THE UNIVERSITY OF WESTERN AUSTRALIA

THE UWA INSTITUTE OF AGRICULTURE

Annual Research Report 2013

Vision

To be recognized for excellence in serving agriculture and the management of natural resources through research, education and training in a regional, national and international context.

Mission

To advance research, education, training and communication in agriculture and natural resource management for the benefit of mankind.

Objectives

To enhance The University of Western Australia's contribution to agriculture and to the management of natural resources in Western Australia, and in selected national and international settings.

Strategies

- **Integrating**: Bringing together UWA's agricultural research, teaching, training and communication activities; integrating complementary activities across disciplines and organizational units, and providing a focus for leading- edge Research and Development (R&D);
- **Connecting:** Fostering national and international linkages and alliances that bring new knowledge and expertise to UWA and allow the university to share its knowledge with the world
- **Resourcing:** Increasing the pool of resources available for investment in critical R&D in Western Australia;
- **Communicating:** Strengthening communication links with regional industry, farmer groups and the broader regional and scientific communities.

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The UWA Institute of Agriculture Annual Research Report 2013

Executive Summary

Throughout 2013 the IOA continued to build its reputation for innovation and excellence with a diverse range of new and ongoing research projects and training activities in local, national and international arenas.

Collaboration with universities and research institutions in Australia and overseas produced positive outcomes, with a high level of keen co-operation which bodes well for the future. IOA researchers and academics forged links with their peers in China, India, Korea, Africa, the USA, Canada, Europe and New Zealand.

Listed below are some of the highlights of IOA's five research and development programs in 2013.

Integrated Land and Water Management Program

Among the subjects investigated in 2013 were the relationship between increased soil carbon and nitrous oxide emissions, the effects of nitrification and biochar, and the efficient use of water and nutrients. An exciting addition to the IOA's portfolio was the establishment of a Critical Zone Observatory at UWA Farm Ridgefield. About 50 Critical Zone Observatories already exist in Europe and the USA, providing a network for scientists studying Earth's 'outer skin' - but this is the first in the Southern Hemisphere. On the home front a project named MicroBlitz connects with the general public by inviting volunteer 'citizen scientists' across WA to collect soil samples for analysis. The goal is to better understand how microbial communities maintain and improve soil sustainability when climate change, population growth and agriculture put the land under pressure.

Plant Production Systems Program

Given that the world's population is expected to reach nine billion by 2050, breeding cereals with a higher yield is vital for food security. Disease resistance is an important part of the issue. Research was conducted on the development of cereal varieties with good resistance to Fusarium crown rot. As this disease causes large losses in bread wheat, durum wheat and barley worldwide, breeding resistant varieties would greatly assist national and international crop industries. Other projects investigated how to improve disease resistance in canola, strawberries and other crops including chickpeas resistant to Ascochyta, with trials of the last achieving positive results. Working with partners in India IOA researchers also studied the abiotic stresses (e.g. drought, heat and salinity) that limit chickpea productivity.

Animal Production Systems Program

The Ruminant Pangenome Project saw the IOA collaborate with international partners in 2013. It is one of several projects focusing on ways to reduce methane in livestock, whose emissions contribute to greenhouse gas; the northern rangelands beef herd alone accounts for 6% of Australia's total emissions. Options include replacing traditional forage plants with different species which, as they ferment, cause less methane to form. Plant methanogenic potential has rarely been examined in this context. Another option is to breed sheep which emit less methane. Genetic studies are also looking at breeding sheep with more physical resilience to breech strike, a problem currently controlled by shearing, mulesing and chemical treatment. One project concerns semiochemicals which repel or are toxic to the flies that cause breech strike. The goal is to synthesise these semiochemicals or extract them to be bred in sheep.

Rural Economy, Policy and Development Program

Projects covered a range of carbon-related topics such as carbon-biodiversity issues in native shrubs on farmland, the economics of carbon emissions in agriculture, and the factors which influence whether or not farmers are willing to adopt carbon-farming practices. The feasibility of multi-peril crop insurance was examined, with the interesting conclusion that shifting the risk of crop failure to an insurance company could mean that farmers lose their incentive to make prudent decisions to protect the crops themselves. Another project studied the factors that influence the sustainability and competitiveness of co-operative enterprises. In international terms the establishment of the Australia-Africa Universities Network is a most significant venture which prioritises food security, public health and education.

Education, Outreach and Technology Exchange Program

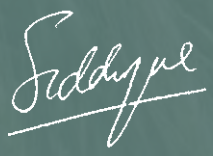
Television audiences learned more about UWA's Future Farm thanks to a segment filmed for the ABC's 'Catalyst', broadcast in February, and UWA's Centre for Integrated Bee Research featured in – and provided a scientific advisory team for – a multi-award winning documentary titled 'More than Honey' by Oscar-nominated director Markus Imhoof.

Major internal events hosted by the IOA included the Postgraduate Showcase, six public lectures and the seventh consecutive annual Industry Forum which in 2013 was themed 'Food 2050'. Thirteen new PhD students commenced their research in 2013.

A training course took place in Bangladesh in February, while in May UWA enhanced its links with China when the Centre for Dryland Agricultural Ecosystems was launched at Lanzhou University.

Fifty-two new research projects were approved in 2013. The IOA issued 57 media statements, and research by the IOA was published in 182 refereed journals, five book chapters, one refereed conference proceedings and one book.

I would like to express my utmost appreciation to everyone involved in IOA research and training activities, and in particular to our national and international collaborators, funding bodies and industry partners.



Winthrop Professor
Kadambot Siddique AM FTSE FAIA
Hackett Professor of Agriculture
Chair and Director
The UWA Institute of Agriculture
The University of Western Australia

1. Integrated Land and Water Management Program

Of the global challenges that society currently faces the basic requirement to feed the increasing world population is of critical importance. Farming systems that are based on sound scientific and practical knowledge need to be designed to support an environmentally and economically sustainable Australia, while addressing the need for soil, water and food security. This necessitates that benefits from applied fertilisers are maximised while off-site impacts, including nutrient flow to waterways and greenhouse gas emissions, are minimised. At the same time the climate is altering and farming systems need to be able to respond to climate change and variability.

Within the Integrated Land and Water Management Program researchers within the IOA are collaborating with leading national and international organisations to address these global concerns.

Greenhouse gas emissions and soil carbon

Does increasing soil carbon in sandy soils increase soil nitrous oxide emissions from grain production?

Project team: Assoc/Prof Louise Barton[1] (leader; email: louise.barton@uwa.edu.au), Prof Daniel Murphy[1], Ms Debra Donovan[1], Mr Chris Swain[1], Dr Frances Hoyle[2,1], Dr Craig Scanlan[2], Prof Dr Klaus Butterbach-Bahl[3]

Collaborating organisations: [1]UWA; [2]DAFWA; [3]Atmospheric Environmental Research, Karlsruhe Institute of Technology, Germany; DAFWA; Liebe Grower Group; National Australian Nitrous Oxide Research Program

Crop production is often a source of greenhouse gas (GHG) emissions including nitrous oxide (N_2O), which is almost 300 times more potent than carbon dioxide (CO_2). Agricultural soils can also be a sink for CO_2 via soil carbon (C) sequestration. However, increasing soil C levels has been shown to increase soil N_2O emissions. Understanding the possible consequences of increasing soil C on GHG is critical when assessing the effectiveness of soil C sequestration to abate GHG emissions from the agricultural land sector. Our knowledge of GHG emissions from cropped soil is largely derived from agricultural systems in the Northern Hemisphere, and their applicability to southern Australian cropping systems remains poorly understood.

The aim of this study is to investigate if increased soil organic C levels result in an increase of N_2O emissions from a cropped soil at Buntine in the Western Australian (WA) grainbelt. This is being studied by continuously measuring GHG emissions over a two and a half year period using automated gas collection chambers on plots at the Liebe Group's long-term soil biology trial where soil organic C levels have been increased by approximately 0.6%.

In 2013 the team completed collecting the first 12 months of N_2O emissions data. Preliminary findings indicate increasing soil organic C has increased N_2O emissions at Buntine, with greatest emissions occurring following summer and autumn rain. However, after one year of measurements annual emissions were found to be low (0.02–0.16 kg N_2O -N/ha/yr) by international standards. Globally, and across a variety of climatic regions, annual N_2O losses from cropped mineral soils have ranged from 0.3 to 16.8 kg N_2O -N/ha/yr. Thus the Buntine data is below or at the lowest levels reported globally. The annual N_2O emission reported for Buntine is also within the range of values previously reported by the team for two other study sites at Cunderdin and Wongan Hills in the Western Australian grain belt.

This research is supported by the Australian Government and the Grains Research Development Corporation (GRDC).

Mitigating greenhouse gases with nitrification inhibitors and biochar in fallows

Project team: Dr Ken Flower[1] (leader; email: ken.flower@uwa.edu.au), Dr Sudheesh Manalil[1], Dr Matthew McNee[2], Mr James Eastern[3]

Collaborating organisations: [1]UWA; [2]WANTFA; [3]CSBP

This project aims to demonstrate the capacity of on-farm practices to decrease N_2O emissions and increase the sequestration of organic C in soil. Nitrification inhibitors, biochar and fallow-crop rotations (including legumes in no-till cropping systems) were tested for their greenhouse gas (GHG) abatement potential, and for any beneficial effect on soil organic C levels, at two sites in the grain belt of WA.

Nitrification inhibitors on nitrous oxide emissions

Nitrification inhibitors are known to decrease N_2O emissions in broadacre cropping by inhibiting microbes capable of converting ammonium into hydroxylamine, the first step of the nitrification process. Research gaps exist regarding the effectiveness of nitrification inhibitors under varying soil types and environments. There is also a lack of knowledge surrounding the effectiveness of nitrification inhibitors in summer time where there is a flush of ammonium, from mineralisation following rainfall, which is available for nitrification.

This project tested the effectiveness of nitrification inhibitors under varying soil types at two trial sites, Pingelly (duplex sand over clay) and Cunderdin (heavy red soil) in 2012 and 2013. In addition, the role of nitrification inhibitors in decreasing emissions when the soil is fallow over summer under wet conditions was tested in 2013. The trial results from 2012 showed nitrification inhibitors to be effective in decreasing N_2O emission from both sites during the winter crop growing season; however, the nitrification inhibitors did not decrease N_2O emissions from harvested wheat and pea crops in the 2013 summer season. The results also suggest that under (relatively) wet conditions during the hot summer fallow period, post-harvest crop residue generates N_2O emissions.

Biochar on nitrous oxide emissions

The project examined the effects of nitrification inhibitors and biochar treatments in 2012 and 2013 at the Pingelly and Cunderdin locations. Biochar is reported under soil and environmental conditions to sequester C, decrease N_2O emissions and improve soil properties leading to improved crop production. Therefore the project tested a combination of biochar and nitrification inhibitors for any combined benefits in reducing N_2O emissions in 2013. The trial results from 2012 showed no difference in N_2O emissions between chemical fallow and biochar that was incorporated into the soil. The 2013 data is not yet available.

Winter fallow systems and nitrous oxide emissions

The project monitored fallows for their GHG emission levels. While fallows are an important moisture conservation strategy in rainfed agriculture, their high soil water content – compared to soil where crops are grown – may increase N_2O and hence increase GHG emissions from agricultural soils. The N_2O emissions from fallow plots were lower than those from wheat during the winter cropping season in 2012. The higher nitrous oxide from the wheat plots occurred following fertiliser application, whereas the fallow plots were not fertilised. The 2013 data is not yet available.

This project is funded by the Australian Government.

Managing biological, physical and chemical constraints to soil carbon storage

Project team: Assoc/Prof Deirdre Gleeson[1] (leader; email: deirdre.gleeson@uwa.edu.au), Prof Daniel Murphy[1]; Assoc/Prof Peta Clode[1], Dr Yoshi Sawada[1], Dr Hazel Gaza[1], Dr Frances Hoyle[1,2], Dr Clayton Butterly[3], Prof Cixian Tang[3], Dr. Samantha Grover[3], Dr Lynne Macdonald[4], Dr Jeff Baldock[4]

Collaborating organisations: [1]UWA; [2]DAFWA; [3]La Trobe University; [4]CSIRO

Sustainable management of soil carbon (C) is essential for the continued viability of Australian agriculture. This project aims to provide options to overcoming constraints to C storage in coarse-textured agricultural soils. It builds on the Australian Government's previous Soil Carbon Research Program (SCaRP) WA component (see IOA Annual Research Report 2012, page 7) which highlighted that the surface soil layer (0–10 cm) of many WA agricultural soils is largely saturated and that if further gains in soil C storage are to be made then soils at depth (10–30 cm) need to be targeted. The project is assessing the potential to increase soil C via management practice by using: (i) existing practices such as claying and liming (i.e. increasing pH) and (ii) emerging practices such as one-off soil inversion using mouldboard ploughing or spading.

The team is investigating lime management as a strategy to overcome constraints on C storage in acid soils and assessing the impact of liming and liming history on soil organic matter (SOM), decomposition and stability. Initial soil sampling from historical lime trials (1994 to 1998) took place at the end of 2013 at the Wongan Hills Research Station to assess the long-term impact of liming on soil carbon; re-liming and sampling is continuing at this site in 2014.

The team is also comparing claying to the emerging practice of soil inversion (by one-off mouldboard ploughing or spading) for influence on soil C storage capacity. C and N cycling are slower at depth than on the surface – thus burying SOM through mouldboard ploughing and spading has potential for increasing C storage in soil as the buried SOM may decompose at a slower rate. In addition the 'new'surface soil layer is likely to have a C content below saturation; thus enabling further soil C capture.

Sampling of claying and soil inversion trials will continue in 2014, with emphasis on long-term lime trials and emerging spading and mouldboard ploughing trial sites.

The project is supported by funding from the Australian Government (2013-2016).

Maintenance of soil organic carbon levels supporting grain production systems

Project team: Dr Frances Hoyle[1,2] (leader; email: frances.hoyle@agric.wa.gov.au), Prof Daniel Murphy[2], Dr Yichao Rui[2], Xiaodi Li[2]

Collaborating organisations: [1]DAFWA; [2]UWA; National Soil Carbon Program (NSCP)

Long-term viability of sequestering C in soil hinges on the stability and availability of C to microorganisms in soil. Although some of the biological mechanisms influencing C and N turnover in soil have been identified, information is still required on the soil C levels (quality and quantity) required to maintain long-term C storage in agricultural soils.

This project investigates the critical point in soil C levels required to

maintain productivity and C storage in dryland grain production systems.

During 2013, a meta-analysis was conducted on data from 1050 sites (4500 samples) from across the WA wheatbelt that was collected as part of the Australian Government's previous Soil Carbon Research Program (SCaRP). Analysis of previous site histories, management and soil physio-chemical data confirmed that soil depth, rainfall, temperature, soil type (i.e. texture/clay content) and land use were the primary drivers of total soil organic C (SOC) in these agricultural soils, with a number of soil and agronomic variables (e.g. pH, stock, fertiliser application) also having a significant effect. The data has been used by the Department of Agriculture and Food (DAFWA) within a soil-landscape mapping framework to produce a report card for SOC stocks (0-0.1 m) in WA agricultural soils (www.agric.wa.gov.au/soil-constraints/report-card-south-west-western-australia).

This research is supported by the Australian Government and DAFWA.

Nutrient use efficiency

Improved nitrogen use efficiency in wheat and barley

Project team: W/Prof Zed Rengel[1] (leader; email: zed.rengel@uwa.edu.au), Asst/Prof Hossein Khabaz-Saberi [1]

Collaborating organisations: [1]UWA

Modern crop varieties have relatively poor N fertiliser use efficiency – rarely better than about 30-40%. Such poor usage rates cost growers money in wasted fertiliser and potentially lead to environmental damage via N leaching into waterways.

In the first phase of the project, the variation in N use efficiency was characterised in a large number of wheat and barley genotypes. Based on these data, 12 genotypes each of wheat and barley were selected for their extreme difference in N use efficiency. In addition, a doubled-haploid (DH) wheat mapping population from parents differing in N use efficiency was tested. All these genotypes were grown at Wongan Hills and Esperance Downs in WA at two N fertilisation rates.

While the majority of the samples are still being processed, it is clear that a large positive response to increased N fertilisation was obtained at both anthesis (vegetative yield) and maturity (grain yield). There was a significant difference in N use efficiency of various genotypes of wheat and barley. For wheat, the DH population showed a typical bell-shaped curve of N use efficiencies extending beyond the range of N use efficiencies of the parents. The next step will be to identify quantitative trait loci (QTL) associated with N use efficiency.

This research is supported by GRDC.

Modelling spatial and temporal dynamics of rhizosphere exudation

Project team: W/Prof Z Rengel[1] (leader; email: zed.rengel@uwa.edu.au), Adj/Assoc/Prof Arthur Diggle[1,2], Dr Yinglong Chen[1]

Collaborating organisations: [1]UWA; [2]DAFWA

This project includes two major components: experimental work and simulation modelling exercises. In 2013 research was focused on rhizosphere exudation of various narrow-leafed lupin (*Lupinus angustifolius*) genotypes for parameterising root models.

Large variation in phosphorus (P) efficiency was found among the tested genotypes with 3.9 times (shoot growth), 4.7 times (relative shoot growth rate) and 2.2 times (P uptake efficiency) greater values in the most efficient genotype than in the least efficient genotype.

Genotypes with contrasting P efficiency with consideration of differential root architecture were used in characterising rhizosphere exudation. The rhizotron system containing a removable clear panel

enabled non-destructive collection of exudates from individual root tips as well as measuring and photographing root development over time. The results showed that lactic, acetic, maleic, fumaric and citric acids were commonly present in all tested genotypes, while trace amounts of malonic, *cis*-aconitic, succinic and trans-aconitic acids were detected in some samples. The P-efficient genotype exuded significantly higher concentration of lactic, acetic, citric and fumaric acids than the P-inefficient genotype, while the inefficient genotype had about threefold higher concentration of maleic acid than the efficient one.

This study will enable comprehensive analysis of genotypic variability in rhizosphere exudation, and will provide a database for the ROOTMAP model to simulate spatial and temporal dynamics of exudation in response to low P supply. This project contributes to developing ROOTMAP into a 3-D computer simulation tool that will aid breeders in producing new genotypes with root system optimised for specific environments and efficient in capturing soil resources (water and nutrients).

This research is supported by the Australian Research Council (ARC).

Management of microorganisms to unlock the phosphorus bank in soil

Project team: Assoc/Prof Deirdre Gleeson[1] (leader; email: deirdre.gleeson@uwa.edu.au), Prof Daniel Murphy[1], Asst/Prof Suman George[1], Mr Pu Shen[2], Prof Xu Minggang[2], Dr Chris Guppy[3]

Collaborating organisations: [1] UWA; [2]Chinese Academy of Agricultural Sciences (CAAS); [3]University of New England

Australian grain producers apply $1 billion worth of phosphorus (P) fertilisers each year, but the fertiliser use efficiency of grain production in Australia is at best 50%, and can be as low as 10%. Much of the remaining fertiliser P becomes fixed in soil and the P 'bank' in Australian arable soils is estimated to be worth $10 billion. The project aims to provide grain growers with practical management options that harness soil microorganisms to unlock part of this fixed P bank.

The current research has focused on studying the influence of plant residue carbon-to-nitrogen ratio (C:N) on the P release capacity of the soil microbial community.

The team applied mixtures of simple organic compounds at different C:N ratios to test the hypotheses that: (i) organic matter inputs with low C:N would increase the microbial biomass until it exhausted the supply of easily available P forcing it to access fixed P in soil and (ii) organic matter inputs with high C:N would support a smaller but more diverse microbial community with more strategies to access fixed P.

Analysis of the data broadly support the hypotheses and where a higher C:N ratio substrate was applied (C:N=50:1) the resultant microbial biomass was smaller but had a higher diversity than the soil microbial biomass where substrates with a lower C:N ratio (12.5:1) were applied. The team is currently assessing further how the soil P cycle is altered as a consequence of changes in diversity and biomass relative to C:N ratio of inputs into these systems.

This project is supported with funding from the GRDC and ARC (2011-2015).

Climate change and water use efficiency

Evaluating the potential for groundwater trading in the Gnangara groundwater system of Western Australia

Project team: W/Prof David Pannell[1] (leader; email: david.pannell@uwa.edu.au), Mr James Skurray[1], Assist/Prof Ram Pandit[1]

Collaborating organisations: [1]UWA

This study examines the potential for trading of groundwater to be an effective policy response to groundwater shortages in a horticultural region of Perth. The development of a market in groundwater usage rights can be inhibited by constraints arising from the institutional context. Such impediments may reduce the potential gains from trade and may generate high transaction costs for prospective traders.

The team has been analysing the regulations and policies influencing groundwater transfers in a case study area – the Gnangara groundwater system around Perth, WA – and has identified significant impediments to groundwater markets, namely: (i) property rights are conditional, temporary and vulnerable to amendment; (ii) regulatory approval is required for all transfers; (iii) facilitating infrastructure is lacking; (iv) price information is unavailable; (v) management area boundaries reflect land ownership and use rather than hydrogeological realities; the limitation of transfers to within these boundaries eliminates much of the potential for gains from trade; (vi) over-allocation and weak monitoring also impede the development of a market; and (vii) the current management system is likely to obscure unmet demand for water-rights transfers between users and usage types.

This research is supported by the National Centre for Groundwater Research and Training.

Polymers for improving soil moisture management and cropping productivity

Project team: Prof Daniel Murphy[1] (leader; email: daniel.murphy@uwa.edu.au), Dr Falko Mathes[1], Dr Jeremy Bougoure[1], Assoc/Prof Matthias Leopold[1], Assoc/Prof Louise Barton[1], Dr Gavan McGrath[1], W/Prof Tony O'Donnell[1], Assoc/Prof Peta Clode[1]

Collaborating organisations: [1]UWA; CRC-Polymers; Swinburne University of Technology; BASF; CSIRO; University of New England

The project aims to develop new products that will help farmers better manage water and nutrients in the soil and thereby improve dryland productivity. Development is occurring in: (i) surfactant-enhanced soil wetting; and (ii) functionalised soil polymers. This collaboration marks an important step in building technology that demonstrates our commitment to farmers in Australia and around the world.

Non-wetting soils comprise up to 30% of Australia's cropping land and produce only 10% of the nation's

broadacre crops, which is well below their water-limited potential, because of run-off and poor furrow efficiencies. Research is targeting the management of soil moisture (controlling soil wettability and nutrient delivery) and optimising the physical, chemical and biological responses, both in the plant root zone and the soil biota. It includes the effects of different soil types, crops and growing conditions on crop yield benefits. The output from this research will be a range of polymers for improving crop productivity by controlling soil wettability. During this initial year research has focused on establishing laboratory experimental techniques together with their validation with model and real WA soils. All techniques have been designed to provide information that allows the results obtained from the collaborating laboratories of the project's three universities and CSIRO Plant Industry to be directly correlated across a range of agricultural soil parameters. Additionally, the project team participated in a field visit to one of the WA grower group test regions to examine non-wetting soils, and to discuss their impact on cropping yields and implementable technical solutions with farmers.

With respect to surfactant-enhanced soil wetting, a suite of physical-chemical test methods have been developed and validated with the aim of providing key information on the surfactant parameters that define effective soil wetting agents based on these WA soil samples. The test methods address the molecular architecture controlling surfactant performance at the advancing wetting front to guide rational formulation for enhanced soil moisture transport. Developments in soil science techniques have focused on the use of soil moisture matric potential and solute sorptivity, rather than on the more conventional non-functional measures such as soil moisture or water-holding capacity. This is being achieved by the integration of soil matric potential techniques into micro-computed tomography scanning instrumentation, which provides both visualisation and quantification of water and soil spatial distribution and connectivity. At a larger laboratory scale, electrical resistivity tomography is being used on experimental plots to act as an intermediate step between laboratory experimentation and field trials, for providing, under controlled conditions, early indications of specific influences of scale on surfactant performance.

In the area of agricultural functionalised soil polymers, the development of techniques has focused on understanding their behaviour within contrasting soil environments. Measurements of physical polymer properties and the corresponding shear rheology have shown the importance of the mechanical stability of soil polymers when under stresses of imposed soil osmotic and physical pressures. A reliable method for assessing the effects of the functionalised polymers of plant performance in a greenhouse environment has been developed. The influence of functionalised soil polymers within the rhizosphere is being investigated in terms of quantitative wheat shoot and root behaviour, growth and nutrient status. The impact of imposed soil osmotic pressures on soil bacterial ingress rates into functionalised soil polymers was quantified. DNA from around the functionalised soil polymers was extracted, quantified and subsequently analysed using metagenomics. It was noted that soil in the region of the functionalised polymers behaves differently, forming soil gradients in the rhizosphere.

This research is supported by Cooperative Research Centre for Polymers and GRDC.

Farming in a biodiversity hotspot – harnessing native plants to reduce deleterious off-site phosphorus flows

Project team: Assoc/Prof Megan Ryan[1] (leader; email: megan.ryan@uwa.edu.au), W/Prof Hans Lambers[1], Prof Ed Barrett-Lennard[1], Mr Dion Nicol[1], Assist/Prof Carlos O'Campo[1], Prof Mark Tibbett[2], Prof Phillip Brookes [3]

Collaborating organisations: [1]UWA; [2]Cranfield, UK; [3]Rothamstead, UK; Greening Australia; the Harvey River Restoration Taskforce; DAFWA; the National Measurement Institute; Alcoa Farmlands

Flow of P from farmland into waterways is contributing towards eutrophication, that is a process where waterways and estuaries (around the world) receive excess nutrients that stimulate excessive plant growth. In WA this is a serious problem in many areas, including the Peel Harvey. A reduction in flow of P into waterways is urgently required in this region.

This project investigates whether uptake of P by P-resistant perennial native plants can reduce flow of P into shallow groundwater and waterways in the Peel Harvey region (a seasonally variable landscape which consists of a patchwork of pastures and highly biodiverse remnant native vegetation). This project was preceded by an 18 month seed project (funded by Greening Australia using funds from the US-based Alcoa Foundation) conducted from 2011 to mid 2012.

