



Primary Industries
Innovation Centre



Industry &
Investment

Primary Industries Innovation Centre

Annual Report 2009



The Primary Industries Innovation Centre is a joint venture partnership between the University of New England and Industry & Investment NSW and incorporates the National Centre for Rural Greenhouse Gas Research

Primary Industries Innovation Centre Annual Report 2009

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ACRONYMS

ACIAR - Australian Centre for International Agricultural Research
CCRSPI - Climate Change Research Strategy for Primary Industries
DAFF - Department of Agriculture, Fisheries and Forestry
GRDC - Grains Research and Development Corporation
I&I NSW - Industry and Investment NSW
MLA - Meat and Livestock Australia
NCRGGR - National Centre for Rural Greenhouse Gas Research
PIIC - Primary Industries Innovation Centre
RCG - Research Coordination Group
SARDI - South Australian Research and Development Institute
SRDC - Sugar Research and Development Corporation
UNE - University of New England



Professor Ray Cooksey

Chair, Board of Management, PIIC
Acting Pro-Vice Chancellor, Research
University of New England

Introduction

I am pleased to present the 2009 Annual Report of the Primary Industries Innovation Centre (PIIC) which also incorporates the National Centre for Rural Greenhouse Gas Research (NCRGGR). PIIC was established to facilitate co-operation between the University of New England (UNE) and Industry and Investment NSW (I&I NSW), with a focus on the New England and North West region of the state.

The highlight of the year has been the appointment of Professor Annette Cowie as the foundation Director of NCRGGR. Professor Cowie has strong credentials to direct the Centre's future research. She is an international expert in greenhouse gas systems and has explored in-depth the opportunities for rural industries from emissions trading. Professor Cowie's experience as a senior research scientist with I&I NSW, along with her strong leadership skills, stand her in good stead for this role. NCRGGR will apply a "whole systems approach" to the task of reducing greenhouse gas emissions and will draw on the work of researchers in fundamental areas of science from throughout the University and I&I NSW.

The initial focus of NCRGGR will be on reducing greenhouse emissions from agriculture, sequestering carbon in soils and developing next generation biofuels. The Centre

has secured \$1.58 million in funding from the Federal Government's Climate Change Research Program to study genetic variation in beef cattle herds and techniques to reduce methane production in ruminants. Meat and Livestock Australia is supplementing these studies with a further \$120,000. A project to assess the potential to sequester carbon in agricultural systems in NSW has received \$1.05 million over three years through the Federal Department of Agriculture, Forestry and Fisheries' Soil Carbon Research Program. This project also received \$400,000 in funding from the Grains Research and Development Corporation (GRDC). The centre's climate change research program will investigate options for mitigating nitrous oxide emissions from cropping soils in North-West NSW. The project will receive \$450,000 in funding from GRDC.

Professor David Herridge joined PIIC in 2009 after a distinguished career in soil biology with I&I NSW. David will manage a Soil Productivity Unit within PIIC. He is well placed to enhance collaboration and research relationships at national and international levels between government, universities and industry partners. David has significantly strengthened PIIC's international profile and this year's annual report includes a special section to feature our "International Outreach".

Throughout 2009, PIIC carried out research projects in a number of areas relevant to its strategic mission. Some of projects have important international connections and implications in countries like Cambodia, Myanmar and Vietnam and deal with issues such as food and crop production, health and security. Other projects have included research into biofuel production, reduction of methane and nitrous oxide emissions and carbon sequestration in soils.

Another highlight of 2009 was the graduation of PIIC's first PhD student, John Wilkie; his thesis was entitled Aspects of Flowering and Flushing of Mango and Macadamia. There are currently a further 12 PhD students continuing their PhD research in conjunction with PIIC in areas ranging from farming systems and functional foods to crop production, soil health and climate change.

As Chair of the PIIC Board of Management, I acknowledge the outstanding efforts of the Board of Management and the Research Coordination Group. Continuing acknowledgement must be made of the efforts of the Director, Professor Bob Martin, and his role in producing this report, which I invite you to examine. You can also keep up to date with the activities of PIIC by visiting our web site at: <http://www.une.edu.au/piic/>

Board of Management

The PIIC Board consists of two members appointed by UNE and two appointed by I&I NSW and is intended to have a rotating Chair between UNE and I&I NSW on an annual basis. The Board determines the broad policies and research priorities of the Centre; potential collaborative projects; allocation of staff and resources; funding sources including government funded research grants. The Board also receives and considers reports from the Director about the Centre's performance; promotes cooperation between the Parties; approves communications and public relations strategies including guidelines for public announcements.

