sup>, Dr Cristina Martinez<sup>2</sup>, Dr Chelsea Janke<sup>1</sup>, Prof Peter Grace<sup>3</sup>, Dr Yash Dang<sup>1</sup>

<sup>1</sup>University Of Queensland, Gatton, Australia, <sup>2</sup>Grains Research and Development Corporation, Toowoomba, Australia,

<sup>3</sup>Queensland University of Technology, Brisbane, Australia

Nitrogen (N) fertilisers are typically applied in concentrated bands at, or prior to, sowing for summer season row crops grown on the alkaline clay soils that dominate the broadacre cropping regions of subtropical northeast Australia. Crop recovery of applied fertiliser N (mainly urea) is typically <40%, with the balance either residual in the soil (15-30%) or lost to the environment (20-40%). Denitrification that occurs during wet conditions, especially early in the growing season, is the predominant environmental loss pathway.

Fertiliser technologies that delay the release of N into the soil solution (Controlled release) or inhibit the N transformation processes leading to the formation of nitrate-N (N-Stabilised) offer the potential to reduce environmental loss and increase crop recovery of applied N. We report a series of experiments that quantified the dynamics of fertiliser N applied as urea or as various N-stabilised and Controlled release products, and the response by irrigated maize (*Zea mays*) crops grown on alkaline clay soils in a subtropical climate in southeast Queensland. The performance of different N fertiliser products was benchmarked against equivalent rates of urea, with the various technologies also evaluated across different methods of application (subsurface banding v dispersed and incorporated with tillage) and application timings (pre sowing and at sowing). Performance of the different technologies was based on nitrous oxide emissions in the year of application and crop growth, yield and apparent fertiliser N recovery over two consecutive growing seasons

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## Assessment of enhanced efficiency fertilisers in sugarcane grown in North Queensland

**Mr Julian Connellan**<sup>1</sup>, Mr Matthew Thompson<sup>2</sup>, Dr Barry Salter<sup>1</sup>, Dr Muyiwa Olayemi<sup>1</sup>, Mr Burn Ashburner<sup>3</sup>

<sup>1</sup>Sugar Research Australia, Brisbane, Australia, <sup>2</sup>Department of Agriculture and Fisheries, Townsville, Australia,

<sup>3</sup>CANEGROWERS, Brisbane, Australia

The EEF60 project tested Enhanced Efficiency Fertilisers (EEFs) on 60 sugarcane farms located in the catchments of the Great Barrier Reef, over three cropping seasons. Four treatments including two urea and two EEF treatments were tested. One urea treatment had N applied at the industry standard SIX EASY STEPS (6ES) recommended rate (Urea 6ES), the three other treatments all received N at 20% lower than the 6ES rate. Applying urea at N rates 20% below 6ES decreased cane yield. Nitrification inhibitor (NI) coated urea and blends of 20% controlled release fertilisers (CRF) with 80% urea applied at N rates 20% less than 6ES maintained similar productivity and profitability to Urea 6ES. Applying an NI or CRF blended with urea at the 6ES N rate did not improve productivity and is likely to decrease profitability. NUE indicators, such as partial factor productivity of applied N and index for efficiency of fertiliser N recovery were improved when EEF's were applied at N rates 20% less than 6ES. Findings indicated that NI and blends of 20% CRF with 80% urea at N rates 20% less than 6ES could be applied at any time during the season without loss of productivity or profitability. However, there was some evidence of better performance when loss conditions were likely to be high. EEFs appeared to obtain higher yields than Urea 6ES in some situations under high rainfall conditions. The concentration of DIN in leachate was shown to be higher in Urea 6ES compared to the lower N rate of urea and EEFs. Findings suggest that more widespread use of EEF's at N rates 20% lower than 6ES would improve NUE without affecting productivity or profitability.