An efficient start to research was achieved: three field sites in the coastal Peel Harvey region (pasture to be revegetated to forest; low input beef; high input dairy) were fully instrumented for collection of groundwater, and preliminary soil data was collected to a depth of 3 to 4 metres. A wide range of

plant species including current commercial pasture species and native and exotic alternatives with unusual P-uptake and P-use characteristics were established at two field sites - low P and high P. Growth and P uptake were measured. At the low P site, plants were harvested before and seven and 28 days after a pulse of fertiliser P was applied. Measurements of groundwater P levels and overland flow were taken at three sites. It was found that shallow groundwater tables link up across the landscape in winter, providing hydraulic connectivity and that P is strongly concentrated in the surface 5 cm of the soil profile.

Twenty five postgraduate students from UWA visited two of the sites and the Alcoa Landcare Education Centre at Yarloop as part of the unit 'Advanced Cropping Systems'. The students integrated the information gained from the fieldsites into assignments on how to ameliorate eutrophication in the Peel Harvey.

This research is supported through an ARC linkage project with Greening Australia, the Harvey River Restoration Taskforce, DAFWA, Alcoa Farmlands and the National Measurement Institute.

Soil quality monitoring

Molecular indicators of soil quality

Project team: W/Prof Tony O'Donnell[1] (leader; email: tony.odonnell@uwa.edu.au), Dr Sasha Jenkins[1], Prof Daniel Murphy [1]

Collaborating organisations: [1]UWA; Victorian DPI

Soils are widely recognised as being among the most biologically complex systems on Earth and one gram of soil can contain thousands of millions of individual organisms and tens of thousands of species. These organisms play a key role in maintaining agricultural productivity by recycling nutrients, fixing nitrogen, suppressing disease, building soil structure and transforming soil organic matter.

Understanding the role of microorganisms in regulating key soil functions is also important in alleviating below ground constraints to crop yield. This is a national program that uses the techniques of molecular biology to identify a set of microbial variables that best describe a healthy and productive soil and how management impacts on these variables.

This project aims to determine whether molecular methods used to quantify the relative abundance of bacteria, fungi, archaea, actinobacteria, mycorrhizae and nitrifiers can be used as indicators of soil quality. It investigates whether relative gene abundance, either singly or in combination with other indicators, can be used to develop a minimum set of

indicators for assessing soil quality. It also aims to use data modelling approaches to identify management options to sustain or enhance soil quality and crop yield.

Approaches include the quantification and diversity of microbial populations using quantitative PCR and high throughput small subunit Ribonucleic Acid (RNA) sequencing. Functional differences between soils subject to different managements (e.g. till, no-till and till with organic matter additions, different fertiliser N and P inputs) are being assessed using shotgun sequencing of soil metagenomes.

More than 200 soil samples from farms across Australia have been analysed to date. These have been sourced through the GRDC's National Soil Quality Monitoring Program, which has soil quality data from 1700 sites. The sampling and analyses are now complete and an extensive database relating microbial diversity (relative abundance of bacteria, fungi and actinobacteria) with function (e.g. N cycling, nutrient availability and microbial biomass) has been developed. These data are currently being analysed using PROCRUSTES rotations and Structured Equation Modelling (SEM) to investigate the link between microbial diversity, nutrient status and the capacity to enhance soil productivity and crop yield. This has already provided novel insights into differences in below-ground microbial diversity in soils under different managements and on marked and unexpected impacts on nutrient cycling.

This research is supported by GRDC.

Ecosystems' response to climate and anthropogenic disturbances: implications for greenhouse gas emissions and nutrient cycling

Project team: Prof Daniel Murphy[1] (leader; email: daniel.murphy@uwa.edu.au), Assoc/Prof Deirdre Gleeson[1], Dr Jeremy Bougoure[1], Assoc/Prof Peta Clode[1], Prof Matt Kilburn[1]

Collaborating organisations: [1]UWA; Bangor University, Wales; Chinese Academy of Agricultural Sciences (CAAS),China; University of Vienna, Austria

Humanity is challenged with climate change, greenhouse gas emissions, declining fertiliser reserves and a need to feed the world's growing population. Central to these challenges is the functioning of soil microorganisms as they are responsible for the many ecosystem services that we take for granted. Linking the physical heterogeneity of soil to microbial processes marks a current frontier in plant and soil sciences. Simultaneous analysis of identity (who are they?) and function (what are they doing?) of microbial populations with consideration for maintaining the soil three-dimentional structure (where are they located?) is a major challenge for microbial ecologists. Yet this is the scale at which microorganisms and plants interact, decompose organic matter and cycle nutrients including the production of greenhouse gases. It requires study of the links between soil physical and chemical heterogeneity and biological processes. Unravelling this complexity at scales relevant to the microorganisms in question requires working at nano-, micro-, meso- and macro-scales. This is now possible through the application of high resolution microanalysis linked to isotopic analysis using nano-scale secondary ion mass spectrometry (NanoSIMS). This instrument, located within the world-class Centre for Microscopy, Characterisation and Analysis (CMCA) at UWA is the only such instrument in the Southern Hemisphere. The aim of this project is to utilise NanoSIMS and molecular techniques to advance scientific understanding of how the microorganisms responsible for ecosystem function respond to climate and anthropogenic (i.e. human) disturbance. The mechanisms for soil-microbial-plant interactions are being studied

in the context of the cycling of C, nutrients (N, P) and the greenhouse gases CO_2 and N_2O. This research focuses on three ecosystems: (i) agricultural soils in WA; (ii) agricultural soils in China; and (iii) tundra ecosystems in the Arctic.

In association with this research Professor Daniel Murphy holds a High-end Foreign Expert visiting Professorship with CAAS. China is the largest consumer of fertiliser in the world and is WA's main export destination; a reflection of the expanding Chinese economy. This research collaboration is quantifying how nutrient applications (inorganic fertilisers versus organic manures) and climate change scenarios regulate C sequestration and the functioning of the soil microbial communities responsible for greenhouse gas emissions. Historical change in soil organic C stocks from long-term field trials that represent major soil types and climatic conditions of northern China were used to validate both soil C and climate general circulation models. These models were then used to predict future change in soil C stocks to the end of the century. Predictions indicated that these Chinese (upland) soils will be a net source of CO_2 under no fertiliser inputs. However, even when inorganic fertilisers were applied the additional C input from increased plant growth could not meet the depletion of soil organic C (due to microbial decomposition) in parts of northern China. Manure or straw application could however improve the soil organic C sequestration potential at all sites. These findings highlight the need to maintain, and where possible increase, organic C inputs into these farming systems which are rapidly becoming inorganic fertiliser intensive.

This research is supported by the Australian Government and GRDC.

Grazing into the future: building soil health and carbon with pasture management

Project team: E/Prof Lynette Abbott[1] (leader; email: lynette.abbott@uwa.edu.au), Dr Zakaria Solaiman[1], Assist/Prof Natasha Pauli[1], Mr Rob Rex[2], Mr Michael Harcourt-Smith[2], Mr Warren Pensini[2], Ms Sally Thompson[2]

Collaborating organisations: [1]UWA; [2]Bugs and Biology Grower Group

This project investigates innovative on-farm practices to increase the sequestration of carbon (C) in soil through a range of pasture and grazing strategies, including cell grazing management (where pastures are grazed briefly but intensively), and continuously grazed (annual) pastures.

Cell grazing management has been associated with increased pasture production compared with set-stocking. Increased above-ground pasture production should occur in tandem with increased root growth and potential for below-ground C allocation.

Perennial grasses may increase soil C storage, due to their deeper and more extensive root systems compared with annual grasses, and at the same time decrease soil C losses through erosion. Some studies have reported reduced respiratory loss of soil carbon in perennial pastures, as perennial pastures can utilise soil moisture from summer rains which would otherwise fuel increased decomposition by soil microbes.

This project studies soil at three properties in WA, situated at Wagin, Woodinalling and Boyup Brook for a range of pasture and grazing strategies. During 2013 the team analysed soil samples for a sequence of six intensively grazed (cell grazed) permanent pastures containing both perennial and annual pasture species established between 2003 and

2012. In addition, soil was collected from a comparison of cell grazed and continuously grazed annual pastures, and a comparison of cell grazed perennial and annual pastures was made.

Soil C at the perennial site established in 2003 was higher in the surface soil layers and at depth than at any of the other five sites within the sequence of pastures established more recently. The perennial pasture plants are well established at each site, but the ground cover is dominated by annual pasture species which are growing between the perennial species. Other soil properties associated with location in the landscape may influence soil C retention in this sequence and this is being investigated.

This project is establishing a monitoring programme for soil C that can extend beyond the three years of this project. It includes measurement of a broad suite of soil chemical, physical and biological properties. This approach recognises that for many farmers, the real long-term benefit of 'carbon farming' may be through improved soil health and productivity, with the potential for soil C storage acting as a catalyst for change.

The project is funded by the Australian Government.

MicroBlitz – social soil science

Project team: W/Prof Andy Whiteley[1] (leader; email: andy.whiteley@uwa.edu.au), Ms Deborah Bowie[1], Dr Christine Whiteley[1], Dr Deepak Kumaresan[1]

Collaborating organisations: [1]UWA; Argonne National Laboratory, USA; Karara Mining; Centre for Ecology and Hydrology, UK

'MicroBlitz', also known as the 'citizen science project' comprises a scientific component and a community engagement component: it investigates the genetic biodiversity, distribution and functionality of microbial communities within Western Australian soils and extends the outreach capabilities of UWA's School of Earth and Environment.

MicroBlitz engages volunteer citizen scientists throughout WA by connecting them with the natural environment as they collect soil samples, which are then sent to a centralised laboratory for DNA sequencing and basic chemical analysis.

The key objectives of the scientific component of the research are: (i) to establish a shared and public knowledge base; (ii) to perform as a benchmark for future monitoring; and (iii) to generate information that will help develop a better understanding of the ecological links between soil microbial communities and their impact on maintaining and improving the sustainability of soils in an environment under increasing pressure (arising from climate change, agriculture and exponential population growth).

The main objectives of the community engagement component are: (i) to promote an awareness of the applications of soil science and biotechnology to the environment; and (ii) to actively engage the general public in 'cutting edge' research, which happens in real-time.

During the first six months of the project, the team set up the parameters, protocols and community interface of MicroBlitz, which included developing the 'Microblitz' branding and a dedicated website (www.microblitz.com.au).

The next phase focused on promoting the project by partnering with various community groups and the media to attract 'sampler' registrations from the community.

The team developed sampling kits and took part in numerous community events. By the end of 2013 over 750 kits had been issued to registered participants from a range of community sectors including agriculture, education, conservation and 'the grey nomads'.

The project also generated significant media interest including radio interviews, newspaper articles and a spot on GWN TV news.

In 2014, the team plans to further broaden the project's impact in the wider community with the development of an 'app' for data capture in the field, the release of a short film and the generation of more opportunities for volunteers to engage in the project.

This project is funded by UWA, the Office of Science at the Department of Premier and Cabinet and receives generous in-kind sponsorship from Life Tech, Grow Safe AMF, The Sunday Times, Bunnings Warehouse Subiaco and the Perth Caravan and Camping Show.

Climate change and water use efficiency

Effectively utilising water allocations for managing turfgrass in open spaces

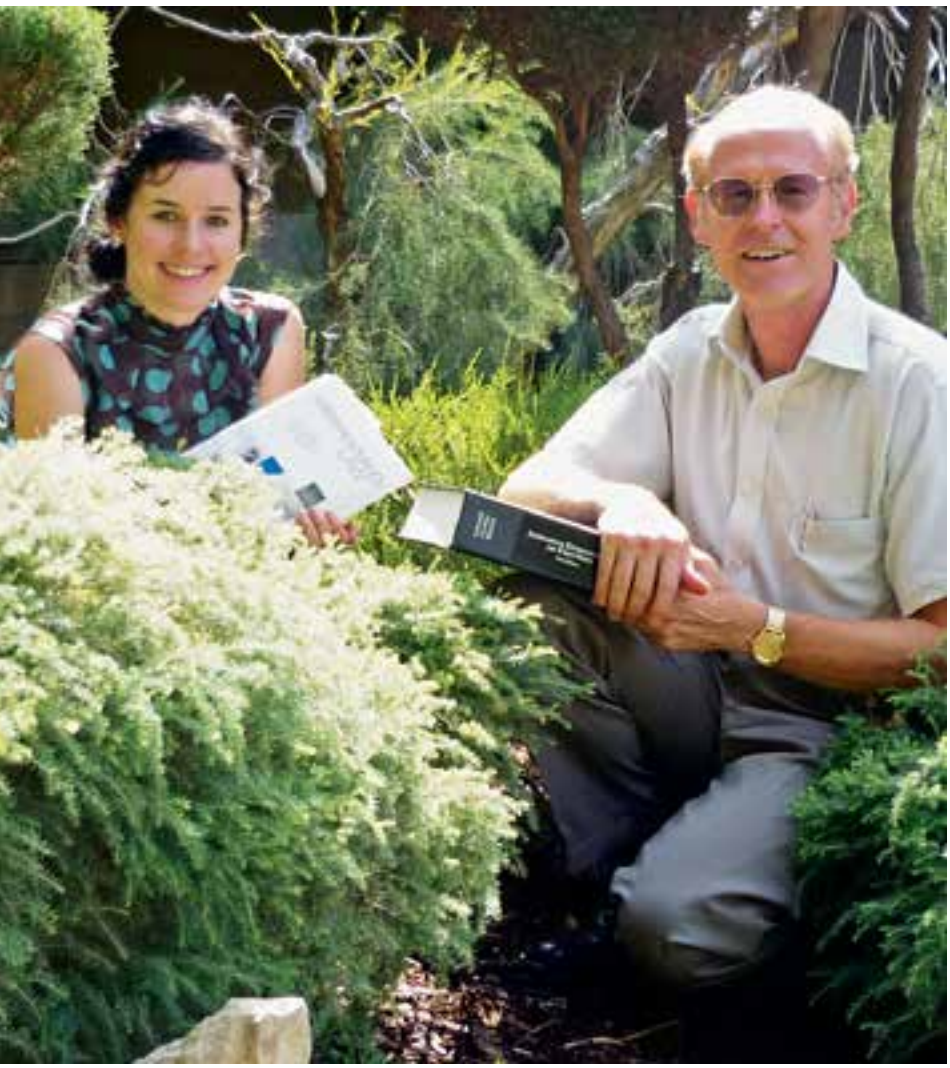
Project Team: Assoc/Prof Louise Barton[1] (leader; email: louise.barton@uwa.edu.au), Prof Tim Colmer[1], Mr Sam Flottmann[1]

Collaborating organisations: [1]UWA

Southern Australia is expected to experience a significant decrease in water resources due to changing climate. Turfgrass managers are under continued pressure to restrict water use, while also maintaining high quality surfaces. The importance of maintaining sports turfgrass so as to encourage physical activity is well recognised within the community; however, there is increasing evidence that well designed and maintained green spaces are also needed for mental health and well-being.

Water allocation is a key water planning method being utilised for irrigating public open spaces in southern Australia. Understanding how to best manage turfgrass on current and possible lower future water allocations is critical for managing these community areas.

The overall objective of this field-based project is to investigate approaches to best manage current and possible future water allocations to turfgrass in public open spaces. Consequently, the project is: (i) investigating if turfgrass can be maintained with a water allocation (7500 kL ha^{-1} per year), and the implications of further lowering the allocation on turfgrass quality; (ii) evaluating how



an annual water allocation is best distributed during the year; and (iii) assessing if using a wetting agent can improve the effectiveness of a water allocation.

The first year of field assessment was completed in 2013. Preliminary findings indicate turfgrass can be maintained on the current water allocation (7500 kL ha-1 per year), if it does not experience excessive wear. Lowering the water allocation will have a negative impact on turfgrass quality, although this may be partially mitigated by using an effective wetting agent as these soils are water-repellent and water loss by runoff and evaporation decreased water use efficiency.

Furthermore, simple approaches utilising historical climate data can be used to effectively distribute an annual water allocation during the irrigation season. The suitability of irrigation strategies evaluated in the project's first year will continue to be assessed for another two years.

This research is supported by Horticulture Australia Limited (HAL) in partnership with the Local Government and members of the Australian Turf Industry.

Cross-jurisdictional approaches to regulating for groundwater use efficiency: analysing the experiences of Colorado, New South Wales, and Western Australia

Project Team: Prof Alex Gardner[1] (leader; email: alex.gardner@uwa.edu.au), Ms Madeleine Hartley[1]

Collaborating organisations: [1]UWA; The Sturm College of Law (SCOL), Denver University, Colorado

Across the globe, burgeoning populations, climate variability, and reductions in groundwater recharge are placing increased stress on groundwater resources. With reduced groundwater reliability comes a need to ensure its use is efficient. Legal frameworks can play an important role in controlling and improving water use efficiency.

This project seeks to identify the requirements of water use efficiency in legal frameworks, focusing on the hypothesis that a crucial link exists between sustainable development and water use efficiency. This is so that increased efficiency does not result in increased consumptive use beyond sustainable limits. The three primary aims of the research are to determine: (i) the ways in which regulatory measures can be used to achieve improvements in water use efficiency; (ii) which of these measures combine to represent best practice in regulating for water use efficiency; and (iii) the role of sustainable development principles in defining regulatory standards of water use efficiency.

Preliminary project findings suggest that groundwater law frameworks will be most effective at regulating for its efficient use when founded on principles of sustainability. The best way for this to occur is through a toolbox approach to regulating for water use efficiency, as it permits the integrated use

of regulatory measures that can ensure sustainability. Although market forces assume a central role in facilitating efficiency, they can be weakened by ineffective regulatory frameworks and government inertia. A regulated approach to improving water use efficiency therefore retains merit in situations with undeveloped or nascent market structures.

This research was supported by the National Centre for Groundwater Research and Training (Flinders University, SA), and the Cotton Research and Development Corporation (Narrabri, NSW).

Critical Zone Observatory

Avon River Catchment Critical Zone Observatory

Project team: Asst/Prof Matthias Leopold[1] (leader; email: matthias.leopold@uwa.edu.au), Assoc/Prof Deirdre Gleeson[1]

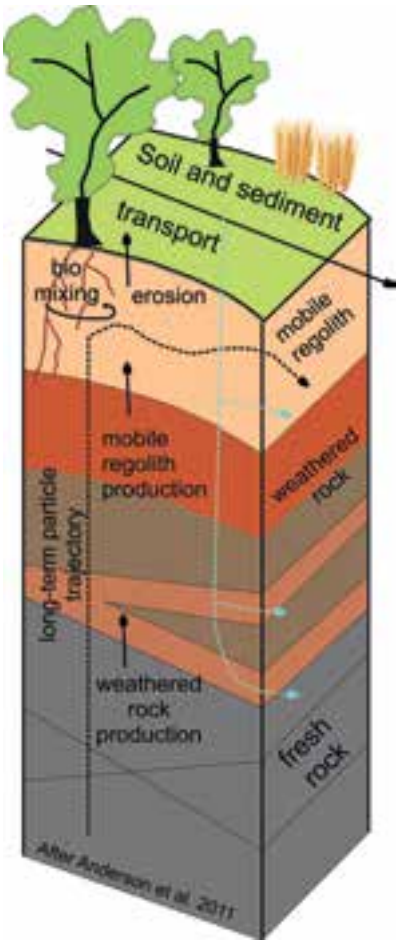
Collaborating organisations: [1]UWA; Critical Zone Observatories

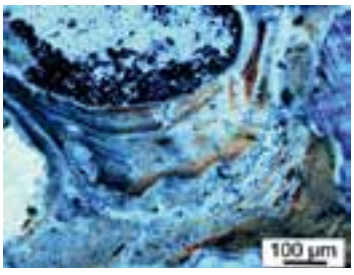
The Critical Zone is Earth's outer skin, where soil interacts with rock, water, the atmosphere and living organisms. This zone is essential for terrestrial life on Earth because it produces food, influences water quality and regulates local micro-climate. An international network of scientists study Earth's Critical Zone at sites around the world that are known as 'Critical Zone Observatories'(CZO). There are approximately 50 CZOs globally, but most are in Europe and the United States. To make the study of Earth's critical zone truly global CZOs are needed in locations where climate, soils and land management differ from that of Europe and the United States.

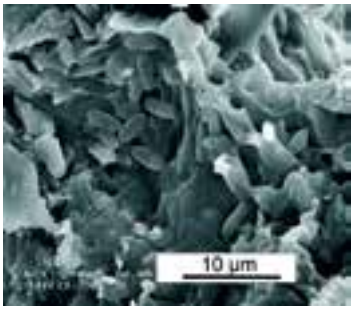
In 2013, a new CZO was established by the Soil Science discipline within the School of Earth and Environment at the UWA Future Farm in Pingelly (www.czen.org/content/uwa-czo-avon-river-catchment). The new Avon River Catchment CZO is the first in the Southern Hemisphere and UWA is the first Australian university to be a part of the network of research sites. The site will provide a focus for local, national and international researchers who study this critical part of the environment.

UWA hosted an International Workshop in April 2014 (to mark the establishment of Australia's first CZO. The workshop brought together local researchers and international experts in CZOs for two days of presentations, workshops and planning future research. Participants visited the UWA Future Farm to hear about the unique landscape, geology and soils at the site.

This research is supported by UWA, the World Universities Network, the Perth USAsia Centre and the Perth Convention Centre.







2. Plant Production Systems Program

The Plant Production Systems Program is made up of a large number of projects in various disciplines (e.g. weed science, pasture science, plant pathology, crop physiology and abiotic stress tolerance, genetics and pre-breeding) that aim to contribute to improvements in productivity and sustainability of agriculture. Most of the research focus is on issues impacting on plant production systems in rain-fed annual temperate crops, and pastures for livestock, but with some work also on perennial plants (e.g. vines) in areas of high rainfall and/or other horticultural crops with irrigation inputs. Current challenges from biotic and abiotic stresses, as well as preparation of robust options in the face of climate change have, again, set the direction for much of the research in 2013, with particular focus on weed management, disease risks, crop adaptation, crop improvement and farming practices.

Improving disease resistance (in crop plants)

Characterisation of a major quantitative trait locus on wheat chromosome 3B responsible for *Fusarium* crown rot resistance

Project team: Assoc/Prof Guijun Yan[1] (leader; email: guijun.yun@uwa.edu.au), Dr Jun Ma[1], Prof Chunji Liu[2], Dr Catherine Feuillet[3], Dr Daniel Mullan[4], Ms Tresslyn Walmsley[4], Mr Jinkao Guo[5], Ms Yanxia Wang[5], Dr John Manners[2]

Collaborating organisations: [1]UWA; [2]CSIRO; [3]National Institute for Agricultural Research, France; [4]InterGrain; [5]Shijiazhuang Academy of Agriculture and Forestry Science, China

With the world population predicted to rise to 9 billion by 2050 breeding cereals with improved yield is gaining in importance for future food security. *Fusarium* crown rot (FCR) is a cereal disease that causes worldwide yield losses averaging 25% in bread wheat, 58% in durum wheat and 20% in barley.

Breeding varieties with good FCR resistance would benefit the crop industry worldwide. Following on from the team's previous research, which identified a major quantitative trait locus (QTL) of the disease on wheat chromosome arm 3BL and developed nine pairs of near isogenic lines (NIL), this project focuses on transcriptomic characterisations of the NILs and the development of a large fine mapping population from the NILs.

Using genome sequence information on wheat and other closely related species the project aims to develop tightly-linked DNA markers which can be used in marker-assisted selection to ensure resistance is quickly incorporated into breeding populations. The project also aims to understand the genetic mechanism of resistance and identify genes responsible for resistance to the disease.

During 2013 the team developed a large fine-mapping population (around 2000 individuals) mainly segregating around the FCR locus on 3BL. They also established

colinearity between the wheat 3BL QTL interval and a model species (*Brachypodium*). As a result, new gene-based wheat genetic markers are being designed based on the sequences of *Brachypodium* genes in the colinear region.

In addition, the team developed a procedure capable of generating up to eight generations of wheat and nine generations of barley per annum (see also cover story of IOA News April 2013 edition: http://www.ioa.uwa.edu.au/__data/assets/pdf_file/0004/2292322/104678_IOA-newsletter-v7-web.pdf).

Funding was recently awarded by the Council of Grain Growers Organisation (COGGO) for another project that will implement the newly developed 'fast generation technology' (see also page xx) for the Australian wheat/barley industry.

This project was funded by the Australian Research Council (ARC) with CSIRO, INRA, InterGrain and Shijiazhuang Academy of Agriculture and Forestry Science.

The role of soil factors and transmission on propagation material of fungal pathogens in the severity of strawberry root and crown disorders in Western Australia

Project team: W/Prof Martin J. Barbetti[1] (leader; email: martin.barbetti@uwa.edu.au), Dr Xiangling Fang[1]

Organisation: [1]UWA

Strawberry (*Fragaria* × *ananassa*) is one of the most important berry crops in the world, with Western Australia (WA) producing up to 90% of Australia's strawberry exports in some seasons. Devastating outbreaks of root and crown disease in WA have impacted severely on strawberry production with up to 50% plant losses on worst-affected properties in some seasons. As a result, WA's role as Australia's major and most reliable exporter ($11 million p.a.) is currently under threat from such disease outbreaks. Of the root and crown diseases on strawberry, Fusarium wilt caused by *Fusarium oxysporum* f. sp*. fragariae* (Fof) and root rot caused by the *Rhizoctonia* spp. pose serious threats to commercial strawberry production.

Part of this project aims to provide new information about these two fungal pathogens (Fof and *Rhizoctonia* spp) and the resistance mechanisms associated with them for strawberry. In two separate studies, the project team set out to identify the resistance mechanisms of strawberry against Fof and to generate information about the genetic diversity and evolutionary history (phylogenetic status) of *Rhizoctonia* spp., to help develop superior disease management strategies and new strawberry cultivars with improved disease resistance.