Professor Ray Cooksey, Acting Pro-Vice Chancellor, Research, University of New England, chaired the Board during 2009. Membership of the Board during 2009 was:

- Professor Ray Cooksey, Acting Pro Vice-Chancellor Research, UNE (Chair);
- Ms Renata Brooks, Executive Director, Science, Innovation and Performance, Primary Industries, I&I NSW;
- Professor Margaret Sedgley, Pro Vice-Chancellor and Dean, Faculty of Arts and Sciences, UNE;
- Ms Helen Scott-Orr, Director Health Science and Strategic Alliances, I&I NSW (Replaced by Mr Rob Young, Director Climate and Water Research, I&I NSW on Helen's retirement in July 2009).

Research Coordination Group

The Research Coordination Group (RCG) advises the Director and oversees the progress, direction and development of the Centre and consists of the Director (chair) and representatives of UNE and I&I NSW. The RCG facilitates the establishment of new projects and monitors project implementation, review and evaluation. It advises the Board on potential collaborative projects; allocation of staff and resources; funding services for projects including government funded research grants.

The RCG advises on dissemination and adoption of research outcomes; reviews general methodology and task performance of research and extension projects; assists in the development of an annual plan; facilitates science communication and extension of the work of the Centre; advises on the integration of training, research and extension activities; and provides an annual performance appraisal of the Activities of the Centre to the Board. The membership of the RCG in 2009 was:

- Professor Bob Martin, Director, PIIC
- Professor Annette Cowie, Director NCRGGR, PIIC
- Dr Chris Fellows, Senior Lecturer, School of Science and Technology, UNE
- Professor John Gibson, Director The Institute for Genetics and Bioinformatics, UNE
- Dr Georgina Kelly, Research Leader, Climate in Primary Industries, I&I NSW
- Mr Bill McKiernan, Research Leader Animal Production, Director Armidale Beef Industry Centre and Glen Innes, I&I NSW

- Professor Paul Martin, Director Australian Centre for Agriculture and Law, UNE
- Mr John Sykes, Research Leader, Farming Systems North, Director, Tamworth Agricultural Institute I&I NSW
- Professor Iain Young, Head, School of Environment and Rural Sciences, UNE

Strategic Plan 2007-2012

Values

- Adherence to the highest standards of professional conduct and integrity;
- Compliance with accepted ethical standards and guidelines for research;
- Ensuring the safety of all those associated with the Centre's activities;
- Adherence to contractual obligations project management protocols;
- Research results and methods open to scrutiny by peers and public;
- Protection of confidentiality and ownership of intellectual property

Performance Indicators

- Number of new collaborative projects involving UNE and I&I NSW staff;
- Number of jointly supervised post-graduate students;
- Number of I&I NSW staff involved in under-graduate teaching;
- Number of joint scientific publications and extension communications;
- Value of external funds attracted to address PIIC strategic priorities;
- Stakeholder and client satisfaction with PIIC performance and profile.

Vision

By 2012, the PIIC will be recognised regionally, nationally and globally as a premier deliverer of primary industries research, extension and training outcomes.

Mission

The Primary Industries Innovation Centre (PIIC) was created to unite the basic research and teaching capabilities of UNE with the applied research and extension capabilities of I&I NSW to provide innovative solutions to priority primary industries issues and problems.

Key Result Area 1

New technologies, new industries and new value-added products developed in response to market demands and regional resource capabilities.

Strategies

- 1.1 Establish a broad-based biotechnology and molecular biology facility to provide solutions for human and environmental health
- 1.2 Develop functional foods for improved human health and disease prevention from regional crop and livestock products
- 1.3 Develop tools for the implementation of a sustainable and regionally based biofuels industry
- 1.4 Develop crop, pasture and livestock technologies that capture carbon, reduce emissions and are adapted to climate change
- 1.5 Develop and promote farming systems that are water-efficient and that conserve the natural resource base
- 1.6 Develop new crop, pasture and livestock management systems for increased productivity and profitability

Key Result Area 2

Validated solutions to environmental, economic and social constraints to practice change consistent with government and community expectations .