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## Comparing nitrogen runoff losses in sugarcane fertilised with urea or EEF

**Mr Tony Webster<sup>1</sup>**, Dr Kirsten Verburg<sup>2</sup>, Mr Jody Biggs<sup>3</sup>

<sup>1</sup>Commonwealth Scientific and Industrial Research Organisation (CSIRO), Cairns, Australia, <sup>2</sup>Commonwealth Scientific and Industrial Research Organisation, Canberra, Australia, <sup>3</sup>Commonwealth Scientific and Industrial Research Organisation, Brisbane, Australia

Sugarcane (*Saccharum officinarum*) is the dominant crop grown in catchments draining to the Great Barrier Reef (GBR), occupying c. 380,000 ha. At the northern reaches of the sugarcane cropping area is the Wet Tropics bioregion, which is characterised by heavy seasonal rain reaching up to an average of 4,500 mm annually. Sugarcane is a biomass crop, requiring annual fertiliser nitrogen (N) applications of up to 160 kg N/ha in the Wet Tropics region. This combination of annual N fertilising, high seasonal rainfall, and proximity to the GBR has meant sugarcane N fertiliser practices have come under high scrutiny over the past 20 years to reduce N reaching the GBR. Whilst progress has been made in reducing N losses from sugarcane during this time frame, N losses are still considered a threat to the GBR, and further reductions required. For these reasons we investigated whether substituting urea N with Enhanced Efficiency Fertiliser (EEF) N could lead to lower losses of N. Here we present the results of five years of experimentation where losses of N from EEF were lower compared to urea across multiple rates and application times. We complement this work with results from modelling using the APSIM cropping systems simulator to better understand the spatial and temporal benefits that could result from adoption of EEF in place of urea. Our results show EEF use can reduce losses of N compared to urea. However, benefits are variable in time and space.

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## Benefits of EEFs to sugarcane and the environment: nitrification inhibition vs. controlled-release

Dr Weijin Wang<sup>1</sup>, Mr Steven Reeves<sup>1</sup>

<sup>1</sup>Department Of Environment and Science, Brisbane, Australia

Enhanced-Efficiency Fertilisers (EEFs), particularly nitrification inhibitor-coated urea (NICU) and polymer-coated urea (PCU), have been trialled extensively on Australian sugarcane farms as a management strategy to improve fertiliser nitrogen (N) efficiency and environmental outcomes. Responses of crop yield to EEFs varied substantially at different sites and in different years; no single product consistently outperformed normal urea, regardless of the application rates. NICU (ENTEC®) and PCUs had markedly different environmental benefits. NICU consistently decreased nitrous oxide (N<sub>2</sub>O) emissions from soil, compared to normal urea. However, PCUs could lead to a decrease, no change or increase in N<sub>2</sub>O emissions, depending on the fertiliser application methods and rates, soil properties and rainfall intensity and timing. Soil mineral N in the top 20 cm depth following NICU or urea application generally declined to low levels within 2.5-3 months, indicating substantial N losses into the environment. PCUs or PCU+urea blends consistently maintained higher mineral N contents in soil during the mid to late season. Substantial downward movements of nitrate N into deep soil were often observed in NICU or urea treatments following high rainfall events. PCUs effectively mitigated the risk of nitrate leaching during the first 2-3 months after fertiliser application, particularly for late harvested crops in the wet tropics. In addition, N release dynamics from PCU fertilisers were similar for the same product applied from late September to early December between different regions in Queensland. PCU fertilisers with a 3.5 to 4-month release duration generally matched plant N uptake well when applied during this period.