The first study focused on the resistance mechanism against Fof. The researchers undertook a comparative proteome analysis of Fof to reveal early activation of defence responses crucial in determining host resistance. The researchers identified 79 proteins involved predominantly in primary, secondary and protein metabolism, stress and defence responses, antioxidant and detoxification mechanisms, and hormone biosynthesis. Among the 79 proteins, certain groups showed great potential in mediating strawberry resistance against Fof.

Furthermore, the team found that protein modification may also play an important part in the resistance mechanism.

This study has provided the first insights into strawberry resistance mechanisms against Fof, opening novel avenues to engineer new strawberry cultivars with improved disease resistance and to develop more effective and sustainable disease management strategies.

The second study focused on the genetic diversity and phylogenetic status of the fungus *Rhizoctonia* spp. The researchers examined diseased strawberry plants in WA and found that 96 *Rhizoctonia* spp. isolates recovered from the diseased plants were binucleate *Rhizoctonia* (BNR). Testing revealed 65 of these isolates to be pathogenic on strawberry, but with wide variation in virulence, with 25 isolates having high virulence. There was no significant association between genetic diversity and virulence of these BNR isolates.

This study showed wide genetic diversity of the pathogenic BNR isolates associated with root rot of strawberry in WA; it also highlighted new genetic groups not previously associated with root rot of strawberry. The wide variation in virulence and genetic diversity identified in this study will be of high value for strawberry breeding programs in selecting, developing and deploying new cultivars with resistance to these multi-genetic groups of BNR.

This project is funded by the ARC, the Department of Agriculture and Food, Western Australia (DAFWA) and the Strawberry Growers Association of WA.

Factors responsible for host resistance to the pathogen *Sclerotinia sclerotiorum* for developing effective disease management in vegetable Brassicas

Project team: W/Prof Martin J. Barbetti[1] (leader: email martin.barbetti@uwa.edu.au), Ms Margaret B. Uloth[1], Dr Mingpei You[1], Assoc/Prof Patrick Finnegan[1], Dr Surinder S. Banga[2], Dr Shashi K. Banga[2], Dr Prabhjot S. Sandhu[2]; Dr Huang Yi [3]

Collaborating organisations: [1]UWA; [2]Punjab Agricultural University, India; [3]The Chinese Academy of Agricultural Sciences (CAAS), China

Sclerotinia rot, caused by the fungal pathogen *Sclerotinia sclerotiorum*, is an endemic and serious disease across the vegetable *Brassica*-growing regions worldwide. Recent surveys of Western Australian *Brassica* producers revealed Sclerotinia rot to be the most important yield-limiting and least controllable of the various diseases that threaten vegetable production, causing yield reductions in *Brassica* crops of up to 30%. The invasion patterns of *S. sclerotiorum* are rapid and destructive under the disease-conducive environments of Australia. Effective host resistance to this pathogen is urgently needed if Sclerotinia rot is to be successfully managed across diverse oilseed, forage and vegetable crucifer crops worldwide.

This project focuses on identifying new sources of resistance to *S. sclerotiorum* for crucifer crops, through two separate experiments. The first experiment involved field screening 127 diverse cruciferous genotypes to *S. sclerotiorum*; the second experiment involved screening a set of 55 *Brassica napus* lines carrying one or more *B. carinata* B genome introgressions.

For the first time worldwide, the researchers succeeded in determining responses to this pathogen on 15 specific *Brassica* species, and on *B. napus* with introgression(s) from *B. carinata*. The responses ranged from highly resistant to highly susceptible across the genotypes tested, while a selection of genotypes across different *Brassica* species showed very high-level resistance against a highly virulent and prevailing

pathogen pathotype. Furthermore, some forage and/or vegetable crucifers also showed high-level resistance to natural epidemics in WA.

In addition, there appeared to be separate genetic control for stem *versus* leaf resistance, crucial to the understanding needed in developing resistant cultivars across different cruciferous crop types; findings indicated that genotypes with high-level stem or leaf resistance are of high value for developing new disease-resistant cultivars of oilseed, forage and vegetable crucifers.

This project is funded by the ARC and DAFWA.

Determination of factors responsible for aphid-borne pea seed-borne mosaic virus epidemics in pea and development of effective virus management tools

Project team: Prof Roger Jones[1] (leader; email: roger.jones@uwa.edu.au), Assist/Prof Michael Renton[1], Ms Brenda Coutts[2], Dr Joop van Leur[3], Mr Benjamin Congdon[1]

Collaborating organisations: [1]UWA; [2]DAFWA; [3]NSW-DPI

Field pea is part of crop rotations in the grainbelt of Western Australia (WA) and is worth more than $50 million a year. It provides weed control options and disease breaks for our important cereal crops as well as enhancing available soil nitrogen via nitrogen fixation. Epidemics of *pea seed-borne mosaic virus* (PSbMV) can cause up to 50% losses in field pea yield and seed quality defects, which can lead to downgrading at the market. Climatic variables are hypothesised to strongly affect aphid arrival and build-up in the crop, which in turn influences virus spread. This

project is focused on understanding these relationships within the PSbMV pathosystem in order to accurately forecast epidemics using a predictive model. This will act as a decision support system when growers are deciding what control measures to use and to use these to higher efficacy through better timing of employment.

While this project only commenced in June 2013 (with the appointment of Benjamin Congdon who is undertaking the research under his PhD project), the project makes use of good quality validation data from field trials setup in Esperance and Avon districts for the fourth consecutive year.

Five field plots were sown in the 2013 growing season at two sites in WA and three sites in New South Wales. Aphid and virus samples were collected at one to two weekly intervals and tested for aphid vector numbers and virus spread. Rainfall from late summer to early autumn and climatic conditions throughout the growing season strongly correlated with aphid arrival and buildup in the crop. The data also showed that early aphid arrival and build up led to higher rates of early spread of PSbMV.

In addition to the field trials, a series of glasshouse experiments are underway to analyse the relative importance of different aphid species as vectors and to examine the possibility of wind/contact transmission of the virus as an alternative to transmission by aphids.

This project is funded by an ARC Linkage grant with DAFWA and the New South Wales Department of Primary Industries (NSW DPI).

UWA-CSIRO collaboration on legume genomics and molecular plant pathology

Innovative approaches to resistance to necrotrophic fungal pathogens and sap-sucking insect pests

Project team: W/Prof Karam Singh[1,2] (leader; email: karam.singh@csiro.au), Assist/Prof Jonathan Anderson[1,2]

Collaborating organisations: [1]UWA; [2]CSIRO; ICRISAT; Curtin University

The root-infecting necrotrophic fungal pathogen *Rhizoctonai solani* causes $77 million damage to wheat and barley and significant losses to legumes and canola while sap sucking insect pests cause about $240 million damage every year for field crops and pastures in Australia. In addition to these existing problems devastating exotic pathogens and pests, including Fusarium wilt of legumes (chickpea, lupin and lentils) and Russian wheat aphid (which causes $US 1 billion total damage to wheat crops internationally), are a threat to the continued profitability of the Australian grains industry.

The overall objective of this project is to reduce the impact of existing and new (exotic) problems for the Australian grains industry caused by necrotrophic diseases and insect pests. The project team has previously identified genes in the model legume *Medicago truncatula* that are able to provide resistance to *R. solani* and some other necrotrophic pathogens as well as candidate genes with the potential to provide resistance to aphids. In this project the characterisation of these genes and their potential use in providing resistance to recalcitrant necrotrophic diseases in crops is investigated further. In addition to studying the plant side of interactions with pathogens and pests, this project tackles diseases caused by *R. solani* and *Fusarium oxysporum* by sequencing the genomes of these pathogens to allow prediction of genes important for the ability of these pathogens to infect their host plants, followed by functional testing. This knowledge will be used to formulate strategies to limit the impact of these pathogen genes in crop plants and hence reduce the ability of the pathogens to cause disease.

During 2013 the project advanced significantly, as reflected by three major accomplishments: the team (i) recognised the plant's role in utilising reactive oxidative species to provide resistance to the necrotrophic pathogen, *R. solani;* (ii) generated an excellent reference genome sequence for *R. solani* AG8 and conducted comparative genomics to identify candidate effectors and pathogenicity genes, and (iii) generated a comprehensive genome assembly for model legume-infecting Fusarium wilt pathogen and initiated collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to compare to a chickpea infecting isolate.

This project is funded by the Grains Research and Development Corporation (GRDC).

Genome sequencing in narrow-leafed lupins

Project team: W/Prof Karam Singh[1,2] (leader; email: karam.singh@csiro.au), Assoc/Prof Lars Kamphuis[1,2], Asst/Prof Matt Nelson[1], E/Prof Craig Atkins[1], W/Prof Grant Morahan[1]

Collaborating organisations: [1]UWA ; [2]CSIRO; BGI, China; Proteomics International; WAIMR

Narrow-leafed lupin (NLL) is the main grain legume grown in WA and forms an important part of sustainable farming systems, reducing the need for nitrogenous fertiliser, providing valuable disease breaks and boosting cereal yields. There are exciting opportunities to accelerate NLL breeding that are opening up through the genomic/sequencing revolution. NLL has only been recently domesticated and there is tremendous scope

for rapid improvements through applying modern pre-breeding and breeding technologies.

The scope of this project is to provide the research and breeding community with extensive information on the NLL genome sequence. Its major focus is to decipher as much of the gene space sequence as possible and to use this valuable sequence information to greatly accelerate marker discovery and identification of candidate genes of interest for lupin crop improvement. Highlights in 2013 were: (i) the in-depth tissue-specific transcriptome sequencing for three NLL accessions (two domesticated and a wild accession); (ii) a draft genome sequence at 45x coverage that has provided 521 MB of genome sequence; and (iii) the generation of large numbers of SSR and SNP markers from lupin genome/transcriptome sequence and using them to genotype NLL recombinant inbred line (RIL) populations.

This project is funded by the GRDC.

Genome sequencing in chickpea

Project team: W/Prof Karam Singh[1, 2] (leader; email: karam.singh@csiro.au) and a large number of international scientists from collaborating institutions below

Collaborating organisations: [1]UWA ; [2]CSIRO Plant Industry; ICRISAT; BGI, China; University of Queensland; Curtin University; University of California- Davis, USA; University of Saskatchewan, Canada; University of Córdoba, Spain; NCGR, USA

Legumes are a critical component for Australian agriculture as they provide disease breaks, help with weed control and fix nitrogen, thereby reducing the economic and environmental costs of using industrial fertilisers for their cultivation and for subsequent cereal crops. An important grain legume grown in Australia is chickpea which is also the third most important pulse crop in the world covering an area of 11.08 million ha. Through the genome revolution and next generation sequencing technologies there are new powerful tools available to the modern plant breeder that could rapidly accelerate pre-breeding and breeding programs for chickpea and other legume crops and lead to major advances in crop improvement.

As part of the International Chickpea Genome Sequencing Consortium (ICGSC), this project aimed to generate a genome sequence using next generation sequencing technology for a kabuli genotype that can serve as a reference genome for this important pulse species and help accelerate molecular based pre-breeding and breeding efforts for crop improvement.

In 2013, the chickpea genome sequence for a kabuli genotype was achieved through Australian participation in ICGSC, to generate a reference chickpea genome sequence. In partnership with BGI, ICGSI used powerful next generation sequencing to: (i) generate a high standard genome assembly for kabuli chickpea; (ii) re-sequence another 90 chickpea genotypes, including desi, kabuli

and wild genotypes; and (iii) begin to identify genes for important traits to greatly accelerate marker discovery and identification of candidate genes of interest.

This collaborative chickpea genome sequencing project is a critical first step that will provide pulse geneticists and breeders a foundational resource for this important crop. The work will have benefits nationally and internationally.

This research was funded by the GRDC and several international partners.

Genomic approaches for stress tolerant chickpea

Project team (in Australia): Dr Tim Sutton[2], W/Prof Tim Colmer[1], W/Prof Kadambot Siddique[1], Assoc/Prof Victor Sadras[3], Prof David Edwards[4], Assoc/Prof Rebecca Ford[5], Dr Nitin Mantri[6], Dr Jiayin Pang[1], Mr John Quealy[1]

Collaborating organisations: [1]UWA; [2]ACPFG; University of Adelaide; [3]SARDI; [4]ACPFG; University of Queensland; [5]University of Melbourne; [6]RMIT; ICRISAT and several other collaborators in India (led by Dr Rajeev Varshney)

Abiotic stresses limit chickpea productivity. The project objectives are to work as a collaborative multi-disciplinary team in Australia, and in collaboration with the project's Indian partners, to: (i) refine and apply field and controlled-environment phenotyping to identify unique and shared differential responses within Indian and Australian germplasm to drought, heat and salinity stresses; (ii) identify tolerant genotypes and enhance understanding of the physiological and genetic mechanisms governing stress responses (including evaluation of the inheritance of key traits); (iii) identify candidate genes associated with the tolerance pathways through trait mapping and positional cloning with the view for marker assisted selection and genes for genetic engineering; (iv) identify functional alleles through genome-wide selection and RNA sequencing, enabling screening and evaluation of alleles at multiple loci that contribute to stress tolerance; (v) develop gene databases and selection tools that have application to chickpea improvement; and (vi) make a significant contribution to training of the next generation of pulse breeders, molecular geneticists and crop physiologists for India and Australia.

The UWA component during 2013 focused on field evaluations of numerous lines in replicated field plots in water-limited environments (two sites), and of a smaller set of lines in field rows for salinity tolerance. This information provides the basis for association to be made between phenotype and genotype. This trial comprised chickpea lines specifically selected for adaption to water-limited environments, as well as current check varieties. The parentage was made up of Indian-derived and Australian breeding lines, strengthening the focus of the project on collaboration and the acquisition of knowledge regarding germplasm relevant to both Australia and India.

Seed of each line was sent to the Australian Centre for Plant Functional Genomics (ACPFG) for genotyping. The field trial evaluated plot yields (machine-harvested), as well as plant traits (hand-harvested) of seed yield per plant, yield components, harvest index and biomass. Crop establishment, plant types, and phenology (flowering

and podding at maturity) were also evaluated. The lines displayed a range of flowering and podding times, plant types, yield component traits and yield.

The data will enable selection of contrasting genotypes for more detailed glasshouse studies of physiological processes, and with two years of data also will enable genotype x environment analyses of chickpea in water-limited environments.

During 2013, the UWA team participated in a project planning meeting of Australian partners held in Melbourne. The UWA team also hosted, in WA, the annual project meeting of all Australian and Indian team members, with organisation of the meeting coordinated by ACPFG. Several of these scientists also participated in the InterDrought IV Conference held in Perth in September.

This project is funded by the Australia-India Strategic Research Fund Grand Challenge.

Enhancing the WA chickpea industry through targeted demonstration and extension of new Ascochyta resistant improved varieties and lines in partnership with grower groups

Project Team: W/Prof Kadambot Siddique[1] (leader; email: kadambot.siddique@uwa.edu.au), Prof Tanveer Khan[1], Mr Alan Meldrum[2]

Collaborating organisations: [1]UWA; [2]Pulse Breeding Australia; WA Grower Groups

Chickpea (*Cicer arietinum*) is the third most widely grown grain legume in the world, and in the mid 1990s WA developed a rapidly growing chickpea industry which covered about 80,000 hectares by 1999. In the same year, the Ascochyta blight disease (caused by the fungus *Ascochyta rabiei*) appeared and the severity of the outbreak caused the industry to all but disappear in WA over the subsequent decade.

New high yielding varieties with resistance to Ascochyta blight and good seed quality have now become available and, as a result, chickpea has the potential to become the most widely grown grain legume in WA. This project aims to rekindle the interest of growers in chickpea through targeted demonstration of new Ascochyta resistant varieties in the southern (chickpea-growing) parts of Australia.

The team conducted six demonstration trials at Mullewa, Mingenew, Wubin, Merredin, Doodlakine and Corrigin, in collaboration with local grower groups and industry.

The trials compared three new (Ascochyta-resistant) desi chickpea cultivars, 'Ambar', 'Neelam' and 'PBA Striker' along with standard cultivars 'PBA Slasher' and 'Genesis 836', following district practices using broadacre machinery. Field days and field walks were held at all trials, with one or more of the project researchers demonstrating the new varieties and their management to more than 150 growers and agri-industry representatives.

All trials were sown at optimum dates but suffered from prolonged lack of rain soon after sowing. Commencing in July, rainfall increased and all trials (apart from Wubin) received average to above spring rainfall. The mean yields in trials varied from 373 kg/ha at Mullewa to 1479 kg/ha at Mingenew.

The three new cultivars complemented each other in adaptation and displayed adequate resistance to the Ascochyta blight disease for WA, and these positive results were disseminated further through media releases and publicity in rural periodicals and through the grower groups' internal communication and reporting channels.

Research will continue during the 2014 season in partnership with grower groups and industry.

This project is funded by the COGGO.

Securing chickpea productivity under contemporary abiotic stresses: improvement of podding and seed-filling under heat, drought and salinity

Project team: W/Prof Tim Colmer[1] (leader; email: timothy.colmer@uwa.edu.au), W/Prof Kadambot Siddique[1], W/Prof Neil Turner[1], Dr Vincent Vadez[2], Dr Pooran Gaur[2], Dr Rajeev Varshney[3], Prof Harsh Nayyar[3], Mr John Quealy[1], Dr Lukasz Kotula[1]

Collaborating organisations: [1]UWA; [2]ICRISAT; [3]Punjab Agricultural University, India

Abiotic stresses are key limiting factors to chickpea productivity, but also more widely to all major staple crops worldwide. Heat, drought or salinity stress can each have a severe impact on yield, but these stresses also often coincide in the field.

This project aims to: (i) determine the physiological bases of sensitivity and tolerance of chickpea at the reproductive stage to heat, drought and salinity stress; (ii) unravel combined effects of stresses on the performance of chickpea (e.g. heat combined with drought; drought combined with salinity) and identify parental genotypes for future multi-stress tolerance breeding; (iii) evaluate promising Ascochyta blight-resistant lines already in Australia that have ICCV 96836 as a parent for salinity tolerance and then for drought and heat tolerance; and (iv) further the understanding of the effect of salinity on the reproductive processes of chickpea and validate existing salinity tolerance QTL.

The work undertaken in this project comprises three components, and each of them had major achievements during the past 12 months:

The UWA component identified three breeding lines with salt tolerance higher (20-27% higher yield under saline conditions) than the most salt tolerant local variety 'Genesis 836'. This is of significance since the salt tolerance was expressed in the field and Genesis 836 has already performed very well against other international germplasm.

The ICRISAT component conducted screening of drought tolerance for a sub-set of chickpea lines (i.e. genotypes) previously identified as having superior heat or salinity tolerance. The screenings have revealed that some sub-sets also show more drought tolerance than standard genotypes.

The Punjab Agricultural University (PAU) component conducted experiments evaluating salinity and heat stress individually, and when in combination. High temperature markedly increased the sensitivity of chickpea to salinity, but genotypes contrast in their sensitivity. Biochemical studies indicated severe inhibition of sucrose and starch metabolism in all genotypes studied, but to varying degrees, providing insight into possible tolerance mechanisms.

During 2013, the UWA team visited ICRISAT and PAU in Ludhiana for discussions on progress and planning for the year. Presentations highlighted the substantial progress made and enabled discussions of a large joint data set obtained in collaborative experiments which involved research officer John Quealy sampling tissues at ICRISAT with chemical analyses conducted at UWA and experimental work by ICRISAT PhD student Pushpavalli.

Pushpavalli had also visited UWA on a Crawford Fund award. Biochemical data from experiments at PAU were also discussed. Joint publications are underway.

This project is funded by the Australia-India Strategic Research Fund.

Improving heat and drought tolerance in canola through genomic selection in *Brassica rapa*

Project team: W/Prof Wallace Cowling[1] (leader; email: wallace.cowling@uwa.edu.au), W/Prof Kadambot Siddique[1], W/Prof Neil Turner[1], Assoc/Prof Matthew Nelson[1], Dr Robert Furbank[2], Assist/Prof Sheng Chen[1], Ms Yiming Guo[1], Dr Shyam Dey[3]

Collaborating organisations: [1]UWA; [2]CSIRO Plant Industry Canberra; [3]Indo-Australia S&T; Norddeutsche Pflanzenzucht Hans-Georg Lembke KG (NPZ-Lembke), Germany; University of Queensland; Justus Liebig University, Germany

Canola is vulnerable to heat and drought stress due to its narrow genetic base, and the canola breeding industry is determined to find sources of heat and drought tolerance to secure the future of the crop. *Brassica rapa*, the field mustard/turnip ancestor of canola, has extremely high global genetic diversity and some types flourish in heat and drought affected regions.

This project aims to develop effective protocols for large-scale screening for heat and drought tolerance in *B. rapa* that can be applied to a rapid-cycle breeding program. The project will exploit genomic selection to build a dynamic population of *B. rapa* enriched for drought and heat tolerance genes that can be transferred to canola.

In 2013, 220 *Brassica rapa* accessions were genotyped. The single nucleotide polymorphism (SNP)-based genetic diversity analysis is on-going. This SNP genotyping data will be used for association mapping analysis together with phenotyping data under heat and/or drought stress.

One hundred and fifty of the SNP-genotyped *B. rapa* accessions from different parts of the world were characterised for several physiological traits related to heat tolerance. At the early flowering stage, each genotype was treated for seven days under normal (25°C) and high (35°C) temperature in controlled environment rooms. Important physiological traits viz. leaf temperature depression, bud temperature depression, stomatal conductance, and leaf chlorophyll were measured. The biomass and the seed yield data will be collected in February 2014; by then relevant association analysis will be applied to identify the heat tolerance genes/QTLs.

During 2013, the project team published several papers on heat and drought tolerance and genetic diversity in *B. rapa* in the international journals: Functional Plant Biology, Journal of Agronomy and Crop Science, and Crop and Pasture Science.

The project team conducted an experiment on transcriptase analysis of drought stress by RNAseq. Using an *in vitro* cultivation system the team investigated two *B. rapa* genotypes showing contrasting physiological responses to drought stress. Whole genome transcriptome sequencing (RNA-Seq) was used to analyse differential gene expression in shoots and roots responding to drought stress. A paper for publication is in preparation.

This research is funded through an ARC Linkage Project with support from COGGO and NPZ-Lembke, Germany.

Importance of nitrate in vegetables for vascular health in humans

Project team: Res/Prof Jonathan Hodgson[1] (leader; email: jonathan.hodgson@uwa.edu.au), Prof Kevin Croft[1], Dr Catherine Bondonno[1], Prof Richard Prince[1], Assoc/Prof Richard Woodman[2], W/Prof Ian Puddey[1], Dr Natalie Ward[1], Prof Joseph Vita[3], Mr Alex Liu[1], Ms Lisa Rich[1]

Collaborating organisations: [1]UWA; [2]Flinders University; [3]Boston University, USA

Plant food-rich diets result in lower blood pressure and reduced risk of vascular disease. Australian dietary guidelines encourage intake of vegetables generally and green leafy vegetables specifically. Green leafy vegetables are the most important dietary source of inorganic nitrate, providing two thirds or more of total intake. Their nitrate content may help to explain blood pressure lowering on a diet rich in green leafy vegetables.

There is now convincing evidence that the reduction of dietary-derived nitrate to nitrite is a major contributor to the nitric oxide pool in the body (responsible for relaxation of blood vessels), and that this can benefit blood pressure. However, there remains little data on the effects of regular ingestion of a diet high in inorganic nitrate from green leafy vegetables on blood pressure and other outcomes related to nitric oxide metabolism.

Recent trials undertaken as part of this project have shown that nitrate supplementation can cause a dose-dependent increase in nitric oxide status, and that ingestion of nitrate-rich green leafy vegetables can reduce arterial stiffness and blood pressure. Studies underway are now looking at the effects of regular ingestion of nitrate-rich vegetables on blood pressure in people with normal and elevated blood pressure.

This research has funding support from the National Health and Medical Research Council (NHMRC).

Understanding the importance of dietary flavonoids for human health

Project team: Res/Prof Jonathan Hodgson[1] (leader; email: jonathan.hodgson@uwa.edu.au)' Prof Kevin Croft[1], Assist/Prof Michael Considine[1], Dr Catherine Bondonno[1], Prof Richard Prince[1], Assoc/Prof Richard Woodman[2], W/Prof Ian Puddey[1], Dr Natalie Ward[1], Ms Lisa Rich[1], Ms Kerry Ivey[1], Dr Joshua Lewis[1], Prof Xinbin Yang [6], Ms Aidilla Mubarak[1], Prof Geoffrey Head[2], Dr Elena Lukoshkova[3], Prof Peter Thompson[1], Prof Roland Stocker[4], Dr Yu Shen [1], Ms Diana Fisher[5]

Collaborating institutions: [1]UWA; [2]Baker IDI Heart and Diabetes Institute; [3]Russian Cardiology Research Centre; [4]Victor Chang Cardiac Research Institute; [5]DAFWA; [6]Shaanxi Normal University, Xi'an, China

Polyphenols (polyhydroxyl phenols) are secondary plant metabolites associated with health benefits in humans. The two main classes of polyphenols are flavonoids and phenolic acids. Important dietary sources of flavonoids include tea, apples and other fruit. The main dietary sources of phenolic acids are coffee and fruits.

There are many hundreds of classes of polyphenols present in the human diet. However, bioactivity related to human health is likely to be restricted to fewer compounds. Many polyphenols are powerful antioxidants in vitro, but it is their effects on nitric oxide and vascular function that is a basis for health benefit.

Data from meta-analyses of observational epidemiological studies indicate that particular flavonoids and their food sources are related to 10 to 20% lower risk of cardiovascular disease. Our research in the area is directed to improving understanding of which bioactive compounds contribute to human health and the mechanisms involved, as well as establishing the efficacy of approaches to increase intake of polyphenols. It involves extensive collaboration with a number of stakeholders.

This research has been supported by grants from NHMRC, Unilever Research and Development, ARC and DAFWA (via the Australian National Apple Breeding Program). Current sources of funding include support from NHMRC, Horticulture Australia Limited, and Fruit West, WA.