Strategies

- 2.1 Generate a policy environment that encourages moves towards sustainable rural communities
- 2.2 Develop integrated systems for management of weeds, diseases and insect pests
- 2.3 Validate the science underpinning new technologies and proposed practice changes for natural resource management
- 2.4 Measure and monitor the environmental, economic, social and legal risks impacting on adoption of new technologies
- 2.5 Develop innovative approaches to coping with extreme climatic events and incursions by exotic weeds, diseases and pests
- 2.6 Provide policy and risk management solutions for drought, fire, invasive weeds, pests and diseases in a climate change scenario



Functional foods for improved human health.

Key Result Area 3

New ways of delivering, extending and commercialising new technologies and practices for a changing socio-economic and physical environment.

Strategies

- 3.1 Identify and provide solutions to socio-economic and regional infrastructure constraints to sustainable development and diversification of primary industries
- 3.2 Develop an integrated framework for primary industries education and training to meet the future needs of landholders, advisers, regulators, researchers and the wider community
- 3.3 Provide advice and undertake research and development on how to prioritise, develop and deliver innovations to primary industries
- 3.4 Analyse the socio-economic viability of value chains and value-adding for existing and new regional primary industry products

Key Result Area 4

Delivery of world class research, development, education and extension outcomes in primary industries innovation and sustainable development through international collaboration.

Strategies

- 4.1 Initiate international research and development partnerships to synergise creativity and inventiveness in primary industries innovation
- 4.2 Extend primary industries research and extension expertise to the Asia-Pacific Region to improve food security, reduce poverty and to address global environmental challenges
- 4.3 Recruit international students to PIIC through development of international partnerships and promotion of PIIC expertise
- 4.4 Develop strategic alliances with tertiary education providers in developing countries to improve learning outcomes for sustainable land management practices
- 4.5 Selectively build international collaborations with individuals and entities strategically aligned with PIIC's vision and positioning

Key Result Area 5

A seamless relationship between UNE and I&I NSW that promotes long-term strategic collaboration to achieve the vision and mission of the PIIC.

Strategies

- 5.1 Create and jointly operate facilities that fill existing gaps in capacity or improve efficiency of operation of existing capacity
- 5.2 Identify and execute co-location of staff that will promote greater synergy and collaboration
- 5.3 Develop and execute plans for co-investment in new staff that will promote greater synergy and collaboration
- 5.4 Create awareness and incentives to stimulate UNE and I&I NSW staff to work towards PIIC goals and source external funding
- 5.5 Promote PIIC externally as the leading provider of research in the area of primary industries innovation



Yadunath Bajgai with the I&J LECO carbon and nitrogen analyser installed in the new soil carbon laboratory at UNE.

National Centre for Rural Greenhouse Gas Research



Prof. Annette Cowie, Director NCRGGR

The National Centre for Rural Greenhouse Gas Research was launched by Minister for Primary Industries Ian Macdonald on 25 May 2009. The Minister also announced the appointment of Professor Annette Cowie as the inaugural director of NCRGGR.

The issue

Agriculture is responsible for 16 percent of Australia's greenhouse gas emissions. As such, it is the second largest greenhouse gas emitter, behind stationary energy (50 per cent).

Increases in greenhouse gases in the atmosphere are causing climate changes, which in turn impact on agriculture and other primary industries.

Reducing emissions, as part of an international approach, is expected to reduce the severity of climate change impacts in Australia. All NSW primary industry sectors have a role to play in reducing emissions. Research is required to enhance available options.

However successful we are in reducing emissions, some climate change is inevitable because of the lag in the effects of greenhouse gases already in the atmosphere. Primary industries must therefore adapt to those inevitable changes. Research is needed to quantify the expected biophysical and socio-economic changes, and develop response strategies.

The response

The National Centre for Rural Greenhouse Gas Research is a new joint initiative between NSW Industry and Investment (I&I) and the University of New England (UNE), working to provide solutions to the challenges posed to primary industries by climate change, and to take advantage of the opportunities that climate change presents. The Centre is based at UNE, Armidale, with activities undertaken throughout NSW. The centre has also established extensive national and international collaborative links.

Current projects

The Centre is undertaking research and delivering solutions on a range of key issues – including reducing emissions of methane from ruminant livestock, and nitrous oxide from cropping soils; increasing carbon sequestration in agricultural and forestry systems; managing risk associated with seasonal climate variability; and developing technologies for second generation biofuels from woody biomass.

The Centre will also educate and inform primary producers about the projected impacts of climate change and the challenges and opportunities it poses, as well as informing the debate on key policy issues, such as emission trading.