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## Nitrogen use efficiency and reducing nitrous oxide in sub-tropical farming systems

**Prof Peter Grace**<sup>1</sup>, Assoc Prof David Rowlings<sup>1</sup>, Dr Clemens Scheer<sup>1</sup>, Dr Johannes Friedl<sup>1</sup>

<sup>1</sup>Queensland University of Technology, Brisbane, Australia

Sub-tropical crop and pasture systems in northeast Australia have an inherently low fertiliser nitrogen use efficiency (fNUE). The most recent <sup>15</sup>N (urea) fertiliser recovery data from dryland sorghum, irrigated cotton, rainfed sugar cane and irrigated dairy systems across multiple N rates and seasons found plant N uptake to be remarkably similar, averaging 28% of the applied. Soils were mainly high clay vertosols except for the cane site. Sorghum was the only system that returned a significant increase in crop N uptake to N rate. Losses of applied N averaged 27, 48, 54 and 40% respectively with losses from cane and dairy systems increasing with N rate. These losses are generally attributed to denitrification which includes emissions of both di-nitrogen (N<sub>2</sub>) and nitrous oxide (N<sub>2</sub>O), the latter a highly significant greenhouse gas. In cotton, the use of the nitrification inhibitor DMPP in combination with a reduced N fertiliser rate, increased fNUE by 11% and reduced N losses by 6%. There was no change in residual fertiliser N at the end of the season compared to the conventional N application. DMPP had no impact on plant N recovery or N losses from applied N in the pasture. DMPP has been consistent in reducing N<sub>2</sub>O emissions by as much as 80% in the grains industry, however this is not translated to reducing overall N fertiliser losses or increasing fNUE.

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## When to expect benefits from enhanced-efficiency fertilisers and why? Insights from modelling

Dr Kirsten Verburg<sup>1</sup>, Mr Jody Biggs<sup>2</sup>, Mr Tony Webster<sup>3</sup>, Dr Maria Vilas<sup>2,4</sup>, Dr Zhigan Zhao<sup>1</sup>, Dr Graham Bonnett<sup>2</sup>, Dr Peter Thorburn<sup>2</sup>

<sup>1</sup>CSIRO Agriculture and Food, Canberra, Australia, <sup>2</sup>CSIRO Agriculture and Food, St Lucia, Australia, <sup>3</sup>CSIRO Agriculture and Food, Cairns, Australia, <sup>4</sup>Dept Environment and Science Queensland Government, Brisbane, Australia

Enhanced-efficiency nitrogen fertilizers (EEF) such as controlled-release fertilisers and nitrification inhibitors provide an opportunity for increasing sustainability in agricultural industries. Trials across a range of industries world-wide have shown inconsistent results. Some trials or meta-analyses have shown reductions in nitrogen loss, increases in yield or improvements of nitrogen use efficiency. Others failed to obtain statistically significant treatment differences. Using the agricultural systems model APSIM we performed many thousands of virtual EEF response trials in sugarcane production systems to determine where, when and why benefits can be expected, or not. We identified prerequisite conditions and system interactions that determine the efficacy of EEF. To get yield benefits requires (Verburg et al. 2022): (1) sufficient longevity of protection of the fertiliser nitrogen, (2) occurrence of a nitrogen loss event during this period of protection and before the nitrogen is taken up by the crop, and (3) the crop being responsive to the fertiliser nitrogen. Considerations for nitrogen loss reductions depend on the nitrogen loss pathway. In this presentation we provide a summary of the findings and highlight their application in (sub)tropical agriculture.



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## Aboriginal legacy for the Brisbane area and historical artifacts connected to food

Ms Madonna Thomson<sup>1</sup>

<sup>1</sup>*Nyanda Cultural Tours, Australia*

Madonna's talk covers artefacts and tools, those traditionally used by her ancestors in the growing, harvesting, and preparation of foods and the ceremonies around them. Madonna also talks about modern artefacts and tools, such as those found in Western science, and the coming together of the two knowledge systems and approaches to ensure the continuation and celebration of the worlds oldest continuous civilisation. Through her explanations around traditional foods, Madonna describes Indigenous ways of knowing, being and doing – all of which are highly sophisticated systems for caring for all living beings in Country: plants, animals, spirits and people. She highlights the importance of now walking together in partnership to foster relationships of respect and two-way knowledge sharing, to ensure that the rights of indigenous people are upheld, to regenerate healthy country, and to provide increased access to healthy Australian native foods for all people.