Development of conservation cropping systems in the dryland of northern Iraq

Project team: Hackett Prof Kadambot Siddique[1] (leader; email: kadambot.siddique@uwa.edu.au), Assist/Prof Ken Flower[1], Assist/Prof Amin Mugera[1], Ms Cara Alan[1], Dr Jens Berger [1,2], Adj/Prof Wal Anderson[2]

Collaborating organisations: [1] UWA; [2]CSIRO; University of Mosul and the Iraqi Ministries, Iraq; ICARDA; University of South Australia; University of Adelaide

UWA, through its Institute of Agriculture (IOA) and with funding support from Australian Centre for International Agricultural Research (ACIAR) and the Department of Foreign Affairs and Trade (DFAT) is playing an important role in the rehabilitation of agricultural sector in Iraq. Since 2005, IOA has participated in a project to assist the re-establishment of agriculture, and enhance cropping practices in the dryland areas of northern Iraq.

The work has involved various phases including crop variety development, field trials on tillage methods, in-country and overseas training and most recently the adoption of aspects of conservation cropping. Partners in the work, in addition to UWA, include the University of Mosul, the Iraqi Ministries, the International Centre for Agricultural Research in Dry Areas (ICARDA), the University of South Australia and the University of Adelaide.

During the first two phases of the project farmers in Ninevah Province in Iraq witnessed the project team using zero till seed drills and they were so impressed with the technology that they immediately began constructing and modifying their existing seeders. Farmers in northern Syria began the same process and zero tillage, the cornerstone of conservation agriculture (CA), has been eagerly adopted in both countries.

The current phase of the project is managed by UWA graduate and former member of the IOA Industry Advisory Board, Dr Stephen Loss employed at ICARDA in Amman.

The project partners met in Amman, Jordan in September 2013 for a review of last year's activities in Ninevah Province in Iraq, northern Syria and the establishment of new sites in Erbil in Iraqi Kurdistan and Jordan.

The project team also discussed and agreed on the manufacture and delivery of new and renovated zero tillage seeders for all the collaborators during the new season and has taken steps to introduce other components of conservation cropping, such as returning of crop residues to the soil each year and the use of diversified rotation crops (including legumes). The project team believes that when CA is more fully implemented, this will lead to even greater benefits through improvement in soil fertility and grain yields.

As part of the project, the UWA team is currently investigating the impact of stubble retention and grazing on soils and on the levels of insects, diseases and weeds in cropping rotations in WA.

The training of Iraqi project participants as one of the project's key benefits to the recipient country and referred to the numerous training projects (past, present and planned) conducted by UWA for Iraqi students, professionals and government officials.

For further information see **www.ioa.uwa.edu.au/data/assets/pdf_file/0003/2152884/97454_IOA-News-No17-web.pdf**)

The Iraqi collaborators recently announced that several new crop varieties of durum and bread wheat, barley, field pea and vetch have been selected, seed increased, and varieties formally registered and released to farmers in Iraq. Multiplication of these varieties will provide farmers with further options to improve their crop yields and diversify their rotations.

The extension of this work through demonstration sites in a further three provinces in Iraq will spread further the positive impact on agriculture in countries that sorely need a boost in their recent fortunes. The project team commended their Iraqi and ICARDA colleagues on their determination and success in seeing this work through despite security challenges that most of us can only imagine.

This project is funded by ACIAR and DFAT.

Farm management

Long-term no-till farming systems

Project team: Dr Ken Flower[1] (leader; email: ken.flower@uwa.edu.au), Mr Neil Cordingley[2], Ms Suzan Mauchline[2], Dr Phil Ward[3], Mr Shayne Micin[3]

Collaborating organisations: [1]UWA; [2]WANTFA; [3]CSIRO

The aim of this long-term project was to determine the effect of rotation and residue level on wheat yield and gross margin at Mingenew and Cunderdin sites.

In 2013 the data for the six-year trial at the Mingenew site were analysed and showed wheat and lupins to be the most profitable crops at that location. At Cunderdin, continuous wheat was the most profitable cropping sequence for the same time period. The findings indicated that residue retention on its own has little impact in summer on soil water storage when measured over longer periods (i.e. several months). However, over shorter periods of days or weeks, particularly in autumn and winter, residue retention can increase infiltration and reduce evaporation, which can be particularly beneficial in extending the sowing window.

The project has provided farmers with information on the economics of cover crops and different rotations, as well as information on changes in stubble levels over time and the impact of stubble retention on soil water retention. This will assist farmers in making decisions to improve soil water retention, crop water use efficiency and soil health/organic carbon levels.

This project is funded by the GRDC.

Effect of stubble grazing in summer on no-till crop yields (Grain and Graze 2 – WA Region)

Project team: Dr Ken Flower[1] (leader; email: ken.flower@uwa.edu.au), Ms Sarah Hyde[3], Ms Suzan Mauchline[2]

Collaborating organisations: [1]UWA; [2]WANTFA; [3]Facey Group

This collaborative project assessed the impact of sheep grazing over summer on crop residues, soil quality and no-tillage crop establishment and yields. Light grazing had little effect on percentage ground cover and amount of stubble; grazing mainly loosened and flattened the residue. Longer grazing of paddocks over winter and summer reduced ground cover, water infiltration and yield on heavy textured soil. Light grazing of stubbles over summer had no significant effect on crop yield.

This project is funded by the GRDC.

Dry seeding into crop residues in the WA wheatbelt

Project team: Adj/Assoc/Prof Art Diggle[1,2] (leader; email: art.diggle@agric.wa.gov.au), Assoc/Prof Michael Renton[1], Mr Mike Airey[1]

Collaborating organisations: [1]UWA; [2]DAFWA

The overall aim of the project is to better understand the factors influencing the success of dry-sowing of grain crops in Western Australia.

The UWA contribution to this project focussed on using modelling to understand the relationship between dry- sowing and weed dynamics. The Weed Seed Wizard was the main modelling tool employed in 2013. Results indicated that dry-sowing can have negative impacts on weed populations due to the reduced options for weed control early in the season. However, if a long-term strategy of maintaining very low weed populations is in place, then dry-sowing becomes more attractive as a tactical option when conditions are suitable.

This project has been funded by the Western Australian No-Tillage Farmers Association (WANTFA) (ex GRDC).

Phosphorus-efficient legume pasture systems (UWA module)

Project team: Dr Richard Simpson[2] (leader; email: Richard.simpson@csiro.au), Assoc/Prof Megan Ryan[1], Mr Graeme Sandral[3], Dr Richard Culvenor[2], W/Prof Hans Lambers[1], Dr Phillip Nichols[4] , Mr Richard Hayes[3], Mr Daniel Kidd[1], Mr Robert Jeffery[1] (PhD student), W/Prof Martin Barbetti[1]

Collaborating organisations: [1]UWA; [2]CSIRO; [3]NSW-DPI; [4]DAFWA

Rock phosphate is a finite resource. As reserves diminish and prices of phosphorus (P) fertilisers rise, it will become necessary to develop more P-efficient farming systems.

This project focuses on Australia's major annual pasture legume, subterranean clover, and utilises the 'core collection', developed in a previous UWA/DAFWA ARC linkage project. The 97 accessions (plant collections) in the core represent 78% of the total diversity in the approximately 10,000 available accessions. The core collection therefore provides a quick means to screen for plant traits of interest.

The project is split among a number of institutions – primarily CSIRO Plant Industry in Canberra (project home), NSW-DPI and UWA.

The aims of the project are to: (i) prove that highly productive pasture systems can be operated with substantially less P-fertiliser by using plants with low 'critical' P requirements; (ii) quantify (benchmark) the critical P requirements of key pasture legume species relative to subterranean clover; (iii) identify the root morphology traits that have the largest influence on the critical P requirements of subterranean clover and alternative legume species; (iv) assess the variation in P-efficient root traits of subterranean clover and quantify the potential for breeding P-efficient clovers; (v) determine a clear decision point for breeding improved subterranean clovers, and/or evaluation of alternative legume species for P-efficient farming systems; and

(vi) develop better environmental credentials for grazing industries with respect to efficiency of fertiliser use, reduced over-applications, and less loss of P to the wider environment.

At UWA, substantial progress was made in 2013:

A large glasshouse screening experiment was conducted using 149 pasture genotypes - 97 subterranean clover lines (i.e. the core collection), 42 subterranean clover cultivars and 10 alternative pasture species. The objectives were to assess the extent to which the roots were colonised by arbuscular mycorrhizal fungi (AMF) and quantify carboxylate release from roots under low P conditions. The soil was sourced from the UWA Future Farm at Pingelly and had a low extractable P concentration (Colwell P = 6 mg/kg) with a high PBI (~550), and a low incidence of root disease. This enabled the soil to be used without steam pasteurisation to maximise the potential for colonisation by AMF. Data are being analysed.

In a second glasshouse experiment, PhD student Rob Jefferies, examined growth and P-uptake of six contrasting subterranean clover cultivars grown as micro-swards in the same field soil as used in the screening experiment, under six levels of P addition. Data are being analysed.

In 2014, further work will be undertaken on AMF to determine whether differences among accessions are consistent among soil types. Rob Jefferies will examine the effect of common root diseases on root traits associated with P-uptake.

This project is funded by Meat and Livestock Australia and Australian Wool Innovation.

Modelling/crop sequence strategies and tactics

National integration of crop sequence strategies and tactics

Project team: Assoc/Prof Michael Renton[1] (leader; michael.renton@uwa.edu.au), Roger Lawes[2]

Collaborating organisations: [1]UWA; [2]CSIRO; this is part of a national project integrating and interacting with regional projects in Queensland, New South Wales, South Australia, Victoria, WA and the ACT

The overall aim of the national project is to improve crop sequencing strategies and tactics across Australia. The focus is on using modelling tools – the Land Use Sequence Optimiser (LUSO) developed at UWA and CSIRO, the Agricultural Production Simulator (APSIM) developed by CSIRO, and statistical analysis, to help integrate and generalise experimental findings from a range of regional projects in different states.

The UWA contribution to this national project has involved updating parameters in the original LUSO model and helping to run analyses to understand the drivers of crop sequencing strategies and tactics. We are also building stochasticity into the LUSO modelling framework to allow seasonal and price variability to be accounted for, updating the parameters of this new stochastic version of the model with input from other project participants, and running analyses to help understand how uncertainty and variability affect crop sequencing strategies and tactics in Australian systems. UWA has also helped run training courses for other scientists in using the LUSO modelling frameworks.

This project is funded by CSIRO (ex GRDC).

Weed Seed Wizard – validation and improvement of a weed management decision support tool

Project team: Assoc/Prof Michael Renton[1] (leader; email: michael.renton@uwa.edu.au), Dr Sally Peltzer[2], Adj/Assoc/Prof Art Diggle[1,2], Mr Mike Airey[1], Mr George Wyatt[1]

Collaborating organisations: This is part of a national project including: [1]UWA; [2]DAFWA; DPI-NSW; DAFFQ

The overall aim of this project was to build a user-friendly software tool to help farmers and agronomists manage their weed seedbanks, accounting for the biology of different weed species, the management actions employed by farmers, and varying environmental conditions.

In 2013 the software tool was finalised. It is now a polished user-friendly interactive piece of software. The underlying model has been validated against field data and expertise of weed scientists across Australia for a range of conditions, species and management actions. A series of workshops were run across Australia (in WA, South Australia, New South Wales and Queensland) in 2012 and 2013 to show consultants and growers how to use the model, and to gain feedback to direct further model improvements. These suggestions have been integrated into the final version of the model which is now freely available from http://grains.agric.wa.gov.au/weed-seed-wizard

This project is funded by the GRDC.

Development of a web-based tool to interpret and quantify spray coverage obtained from commercial pesticide applications

Project team: Assoc/Prof Christian Nansen[1] (leader; email: christian.nansen@uwa.edu.au), Mr Rob Emery[2], Mr Nicolas Garel[3]

Collaborating organisations: [1]UWA; [2]DAFWA; [3]ngperceptive

Low and inconsistent pesticide spray coverage leads to poor pest control and is also believed to contribute to resistance development in pest populations of weeds, insects and mites. The project aims are to collect spray coverage data to develop a regression model, and use the model to develop a user-friendly decision tool with two main functionalities: (i) prediction of spray

coverage based on agronomic variables, weather conditions, and spray settings, and (ii) quantification and interpretation of spray coverage data.

During 2013 the team established a project website http://agspsrap31.agric.wa.gov.au/snapcard/ and developed a phone App which has become available on both Android App store and iphone App store.

The project leader presented project outcomes to regional grower groups (in Kojonup, Moorine Rock, Cranbrook, Dandaragan and Mingenew) and at national and international events, i.e. at the annual meeting of the Australian Entomological Society, Adelaide Sept 29-Oct 2, 2013, and at the annual meeting of the Entomological Society of America, Nov 10–13, Austin, Texas, USA.

In addition, the project received media publicity through an interview with the project leader on ABC Rural Radio (Aug 6, 2013), and through a number of regional newspaper articles. (Podcast and articles can be accessed via the project website http://agspsrap31.agric.wa.gov.au/snapcard/).

This project has been funded by COGGO.

Completing the smoke effect picture - systems development to reduce the negative effects of smoke on grapes and wine

Project team: Assoc/Prof Michael Renton[1] (leader of UWA component; email: michael.renton@uwa.edu.au), Mr Glynn Ward[2], Adj/Assoc/Prof Art Diggle[1,2], Dr Kristen Brodison[2], Mr Mike Airey[1]

Collaborating organisations: [1]UWA; [2]DAFWA

The overall aim of this DAFWA-led project was to develop a web-based tool that predicts the risk of grape crops suffering smoke taint at various times of the year across WA. Underlying the tool is a model of the phenology of grapevines that accounts for differences in weather conditions in different locations and years, and also differences between grape cultivars.

The UWA contribution to this project involved constructing the underlying model and the web-interface for the model, linking this with real-time weather data, helping to parameterise the model based on data collected by DAFWA and refining the model and interface based on ongoing feedback from research scientists, growers and land managers involved in fire planning. UWA has also helped run training in the use of the model. In 2013 the model and web interface were successfully finalised and launched.

This project was funded by the Grape and Wine Research and Development Corporation.

AHRI: Weed herbicide resistance research

Weed herbicide resistance research at UWA is primarily undertaken by the Australian Herbicide Resistance Initiative (AHRI), led by W/Prof Stephen Powles.

Much of AHRI's research builds from the large scale WA grainbelt-wide late-season field surveys in which mature seeds of the major weeds of crops are collected for subsequent resistance evaluation. Ryegrass, brome grass, barley grass, wild oats and wild radish are the significant species collected. Evaluation of the 466 collected populations was substantial from 2012 onwards and resistance screening was completed for wild radish, barley grass and brome grass.

A major AHRI research thrust in recent years has been research and demonstration of the importance of using full herbicide label rates and the adverse effects of herbicide rate-cutting. AHRI research has demonstrated rapid resistance evolution from cut-rates of several herbicides. Prominent in 2013 has been the extension of results from completed work with the new herbicide pyroxasulfone (Sakura®) as well as ongoing research with herbicides such as prosulfocarb (BoxerGold®) and trifluralin and pyrasulfatole (Velocity®). AHRI evidence is that cut rates of pyroxasulfone can lead to rapid resistance evolution and can also lead to cross resistance to prosulfocarb.

Understanding the mechanistic basis of herbicide resistance in Australian crop weeds is core research within AHRI. Defining the biochemical basis for resistance in Australian crop weeds to ACCase, ALS (Group A & B) herbicides as well as glyphosate continues to be a major research activity. Research extending over several years on target site-based resistance to ACCase and ALS herbicides in ryegrass, wild oats and wild radish (ALS only) was wrapped up in 2012. This research has and is being published in appropriate research journals and the information captured within the PERTH resistance model and disseminated to appropriate audiences. AHRI research is now turning to the previously intractable study of non target site resistance mechanisms in *ryegrass*, particularly the role of cytochrome P450 and glutathione transferase enzyme ability to metabolise herbicides to inactive molecules. The advent of cheap deep sequencing technology is allowing this technology to be applied to identifying the genes involved in non-target site resistance. This research commenced in 2012 and continues to be a major activity over the next few years for research with resistant ryegrass and wild oat biotypes.

DAFWA collaborative research continues with investigation into east-west planting versus north-south planting which showed that east-west orientation of crops reduced available light to the inter-row space during the hottest part of the day throughout the growing season. This meant that annual ryegrass seed production was reduced. DAFWA researchers have also established long-term monitoring sites to quantify the impact of harvest weed seed control techniques on weed seedbanks.

Applied research, demonstration and extension of harvest weed seed control measures was another focus area in 2013. AHRI research to quantify the benefits of using narrow windrows (plus burning), chaff carts, harvest baling or the Harrington Seed Destructor shows that the use of any one of these

techniques will increase crop profitability. The findings indicate that harvest weed seed control continues to be a very useful tool in diversified weed management and essential to sustainable crop weed control in Australia. In the WA grainbelt, harvest weed seed control techniques are routinely employed, but in eastern Australia adoption has been slow.

AHRI extension and communication activities in 2013 included farmer-dominated AHRI harvest weed seed control workshops, held in WA, Victoria, South Australia and New South Wales, and additions to the AHRI website (**www.ahri.uwa.edu.au**), including: (i) financial fact sheets for weed seed control measures; (ii) the upgraded Ryegrass Integrated Management (RIM) model which incorporates tutorial videos and reading material to enhance the RIM experience; and (iii) video recordings of presentations from the Global Herbicide Resistance conference held in Perth in February 2013 (see also page xx) and a full list of AHRI publications and media.

AHRI is funded by the GRDC.

3. Animal Production Systems Program

The Animal Production Systems Program is pursuing a vision of 'clean, green and ethical (CGE) systems for animal management':

Clean – minimise use of hormones, drugs and chemicals;

Green – minimise environmental footprint, especially emissions of greenhouse gas (GHG);

Ethical – maximise animal welfare.

The CGE concept underpins all of our degree programs, outreach activities and research. By its nature, much of the research into CGE management is interdisciplinary and is carried out within the context of the 'UWA Future Farm 2050' project. The research within this program has been focused on the role of, and need for, livestock in the landscape, their potential to provide versatility to mixed farming enterprises and minimising their environmental footprint. The strong partnership we have developed with CSIRO's Livestock Industry group at Floreat has enabled us to pursue interests in versatile livestock systems and livestock management in rangelands.

Methane-fighting forages

Exploiting subterranean clover genetic variation for methane mitigation and ruminant health challenges to the Australian livestock industries

Project team: Prof William Erskine[1](leader; email: william.erskine@uwa.edu.au), Dr Parwinder Kaur[1], Assoc/Prof Philip Vercoe[1], Asst/Prof Zoey Durmic[1], Prof Rudi Appels[2], Dr Phillip G Nichols[3], Dr Andrew N Thompson[3], Dr Clinton K Revell[3,1], Mr Richard Snowball[3], Dr-Sachiko Isobe[4]

Collaborating organisations: [1]UWA; [2]Murdoch University; [3]DAFWA; [4]Kazusa DNA Research Institute, Japan

Methane emitted from livestock is a major contributor to total atmospheric greenhouse gas (GHG) levels. In Australia, it accounts for 23% of the national GHG emissions, with half of the methane emission coming from enteric fermentation of feed in the rumen. Consequently, animal diet plays a significant role in enteric methane emissions. Although microbes in the rumen process fodder and provide energy for the animal in the form of volatile fatty acids, they also produce methane as a by-product, and this is a significant loss of dietary energy from animal feed. In general, ruminal methane output decreases with increased digestibility of the diet and is lower in animals fed grain-based diets than those fed fibrous diets. Methane emissions from animals grazing pasture legumes are often lower than from animals grazing pasture grasses, which is likely to be related to the lower plant fibre content and higher digestibility of legumes.

While various nutritive traits are used for plant selection and breeding, plant methanogenic

potential has rarely been examined in this context and the current project set out to fill this knowledge gap and identify environmentally friendly pasture species.

The multi-disciplinary project team conducted fermentation testing that showed significant variability in the (*in vitro)* rumen fermentation characteristics, including methanogenic potential (the ratio of methane in gas produced by rumen microbes) among 13 current and potential pasture species for Australia. Biserrula emerged as the lowest methane-producing species, producing 90% less methane than the highest methane-producing bladder clover. There were significant differences in fermentative traits, including methane production, among selected pasture species, indicating that the choice of fodder species may offer a way to reduce the impact on the environment from enteric fermentation.

The findings suggest that *in vitro* fermentation testing can be used as a screening tool to predict a plant's fermentation characteristics, and assist plant breeders in making better plant selection choices, in particular towards methane mitigation from livestock. Selection for mainstream pasture species that have a low methanogenic potential without compromising productivity could reduce methane emissions from the livestock industry without major changes in the current practices.

This research is funded by the Australian Government and the Australian Research Council (ARC) Linkage project in partnership with the Department of Agriculture and Food, Western Australia (DAFWA)

For further information see www.news.uwa.edu.au/201304045554awards-and-prizes/farmers-benefit-key-research-projects

Transitioning to resilient perennial pasture systems to abate greenhouse gases and sequester carbon

Project Team: Dr Julian Hill[4] (leader; email: upweyag@optusnet.com.au), Dr Dean Revell[2], Assoc/Prof Phil Vercoe[1], Dr Joe Jacobs[3]

Collaborating organisations: [1]UWA; [2]CSIRO; [3]Victoria DPI; [4]Ternes Agricultural Consulting

This project compares the greenhouse abatement potential (methane and nitrous oxide) and carbon sequestration potential of using perennial legumes and shrubs in a ryegrass base in relation to the 'business as usual' scenario of ryegrass only systems and establishes the basis of how producers can transition from their normal operating system to a low emissions system while improving productivity.

It is proposed that the integration of the correct choice of perennial shrubs with antimethanogenic properties integrated into ryegrass-lucerne systems will reduce emissions intensity (methane/kg meat) while increasing farm profit through increased growth rates and earlier slaughter. Normally sheep production in eastern Victoria is based on perennial ryegrass with supplementary grain feeding in the feed gap in summer and lucerne for hay production and grazing. These systems are generally located on low fertility, fragile soils (psamment [arenosol] or podsolic sands). The farming systems are not suited to integration of annual legume systems that have been demonstrated to abate methane emissions (e.g. biserrula) and are based on perennial pasture production.

To protect these soils from erosion, the use of integrated perennial shrub-legume farming systems is a feasible option to increase individual animal production as well as whole-farm performance. These systems have a low adoption rate in the district reflecting the lack of knowledge concerning the establishment of these systems rather than their 'lack of fit' to the location. Lucerne is frequently grown in the low-medium rainfall zone in eastern Victoria (<550 mm) for grazing or as a dual purpose system for hay production and grazing of re-growth. Lucerne, being a deep-rooted perennial forage crop, provides good forage supply throughout the growing season and summer feed without irrigation. This allows the finishing of prime lambs for the Christmas & Easter market, and maintenance of live weight and body condition of ewes over the summer. Recent evidence from the Reducing Emissions from Livestock Program (RELP; variability in fermentability and methane production in lucerne [*Medicago sativa*]) demonstrated

considerable potential in the crop to abate methane if the correct cultivars are selected. Furthermore research commissioned by DAFWA as identified that enteric methane emissions from sheep can be reduced using a range of Australian native shrubs (antimethanogenic bioactivity of Australian plants for grazing systems) and methane emission intensity can be reduced under field conditions (Drought-hardy, C-conscious grazing). These shrub systems are used in conjunction with perennial grasses and/or annual legumes in integrated farming systems and can increase whole-farm profit by up to 10 to 20% reflecting savings in pasture used during the summer and autumn and reduced supplementary feeding (MLA-FFI CRC funded program ENRICH).

This project is funded by the Australian Government.

Best choice shrub and inter-row species

Project team: Assoc/Prof Phil Vercoe[1] (leader; email: philip.vercoe@uwa.edu.au), Assist/Prof Zoey Durmic[1], Ms Kirrin Lund[1], Dr Dean Revell[2], Nathan Phillips[2]

Collaborating organisations: [1]UWA; [2]CSIRO

Grazing systems based on shrubs and pasture species that are selected for their nutritive value and antimethanogenic bioactivity offer a practical means to reduce methane emissions and emissions intensity from grazing livestock. Recent bioeconomic modelling has indicated shrub-based systems over a modest 10 to 20% of a mixed farm could increase whole-farm profit and/or reduce business risk.

The hypothesis in this project is that the shrub-based system with the most potential to reduce methane emissions and/or emissions intensity will be one that takes into account the bioactivity and productivity of both the shrub and inter-row components of the plants being grazed.

To test this hypothesis, the project team will establish five treatments: (i) conventional pasture (without shrubs and managed according to 'business as usual' [BAU]); (ii) conventional pasture (without shrubs) defer-grazed in autumn to maximise autumn biomass from the pasture; (iii) antimethanogenic pasture (without shrubs) defer-grazed in autumn to maximise autumn biomass from the pasture; (iv) anti-methanogenic pasture with productive shrubs grazed in autumn; and (v) antimethanogenic pasture with antimethanogenic shrubs grazed in autumn.

Livestock productivity and in-field methane emissions of animals will be measured during the autumn feed gap period over two successive years (2014 and 2015). Plant establishment and survival, *in vitro* fermentation characteristics, nutritive value and biomass will also be measured.

The team has selected, planted and monitored 10 shrub species, and selected and sown pasture species that will be planted in the inter-row in preparation for the first grazing event. In addition, the researchers have established and monitored separate plots of pasture adjacent to the main shrub plots to compare the effects of animal productivity and methane emissions with or without shrubs.

The survival and biomass of the shrubs, inter-row pasture and pasture plots have been determined and recorded and the experimental design for the grazing experiment has been completed and approved by the UWA animal ethics committee.

The team has planted a simple mix of biserrula and subterranean clover in the inter-row, as well as in adjacent plots to assess the impact of shrubs and inter-row pasture on

sheep productivity and emissions in autumn, the time of the year when a shrub system (i.e. forage shrubs with managed inter-row pasture) plays a critical role in filling the feed gap typical of Mediterranean and southern temperate climates.

The grazing study has been initiated with spring grazing of the BAU-plots; this treatment represents standard practice of spring grazing followed by autumn grazing with a reliance on supplementary feeding to meet animal requirements.