Research priorities

Research priorities for the National Centre for Rural Greenhouse Gas Research are articulated as:

Assessing the impacts of climate change

Better understanding the likely impact of climate change on key primary industries, at the regional level, through:

- scenario modelling of regional impacts of climate change;
- development of a Geographic Information System (GIS)-based tool for assessing the risk of climate change;
- decision support systems to assist primary industries to cope with climate variability;
- assessment of the coping range of key systems to determine likely impacts of projected changes in climate extremes and the effectiveness of adaptation strategies;
- assessment of the socio-economic impacts of climate change.

Climate change mitigation

Developing options for primary industries to mitigate emissions through:

- reducing emissions (e.g. methane from livestock and nitrous oxide from cropping soils);
- sequestering carbon (e.g. strategic inclusion of woody plants in agricultural systems, management of soil organic matter in cropping and grazing lands, application of biochar);
- substituting bioenergy for fossil fuels (e.g. biofuels from forestry residues);
- developing the supporting science to facilitate emissions trading (e.g. data on soil carbon dynamics for input to models for greenhouse gas accounting);
- decision support systems to assist primary producers to assess alternative mitigation options.

In developing agricultural and forestry systems to help mitigate climate change, the Centre will consider three key criteria:

1. life-cycle greenhouse gas and energy balance to ensure systems deliver net benefits;
2. sustainability of production systems, including broader impacts on the environment; and
3. adaptation capacity of new systems.

Climate change adaptation

Developing capacity for the primary industry sector to adapt to climate change and, where possible, take advantage of any opportunities that arise, through:

- developing resilient agricultural and forestry production systems with increased capacity to cope with: elevated atmospheric CO₂; increased climate variability and more extreme events; changes in climate parameters; and indirect impacts (e.g. fire, pests and diseases) anticipated under climate change;
- researching sustainable management of natural systems, to ensure that they are both ecologically healthy and economically productive under the predicted impacts of climate change.

Centre activities in 2009 have focused largely on climate change mitigation.

Soil Productivity Unit



Professor David Herridge (pictured) joined PIIC in 2009 after a distinguished career in soil biology with I&J NSW.

David will manage a Soil Productivity Unit within PIIC. He is well placed to enhance collaboration and research relationships at national and international levels between government and industry partners, the I&J NSW and the University of New England.

David's current project involvements include:

- ACIAR SMCN-2006-013 – 'Increasing food security and farmer livelihoods through enhanced legume cultivation in the Central Dry Zone of Myanmar'.
- GRDC – Nitrogen and legumes in farming systems: a compendium and interactive excel-based packages for improved nitrogen management.
- GRDC – 'Mitigating N₂O emissions in rainfed and irrigated farming systems through N₂-fixing legumes and precision sowing technology'.

Professor Herridge will also coordinate the GRDC Next Generation Beneficial Microbes Collaborative research and Development program. This program seeks to identify new approaches and technologies that will provide the next generation of beneficial microbial products for Australian farmers.

Primary Industries Innovation Research

Enhancing production and marketing of maize and soybean in north-western Cambodia

Project leader: Professor Bob Martin

ASEM/2006/130 commenced in May 2008. The overarching aim of the project is to improve the functioning of the production – marketing system for maize and soybean in north-western Cambodia as a key to increasing cash income, sustainable growth and poverty reduction for smallholder farmers. In north-western NSW, the aim is to develop strategies for adaptation of farming systems to climate variability and climate change.

Down-scaled future climate scenarios were completed for sorghum in NW NSW and APSIM simulation runs were completed for farming systems options for sorghum. Economic analysis of farmer preferences were completed and submitted for presentation/publication in the Australian Summer Grains Conference June 2010. Linear programming will be used in conjunction with @Risk to analyse the outcomes of farming systems options for adaptation to climate change.

In Cambodia, the trial and demonstration program in 2009 included improved varieties, rhizobium inoculation of legumes and nitrogen nutrition of maize. In 2009, feedback from farmers highlighted the need for trials on herbicides for weed control in maize and soybean because the cost of labour had become too great to allow for hand-weeding. The production technologies being evaluated

now include: improved varieties, rhizobium inoculation, nitrogen nutrition of maize, crop rotation, reduced tillage, integrated pest management and weed management.