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## Cultural and modern connections to native foods

Ms Michelle On

talks about her own journey into starting and running Kiril Park Wild Harvest. She shares her reflections on the cultural, spiritual, learning, health and economic significance of her business – both for her own family and her hopes of what native bushfoods businesses and products can do for others. Michelle describes how her ancient cultural practices, passed down through generations in her family to her, remain strong and present in her modern day business and how in turn, her wild harvest business strengthens her cultural connections and practices, and provides a medium through which she can pass her culture on to her family and others. Michelle discusses the important role that native bushfoods, and the associated Indigenous approach to caring for Country, have in the responsible and sustainable custodianship of the Australian bush, contributing to a sustainable and healthy world for many generations to come.

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## 65,000 years of anme (plant foods) at Madjedbebe, Mirarr Country, northern Australia

[Dr Anna Florin<sup>1,2,3</sup>](#), May Nango<sup>4</sup>, Djaykuk Djandjomerr<sup>4</sup>, Prof. Andrew Fairbairn<sup>5</sup>, Prof. Chris Clarkson<sup>5</sup>

<sup>1</sup>St John's College, University of Cambridge, Cambridge, United Kingdom, <sup>2</sup>McDonald Institute for Archaeological

Research, University of Cambridge, Cambridge, United Kingdom, <sup>3</sup>ARC Centre of Excellence for Australian Biodiversity and Heritage, University of Wollongong, Wollongong, Australia, <sup>4</sup>Gundjeihmi Aboriginal Corporation, Jabiru, Australia,

<sup>5</sup>School of Social Science, University of Queensland, Brisbane, Australia

Madjedbebe, a rockshelter on Mirarr Country in the Alligator Rivers region of northern Australia, preserves evidence of 65,000 years of Aboriginal lifeways. Alongside a rich assemblage of stone tools, grinding stones and ochre crayons, archaeological excavations at Madjedbebe also recovered the scraps of anme (plant foods) once charred in the site's fireplaces. These charred leftovers allowed us to explore what Aboriginal communities ate at the site, how they cooked and even how they managed their landscape over time. This talk will discuss the broad plant diet eaten at Madjedbebe and how it helped communities to continue to visit this site, despite large-scale changes in climate, sea levels and vegetation.

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## Future flavours from the past: sensory analysis of fruits from Arnhem Land

**Ms Selina Fyfe**<sup>1,2</sup>, A/Prof Horst Joachim Schirra<sup>3,2,4</sup>, Prof Michael Rychlik<sup>5,1</sup>, Dr Annemarie van Doorn<sup>6</sup>, Dr Ujang Tinngi<sup>7</sup>, Prof Yasmina Sultanbawa<sup>1</sup>, A/Prof Heather E Smyth<sup>1</sup>

<sup>1</sup>The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Indooroopilly, Australia, <sup>2</sup>Griffith University, Griffith Institute for Drug Discovery, Nathan, Australia, <sup>3</sup>Griffith University, School of Environment and Science, Nathan, Australia, <sup>4</sup>The University of Queensland, Centre for Advanced Imaging, St Lucia, Australia, <sup>5</sup>Technical University of Munich, Chair of Analytical Food Chemistry, Freising, Germany, <sup>6</sup>The Arnhem Land Progress Aboriginal Corporation, Yirrkala, Australia, <sup>7</sup>Queensland Health Forensic and Scientific Services, Brisbane, Australia