Two other pasture treatments have been included: conventional pasture and a fifty-fifty mixture of sub-clover-biserrula that will be 'defer-grazed' in autumn 2014 (i.e. not grazed in spring but allowed to accumulate biomass to provide dry forage in the following autumn). The sub-clover-biserrula mix represents an antimethanogenic pasture, and is also the chosen pasture mix for the inter-row between forage shrubs destined for grazing in autumn 2014.

Two shrub combined with inter-row treatments have been included that differ in the proportion of antimethanogenic shrub species. The first measurements of animal productivity and methane production will occur when all treatments are grazed in autumn 2014.

This research is funded by the Australian Government and Meat and Livestock Australia (MLA)

Enrich - demonstrating resilient, healthy and profitable livestock systems with Australian perennial shrubs

Project team: Dr Jason Emms[3] (leader; email: jason.emms@sa.gov.au), Dr Dean Revell[2], Dr Hayley Norman[2], Assist/Prof Zoey Durmic[1], Assoc/Prof Phil Vercoe[1]

Collaborating organisations: [1]UWA; [2]CSIRO; [3]SARDI

Now in its third phase, the ENRICH research project commenced in 2004 to explore the potential of Australian native shrub species for grazing systems. Researchers from across Australia have been assessing the traits of a large number of shrub species, and have been testing different grazing management approaches with a particular focus on grazing diverse mixtures of plant species.

It is proposed that grazing of perennial forage shrubs can increase profitability by up to 20%. This project will lead to new options for producers to increase the resilience of livestock enterprises by incorporating a mix of Australian shrub species into the feedbase.

The work entails quantification of livestock performance in diverse shrub-based systems, facilitating Enrich species commercialisation and packaging information for next users.

The current stage of the project aims to: (i) quantify gains in animal live weight and condition when grazing diverse shrub-based grazing systems over periods otherwise experiencing feed shortage, and measure indicators of rumen function and health; (ii) work with plant nurseries to ensure at least six 'Enrich forage shrubs' are propagated in quantities to help meet the demand of early adopters; (iii) convert existing 'researcher databases' on characteristics and traits of Enrich shrub species to an integrated and more user-friendly database as a legacy of Enrich phases 1 to 3; and (iv) improve the level of interaction between Enrich researchers and regional producer

groups involved in forage shrub activities

Field trials during 2013 included a shrub site at UWA's Future Farm (see also page xx).

The groundbreaking research and its contribution to the long-term sustainability of agriculture and natural resource management, earned the team the '2013 Caring for our Country Landcare Eureka Prize for Sustainable Agriculture'. (See also page 5, IOA News, December 2013: www.ioa.uwa.edu.au/__data/assets/pdf_file/0019/2461501110666_IOA-newsletter-Dec-2013-WEB.pdf)

For further information and key findings of the ENRICH program visit see www.futurefarmonline.com.au/knowledge-base-1perennial-fodder-shrubs-key-findings-from-enrich

This research is funded by the FFI-CRC.

Nitrate and sulphate rich shrubs to reduce methane and increase productivity

Project Team: Dr Hayley Norman[2] (leader; email: hayley.norman@csiro.au); Prof Ed Barrett-Lennard[1], Assoc/Prof John Milton[1], Assoc/Prof Phil Vercoe[1]

Collaborating organisations: [1]UWA; [2]CSIRO

Feeding nitrate and sulphate to ruminants to reduce methane is a proven abatement strategy. In extensive systems, provision of these compounds in supplements can be problematic due to issues with individuals selecting an appropriate dose and associated risk of toxicity. A number of drought-hardy Australian native shrub species accumulate significant concentrations of nitrate and sulphate. Several of these species are planted by farmers in the low to medium mixed crop/livestock zone to provide forage for livestock.

This project aims to quantify the potential of these shrubs to offer a safe, profitable, environmentally positive and 'natural' means of reducing methane emissions from sheep grazing cereal stubbles by incorporating these shrubs into grazing systems in the mixed crop/livestock zone.

Based on previous research the team hypothesises that a 10 to 15% reduction in methane per day is possible. Additionally, these shrubs offer an opportunity to increase productivity of wool and meat by providing nutrients that are deficient in stubble grazing systems.

The project addresses research questions that are critical for the development of a Carbon Farming Initiative (CFI) methodology. Over three years the researchers will use a combination of on-farm benchmarking trials, field experiments and in vitro fermentation studies to quantify the capacity of these shrubs to reduce methane and increase productivity of sheep during summer and autumn. In the final year, respiration chambers will be used to quantify the impact of the shrubs, when fed at levels that are representative of on-farm voluntary intake. The data will be used to develop a multivariate risk analysis tool which explores probabilities of methane reduction, hazards, synergies and trade-offs within the grazing systems.

Objectives include: (i) to quantify the variation in nitrate and sulphate accumulation within and between four shrub species and investigate the impact of the shrubs' growth environment on nitrate and sulphate levels; (ii) to determine the variation in 'dose' of nitrate and sulphate that is voluntarily ingested by sheep grazing the shrubs (this will inform for laboratory experiments, address issues concerning the risk of toxicity and provide productivity data to support extension of the potential methodology); (iii) to quantify the *in vitro* methane reduction associated with addition of shrub biomass at levels that are voluntarily consumed by sheep; (iv) to measure the *in vivo* methane and production

benefits arising from inclusion of shrub biomass to a cereal stubble-based diet; and (v) to develop a multivariate risk assessment tool that draws together the data and explores risks, synergies and trade-offs associated with the use of these shrubs in cereal grazing systems.

This research is supported by the Australian Government and Australian Wool Innovation Limited.

Efficient livestock with low emissions (ELLE)

Project team: Assoc/Prof Phil Vercoe[1] (leader; email: philip.vercoe@uwa.edu.au), Assist/Prof Zoey Durmic[1], Dr Joy Vadhanabhuti[1], Dr Dean Revell[2], Dr Hayley Norman[2], Ms Elizabeth Hulm[2], Mr Paul Young[2], Dr Alan Humphries[3], Mr Steve Hughes[3]

Collaborating organisations: [1]UWA; [2]CSIRO; SARDI; MLA; CSIRO

The potential of the Australian temperate feedbase to reduce methane production (either per unit of feed intake or per unit of animal production) has not been thoroughly investigated.

There are significant differences across annual and perennial species of grasses and legumes and this project aims to benchmark the variation between and within temperate, herbaceous forage species for antimethanogenic effects and identify variability in the provision of digestible nutrients at times of the year where scarcity of nutrients typically limits animal production.

This phase of the project uses *in vitro* fermentation, wet chemistry and Near-Infrared-Reflectance (NIR) to examine 40 commercial, 'pipeline' and/or experimental species of annual and perennial grasses and legumes for their agronomic value, production value and nutritive value and for their fermentative characteristics, with the aim to help: (i) identify species with antimethanogenic properties; and (ii) identify species/genotypes with potential to reduce methane emissions intensity via improved nutritional traits including the temporal pattern of digestibility.

An additional five species have been included because they have been the subject of student projects associated with the ELLE.

The team established a total of 450 plots (1.2 m x 8 m), comprising 150 accessions from 109 species, of which 40 were chosen for ELLE. They scanned over 2500 samples using NIR and linked the scans back to laboratory analyses. These have been used to develop an initial set of prediction equations that are very broad and include grasses, herbs and legumes as well as both annuals and perennials. The predictions have subsequently been tested with samples that were not used to develop the predictions and there is a high correlation between

the prediction equations and the laboratory assessment.

Biserrula clearly stood out as an antimethanogenic pasture species that needs to be examined in more detail.

The results of this work will enable researchers to assess whether NIR spectrometry can be used to provide rapid and inexpensive predictions of methanogenic properties of pasture species, which would add a valuable tool to assist livestock producers in making good decisions.

This project is supported by the Australian Government and the MLA.

The mechanism of antimethanogenic bioactivity of plants in the rumen

Project Team: Assoc/Prof Phil Vercoe[1] (leader; email: philip.vercoe@uwa.edu.au); Assist/Prof Zoey Durmic[1], Dr Joy Vadhanabhuti[1], Dr Chris McSweeney[2]

Collaborating organisations: [1]UWA; [2]CSIRO

Plants contain secondary compounds that have antimicrobial properties that have the potential to reduce methane emissions from ruminants.

This project aims to extract and fractionate these plant secondary compounds to identify specific compounds that reduce methane emissions and understand the mechanism behind their action.

Evidence has shown that *Eremophila glabra, Biserrula pelecinus*, *Kennedia prorepens, Calliandra calothyrsus, Leucaena leucocephala*, *Dorynicium hirsutum* and *Cichorium intybus* contain plant secondary compounds that are bioactive in the rumen and have the potential to reduce methane. There is also evidence that some essential oils (e.g. *Eucalyptus occidentalis*, *Melaleuca ericifolia, Melaleuca teretifolia and Santalum spicatum)* may also reduce methane production in the rumen.

The project team has started a step-wise fractionation and purification process to identify the simplest 'mix' of compounds or, preferably, single compound that maintains the antimethanogenic effects observed in the plant.

The team also tested the essential oils and determined that tannins could be responsible for the antimethanogenic effect in four plants (*C. calothyrsus, D. hirstum, K. prorepens* and *L. leucocephala)* and some affected both methane production and total gas production. *L. leucocephala* and *D. hirstum* were the most active and were chosen for detailed fractionation studies.

The project team has made significant progress towards the isolation and identification of plant secondary compounds responsible for antimethanogenic effects for two candidate plant species: *E. glabra* and *B. pelecinus*. *E. glabra* has undergone four rounds of extraction/fractionation, resulting in: (i) confirmation that the compounds responsible for the antimethanogenic bioactivity are extractable; (ii) fractionation to a relatively simple mix of compounds that have potent antimethanogenic activity; and (iii) isolation and identification of one purified compound. *B. pelecinus* has undergone crude extraction and two fractionation steps.

The project team also determined that: (i) the antimethanogenic activity in *B. pelecinus* is not related to tannins; and (ii) the antimethanogenic effects are linked to extractable compounds.

Five other plants were selected for further testing, based on their antimethanogenic potential in previous or current projects: These plants were tested in a tannin binding assay to confirm or rule out the role of tannins in their antimethanogenic effects. Tannins were confirmed as being responsible for the antimethanogenic effects in four of these plants and further work is being conducted to determine the type of tannins in these plants and confirm their effect as purified compounds. Nine essential oils

from Australian plants were tested in a dose-response experiment. *Melaluca erecifolia* was selected for further testing, based on the size of its antimethanogenic effects and plant secondary compound profile.

The project results indicate that there are a number of different plant secondary compounds that are antimethanogenic *in vitro* and some do this without affecting overall fermentation. Identifying more than one type of compound is exciting because it increases the opportunities to achieve a persistent effect on reducing methane.

This project is funded by the Australian Government and MLA.

Host control of methane emissions from sheep

Project team: Assoc/Prof Phil Vercoe[1] (leader; email: philip.vercoe@uwa.edu.au), Dr Hutton Oddy[2], Prof Roger Hegarty[3], Prof Stephen Moore[4], Dr Brian Dalrymple[5], Dr Stuart Denman [5], Mr John McEwan[6], Prof Noelle Cockett[7], Prof John Wallace[8]

Collaborating organisations: [1]UWA; [2]NSW-DPI; [3]University of New England; [4]University of Queensland; [5]CSIRO; [6]AgResearch, New Zealand; [7]Utah State University, USA; [8]University of Aberdeen, UK

Ruminant methane emissions are a product of microbial fermentation. The host animal influences microbial populations by feed choice and through morphological/functional variation in its fore-stomachs.

There is evidence that these are heritable through the host. This

project aims to generate new insights into the fundamental biology of variation in rumen function and methane emissions in sheep, by measuring host phenotype (methane emissions, rumen size and morphology, digesta flow rate) in detail and linking this to host genotype (imputed genome sequence), transcriptome (RNA sequence, species identification) of GI tract, and the metagenome of the rumen microbial population.

Outcomes from this work will underpin discovery of new tools to breed low methane emitting sheep, permitting the Australian sheep industry to participate in the Carbon Farming Initiatives (CFI) program. The project will be conducted by partners in Australia, New Zealand and the United States.

In 2013, the team undertook a review of the literature of protein and gene expression in the digestive tract of ruminants. A survey of annotated genes from the gastrointestinal tract has been completed and a research database established. A previously unannotated gene encoding a major structural protein has been identified and annotated.

In addition, novel members of a family of genes encoding small cross-linking proteins and highly expressed in the rumen has been characterised in detail.

In Australia, 96 ewes from four sires with known methane production under a range of different testing procedures have been measured for methane production at 12 and 18 months of age. At 12 months of age a mixture of lucerne and oaten chaff was provided at both ad-lib and maintenance feed intake. Measurements of methane production were made in field chambers for one hour and in open circuit respiration chambers for 22 hours. The ewes were CT-scanned while at both levels of feed intake.

Samples of host DNA, rumen fluid and faeces have been collected and are available for subsequent studies.

Samples of digestive tract associated tissues have been collected from Hi and Lo methane divergent sheep in New Zealand, with measurements of methane phenotypes (respiration chamber and PAC chamber) and a wide variety of pre- and post-slaughter measurements. Samples of rumen contents collected from different locations have been stored for future use within this project, including RNA sequence experiments from: parotid gland, rumen, reticulum, omasum, abomasum (gastric region), small intestine, large intestine (near caecum outlet) and caecum.

This project is funded by the Australian Government and MLA.

International coordination of the Ruminant Pangenome Project

Project team: Assoc/Prof Phil Vercoe[1] (leader; email: philip.vercoe@uwa.edu.au); Dr Hutton Oddy[2], Dr Chris McSweeney[3], Prof Andrew Thompson[4], Prof Roger Hegarty[5], Dr Julian Hill[6]

Collaborating organisations: [1]UWA; [2]NSW-DPI; [3]CSIRO; [4]Murdoch University; [5]University of New England; [6]Ternes Agriculture Company; EU Framework 7 Ruminomics project; Utah State University, USA; AgResearch, New Zealand

The Ruminant Pangenome Project (RPP) has been developed to coordinate an Australian and international research network under a collaborative program that will build on current research - undertaken through the RELP and the National Livestock Methane Program - and

deliver effective and practical strategies for reducing enteric livestock methane emissions while maintaining productivity.

The RPP comprises five projects: four research projects - with an emphasis on the genetic control of methane emissions – and (this) one project to coordinate the research projects. This will include the integration of research and development activities across all research providers and the synthesis of research findings. The RPP will provide high quality data and new knowledge that will be used to deliver a comprehensive understanding of animal genotype x rumen environment x management interactions that drive methane emissions from livestock. This knowledge will shape future / potential strategies to reduce emissions and will underpin the development of methodologies under CFI.

RPP's specific research objectives are to develop a better understanding about: (i) host control of methane emissions from sheep; (ii) genetics to reduce methane emissions from Australian sheep; (iii) the trade-offs between feed use efficiency, methane and reproduction in sheep; and (iv) maximising energy yielding rumen pathways in response to methane inhibition.

In 2013 RPP has demonstrated close international cooperation between Australian researchers and those from New Zealand and elsewhere: extensive scientific exchanges have occurred in relation to the Global Research Alliance project and in relation to samples and biological materials taken for analysis in Australia.

This project is funded by the Australian Government and Meat and the MLA.

Measuring and managing methane emissions from livestock: from laboratory to landscape

Project team: Prof Deli Chen[2] (leader; email: delichen@unimelb.edu.au), Prof Roger Hegarty[3], Dr Frances Phillips[4], Prof Kourosh Kalantar[5], Dr Tom Flesch[6], Assoc/Prof Phil Vercoe[1]

Collaborating organisations: [1]UWA; [2]University of Melbourne; [3]University of New England; [4]University of Wollongong; [5]RMIT; [6]University of Alberta, Canada; CSIRO

Methane emissions from the livestock sector account for more than 65% of agricultural emissions or 10.7% of Australia's national greenhouse account. The vast majority (94%) of methane emissions from the livestock sector come from microbial fermentation of livestock feeds with the balance comprising methane emissions from manure management systems.

Australia's northern rangelands generate approximately 45% of northern Australia's estimated total value of agricultural production (ABARE 2007) through its beef production and extensive grazing systems. It is estimated that the northern beef herd is responsible for 6% of Australia's greenhouse gas emissions.

This project aims to assist the northern Australian livestock industries in achieving a reduction in its methane emissions, through: (i) considering the challenges and constraints to measurement of emissions; (ii) developing effective and efficient mitigation and abatement strategies appropriate to northern rangeland conditions; (iii) fostering the adoption of those policies by the northern livestock Industries; (iv) validation and further development of existing measurement technologies to quantify methane fluxes under field conditions ('the challenge of measurement'); and (v) reliable quantification of net methane emissions from the northern beef industry to enhance the development of effective and efficient mitigation and abatement strategies that inform the methodologies of the national inventory.

This project is an important initiative under the CSIRO Sustainable Agriculture flagship which aims to secure Australian agriculture and forest industries by increasing productivity by 50% and reducing carbon emissions intensity by at least 50% between now and 2030.

For further information see www.csiro.au/Organisation-Structure/Flagships/Sustainable-Agriculture-Flagship/Sustainable-Agriculture-Flagship-Cluster-Specification-livestock-methane.aspx

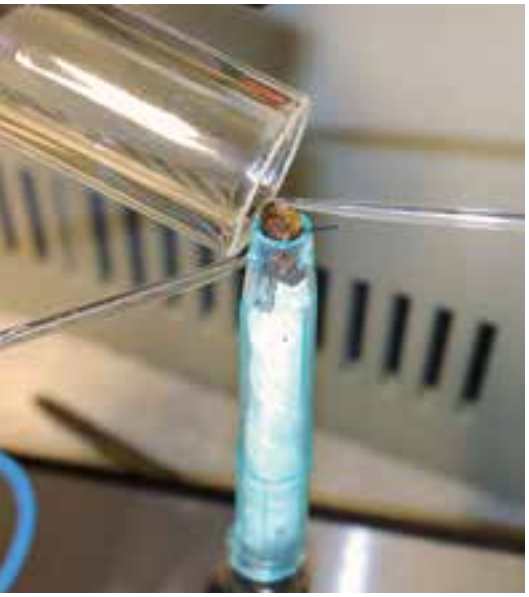
This project is the CSIRO Flagship Collaboration Fund through the University of Melbourne as the lead organisation.

Genetics of breeding for breech strike resistance

Project Team: Mr Joseph Steer[1] (leader; email: 20252861@student.uwa.edu.au), Assoc/Prof Phil Vercoe[1], Dr Johan Greeff [2], Adj/Assoc/Prof David Cook[1], Assoc/Prof Gavin Flematti[1], Res/Prof Shimin Liu[1], Dr Tony Schlink[2]

Collaborating organisations: [1]UWA; [2]DAFWA; CSIRO

Global wool production and specifically Australian wool production is hindered by diseases and the changing nature of consumerism. Breech flystrike or *cutaneous myiasis* is one of the major diseases affecting wool



sheep in Australia and results in a substantial annual loss to the Australian sheep industry. Breech strike is currently controlled through management such as shearing and crutching sheep, and application of chemical treatment. These methods are costly and alternative sustainable methods needs to be found to reduce the incidence of breech strike. One method is to increase the host resistance of sheep against flystrike by using selective breeding. Previous research has shown that skin wrinkle located in the breech area (surrounding the anus) is a major predisposing factor in flystrike. Approximately 90% of flystrike occurs within the breech and has since 1940 been controlled by mulesing. Mulesing is a surgical procedure that removes skin wrinkle from the breech. While it remains the most efficient control for flystrike and cannot be matched by alternative controls (including the use of chemicals, more effective management or through genetics), it has come under increased scrutiny during the last decade, as public awareness of animal production systems has increased.

This triggered a research focus into the development of alternative flystrike control methods that are clean, green and ethical. The favoured alternative is selective breeding and Australian Wool Innovations Ltd (AWI) is funding a large genetic investigation to identify effective indicator traits that could be used to select indirectly for breech strike resistance.

Selective breeding for flystrike resistance

Natural variation in sheep allows for selective breeding of desirable traits. Observable traits (breech wrinkle, breech cover, dags, urine stain, and wool colour) explain only up to 22.4% of the variation in breech strike. The variation in flystrike resistance/susceptibility that is not explained by the observable traits could be explained by traits of the skin, wool, and faeces that are less easily observed. The first step to help explain the variation in flystrike resistance is to understand what is attracting flies to sheep.

Characterisation of chemical odours that attract Lucilia cuprina

Lucilia cuprina flies orientate themselves towards a host using sensory cues such as olfaction of chemical odours. While semiochemicals, or natural chemicals released by an organism that attract or repel *Lucilia cuprina* to fleece are unknown and require characterisation, multiple chemicals have been found that repel or are toxic to *Lucilia cuprina* flies. The repellent and toxic chemicals provide an indication of the structure of semiochemicals that may be providing sheep with flystrike resistance.

Semiochemicals that repel or kill flies can then be synthesised or extracted as natural deterrents or be selectively bred within sheep.

The aim in this project is to characterise the organic compounds released from the wool of merino sheep from the AWI breech strike flocks hosted in WA by DAFWA and in Armidale, NSW, by CSIRO. These flocks have been evaluated for breechstrike resistance and lines of resistant and susceptible sheep have been established at both sites.

Wool sourced from the breech area on animals from these resource flocks will be characterised for their ability to attract, repel and/or kill the flies *Lucilia cuprina* that cause flystrike. The aim is to identify those semiochemicals that may play a significant role in resistance/susceptibility to breech strike and to estimate the heritability of the bioactive semiochemicals to determine whether it would be feasible to breed for flystrike resistance.

For further information see http://www.ioa.uwa.edu.au/__data/assets/pdf_file/0019/2461501110666_IOA-newsletter-Dec-2013-WEB.pdf

This project is funded by AWI.

Visit to Food Animal Initiative (FAI), Oxford, UK

In late 2013, Bill Biggs (UWA Senate), Christine Shervington and Graeme Martin were welcomed at the FAI Farm at Wytham, Oxford, by Mike Gooding, the Managing Director of FAI. Mike explained the history and current status of FAI, and demonstrated some of the primary projects, with a focus on pig production, using the iconic Gloucester Old Spot breed. Two major aspects were described: (i) on-floor feeding within group pens that provides sufficient environmental enrichment to avoid the need for tail-docking; and (ii) a farrowing system that avoids the need for farrowing crates yet improves piglet survival.

During his sabbatical year at Oxford, Graeme is working with FAI to explore opportunities for collaboration with UWA Future Farm, especially in the area of direct linkages to markets via supermarket and fast-food chains. This interaction follows on from the visit to UWA, and participation in the UWA Future Farm Open Day in 2013, by Professor Marian Dawkins, a world leader in farm animal welfare science, who was awarded an Order of the British Empire (OBE) in the Queen's New Year Honours List for her contributions.

UWA and Rothamsted Research unite to swat flystrike in sheep

In late 2013, Graeme Martin and Adjunct Professor Johan Greeff (DAFWA) visited the famous Rothamsted Research laboratories, just north of London, to meet Professor Mike Birkett, a world authority on the physiology of the sense of smell of insects. The focus of this meeting was to link Professor Greeff's work on genetic selection for resistance to flystrike in merino sheep, a probable alternative to the controversial practice of mulesing, with Rothamsted's technical capabilities. This topic is the subject of the thesis work of UWA PhD student Joseph Steer (see IoA Newsletter December 2013, page 13). The plan is for Joe to go Rothamsted to use their systems for studying insect antennae (where the sense of smell is located in insects). Electrodes are placed at both ends of the antenna to detect changes in the electrical activity of the nerve cells as they respond to an odour molecule. By observing this response simultaneously with the read-out of a gas chromatograph, it should be possible to guess the chemical identity of the molecules that attract flies to sheep skin. This avenue of investigation could explain the mechanism underlying genetic variation in the resistance of sheep to blowfly strike, and improve the power of industry breeding programs.

4. Rural Economy, Policy and Development Program

The Rural Economy, Policy and Development Program aims to enhance the sustainability of rural industries, communities and regions. This is achieved through innovative education and research with a focus on: improving rural productivity and prosperity; addressing their environmental challenges; contributing to their broader economic and social development; and enhancing rural policy and planning processes.

Here we highlight some of the ongoing research projects in this program. We also highlight some of the new initiatives towards developing collaborative research partnership with African universities and scientists with the aim of helping Africa improve its agricultural productivity and food security.

The value of carbon and biodiversity services provided by native shrubs on farmland

Project Team: Assist/Prof Marit Kragt[1] (leader; email: marit.kragt@uwa.edu.au), Dr Kerrie Wilson[2], Assoc/Prof Yvonne Buckley [2]

Collaborating organisations: [1]UWA; [2]UQ; ARC Centre of Excellence for Environmental Decisions

Highlight of the project was a three-day workshop organised at UWA in November 2013, which brought together researchers from across Australia who are working on carbon-biodiversity issues. The two days involved brief research presentations and stimulating discussions between the participants (ecologists, economists, agricultural scientists, and representatives from Federal government and NGOs). Research issues that were identified for collaborative research included: the spatial mapping of co-benefits; appropriate mechanisms to incentivise biodiverse carbon farming; an examination of what we have learned from the various multi-species planting experiments across Australia; drivers and

barriers of participating in carbon farming; the willingness to pay for the multiple benefits of carbon farming practices; defining metrics for measuring biodiversity and carbon values; avoided deforestation as a method to meet national carbon sequestration goals; and the potential role of insurance providers as important players in the voluntary carbon offset market.

Responding to these themes is challenging because they require interdisciplinary collaboration. Workshops like these are helpful to increase mutual understanding, and can help to develop a shared language required to progress interdisciplinary research. The researchers formed a number of multi-disciplinary teams that will each work on a theme. Plans were drawn up on how each topic would be tackled over the coming months. A follow-up workshop in Brisbane took place in March 2014 to further exchange ideas and enable the various projects to be written up.

This project is funded through a UWA-University of Queensland Bilateral Collaboration Award.