Farmer workshops investigated key socio-economic issues related to adoption of the improved crop technologies - the major issue in 2009 has been the increasing cost of farm labour. In June 2009 the village workshops developed partial budgets for return on investment for the application of nitrogen fertilizer to maize and inoculation of legume seeds with rhizobium. In October 2009 further partial budgets were developed for weeding of crops - hand weeding versus chemical sprays.

A review of marketing arrangements in northwest Cambodia revealed there is essentially a single buyer for upland crops in the region (CP Foods, Thailand). Thus, Professor Spriggs provided assistance to establish the Northwest Agricultural Marketing Association (NAMA) to improve the marketing arrangements in the region. NAMA is anchored by three major silos (Pailin, Kamrieng and Malai) which are important potential crop marketing hubs for inputs, outputs and communications in the region. An action plan was developed with NAMA with two components: (1) to help NAMA

with export market development and (2) to help NAMA develop its vision for the future.

A SMS service was developed based on a simple, robust framework for contact dissemination which includes the potential for peer-submitted and peer-reviewed content. A prototype system was completed in January 2010, using a more modular architecture and popular open-source software solutions. Field research in February 2010 resulted in a revised focus for the system towards mapping and disseminating information about market players relevant to users. The FrontlineSMS server is being hosted at the Royal University of Phnom Penh (RUPP).

Value chain mapping has been completed including a grain trader survey in 2009. These data will add significantly to the knowledge about the farmer/ grain trader relationships. A social network analysis (SNA) was carried out to identify the key actors in the farmer/ grain trader network. The main immediate opportunities to address constraints in the value chain include the creation of a farmer's association, a grain trader association and the investigation of grain storage facilities at the farmer and trader level. A farmer association has been established by the CARE Pailin team in cooperation with the local Provincial

Department of Agriculture (PDA). Preliminary work has also been done to establish a grain trader (middleman) association. Planning has been in cooperation with the Pailin Department of Commerce (DoC).

The Suranaree University of Technology, Nakhon Ratchasima, North-East Thailand was identified as a source of liquid rhizobium and supplies were obtained to provide farmers with inoculants to try out in their own fields in EWS 2010. A TOT activity was developed to assist with the roll out of the technology.

An illustrated children's book "Jorani and the Green Vegetable Bugs" was published in Khmer language to teach children about integrated pest management (IPM) in upland crops. A pilot activity involved introducing the concept to school directors and teachers; development of a teacher guide; implementation in schools; celebration and public launch. The pilot was a success and further units are being considered for the Life Skills program. The concept will be presented to the MoEYS for endorsement and roll-out to primary schools in Cambodia. Negotiations are now underway to publish a Lao version of the book in collaboration with the Lao/Japanese NGO "Action with Lao Children."



Farmer socio-economic workshop in Smlaut District NW Cambodia.

Increasing food security and farmer livelihoods through enhanced legume cultivation in the Central Dry Zone of Myanmar

Project leader: Professor David Herridge

This 4-year project (2007–10), funded by the Australian Centre for International Agricultural Research (ACIAR), aims to improve production of groundnut, pigeonpea and chickpea in the Central Dry Zone of Myanmar through varietal improvement and supply of high-quality rhizobial inoculants.

Legumes are major crops in Myanmar with about 3–4 million t grain produced annually from 3–4 million ha. Principal species are pigeonpea (*Cajanus cajan*), green gram (*Vigna radiata*), black gram (*Vigna mungo*), chickpea (*Cicer arietinum*) and groundnut (*Arachis hypogaea*). The crops are primarily grown by small-holder farmers with minimal inputs of fertilisers, pesticides and herbicides. Yields are low because of the lack of nutrient inputs, improved high-yielding varieties and limited options for pest and disease management. Experimental and anecdotal evidence suggests also that productivity and yield may be further diminished because of poor nodulation resulting in crop nitrogen (N) deficiencies. In the past, Myanmar farmers routinely used rhizobial inoculants when sowing legumes, but the practice is currently not widespread. The Department of Agricultural Research (DAR), Yezin, is responsible for producing inoculants in Myanmar. Production peaked during the 1980s at 600–700,000 packets annually. Current production is <30,000 packets, due to limitations in the whole supply chain from production and quality assurance (QA) to distribution to demand. Myanmar farmers use nitrogenous (N) fertilisers sparingly, particularly on legume crops. Thus, N deficiencies of the legumes induced by low



After a long day in the Central Dry Zone, Myanmar.

nodulation are not remedied by inputs of fertiliser N and the value of lost production could exceed \$100 million annually.