The green plum (*Buchanania obovata*), red bush apple (*Syzygium suborbiculare*) and wild peach (*Terminalia carpentariae*) are all summer fruit that grow in remote East Arnhem Land, in the Northern Territory, Australia. They are eaten by the Yolŋu Aboriginal people and there is interest in using these fruits as foods or in food products to create sustainable Indigenous agribusinesses. The aim of this study was to provide sensory descriptions for the three fruit as whole or cut up pieces of fruit, as purees and as freeze-dried powders in semolina and in yoghurt to obtain a better understanding of ways these fruit could be used in food products. Free choice profiling was used with 15 trained and experienced panellists who tested each sample twice over two days. The results describe the green plums flavour as *sweet, tart* and *stewed apple* and the red bush apples as *sour, raspberry, citrus, apple, sweet, floral, herbaceous* and *spiced tea*. The sensory analysis shows that the green plum and red bush apple could be used in novel food products for their unique, natural and well-liked flavours. The sensory profiles of these three fruit show they have potential for commercialisation in sustainable Indigenous agribusinesses. They could be future flavours in novel future food products which could give employment opportunities to remote Aboriginal communities through food industry uptake and use as food ingredients.

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## Value added food products from wattle seed

**Mr Oladipupo Adiamo**<sup>1</sup>, Dr Michael Netzel<sup>1</sup>, Professor Louwrens Hoffman<sup>1</sup>, Professor Michael Gidley<sup>1</sup>, Dr Simone Osborne<sup>2</sup>, Professor Yasmina Sultanbawa<sup>1</sup>

<sup>1</sup>ARC Industrial Transformation Training Centre for Uniquely Australian Foods, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Brisbane, Australia, <sup>2</sup>Commonwealth Scientific and Industrial Research Organisation (CSIRO), St. Lucia, Brisbane, Australia

Continual growth in the world population, global warming, and high costs of animal production have necessitated the search for alternative and sustainable protein sources, particularly from plants such as wattle seed (WS). Wattle seed is one of the main Australian native plants with substantial economic potential due to its wide availability from both soil cultivation and wild harvest as well as high nutritional value. About 40 species of WS are deemed edible and have been used for thousands of years as food by Australian Indigenous peoples. Roasting is a well-established WS processing method primarily used to develop a desirable aroma and flavour. Roasted WS flour has been utilized as functional ingredients alone and in the development of many food and beverage products such as bread, coffee, spice blends, extracts, and others. Commercial WS products are mainly derived from one species, *Acacia victoriae* (Elegant wattle), which is considered as the food industry standard and are available as commercial native spices. However, other promising wild harvest and cultivated species, such as *A. longifolia ssp longifolia* (Golden wattle), *A. retinodes* (Swamp wattle) and others, remain underexploited in food formulations due to limited information being available about the properties of processed flour from these *Acacia* species.

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## Functional ingredients from *Terminalia* sp. Kakadu plum as a case study

Anh Dao Thi Phan, [Prof Yasmina Sultanbawa<sup>1,2,3</sup>](#), Dr Saleha Akter, Mr Eshetu Bobasa, Dr Michael Netzel

<sup>1</sup>ARC Industrial Transformation Training Centre for Uniquely Australian Foods, <sup>2</sup>Centre for Nutrition and Food Sciences, <sup>3</sup>Centre for Nutrition and Food Sciences, Australia

The Australian native food industry with its diverse and rich flora has a huge potential to contribute to the growing natural functional ingredient market.

Kakadu plum (*Terminalia ferdinandiana* Exell) is a tree endemic to northern Australia and belongs to the family Combretaceae the wild harvested fruit commonly known as the Kakadu Plum. Other names, depending on location are Gubinge, Billygoat plum, and Mi Marrarri. The fruit has been consumed for its nutritional and therapeutic value by the Aboriginal and Torres Strait Islander peoples for thousands of years. Research has focused on the beneficial nutritional and phytochemical composition and biological activities of the fruits, leaves and seeds. Kakadu plum fruit is known for its high vitamin C and ellagic acid content which makes it a rich source of antioxidants. These properties combined with the antimicrobial activity make Kakadu plum very attractive for use as a functional ingredient in food, beverage, and other industries. The demand created by these cross-industry applications has led to a First Nations Peoples owned and led Kakadu plum value chain.

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