Achieving least cost greenhouse gas abatement opportunities in Australian grains farms

Project Team: Dr Peter Thornburn[2] (leader; email: Peter.Thorburn@csiro.au), Assist/Prof Marit Kragt[1]

Collaborating organisations: [1]UWA; [2]CSIRO and several grower groups

This three-year joint project between the CSIRO and UWA commenced mid 2013. The project aims to identify what carbon farming practices can be profitable to grain farmers in Australia. This will involve biophysical modelling of carbon sequestration and whole-farm economic modelling to assess the farm-financial impacts of adopting carbon farming practices.

A steering committee was formed with members from DAFFWA, QLD-DAFF, GRDC, and CSIRO.

The researchers identified a number of grower groups with whom they will collaborate in this project. In Queensland, they will work with the Brigalow Group and the Chinchilla Landcare Group; in South Australia-Victoria, they will work with the Ag Excellence Alliance.

In WA, Assistant Professor Marit Kragt visited several grower groups to discuss project opportunities. The Liebe Group and the WA No-Till Farmers Association undertook to contribute to the project through working groups and feedback on the modelling.

This project is funded by the Australian Government.

Farmers' willingness to adopt carbon farming practices

Project team: Assist/Prof Marit Kragt[1] (leader; email: marit.kragt@uwa.edu.au), Research Assist/Prof Fiona Gibson[2], Ms Nikki Dumbrel[1]

Collaborating organisations: [1]UWA (SARE); [2]UWA (CEEP)

A survey was conducted among cropping-only and mixed cropping-livestock farmers in the New South Wales and WA grain belts that aimed to elicit farmers' willingness to adopt carbon farming practices. This study was the first to use a technique called 'Best-Worst Scaling' to assess farmers' preferences for different carbon farming practices.

The survey was distributed via grower groups in WA and New South Wales in August 2013. The carbon farming practices that farmers are most likely to adopt were retaining stubble after crop harvest and no-till cropping practices. The practices that farmers were least likely to adopt were applying biochar and planting trees for harvest.

Conditional logit models were used to model the impact of socio-demographic factors on choices. Farmers who perceive they are experiencing climate change have a greater preference to apply biochar, establish areas of native vegetation, or plant trees

as mitigation options, compared to farmers who do not believe they are experiencing climate change. Farmers who believe humans are at least partially contributing to climate change are more likely to apply mulch, plant tree belts, and adopt no-till cropping practices, relative to those who do not believe climate change is happening or caused by humans. The research outcomes have implications for Australia's greenhouse gas abatement policies, if they aim to promote practices that will actually be adopted by farmers.

The study was presented at the Australian Agricultural and Resource Economics Society (AARES) conference in Port Macquarie in February 2014. A paper based on this project is currently in preparation for submission to the Journal of Agricultural Economics.

This project is funded through a UWA Research Development Award.

Wheat price behaviour and volatility in Western Australia's cash market

Project team: Assist/Prof Amin Mugera[1] (leader; email: amin.mugera@uwa.edu.au), Prof Ben White[1], Mr Reece Curwen[2]

Collaborating organisations: [1]UWA; [2]MarketAg

Time series data for WA wheat prices starting from 20 May 2003 to 14 September 2010 were analysed to investigate whether deregulation of the Australian wheat export market induced a structural change in the price data generation process. The unit root properties of Western Australian wheat price series are analysed by testing for the possibility of single and double structural breaks. The deregulation of the wheat industry in Australia coincided with a period of unusually high volatility in the world wheat prices. Some growers blamed the price volatility on the move to deregulate the industry. Given this inference, the question arises: has there been a permanent change in the wheat price in response to the deregulation policy?

A paper based on this project has been accepted for publication in the Journal of International Food and Agribusiness Marketing.

This project is funded through a UWA Research Development Award.

The environmental impact of Gamba grass invasion in the Northern Territory and Queensland

Project team: Assoc/Prof Morteza Chalak[1,2] (email: morteza.chalak@uwa.edu.au)

Collaborating organisations: [1]UWA (SARE); [2]UWA (CEEP)

Gamba grass was introduced into Australia as an improved pasture plant and competes strongly with native pasture. Gamba

grass infestations have spread extensively across Queensland and the Northern Territory where it has significantly altered soil-nutrient cycles, water cycles and fire regimes. Gamba grass reduces biodiversity by 50% and its high biomass can fuel intense bushfires, damaging ecosystems and threatening the safety of people and property.

Associate Professor Chalak visited researchers at the Resources for the Future (RFF) in Washington DC, USA, looking at strategies to improve resource management, specifically in relation to the control of invasive species. RFF is a non-profit organisation in USA that conducts independent research in environmental, energy, and natural resource issues.

Chalak collaborates with RFF Professor Becky Epanchin-Niell on analysing a spatially explicit dynamic process of controlling invasive species in a stochastic setting, including the most cost-effective ways to control a spreading weed. Chalak also met with other researchers at RFF including Senior Fellow Alan Krupnick, Director of RFF's Centre for Energy Economics and Policy, whose work on non-market valuation of ecosystem services is very relevant to this project.

Chalak also visited the University of Alberta to collaborate with Dr Vic Adamowicz on the economic impact of Gamba grass invasion in Australia. In February 2013, he gave a presentation on 'Climate Change, Threshold and Uncertainty' at the 57th AARES Conference in Sydney (5-8 Feb).

This project is funded through a UWA Research Development Award.

Evaluating the management of agri-environmental assets in Tuscany

Project team: W/Prof David Pannell[1] (leader; email: david.pannell@uwa.edu.au), Dr Gaio Cesare Pacini[2], Mr Leonardo Gabellini[2]; Dr Concetta Vazzana[2], Dr Anna M. Roberts[3], Mr Geoff Park[3]

Collaborating organisations: [1]UWA; [2]University of Florence, Italy; [3]FFI-CRC

In the European Union (EU), as in many parts of the world, there is increasing pressure to demonstrate that environmental projects achieve expected outcomes and are cost-effective. This project involves a trial application of an environmental investment framework, the Investment Framework for Environmental Resource (INFFER).

The framework, based on benefit: cost analysis principles, was applied to agro-environmental assets in the Mugello and Valdisieve areas of northern Tuscany, Italy – regions with a variety of agricultural systems, including crops, livestock, fruit and vegetables. Farmers, environmental and institutional representatives and technical experts took part in the process of identifying agro-environmental assets in the region. A total of 26 assets were identified, including grasslands, agricultural lands, ecological corridors and rivers. Of these, two (the last remaining population of Cistus laurifolius within the natural protected area of local interest [Area Naturale Protetta di Interesse Locale, ANPIL] of Santa Brigida, and the Sant' Antonio forest were selected as having reasonable prospects of progressing to cost-effective projects (benefit:cost ratio>1).

Detailed projects were developed for both assets and found to be cost-effective based on available information. While the mindset of being clear about identifying and valuing natural assets was a new concept to participants, overall the process worked well. The factors considered in calculating a cost:benefit ratio, including technical feasibility, adoption and compliance factors, socio-political risks, costs and the likelihood of obtaining long-term funding to maintain project benefits, were all relevant in Tuscany and required the knowledge of local experts.

Overall, INFFER appears relevant and useful in an EU context as a tool for increasing the benefits from agri-environmental programs, by helping program managers to select superior projects.

This project is funded by CEED and the CGIAR Independent Science and Partnership Council (ISPC).

Adapting dryland agriculture to climate change: Farming implications and research and development needs in Western Australia project

Project Team: W/Prof David Pannell[1] (leader; email: david.pannell@uwa.edu.au), Assoc/Prof Senthold Asseng[2]

Collaborating organisations: [1]UWA; [2]CSIRO

The WA grainbelt has experienced more rainfall decline than any other wheat-cropping region in Australia. Future climate change scenarios suggest that the Western Australian grainbelt is likely to see greater future reductions in rainfall than other regions, together with a further increase in temperatures.

While these changes appear adverse for water-limited rain-fed agriculture, a close analysis of the changes and their impacts, undertaken in this project, has revealed a more complex story. Twentieth century changes in rainfall, temperature and atmospheric CO_2 concentration have had little or no overall impact on wheat yields. Changes in agricultural technology and farming systems have had much larger impacts. Contrary to some claims, there is no scientific or economic justification for any immediate actions by farmers to adapt to long-term climate change in the Western Australian wheatbelt, beyond normal responses to short-term variations in weather. Rather than promoting current change, the most important policy response is research and development to enable farmers to facilitate future adaptation to climate change.

This project is funded by CEED and the CGIAR Independent Science and Partnership Council (ISPC)

Cost-effective strategies to mitigate multiple pollutants in an agricultural catchment in north-central Victoria

Project team: W/Prof David Pannell[1] (leader; email: david.pannell@uwa.edu.au), Dr Graeme Doole[2], Dr Olga Vigiak[3], Dr Anna Roberts[3]

Collaborating organisations: [1]UWA; [2]CEED; [3]DPI VIC; [4]University of Waikato, Hamilton, New Zealand

This study identifies strategies to reduce phosphorus and sediment yields from agricultural lands into waterways for two Australian agricultural catchments. It also provides insight into the cost-effective management of pollutants of watercourses in Australia.

The research highlights a strong degree of complementarity between the two pollutants (phosphorus and sediment) based on the adsorption of phosphorus to sediment that augments the value of gully and streambank management for mitigation. However, the relationship between the two pollutants was found to be asymmetric: A 30% reduction in phosphorus yield (achieved in the cheapest way) achieves a 75% reduction in sediment yield in one catchment, while a 30% reduction in sediment yield (achieved in the cheapest way) achieves only a 12% reduction in phosphorus yield.

Sediment abatement costs are low given the efficiency of gully and streambank management. A

30% phosphorus reduction lowers agricultural profit by 3 to 7 per cent, while a 30% sediment reduction lowers profit by around 1%.

Overall, this research demonstrates the need to determine whether one pollutant is more important than another, while recognising the inherent potential of mitigation practices to reduce multiple emissions during their evaluation.

This project is funded by CEED.

The economics of carbon emissions in agriculture

Project team: W/Prof David Pannell[1] (leader; email: david.pannell@uwa.edu.au), Mr Tas Thamo[1], Assist/Prof Marit Kragt[1], Prof Ross Kingwell[1], Dr Michael Robertson[2]

Collaborating organisations: [1]UWA; [2]CSIRO

This project is about the economics of greenhouse gas emissions in agriculture, with this year's focus being on issues related to the accurate measurement of emissions. If agriculture were to be included in a national carbon price scheme, a key decision for government would be how to estimate greenhouse gas emissions.

This project has explored the consequences of three different methods for measuring on-farm emissions: national accounting methods, an amended version of those methods and use of best-available local data.

Estimated emissions under the three methods can vary widely; for example, on a case study farm in WA, local data indicated 44% lower emissions than did the national accounts method. If on-farm emissions are subject to an emissions price, the impact on farm profit is large and varies considerably with different measurement methods. For instance, if a price of $23/t of CO_2 emission applies then farm profit falls by 14.4 to 30.8% depending on the measurement method.

Thus, the choice of measurement method can have large distributional consequences. On the other hand, inaccurate measurement results in relatively minor levels of overall inefficiency for the program.

On-farm sequestration through reforestation may lessen the impact of an emissions price on farm businesses, although it will require a high carbon price to be viable, especially if sequestration rates are underestimated or low.

This project is funded by CEED, the National Environmental Research Program and CSIRO.

Multi-peril crop insurance

Project team: Assoc/Prof Professor Ernst Juerg Weber[1] (leader; email: juerg.weber@uwa.edu.au), Ms Amy Khuu[1]

Collaborating organisations: [1]UWA and numerous WA grower groups

Australian farmers can insure their crops against hail and fire damage but not against losses caused by drought and frost. This is despite the fact that variation in rainfall and frost are the largest causes of uncertainty in broadacre farming and may increase with future climate change.

Research by Associate Professor E. Juerg Weber and Ms Amy Khuu into the feasibility of multi-peril crop insurance (MPCI) found that while demand for insurance would be high, the market for private MPCI insurance fails because insurance companies lack data about individual farm risk.

The authors collaborated with agricultural grower groups in order to survey attitudes toward risk and risk management practices of farmers

in the West Australian grain belt. They found that an increase in crop yield volatility of 20% would raise the farmers' willingness to pay for crop insurance one-to-one, by 20%.

Despite this strong demand for insurance, insurance companies do not offer MPCI because more private information is hidden in the markets for drought and frost insurance than in the market for hail insurance. The hail risk is a given quantity that is based on historical observations, whereas the drought and frost risks change from one growing season to the next, depending on the El Niño cycle and other meteorological factors. Insurance companies do not know how skilfully an individual farmer uses seasonal weather forecasts and meteorological information, if at all.

Without MPCI, farmers manage the risk of crop losses using seasonal weather forecasts at the time of the planting decision and through prudential farm management practices, such as staggered sowing programs that reduces the risk of frost damage to wheat. The research shows that farmers reduce the crop area if they expect unfavourable conditions during the growing season. This suggests that they are able to predict weather conditions and manage the risk appropriately.

The research concludes that a future supplier of MPCI must take into consideration that the introduction of drought and frost insurance may change the risk management practices of farmers. As crop insurance shifts the risk of crop failure to the insurance company, there would be less incentive for farmers to behave prudently, resulting in unexpected losses to the insurer.

For further information see **www.ioa.uwa.edu.au/__data/assets/pdf_file/0019/2461501/110666_IOA-newsletter-Dec-2013-WEB.pdf**

Sustainable co-operative enterprise: an investigation into the factors influencing the sustainability and competitiveness of co-operative enterprises

Project team: W/Prof Tim W Mazzarol[1] (leader; email: tim.mazzarol@uwa.edu.au), W/Prof Geoffrey N Soutar[1], W/Prof Kadambot Siddique[1], W/Prof John Watson[1], Assoc/Prof Joanne N Sneddon[1], Mr Peter T Wells[1], Assist/Prof Elena Mamouni Limnios[1], Dr I. Allemand, Dr I.A. Berriozabalgotia, Dr J. Bijman, Prof J.Birchall, Prof B. Brullebaut, Dr N. Byrne, Assist/Prof F.R. Chaddad, Prof D. Clark[3], Prof M.L. Cook, Prof M.E. Fulton, Prof M. Gmür, Mrs Y. Gao, Assist/Prof I. Hatak, Assoc/Prof C. Iliopoulos, Dr E. Juno-Delgado[2], Assist/Prof R. Lang, Dr Q. Liang, Dr M. Martin[2], Assoc/Prof M. Mazzoli, Dr O. McCarthy, M. McCulloch, Dr B. Plunkett, Mr G. Quadrelli, Prof S. Raimbault[2], Prof S. Reboud[2], Mag E. Reiner, Prof D. Roessl, Dr S. Sacchetti, Dr L. Savery, R. Simmons, Prof C. Sinapi[2], Mr P. Suter, Assist/Prof C. Tanguy[2], Dr I. Theodorakopoulou, Dr E.C. Tortia, Dr F.N. Uzea, Prof M. Ward, Ms G. Whyatt, Prof X. Xu

Collaborating organisations: [1]UWA; [2]Group ESC Dijon Bourgogne, France; [3]University of Waikato, Hamilton, New Zealand

Co-operatives and mutual enterprises are a special type of business characterised by a patronage relationship where the buyers or suppliers are also the owners as members. At the global level co-operative enterprises rank among the largest business organisations. The 300 largest co-operatives have a combined annual turnover of US$ 963 billion and are to be found in such industries as banking and finance, agriculture, and retailing and wholesaling.

Australia has around 1,600 businesses that are registered as co-operative or mutual enterprises with an estimated 13.5 million members. Despite their significance there is relatively little research available on drivers of the co-operative business model and what makes it both unique and competitive. This study addresses these issues and assists co-operatives in WA to prepare for the introduction of new State legislation and provide research of benefit to co-operatives at the national level.

The project addresses five questions: (i) What causes a co-operative to abandon its principles, values and business mode and transform into an investor-owned enterprise? (ii) How does a Co-operative measure and communicate the true value of membership? (iii) Are there best practice examples of Co-operative Boards that provide lessons for future business models? (iv) How does a Co-operative successfully participate in financial markets without compromising its principles, values and business model? (v) What are the alternatives to the "one-member-one-vote" principle normally associated with Co-operatives and how do these alternatives strengthen or weaken a Co-operative's ability to operate in a sustainable and competitive way over time?

As part of this project, an international network of around 40 researchers has been formed to collaborate and address the above questions through case study research. Seven in-depth Australian case studies have been completed and multiple international cases. The findings of this work have been collated in 2013 and are published in an Edward Elgar book titled 'Research Handbook on Sustainable Co-operative Enterprise: Case Studies of Organizational Resilience in the Co-operative Business Model'.

In the final year of the project the team has conducted a quantitative member survey, collecting data from eight Australian and New Zealand co-operatives and mutuals. The modelling has led to a better understanding of the drivers of members' commitment and identification with their co-operative. The study has advanced a new conceptualisation of member-owned businesses as a unique type of service provider to customers that wear multiple 'hats', calling for a paradigm shift in the way co-operatives engage with their members.

This project was funded through an ARC Linkage project in partnership with CBH Group, Capricorn Society Limited – Australia, Co-operatives WA, Ravensdown Limited.

Partnership with African Universities

Australia-Africa Universities Network (AAUN)

UWA researchers have shown a keen interest to partner with universities and research institutes in Australia and Africa in addressing the food security and development challenges facing the continent.

A key forum for this has been the AAUN, a consortium of Australian universities working with African partner universities to sustain research and education collaboration and leadership across areas of priority for Australia and Africa. The main priority themes for collaboration are in food security, mining and minerals, public sector reform, public health and education.

IOA Director W/Prof Kadambot Siddique represents UWA in AAUN's Steering Group, with other initiatives and projects as outlined below.

Regional Universities Forum for Capacity Building (RUFORUM) meeting

In June 2013 Assistant Professor Amin Mugera was nominated to represent AAUN in Entebbe, Uganda for a two- day meeting organized by RUFORUM in Africa. This is a member-based consortium of 32 universities from eastern, central and southern Africa with the objective of promoting innovative and responsive research, high performing and proactive graduates and a dynamic platform

for university networking. The objective of the meeting was to develop thematic areas for joint AAUN/RUFORUM activities. Twenty participants attended the meeting – five from the AAUN network, five from the RUFORUM Secretariat and 10 from the RUFORUM network and developed five concept notes.

AAUN meeting

In July 2014, Winthrop Professor Kadambot Siddique and Assistant Professor Amin Mugera participated in a two-day AAUN International forum workshop dubbed 'The Power of Partnership' at the University of Sydney. The objective of the workshop was to identify common interests, capacity and potential for collaborative projects among member universities in Australia and Africa.

Seed money for collaborative research

In collaboration with other AAUM partners, Winthrop Professor Kadambot Siddique and Assistant Professor Amin Mugera developed two concept notes that received a total of $30,000 from AAUN's Partnership and Research Development Fund as seed money to develop joint research proposals in the area of food security and nutrition. Professor Siddique is leading the project on '*Harnessing the benefits of agro-biodiversity for sustained food security in the context of climate change and variability.*' Assistant Professor Mugera is leading the project on '*Improved Productivity, Postharvest Handling, Safety and Biosecurity of Cowpeas/Bambara groundnuts: A Value Chain Analysis in Eastern, Western and Southern Africa*.'

Cultivate Africa's Future (CultiAF)

In 2013, IOA contributed to three concept proposals developed under an initiative dubbed CultiAF. This initiative is a four-year CAD 15 million partnership between Canada's International Development Research Centre (IDRC) and the Australian Centre for International Agriculture Research (ACIAR). The main objective of this competitive research fund is to support applied research in areas vital to achieving long-term food security with a focus on post-harvest losses, nutrition and water use in Eastern and Southern Africa.

The three concept notes proposals to which IOA contributed were:

i. *'Sustainable intensification of wheat-based agriculture systems for improving the livelihoods of resource poor farmers in Ethiopia and Tanzania.*' This initiative was led by ICARDA with a focus in Ethiopia and Tanzania. UWA participants are Winthrop Professor Kadambot Siddique, Dr Ken Flower and Assistant Professor Amin Mugera.

ii. *'Sustainable Water use for Efficient Commodity Value-chain in the Great Lakes Region of Africa.'* This initiative was led by Makerere University in Uganda with a focus in the Great Lakes Region of Africa. UWA participant is Assistant Professor Amin Mugera.

iii. *'Developing sustainable and economically viable agriculture systems for smallholder farmers in southern Africa.'* This initiative was led by Rivers of Life-Foundations for Farming in Zimbabwe, and the International Maize and Wheat Improvement Center (CIMMITY) in Mexico. UWA participants are Dr Ken Flower & Assistant Professor Amin Mugera.

Visit to Perth by AAUN Chair

Professor John Hearn, Chair of AAUN visited Perth (5 Nov 2013) to meet with AAUN representatives and researchers from UWA, Murdoch University and Curtin University. He also met with the UWA Vice Chancellor and Pro Vice Chancellor (International). The main objectives of the meetings were to review and consult on AAUN's future objectives and programs, in order to gain maximum benefit for partners in the AAUN Future Action Plan 2014. The outcome of these meetings will also assist Professor Hearn to approach government, business and international agencies for resources and funding.

Economic viability of African agriculture

Project team: Assist/Prof Amin Mugera[1] (leader; email: amin.mugera@uwa.edu.au);

Collaborating organisations: [1]UWA; [2]California State University, USA; [3]Konkuk University, Korea

IOA's Rural Economy Program leader, Assistant Professor Amin Mugera and his team aimed to determine: (i) whether or not poverty-reducing, low-interest loans from organisations such as the International Monetary Fund (IMF) and the World Bank had an impact on agricultural productivity; and (ii) whether African countries were adopting available technological advances in agricultural production. In two separate studies they examined statistics for 33 African countries from 1996 to 2001 using new economical approaches and models. Controlling for the effects of globalisation, civil violence, levels of development of physical and financial infrastructure and natural resource factors that influence agricultural productivity, one study found that macro-economic policy reforms instituted by the IMF and World Bank indeed improved agricultural productivity. The other study found that uptake of existing agricultural technologies differed across regions and countries.

They outlined ways for improvement in the agricultural sector across Africa, which were subsequently published in two journals.

For further information see http://www.ioa.uwa.edu.au/__data/assets/pdf_file/0005/2353829/107098_IOA-News-Aug-2013-FLIP-BOOK-single-page.pdf

International Conferences

Program Leader Assistant Professor Amin Mugera, together with his PhD students, participated in a number of international conferences, presenting papers on a range of topics related to the rural economy and policy.

In August 2013, Assistant Professor Mugera presented a paper at the Agriculture and Applied Economics Association (AAEA) 2013 conference in Washington DC, USA, titled 'Contributions of productivity and relative price changes to farm level profitability change' This is a joint research project with Professor Michael Langemeier of the Center for Commercial Agriculture at Purdue University.

Post graduate students Arif Watto, Manoj Mudalinge, and Zhibo Guo also presented papers at the Australian Agricultural and Resources Economics Society (AARES) annual conference in Sydney in February 2013. The topics ranged from groundwater use efficiency in Pakistan, production efficiency of rice production in Sri Lanka, and hedging effectiveness of Western Australia's crops.

New Honours unit

In response to the growing global demand for skilled labour in rural development, the School of Earth and Environment (STET) in collaboration with the School of Agriculture and Resource Economics (SARE) launched a new unit 'Development in Rural Areas'. ENVT 4404 is a Level 4 unit with a focus on economic, social and institutional challenges facing rural areas in developing and developed countries. Students are taught how to apply development theory and quantitative tools to a range of rural development issues including: social demography (e.g. gender, cultural and social organisation, population health and education); governance and conflict; rural economies and employment; agriculture and food security; and natural resource management.

Thirty six Master level students enrolled in the unit the first time it was offered.

5. Education, Outreach and Technology Exchange Program

The Education, Outreach and Technology Exchange Program aims to raise UWA's profile in agriculture and resource management and to help take the achievements made across the Institute's programs from the laboratory into the paddock, through education and training programs in regional and selected national and international settings.

With access to world-class teachers, researchers and facilities, the program fosters industry contacts, strengthens links with rural communities, promotes research partnerships and postgraduate teaching and training programs at UWA as well as research and agribusiness activities at the university.

Postgraduate Showcase

IOA's annual Postgraduate Showcase provides a platform for some of UWA's top postgraduate students in an agriculture-related field to present their research to an audience of farmers, academics, scientists and representatives from industry and government.

In 2013, six presentations from PhD students in four different schools highlighted, again, the diverse and multidisciplinary nature of agriculture, and the role of science in sustaining productive agriculture well into the future. The presentations can be viewed at www.ioa.uwa.edu.au/publications/showcase.

Table 1: Postgraduate Showcase 'Frontiers in Agriculture' 2013

Ms Monica Kehoe, School of Plant Biology and IOA, Faculty of Science: Unravelling the cause of Black Pod Syndrome of narrow-leafed lupin
Ms Renu Saradadevi, School of Plant Biology and IOA, Faculty of Science: Modulation of stomatal conductance in wheat under terminal drought: role of ABA
Mr Alex Liu, School of Medicine and Pharmacology, Faculty of Medicine, Dentistry and Health Sciences: Acute benefits of a rich green-leafy-vegetable diet on arterial stiffness and blood pressure in healthy volunteers
Ms Madeleine Hartley, School of Law, Faculty of Law: Governance and groundwater use efficiency in Western Australia: the Gnangara Mound
Ms Kelsie Moore, School of Animal Biology and IOA, Faculty of Science: Fleece characteristics and vitamin D3 synthesis in alpacas in South Western Australia
Mr Cesar Rosales Nieto, School of Animal Biology and IOA, Faculty of Science: Advancing puberty in female sheep: it's all about muscle and fat

IOA News

IOA News is an important channel through which the Institute promotes its activities, research, and collaborations as well as the achievements of its students and staff to alumni, agribusiness, growers, industry, funding bodies, research institutions, and UWA staff.

IOA News is published three times per year (April, August and December) and represents one of the key tools to engage stakeholders and to further strengthen the Institute's strong connection with them. The IOA News publication is circulated widely in electronic format (2918) and as a printed magazine (2775).

Besides providing information on the latest research activities in agriculture and related areas at UWA through feature articles and links to online information and outreach activities, IOA News also serves as a valuable reference material through its list of new publications, visitors and research projects.

Website: www.ioa.uwa.edu.au

The IOA website is the first port of call for information on UWA agriculture-related reserach, development and teaching activities.

The website is updated regularly with information about IOA events and with hyperlinks to other relevant (internal and external) web pages, to enable visitors to explore the activities of IOA and its partners in depth.

Current information is complemented by archived media statements, public lectures and industry forms, all of which are readily accessible to provide a comprehensive picture of the Institute's activities.

In 2013 the UWA Farm Ridgefield extended its web presence from a single web page to a subsite www.ioa.uwa.edu.au/future-farm containing more than 20 pages, to reflect and better promote the growing number of activities taking place at the farm as part of the overarching Future Farm 2050 Project, which manages the research and extension activities undertaken at the farm.

Other web developments in 2013 include the presentation of IOA News in flipbook format, in addition to the traditional pdf format (www.ioa.uwa.edu.au/publications/newsletters)

Public lectures

In 2013, IOA hosted six public lectures (see www.ioa.uwa.edu.au/publications/lectures/2013) attracting audiences of between 30 and 120 people.

The national and international speakers covered diverse topics and disciplines, underpinned by the theme 'food and agriculture'. The lectures generated a high level of public interest, which was reflected in strong attendances and stimulating discussions following the presentations.

Date	Presenter	Organisation	Title
17 April	Prof Rana Munns	Honorary Fellow, CSIRO and Winthrop Professor UWA	(Hector and Andrew Stewart Memorial Lecture) Improving salt tolerance of wheat
July 18	Prof Ron Madl	Director, Wheat Research Centre, College of Agriculture, Kansas State University, USA	Reaching new heights: Antioxidants in wheat
August 6	W/Prof Kadambot Siddique	Hackett Chair of Agriculture and Director, UWA Institute of Agriculture; Co-sponsored by the UWA Institute of Advanced Studies	(Food 2050 Lecture Series:) Australian agriculture and global food security
August 12	Prof Ylva Hilbur	Deputy Director General for Research, International Institute for Tropical Agriculture (IITA), Ibdan, Nigeria	Lifting Africans out of poverty
September 4	E/Prof Fred Allendorf	Regents Professor Emeritus, Biological Sciences, University of Montana and 2013 US Fulbright Senior Specialist, UWA	(Food 2050 Lecture Series:) Do genetic effects threaten the sustainability of marine fisheries?
October 10	Prof Marian Stamp Davis	Professor of Animal Behaviour, University of Oxford	(Food 2050 Lecture Series:) Is 'more efficient' food production in conflict with animal welfare?

Media statements

The Institute cemented its media presence during 2013 with 54 media statements, which in turn, generated a substantial number of follow-up articles in mainstream newspapers and farm magazines; and a number of radio and television interviews with key protagonists.

Date	Title
January 29, 2013	Chickpea breakthrough aims to feed millions
January 29, 2013	Investigating best water practices for Perth's parks and ovals
January 30, 2013	Miniature probes help tackle climate change
February 1, 2013	Ecologists propose 4-point plan for global land restoration
February 19, 2013	UWA scoops agricultural and resource economics awards
February 20, 2013	Soil carbon study to test nitrogen gas risk
February 22, 2013	Slight climate change can reduce drought effect in wheat
March 26, 2013	Superfast plant breeding slashes production times
March 27, 2013	UWA scoops prestigious international prize – again
March 27, 2013	Molecular study cuts the mustard for climate change
April 2, 2013	How to feed nine billion hungry mouths by 2050?
April 4, 2013	Farmers to benefit from key research projects
April 9, 2013	Wheat farmers to reap benefits of UWA public lecture
April 15, 2013	First Australian win for US plant biology award
April 16, 2013	New sweet potatoes turn to 'gold' for Timor-Leste
April 17, 2013	Plight of bees to premier in Perth for Honey Week
May 7, 2013	Plant biology advances rapidly to help feed the world
May 15, 2013	African agriculture in the spotlight
May 16, 2013	UWA engineers tackle precision seeding challenge for sandalwood
May 16, 2013	Getting to the root of better crops
May 21, 2013	Strawberry fields forever and fungus-free
May 24, 2013	UWA-China link to boost sustainable food production in drylands
May 30, 2013	The right amount of coffee
June 10, 2013	Grains champion to chair UWA Institute of Agriculture Industry Advisory Board
June 26, 2013	A stellar team from Shenton College
July 3, 2013	New grants are the bees knees for one-third of what we eat
July 16, 2013	Fertilisers play key role in reducing crop pests
July 30, 2013	Stressed plants say it with flowers
August 9, 2013	Breast cancer and Landcare projects make Eureka award finals
August 15, 2013	UWA rankings leap higher in Centenary Year
August 26, 2013	Guerilla tactics to target war on weeds: world expert
August 27, 2013	Pingelly Field Day to showcase cutting-edge Future Farm science
August 30, 2013	Solving secrets of the wine cellar
September 2, 2013	Lambs to woo Future Farm scientists
September 5, 2013	Minister for International Development visits 'Seeds of Life' project in Timor-Leste
September 6, 2013	Sustainable agriculture project wins Eureka award
September 10, 2013	Digging deeper for soil carbon storage
September 11, 2013	Moving genes have scientists seeing spots
September 19, 2013	Breakthrough discovery could result in fragrant golden harvest
September 24, 2013	Agriculture expert wins top Chinese award
September 25, 2013	How will livestock react to global warming?
October 15, 2013	Timely book reveals economic growth fails to end India's food crisis
October 21, 2013	Two-pronged approach to boost forest carbon storage
October 25, 2013	Tough new varieties set to revive profitable chickpea in industry
October 29, 2013	Study reveals local council mergers depend on efficiency
October 31, 2013	Strong showing of UWA finalists in 2013 WA Science Awards
November 11, 2013	New phone App SnapCard now available for farmers
November 11, 2013	Science fights back against rice blast
November 15, 2013	Graduates explore new ways of managing drought
November 21, 2013	Recognition of Lifetime Contribution: Capacity building and food security
November 27, 2013	Biological scientist named state's 'Tall Poppy'
November 28, 2013	Rural-urban migration constrains future agricultural productivity in China
December 4, 2013	Vitamin C-rich native fruit ripe for cash crop study
December 9, 2013	UWA leads international research teams on climate change
December 9, 2013	Weed scientists to iron out farmers' frowns with assault on Crowsfoot Grass
December 17, 2013	Tiny organisms may hold key to global food supply
December 20, 2013	New national centre at UWA to research energy capture and use by plants

Outreach and teaching activities at UWA's Farm Ridgefield

2013 has been a busy year for outreach and education activities at UWA's Farm Ridgefield.

On 7 February 2013, ABC Television aired a segment on the UWA Farm Ridgefield on its 'Catalyst' program.

To view the program, visit www.abc.net.au/catalyst/stories/3685323.htm

In the same month, 30 climate champions from across Australia visited the farm, followed in May by a group of students from six agricultural colleges across WA's south west.

In July, Professor Ron Madl from Kansas State University visited with a group of his students to view sustainable agriculture practices, projects and technology on site.

On 6 September, an Open Day was held as part of UWA Gives Back, a major initiative of the UWA Centenary celebrations in 2013. Sixty students from local schools (Pingelly Primary School, Brookton District High School and Narrogin Senior High School) participated in hands on activities about soil, biodiversity, restoration of vegetation and plant cells. Professor Marian Stamp Dawkins, Professor of Animal Behaviour, Oxford University, was the keynote speaker at the presentations and demonstrations for the local community and visitors. This was preceded by a Master Class in Soil Health, co-ordinated by UWA's Institute of Advanced Studies and conducted by Adjunct Professor Brent Clothier (for further details see IOA News, December 2013 edition, page 2, www.ioa.uwa.edu.au/__data/assets/pdf_file/0019/2461501/110666_IOA-newsletter-Dec-2013-WEB.pdf)

Student groups from China's Northwest Agricultural and Forest University (NWAFU), and from the South China Agricultural University (SCAU) further boosted the number of international visitors to the farm.

UWA's Ecosystem Restoration and Intervention Ecology Research Group (ERIE) commenced using the farm to explore innovative options for ecosystem management that reconcile future farming enterprises with biological diversity and the provision of ecosystem services; the first experiment is underway and addresses the question *'Do trees planted for carbon benefit other ecosystem services such as soil health and resistance to weed invasion?'*

Local students from three high schools across Perth also participated in the farm's ecosystem restoration program under the 'City Kids to the Country' initiative; students from Applecross Senior High School, John Curtin College

of the Arts and Ardross Primary School grew seedlings which they planted at a restoration site on the farm and were introduced to ongoing research activities.

In May, more than 50 students from the WA Colleges of Agriculture at Harvey, Denmark, Narrogin, and Cunderdin, Bindoon Catholic Agriculture College and Kelmscott Senior High School visited the farm, and in December, students from Esperance Senior High School attended a one-day workshop on the farm.

UWA undergraduate students enrolled in Soil Science (EART3338) conducted intense soil mapping and characterisation at the farm, which involved taking soil samples for lab work and preparation of a report of WA's land capability assessment.

UWA postgraduate students enrolled in the Master of Architecture program paid three visits to the farm to develop a research design project based on the proposed development of the Future Farm accommodation and operational needs to 2050.

In addition, the above outreach activities were complemented by a series of three public lectures on 'Food 2050' (http://www.ias.uwa.edu.au/lectures/2050-food) held between August and October. 'Food 2050' was also the theme of this year's IOA Industry Forum (see below) to which the UWA Farm Ridgefield Project contributed 16 presenters.

For further details about the UWA Farm Ridgefield's outreach activities visit www.ioa.uwa.edu.au/future-farm-2050/news-and-events

IOA Industry Forum 'Food 2050'

On 10 April 2013, the annual IOA Industry Forum was held for the seventh consecutive year. The theme was 'Food 2050' and explored the role of science and technology in feeding nine billion people by 2050, without destroying the planet.

An audience of approximately 120 listened to speakers from a wide range of disciplines who presented the opportunities inherent in each discipline to help address this challenge. The disciplines included Animal Biology, Plant Biology, Soil Science, Electronic/Computer Engineering, Forensic Science, Medicine, Architecture, Business and Finance.

For the full program see www.ioa.uwa.edu.au/_nocache/?a=2272803; the presentations can be accessed from www.ioa.uwa.edu.au/publications/industry-forum.

UWA Learning Links Outreach Program

Two groups of Shenton College high schools students, mentored under the UWA's Learning Links Outreach Program by IOA scientists Associate Professor Matthew Nelson and Assistant Professor Michael Considine respectively, took out the gold medal at the Beijing Youth Science competition, and the award for the most successful international team.

For further information see www.ioa.uwa.edu.au/__data/assets/pdf_file/0005/2353829/107098_IOA-News-Aug-2013-FLIP-BOOK-single-page.pdf.

Young Professionals in Agriculture top awards go to UWA graduates

The annual Young Professional in Agriculture event is hosted by WA's Division of the Ag Institute Australia and showcases the work of tertiary students studying agriculture-related subjects at WA universities and who have completed an undergraduate degree.

UWA Agricultural Science graduate Emma Downsborough took out the highest award for her work on consumer preferences and willingness to pay for local food products.

Caris Jones, another UWA graduate, claimed the second prize and the best-presentation award for her work on feed-use efficiency and its impact on the fertility of merino ewe lambs.

For further information see www.ioa.uwa.edu.au/__data/assets/pdf_file/0004/2292322/104678_IOA-newsletter-v7-web.pdf.

Bees and honey create a buzz

'More than Honey' documentary

UWA's Centre for Integrative Bee Research (CIBER) featured and was part of the scientific advisory team in the multi-award winning documentary "More than Honey", by Oscar-nominated Swiss movie director Markus Imhoof.

The most up-to-date equipment was used to create 105 hours of close-up footage of bees in a hive, of which 46 minutes were used for the documentary itself, to educate the audience about the significance of the honeybees for agriculture and to shed light as to why their populations are in dramatic decline all over the world. Since bees move too fast for the human eye, the footage was slowed down so the

audience could literally come face-to face with them and follow their movements.

The film was screened as part of the German Film Festival in all major cities in Australia and had its premiere in Perth on 3 May 2013 at Cinema Paradiso, with CIBER staging this public event. Professor Lyn Beazley, Chief Scientist of WA, gave the introductory address and the Deputy Consul General for Switzerland Bernhard Furger, the Honorary Consul for Switzerland Jürg Weber, and the Honorary Consul for Germany Torsten Ketelsen were among the 300 guests.

The documentary created a significant amount of publicity for CIBER and UWA across Australia in newspapers, radio programs and on the National News on TV (http://www.news.uwa.edu.au/201304175581/arts-and-culture/plight-bees-premiere-perth-honey-week). CIBER's movieblog (www.ciber.science.uwa.edu.au/blog/) also generated significant traffic and plans are underway for further screenings of the new English John Hurt-narrated version of 'More than Honey' in Australia.

CIBER director Professor Boris Baer received the prestigious Swiss Award as part of a SAAN (Swiss Australian Academic Network) event at the Swissotel a day after the first Sydney screening (http://saan.com.au/content/saan-board-member-receives-swiss-award-2013 and http://issuu.com/swisschamber/docs/newsflash2)

National Honeyweek (Apr 29 – May 5)

Scientists at UWA's Centre for Integrative Bee Research (CIBER) engage in many outreach activities (e.g. school visits, exhibitions and public talks) to educate the public about the significance of honeybees

for pollination and their dramatic decline worldwide.

One of its key outreach events is the annual National Honey Week, which educates the public about the important role played by the honeybee industry in keeping bees healthy and assuring the pollination of our crops. National Honey Week is also a celebration of all things honey and other bee products and of CIBER's close and successful collaboration with the honeybee industry and hobby beekeepers. Honey Week offers the public an opportunity to meet and talk to real beekeepers and researchers and to learn more about the production of honey and beeswax, as well as beekeeping in their own backyard. 2013 was the third successive year of CIBER'S participation.

Highlights of the 2013 Honey Week included:

- a bee exhibition for SciTech, developed by scientists from UWA. SciTech counted 7666 visitors during Honey Week and the interest in the exhibition was enormous with visitors especially appreciating the honey tasting, the show hive and the discussions with scientists and beekeepers. The popularity of the exhibition led SciTech to install a permanent CIBER/Bee exhibit in December 2013, in close collaboration with CIBER.
- screening of 'More than Honey'.
- a very well attended public lecture by Prof Boris Baer, founder of CIBER, on his latest research and outreach activities, followed by a lively discussion.

- the closing festival (organised at the House of Honey in the Swan Valley) which attracted 6000 visitors, three times more than in 2012.
- visit from delegates of the Perth Royal Agricultural Society asking CIBER to set up a stall at the Perth Royal Show 2013 .

Feedback forms were collected and will be evaluated to guide CIBER's planning and preparation for Honey Week 2014 to optimise CIBER's community engagement even further.

Perth Royal Show: from hive 2 honey

Following the invitation to organise a stall and exhibition about honey production at the Royal Show 2013, CIBER developed a display suited to the Agricultural Society's new "Farm 2 Food" pavilion, which was created to educate the children about where their food comes from.

CIBER's display "From Hive 2 Honey" was designed in collaboration with beekeepers to explain how honey is produced in WA. The display also included a stall, which allowed children of all ages to observe live honeybees, investigate dead bees under a microscope, taste honey, touch and smell bee wax and discover how an industrial beehive is built.

During the week of the Perth Royal Show (28 Sep to 5 Oct) CIBER co-ordinated 25 volunteers to man the honeybee stall daily from 9 am to 6 pm. The Farm 2 Food-pavilion attracted 2400 visitors per hour, and 35,000 overall, including WA Premier Colin Barnett. The volunteers from CIBER and the WA Apiarists Society distributed 15,000 honey samples. In a thank you letter received, CIBER was asked to participate again at the Perth Royal Show 2014.

Turf Research Open Day

The Turf Research Program within UWA's School of Plant Biology focuses on water use and drought tolerance in turf, on the use of soil amendments to improve water and nutrient management, and on turf nutrition and fertiliser efficiency.

UWA's Shenton Park Field Station provides the research facility where turf is evaluated under different management practices. In February 2013, the research group held an Open Day at the site, which attracted over 100 visitors from major stakeholders in industry, government and research.

For further information see **www.ioa.uwa.edu.au/__data/assets/pdf_file/0004/2292322/104678_IOA-newsletter-v7-web.pdf**

This research is funded by Horticulture Australia, in partnership with the Turf Industry and various State and Local Government groups.

Australia's first Critical Zone Observatory

In 2013 the first Critical Zone Observatory in the Southern Hemisphere was established at the UWA Farm Ridgefield in Pingelly (**www.czen.org/content/uwa-czo-avon-river-catchment**)

Intensive course: QTL Mapping and Breeding Simulation

In February, UWA's International Centre for Plant Breeding Education and Research (ICPBER) presented a three day course (Feb 6-8) 'QTL Mapping and Breeding Simulation'**.** The course was run in cooperation with Murdoch University and taught by Dr Jiankang Wang (CIMMYT China and Chinese Academy of Agricultural Sciences), together with Professor Rudi Appels (Murdoch University) and Dr Parwinder Kaur (UWA).

The course covered theoretical and practical aspects of the use of software to map molecular markers, including a new-generation mapping software *Inclusive Composite Interval Mapping (ICIM)* which can handle the range of challenges associated with thousands of molecular markers. The ICIM software also has the facility for integrating different molecular marker maps based on the presence of shared markers.

The course was filled to capacity and comprised 34 participants from industry and academia who provided very positive feedback in a survey conducted at the end of the seminar.

Capacity building for statistics

Project team: Prof Brian Cullis[2] (leader; email: bcullis@uow.edu.au), Assoc/Prof Katia Stefanova[1], Dr Alison Smith[2], Prof Ken Russel[2], Dr Olena Kravchuck[3]

Collaborating organisations: [1]UWA; [2]University of Wollongong; [3]University of Adelaide, [5]Charles Sturt University; Wageningen Institute for Applied Plant Research,The Netherlands

Productivity of primary industries is vital for the future of Australian agriculture and statistical analysis plays an important part in this. Despite this, the focus on biometrics, a discipline of statistics that develops and applies statistical theory and methods in the biosciences, including agriculture, has lessened significantly with no real growth in the number of biometricians working in public sector organisations for the past decade.

This project sets out to deliver increased and sustained training in statistics and biometrics to UWA tertiary students to meet the future statistical needs of the grains industry, and significant progress has been made in 2013, including: (i) modules for existing honours/Masters units 'Data Use in the Natural Sciences' (SCIE 4401); and (ii) 'Data Management and Analysis in the Natural Sciences' (SCIE 4402) have been written or updated. The units are offered every semester. The modules focus on: (i) design of experiments and ANOVA (SCIE4401) and on Linear Mixed Models (SCIE4402); (ii) design and delivery of a two-day course for PhD students on *Advanced Experimental Design* and *Linear Mixed Models;* and (iii) provision of regular statistical support for postgraduate students in the Faculty of Science.

This project is funded by GRDC.

Statistics for the Australian Grains Industry (SAGI 2)

Project team: Prof Brian Cullis[2] (leader; email: bcullis@uwa.edu.au), Assoc/Prof Katia Stefanova[1], Dr Alison Smith[2], Dr Alison Kelly[4], Dr Julian Taylor[3], Dr David Butler[4], Dr Bev Gogel[3], Mr Chris Lisle[5]

Collaborating organisations: [1]UWA; [2]University of Wollongong; [3]University of Adelaide; [4]DEED Queensland; [5]Charles Sturt University**;** VSN International, UK

The role of statistics in the grains industries is to provide optimal experimental designs and statistical analyses, to be instrumental in the variety release selection - through National Variety Trials (NVT) system support - and to provide plant breeders, agronomists and growers with reliable predictions regarding yield and quality traits.

The primary objective of this project is to deliver ongoing high quality statistical support and training, develop innovative statistical technologies and statistical software for the grains industries in Australia, in particular for national public pre-breeding and breeding programs and other GRDC funded projects.

In 2013, the team: (i) maintained the implementation of the standard operating procedure for SAG 2 support of grains industry research, development and extension projects; (ii) provided timely design and analysis for near-to-market research and extension projects, including agronomy system trials, National Variety Trials (NVT), farming system/agronomy trials and disease resistance/tolerance trials, including the provision of refereed reports to project leaders and broader grains industry; (iii) implemented a new cluster based approach to NVT multi-environment trials; and (iv) provided support to postgraduate students in Agriculture, Plant Biology and Soil Science.

This project is funded by GRDC

AHRI hosts inaugural international conference

In February 2013, the Australian Herbicide Resistance Initiative, located within UWA's School of Plant Biology, hosted the inaugural Global Herbicide Resistance Challenge Conference. The one-week event included 100 speakers and over 60 poster presentations and attracted more than 300 delegates.

For further details see **www.ioa.uwa.edu.au/__data/assets/pdf_file/0004/2292322/104678_IOA-newsletter-v7-web.pdf**

AHRI is funded by GRDC.

InterDrought-IV Conference

Drought is one of the biggest threats facing agriculture today and in 2013 UWA was involved in two significant extension events addressing the challenges arising from drought.

In September UWA and Curtin University co-sponsored the InterDrought-IV Conference, together with principal sponsor Murdoch University. The InterDrought-IV Conference is a major international platform to debate strategies to increase yield and stability of crops under drought conditions by genetic and crop management approaches. IOA played a significant role in organising the conference.

The event attracted 350 of the leading drought researchers worldwide. UWA's ICPBER leveraged on their presence to run a Master Class on *'Adaptation to Drought'* in the week prior to the Conference.

The Master Class (MC) aimed to increase participants' understanding of: (i) practical selection for drought tolerance: phenotyping; (ii) new techniques for drought selection: genotyping; and (iii) crop management options to cope with drought. The MC attracted 19 participants – all of them experienced and practicing drought scientists from a wide range of developing countries. The MC was sponsored by the Crawford Fund, ACIAR, GRDC, and the organisers: UWA, Murdoch University, DAFWA and ICRISAT. In addition the MC was supported by scientists from the organisers; InterGrain; AGT; ACPFG; the University of Tasmania and the Managed Environment Project from CSIRO Plant Industry.

Visitors to IOA

In 2013, IOA further strengthened its research links and collaborations with institutions and industry in Australia and overseas through hosting more than 20 national and international visitors including scientists from partner organisations, industry stakeholders and government representatives.

Among them were delegations from some of UWA's foremost partner organisations: ACIAR, ICARDA, KVASU in India and Lanzhou University in China.

For further information see www.ioa.uwa.edu.au/__data/assets/pdf_file/0003/2233335/2012-December-Newsletter.pdf);

Collaboration with overseas institutions

Flourishing alliances with China

Joint Centre for Dryland Agricultural Ecosystems

The extensive links between UWA and China were boosted further, with the launch of the Centre for Dryland Agricultural Ecosystems in May 2013 at Lanzhou University (LZU). The centre is a joint endeavour between LZU, UWA and ICARDA and is testimony to the important role of drylands in ensuring food security and the high priority placed by leading institutions in pooling their expertise and know-how to advance sustainable agricultural production. UWA's flourishing partnership with LZU dates back to 2006 and has led to numerous (training) initiatives, visits and joint research projects.

For further information see www.ioa.uwa.edu.au/__data/assets/pdf_file/0005/2353829/107098_IOA-News-Aug-2013-FLIP-BOOK-single-page.pdf

Three Brothers Initiative

In April 2013, a new academic partnership was formed between UWA, Zhejiang University and Tarim University.

This new international collaboration is referred to as the 'Three Brothers Project' and forms part of the Three Brothers framework founded in 2005 by the Ministry of Education in China to support relationships between high-performing universities abroad and emerging universities in China. Closer ties between the three institutions are of most interest in the research area of arid horticulture.

For further details see www.ioa.uwa.edu.au/__data/assets/pdf_file/0005/2353829/107098_IOA-News-Aug-2013-FLIP-BOOK-single-page.pdf

Joint soils laboratory with Chinese Academy of Sciences

UWA's history of close collaboration the prestigious Chinese Academy of Sciences (CAS) culminated in the

launch of a joint soils laboratory – the first joint laboratory for the two institutions in December 2013.

For further information see **www.news.uwa.edu.au/201312176372/research/tiny-organisms-may-hold-key-global-food-supply**

Improved food crop varieties for Timor-Leste

Seeds of Life III

Project team: Prof William Erskine[1] (leader; email: william.erskine@uwa.edu.au), Adj/Prof Harold Nesbit[1], W/Prof Kadambot Siddique[1], Adj. Senior Research Fellow Rob Williams[1]

Collaborating organisations: [1]UWA; Department of Foreign Affairs and Trade; Timor-Leste Ministry of Agriculture and Fisheries; CLIMA (now called Centre for Plants, Genetics and Breeding)

A long-term agricultural development program, Seeds of Life (SoL), continues to improve Timor-Leste's capacity to feed itself and lift subsistence farmers out of poverty, through production increases in Timor-Leste's staple food crops.

SoL commenced as an ACIAR project in 2000, following Timor-Leste's independence. Since then the program has progressed through various phases of research and development. In February 2011, SoL entered its third (and current) phase, led by CLIMA, with a $27.5 million grant over five years to ensure continuous and widespread access to seeds of high-yielding crop varieties by local farmers by the end of the five-year period. SoL III has components of research, seed multiplication, community seed development and during 2013, SoL III expanded its activities into all 13 Timor-Leste districts, and is on track to provide more than 50% of all cropping farmers in Timor-Leste with continuous access to seeds of superior crop varieties, before the end of 2016.

The research program has resulted in the release of improved varieties of maize, sweet potato, rice, cassava and peanuts which out-yield local varieties by up to 150%. All released varieties were selected after being cultivated under farmer conditions over a number of years and passing through a rigid consumer evaluation system. The array of available improved food crop varieties continues to expand with trials being conducted on winged bean, mung beans and other legumes. Pro-vitamin enriched maize varieties and other nutrient enhanced crops are also being examined.

Seed of the most recently released variety, a white maize aptly named Noi Mutin or 'Little Princess', was multiplied on research stations throughout 2013 and disbursed to seed growers across the nation. Meanwhile seed of the popular yellow maize (Sele), peanut (Utamua) and rice (Nakroma) were multiplied by Government and non-governmental organisations, seed producers, community seed production groups and individual farmers for cultivation or sale. Sweet potato (Hohrae 1, 2 and 3) and cassava (Ai-Luka 2 and Ai-Luka 4) cuttings were alsomultiplied in small plots in each district for sale to farmers.

The Timor-Leste variety release committee is considering releasing a bitter cassava variety suited to starch production. This variety (Ca 109) is high yielding and has a high starch content but possesses an elevated cyanide content making it unsuitable for human consumption. Rats and other predators are deterred by its bitter taste allowing Ca 109 to be stored for long periods prior to processing. There is commercial demand for this variety and it is expected that sufficient on-farm productivity data will be available for its official release in 2014.

In 2013, more than 1,000 community seed production groups were being supported directly by SoL and 500 others by NGOs. Thirty-five of these groups formed large Farmers' Associations, all of which are developing the capacity to sell their own labelled seed. In July, 2013, the first three of these associations were registered to sell seed under the newly developed National Seed System for Released Varieties (NSSRV).

The success of the SoL program is being measured in both improvements to food security and in the capacity of the MAF to continue to support the NSSRV into the future. Five MAF staff members were sponsored through MSc studies during the year, with three of them attending courses at UWA. At the end of their studies, all SoL sponsored students will return to Timor-Leste to work with Government agricultural development agencies.

This project is funded by ACIAR and the Department of Foreign Affairs and Trade (DFAT).

Memoranda of Understanding (MoU)

2013 was a successful year both for cementing existing international partnerships and for forging new ones. This was reflected in a number of new formal agreements (MoUs), as well as a range of activities as part of an ongoing collaboration.

Date	MoU Partners
February 11	Letter of Extension of the Memorandum of Understanding between UWA and University of Ghana (UOG) signed 11 February 2013
September 9	Letter of Extension of the Memorandum of Understanding between UWA and Huazhong Agricultural University (HAU)
October 19	UWA and Kerala Veterinary and Animal Sciences University (KVASU)

Training in Bangladesh

Quantifying epidemiology and forecasting risks of crop diseases

This one-week training course, held 3 to10 February 2013 in Bangladesh, was created in response to a severe epidemic of Stemphylium blight in 2012, which threatened the sustainability of lentils in many (pulse) cropping systems in the region.

The course aimed to provide (early and mid-career) scientists of South Asian countries with theoretical and practical knowledge to understand and quantify epidemiology of crop diseases and apply the methodology in forecasting risks of crops diseases.

The course was hosted by the Bangladesh Agricultural Research Institute (BARI), Joydepur, Bangladesh, and taught by Dr Moin Salam and Mr Bill MacLeod (DAFWA). It attracted 16 participants from Bangladesh, Nepal and India who provided positive feedback on the course. As follow-up, two working groups were formed to develop, test and apply disease forecasting models, one on potato late blight disease and the other on Stemphylium on lentil. Dialogue will continue with the trainers in mentoring the two working groups.

The course was supported by the Crawford Fund, ICARDA, BARI, CLIMA, DAFWA and ACIAR

Awards and industry recognition for staff in 2013

Prof Kingsley Dixon	Linnean medal awarded by the Linnean Society of London for his contribution to research on native plants and the regeneration of ecosystems; www.news.uwa.edu.au/201305275711/awards-and-prizes/plant-hero-lauded
E/Prof Alan Robson	Order of Australia (General Division) for distinguished service to tertiary education through governance and administrative roles, to the advancement of scientific and medical research, and to the community; www.news.uwa.edu.au/201306115742/queens-birthday-honours-leading-uwa-academics
Assist Prof Marit Kragt	Essay Prize of the Agricultural Economics Society International Award for Research Excellence from the Modelling and Simulation Society of Australia and New Zealand; www.news.uwa.edu.au/201312126362/awards-and-prizes/international-award-young-uwa-scientist UWA-UQ Bilateral Collaboration Award
Ms Xixi Li	Best young scientist oral presentation award at the 8th International Meeting on Anaerobic Microbiology
Prof Michael Burton and Adj/Assoc/Prof Dan Rigby	Winners of the Quality of Research Discovery Award for their paper presented at 57th Annual Australian Agricultural and Resource Economics Society (AARES)
W/Prof David Pannell	Finalist for WA Science Ambassador of the Year Award www.news.uwa.edu.au/201312046315/features/uwa-staff-and-students-shine-wa-science-awards
Prof Ben White	Best Paper Award by the AARES-Wiley Blackwell Australian Journal of Agricultural and Resource Economics
W/Prof Stephen Powles	Finalist for WA Scientist of the Year Award www.news.uwa.edu.au/201312046315/features/uwa-staff-and-students-shine-wa-science-awards
W/Prof Kadambot Siddique	Dunhuang Award www.news.uwa.edu.au/201309246081/awards-and-prizes/agriculture-expert-wins-top-Chinese-award Ag Institute Australia Fellow Award
E/Prof Bob Gilkes	Crawford Fund Medal www.news.uwa.edu.au/201311216268/awards-and-prizes/recognition-lifetime-contribution-capacity-building-and-food-security
Prof Ryan Lister	Tall Poppy WA Award recognizing the brightest young scientists in WA www.news.uwa.edu.au/201311276286/awards-and-prizes/biological-scientist-named-states-tall-poppy
Future Farm Industries CRC	Caring for our Country Landcare Eureka Prize www.news.uwa.edu.au/201309066039/awards-and-prizes/sustainable-agriculture-project-wins-eureka-award
ARC Centre of Excellence in Plant Energy Biology	Winner of the Chevron Science Engagement Initiative of the Year.
Prof Boris Baer	Winner of the Swiss Award of the Swiss-Australian Chamber of Commerce & Industry (SACCI) for his outstanding achievements in his bees research project (see http://saan.com.au/content/saan-board-member-receives-swiss-award-2013)

Research Projects and Research Training

New research projects 2013

Title	Funding period	Funding body	Supervisor/s
Grand challenge: genomic approaches for stress tolerant chickpea	2012-2015	Australian Centre for Plant Functional Genomics (ex DIISR Australia India Strategic Research Fund)	W/Prof Timothy Colmer, W/Prof Kadambot Siddique
Maintenance of soil organic carbon levels supporting grain production systems: the influence of management and environment on Carbon and Nitrogen turnover	2012-2014	DAFWA (ex DAFF Carbon Farming Futures Filling the Research Gap)	Prof Daniel Murphy
Economic analysis of gene deployment strategies for high priority exotic pests and chemical supply to manage pest incursions	2012-2014	CRC Plant Biosecurity	Prof Benedict White
Enhancing WA chickpea industry through targeted demonstration and extension of new Aschocyta-resistant improved varieties and lines in partnership with grower groups	2013-2014	COGGO	W/Prof Kadambot Siddique, Prof Tanveer Khan
Polymers for improving soil moisture management and cropping productivity	2012-2014	CRC for Polymers	Prof Daniel Murphy, W/Prof Tony O'Donnell, Assoc/Prof Louise Barton, Assist/Prof Deirdre Gleeson
Better regulatory frameworks for water-sensitive cities	2012-2016	CRC Plant Biosecurity	Assoc/Prof Alex Gardner
Research & technical support for the project empowering farmers to adopt behaviour change in a carbon economy	2012-2014	South Coast Natural Resource Management Inc	Assoc/Prof Barbara Cook
New technologies and enhanced techniques for water resource assessment in a changing climate	2013	Worldwide Universities Network (WUN)	Prof Neil Coles, Prof Mark Rivers
The value of carbon and biodiversity services provided by native shrubs on farmland	2013	UWA-UQ bilateral Collaboration Award	Assist/Prof Marit Kragt
Development of a web-based tool to interpret and quantify spray coverage obtained from commercial pesticide applications	2013-2014	COGGO	Assoc/Prof Christian Nansen
Investigation of respiratory control in dormant grapevine bud	2013	Grape and Wine Research Development Corporation	Assist/Prof Michael Considine
Identifying the biochemical and molecular bases of 2,4D herbicide resistance in the economically important weed *Raphanus raphanistrum* (wild radish)	2013-2015	Nufarm	W/Prof Stephen Powles
Managing soil-borne root disease in sub-clover pastures	2013-2017	MLA	W/Prof Martin Barbetti
Fertility crisis: harnessing the genomic tension behind pollen fertility in sorghum	2013-2014	University of Queensland (ex ARC Linkage)	Assoc/Prof David Jordan, Prof Ian Small, Dr Emma Mace, Prof Robert Klein, Dr Diana Dugas
Grazing into the Future: building soil health and carbon with pasture management	2012-2015	DAFF Carbon Farming Futures Action on the Ground	W/Prof Lyn Abbott, Dr Natasha Pauli
Mechanisms of drought tolerance of tedera (Bituminaria bituminosa var. albomarginata)	2013	Future Farm Industries CRC	Assoc/Prof Megan Ryan, Mr Kevin Foster
Opportunistic sampling of Cullen field experiment regrowth	2013	Future Farm Industries CRC	Assoc/Prof Megan Ryan, Mr Dion Nichol
Proof of concept – remote sensing of frost induced stress in wheat paddocks	2013	GRDC	Dr Ken Flower, Assist/Prof Bryan Boruff, Assoc/Prof Christian Nansen
Harnessing soil biological functions to improve grapevine management for a sustainable industry	2013-2014	Victoria DPI (ex Grape and Wine Research and Development Corporation)	Prof Daniel Murphy, Dr Linda Maccarone, Assist/Prof Deirdre Gleeson

Title	Funding period	Funding body	Supervisor/s
Safeguarding honeybees: understanding host-parasite interactions at the level of proteins	2013-2016	ARC Linkage	Prof Boris Baer, Prof Richard Oliver, Mr John Davies, Prof Paul Schmid-Hempel
Genomic basis of clonal variation in Cabernet Sauvignon wine grapes	2013-2016	ARC Linkage	Assist/Prof Michael Considine, Prof James Whelan, Prof Ryan Lister, Mr Glynn Ward, Dr Kristen Brodison, Mr James Campbell-Clause, Mr Daniel Newson, Dr Paul Chambers
The Fourth Australia-China Wheat Genetics and Breeding Workshop	2013	GRDC	Assoc/Prof Guijun Yan
Achieving least cost greenhouse gas abatement opportunities in Australian grains farms		DAFF Filling the Research Gap	Assist/Prof Marit Kragt, Peter Thornburn (CSIRO)
Modifications and update of dam design software tool - Damcat5	2013	WA Dept of Water	Assist/Prof Chun Baek, Mr David Stanton, Prof Neil Coles
Managing biological physical and chemical constraints to soil carbon storage	2013-15	DAFF Carbon Farming Futures Filling The Research Gap	Assist/Prof Deirdre Gleeson, Assoc/Prof Daniel Murphy, Assoc/Prof Peta Clode, Dr Lynne Macdonald, Dr Jeff Baldock, Dr Clayton Butterly, Assoc/Prof Caixian Tang
Novel business structures for adaptation to a changing climate	2013-15	DAFF Carbon Farming Futures Filling The Research Gap	Prof Ross Kingwell
Host control of methane emissions from sheep	2013-15	DAFF Carbon Farming Futures Filling The Research Gap	Prof Philip Vercoe
Information management and regional development partnership	2013	Wheatbelt Development Commission	Prof Matthew Tonts, Prof Paul Plummer
Provision of services specialist independent peer reviewer and advisor - water resources	2013	Buru Energy Ltd	Prof Neil Coles
Innovative livestock systems to adapt to climate change and reduce emissions	2013-2015	DAFF Carbon Farming Futures Filling the Research Gap	Prof Phil Vercoe
International coordination of the *Ruminant Pangenome Project*	2013-2015	DAFF Carbon Farming Futures Filling the Research Gap	Prof Phil Vercoe
Western node of the *National Brassica Genetic Improvement Program* - (NBGIP-2) heat tolerance research	2013	NSW Dept of Primary Industries (ex GRDC)	Assist/Prof Sheng Chen, W/Prof Kadambot Siddique, W/Prof Wallace Cowling
Model upgrade and development of input data Generating Tool for DAMCAT5 and RAINTANK2	2013	WA Dept of Water	Prof Neil Coles
Achieving least cost GHG abatement – opportunities in Australian grain farms		DAFF Filling Research Gap	Assist/Prof Marit Kragt
Genomic approaches to explore plant-insect interactions	2014	UWA UQ Bilateral Research Collaboration Award	W/Prof Karam Singh, Dr Lars Kamphuis, Assoc/Prof David Edwards, Dr Jacqueline Batley
Can frost tolerance be induced in wheat plants? A 100 million dollar question	2014	UWA UQ Bilateral Research Collaboration Award	W/Prof Stephen Powles, Assist/ Prof Roberto Busi, Prof John Christopher

Title	Funding period	Funding body	Supervisor/s
Management of insecticide resistance in RLEM and screening new MoA chemistry	2013-2014	University of Melbourne ex GRDC	Assoc/Prof Christian Nansen
Separating the adverse neurodevelopmental consequences of mechanical ventilation and postnatal steroids in preterm lambs	2013	NHMRC	Prof Jane Pillow, Assoc/Prof Dominique Blache, Prof Kurt Albertine, Dr Peter Noble, ASSOC/Prof Andrew Gill, ASSOC/Prof Mary Black, Dr Jonas Rubenson
Molecular mechanisms underlying extensive replacement of phospholipids by galactolipids and sulfolipids in *Hakea prostrata* during leaf development	2014-2016	ARC Discovery Projects	W/Prof Hans Lambers, Assoc/Prof Patrick Finnegan, Dr Patrick Giavalisco
Revealing novel mechanisms conferring evolution of resistance to glufosinate and glyphosate in Eleusine indica	2014-2016	ARC Discovery Projects	W/Prof Stephen Powles, Assoc/Prof Qin Yu
Understanding the biological functions of the karrikin-responsive signaling system of plants in growth, development and responses to the environment	2014-2016	ARC Discovery Projects	Dr Steven Smith
Dissecting novel roles of succinate dehydrogenase in stomatal aperture and root elongation in plants	2013-2017	ARC Future Fellowships	Dr Shaobai Huang
Evolutionary adaptation of the chemical language of nutrient acquisition strategies in higher plants	2014-2016	ARC Discovery Early Career Researcher Awards	Dr Margaretha van der Merwe
Nitrate and sulphate rich shrubs to reduce methane and increase productivity	2013-2015	CSIRO (ex DAFF Carbon Farming Futures Filling Research Gap)	Dr Hayley Norman, Prof Philip Vercoe, Prof Edward BarrettLennard, Assoc/Prof John Milton
Options for improved insecticide and fungicide use and canopy penetration in cereals and canola	2013-2015	GRDC	Assoc/Prof Christian Nansen
Long-term no-till farming systems	2013-2015	GRDC	Dr Kenneth Flower
Phenotyping and simulation of barley root architecture for edaphic stress adaption	2014-2015	Group of Eight DAAD German Research Cooperation	W/Prof Zed Rengel, Dr Johannes Postma, Dr Yinglong Chen

New PhD research students

During 2013, 13 new PhD students joined the disciplines of agriculture and related areas at UWA and commenced their studies.

Name	Topic	School	Supervisor(s)	Funding Body
Mr Bidhyut Banik	The mechanism of antimethanogenic potential in *Biserrula pelecinus*	Animal Biology, Plant Biology and IOA	Prof William Erskine, Assist/Prof Zoey Durrmic, Dr Clinton Revell	UPA
Ms Rasika Kankanamalage	Racial status of Pseudocercosporella capsellae in Western Australia, the identity and mechanisms of host resistance in oilseed Brassica	Plant Biology and IOA	W/Prof Martin Barbetti, Dr Mingpei You	UWA SIRF
Ms Yupin Li	Pythium root rot of Phaseolus bean – interactions of host resistance with water availability	Plant Biology and IOA	Prof Martin Barbetti, Dr Mingpei You, W/Prof Tim Colmer	IPRS
Mr Hieu Sy Tran	Black spot disease complex in field pea – pathogens involved and interactions with host resistance	Plant Biology and IOA	Prof Martin Barbetti, Dr Mingpei You, Prof Tanveer Khan	AusAID Scholarship
Ms Louise Fisk	The balance between microbial nitrification and nitrogen immobilisation rates and variation in a Western Australian semiarid soil	Earth and Environment and IOA	Prof Dan Murphy, Assoc/Prof Louise Barton	APA; UWA Establishment/ Relocation Award UWA Safety-Net Top-Up Scholarship
Mr Habtamu Ayalew Tamir	Genetic analysis of drought resistance in bread wheat *(Triticum eastivum.L)*	Plant Biology and IOA	Assoc/Prof Guijun Yan, Dr Xuanli Ma	AusAID Scholarship
Ms Myrtille Lacoste	Understanding the strategies of outstanding performers in dryland farming enterprises	Plant Biology and IOA	Dr Ken Flower, W/Prof Stephen Powles	GRDC
Ms Louise Blackmore	Achieving joint carbon and biodiversity outcomes in Australia: social and economic dimensions	SARE and IOA	Prof Steven Schilizzi, Assist/Prof Marit Kragt, Assist/Prof Abbie Rogers	APA National Environmental Research Program – Environmental Decisions (NERP-ED) Top-Up Scholarship
Mr Benjamin Congdon	Unravelling the complex factors that drive pea seed-borne mosaic virus epidemics in peas and development of an innovative predictive model	Plant Biology and IOA	Prof Roger Jones, Assoc/Prof Michael Renton	ARC Linkage Project
Ms Suzanne Orchard	Fine endophytic mycorrhizal fungi in pasture plant species	Plant Biology and IOA	Assoc/Prof Megan Ryan, Assist/Prof Rachel Standish	APA Henry Schapper Postgraduate Scholarship MLA Scholarship
Ms Asha Gunawardena	Optimal use of policy instruments to control waste water pollution in Kelani River in Sri Lanka	ARE and IOA	Prof Ben White, Assist/Prof Ram Pandit, Assoc/Prof Hailu Atakelty	Endeavour Postgraduate Award
Ms Olive Onyemaobi	Molecular basis of drought tolerance in wheat	Plant Biology and IOA	Assoc/Prof Guijun Yan, Dr Xuanlin Ma, W/Prof Kadambot Siddique	Self-funded
Ms Gayle Somerville	Herbicide resistance modelling	Plant Biology and IOA	Assoc/Prof Michael Renton, W/Prof Stephen Powles	APA

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The Program leaders and Deputy leaders co-ordinate research, development and related activities in their respective areas.

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Prof Daniel Murphy (from August)
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Rural Economy, Policy and Development

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Deputy Leader: Position vacant

Education, Outreach and Technology Exchange

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Deputy Leader: Position vacant

Animal Production Systems

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Deputy Leader: W/Prof Graeme Martin
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Plant Production Systems

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Executive Management Board (EMB)

The Institute is governed by its Executive Management Board with the Deputy Vice Chancellor (Research) as Chair. The Board consists of representatives from relevant schools within UWA's Faculty of Science and other faculties, the IOA Director and on a rotational basis a representative from relevant Research Centres.

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Industry Advisory Board (IAB)

The IAB provides the Institute with industry interaction, advice and feedback. IAB members represent a cross-section of agricultural industries and natural resource management areas.

Mr Bruce Piper
(until May 2013)
Dr Terry Enright (Chair)
(since June 2013)
Director of Livecorp; Director of Grain Producers Australia

Mr Neil Young
Farmer

Mr Rod Birch
Farmer

Mr Philip Gardiner
Farmer

Mr David Fienberg
Managing Director, Australasian Lupin Processing, CBH

Dr Jim Fortune
Agricultural Consultant

Dr Dawson Bradford
Farmer, Chair of Lambex, and Chairman, WAMMCO

Ms Verity Klemm
Strategic Project Manager, Science and Planning Directorate, Department of Water

Dr Don McFarlane
(until October 2013)
CSIRO, WA Co-ordinator: Water for a Healthy Country Flagship

Dr Michael Robertson
(from November 2013)
CSIRO, Deputy Chief, Ecosystem Sciences

Mr Terry Hill
Regional Services Director, DAFWA

Mr Ben Sudlow
Manager, Fertiliser Sales and Marketing, CSBP

Mr Andrew Ritchie
(until July 2013)
President of the Australian Association of Agricultural Consultants

Mr Shane Sander
(from August 2013)
Founder of Agvise Management Consultants

W/Prof Tony O'Donnell
Dean, Faculty of Science, UWA

W/Prof Kadambot Siddique, AM, FTSE, FAIA
Hackett Professor of Agriculture Chair and Director, IOA, UWA

Mr Michael Perry
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IOA Members 2013

IOA members comprise relevant staff and adjunct staff from UWA who have accepted the invitation to join the Institute as members.

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UWA IOA Publications 2013

Refereed journals

1. Ahmad I, Basra SMA, Afzal I, Farooq M and Wahid A (2013). Stand establishment improvement in spring maize through exogenous application of ascorbic acid, salicylic acid and hydrogen peroxide. *International Journal of Agriculture and Biology* **15:** 95-100.
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Acronyms

AAAC	Australian Association of Agricultural Consultants
ACPFG	Australian Centre for Plant Functional Genomics
ACIAR	The Australian Centre for International Agricultural Research
AHRI	The Australian Herbicide Resistance Initiative (at UWA)
AEC	Animal Ethics Committee
ACIAR	The Australian Centre for International Agricultural Research
ANU	Australian National University
APA	Australian Postgraduate Award
APL	Australian Pork Limited
ARC	Australian Research Council
ASGGN	Animal Selection, Genetics and Genomics Network
AusAID	Australian Government's overseas aid program
AWI	1) Animal Welfare Institute
	2) Australian Wool Industry
BGI	Beijing Genomics Institute, China
CAAS	The Chinese Academy of Agricultural Sciences
CAP	covered anaerobic pond
CBH	Corporate Bulk Handling Group (company)
CEED	Centre of Excellence for Environmental Decisions (an ARC partnership between UQ, ANU, The University of Melbourne, RMIT University, UWA, Imperial College London, US Geological Society, CSIRO, The Hebrew University of Jerusalem.)
CEEP	Centre for Environmental and Economic Policy (at UWA)
CENRM	UWA Albany's Centre of Excellence in Natural Resource Management
CGE	Clean, green, ethical
CIBER	Centre for Integrative Bee Research (at UWA)
CLIMA	Centre for Legumes in Mediterranean Agriculture (at UWA)
COGGO	Council of Grain Growers Organisation
CSBP Ltd	The Chemicals and Fertilisers business units of Wesfarmers Chemicals, Energy and Fertilisers, a division of Wesfarmers Limited
CSIRO	Commonwealth Scientific & Industrial Research Organization
CSU	Charles Sturt University

DA	Department of Agriculture (formerly DAFF, Department of Agriculture Fisheries and Forestry)
DAFFQ	Department of Agriculture, Fisheries and Forestry, Queensland
DCCEE	Department of Climate Change and Energy Efficiency
DAFWA	Department of Food and Agriculture Western Australia
DEEDI	Department of Employment, Economic Development and Innovation, Queensland
DFAT	Department of Foreign Affairs and Trade (incorporates AusAID)
DIIR	Department of Innovation, Industry and Regional Development
EERIE	Ecosystem Restoration and Intervention Ecology
ERISS	Environmental Research Institute of the Supervising Scientist
FAO	Food and Agriculture Organization (of the United Nations)
FFI CRC	Future Farm Industries Co-operative Research Centre
GHG	Greenhouse Gas
GGA	Grower Group Alliance
GIS	Geographic Information Systems
GRA	Global Research Alliance
GRDC	Grains Research and Development Corporation
HSD	Harrington Seed Destructor
ICARDA	International Centre for Agriculture Research in the Dry Areas, Syria
ICPBER	International Centre of Plant Breeding Education and Research (at UWA)
ICRAF	World Agroforestry Centre, Nairobi
INRA	National Institute for Agricultural Research; Paris, France
IOA	The UWA Institute of Agriculture
IPM	Integrated Pest Management
IPRS	International Postgraduate Research Scholarships
IRRI	International Rice Research Institute, Philippines
ISI	Institute for Scientific Information
KAU	Kerala Agricultural University, India
LCA	Life Cycle Assessment
LIEF	Linkage Infrastructure, Equipment and Facilities (funding scheme)
LZU	Lanzhou University, China

MLA	Meat and Livestock Australia
NAWFA	Northern Australia Water Futures Assessment
NCGR	National Centre for Genome Resources, USA
NSW-DPI	New South Wales Department of Primary Industries
NWAFU	Northwest Agricultural and Forest University (in China)
OECD	Organisation for Economic Cooperation and Development.
IPPC	Intergovernmental Panel for Climate Change
PEC	Perth Education City
QPCR	Quantitative Polymerase Chain Reaction
QTL	Quantitative Trait Locus
RIRDC	Rural Industries Research and Development Corporation
RMIT	Royal Melbourne institute of Technology
RSPCA	Royal Society for the Prevention of Cruelty To Animals
SARDI	South Australian Research and Development Institute
SARE	School of Agricultural and Resource Economics (at UWA)

SEWPAC	Department of Sustainability, Environment, Water, Population and Communities
SCAU	South China Agricultural University
SIRF	UWA Scholarships for International Research Fees
SoL	Seeds of Life (project in Timor-Leste)
UA	University of Adelaide
UIS	University International Stipend
UNE	University of New England
UoW	University of Wollongong
UPA	University Postgraduate Awards
UPAIS	University Postgraduate Award (International Students)
UWA	The University of Western Australia
UQ	University of Queensland
WAIMR	Western Australian Institute of Medical Research
WANTFA	Western Australian No-Tillage Farmers Association
WAPPA	Western Australian Pork Producers' Association
WUN	World Universities Network

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