During 2009, substantial progress was made to improve the quality of inoculants produced by DAR through training (post-graduate and short-term), infrastructure development (laboratory equipment, plant-growth facility, building and laboratory maintenance) and laboratory procedural changes (e.g. broth dilution and solid-state fermentation, plant-infection most-probable number counting). Daw Maw Maw Than from the DAR inoculant production unit, Yezin, submitted her PhD thesis on chickpea rhizobia to the Yezin Agricultural University, following completion of a 4-month 'sandwich program' at the Suranaree University of Technology, Thailand, during the latter part of 2008. Also in late 2008, Daw Thi Thi Aung, inoculant production unit, Yezin, commenced her 3-year full-time PhD program on co-inoculants for soybean at the Suranaree University of Technology, Thailand.

Replacing fertiliser N with rhizobial inoculants for legumes in Vietnam for greater farm profitability and environmental benefits

Project leader: Professor David Herridge

This 3-year project, funded by AusAID through the CARD (Collaboration for Agriculture and Rural Development) program in Vietnam, aims to increase production and use of high-quality legume inoculants in the country through improved inoculant production capacity and quality assurance (QA), inoculant RandD and effective on-farm extension programs. Collaborating institutes are the National Soils and Fertilisers Institute, Hanoi, (SFI), the Research Institute for Oil and Oil Plants, HCM City, (IOOP) and the Institute of Agricultural Science, HCM City, (IAS). The Vietnam agricultural extension service, MARD (Ministry for Agriculture and Rural Development), and a number of private sector companies are also involved in extension and marketing. With the private sector companies, the aim was that they would scale-up inoculant production and progressively take over supply as the technology and markets were developed.

The context of the project is that farmers in Vietnam currently fertilise legumes such as soybean and groundnut with N, rather than inoculate with rhizobia. Replacing fertiliser N with rhizobial inoculants would save Vietnamese farmers A\$50-60 million annually in input costs and, at the same time, help facilitate the desired expansion in legume production. There would also be positive environmental outcomes.

During 2009, all three institutes continued to be engaged in training and research on all aspects of inoculant production, viz fermentation, carriers, rhizobial strains, quality assurance etc. Two milestone reports were submitted to CARD – Capacity Improvement Report and the High Quality Inoculants Technical Report.

The major experimental and extension activities were essentially completed during 2009. During the life of the project, a total of 36 replicated, multi-treatment research and 168 unreplicated, single treatment demonstration field trials were conducted in the major legume-production areas of Vietnam. The Australian rhizobial strains were the most effective in terms of nodulation, biomass yield and grain yield. Compared with the uninoculated control, strains CB1809 and NC92 increased nodulation of soybean and groundnut, respectively, by an average of 58%, biomass yield by 30% and grain yield by 29%. Economic analysis of the demonstration trials indicated an average increase in farmer profits of 4,500,000 VND/ha, through a combination of reduced inputs of fertiliser N and increase grain yields. The trials also proved effective for training and extension purposes with 3400+ person visits to the sites and evidence from farmer surveys of dramatically increased knowledge of inoculants.



Sowing soybean rhizobial inoculant trials in Tra Vinh province, Mekong Delta, Vietnam.

Consultancy to the GRDC Beneficial Microbes Program - progressing new microbial products for Australian grain production to commercialisation

Project leader: Professor David Herridge

Australian farmers are keen to reduce on-farm chemical inputs and replace them with biological alternatives. There is potential to increase the occurrence of specific, beneficial microorganisms in the soil by applying them as inoculants, similar to the way that rhizobia, a bacteria, is applied to the soil with sown legume seed.

Early in 2009, the GRDC invited expressions of interest for research to develop and commercialise new microbial products for Australian agriculture. Eleven Expressions of Interest were evaluated and the four successful tenderers – Flinders University (Adelaide), CSIRO Entomology (Adelaide), SARDI (Adelaide) and Murdoch University (Perth) – were notified by the end of May 2009. This consultancy for Professor Herridge to coordinate the project commenced 1st July 2009

and has a projected completion date of 30th June 2011.

The project aims to develop the next generation of beneficial microbes, including both bacteria and fungi and which may have one of a number of modes of action, eg plant disease suppression through production of antibiotics or other means, plant root stimulation through production of phytohormones etc. For registration of the disease suppressing microbes through APVMA, there also needs to be substantial data on efficacy and modes-of-action, the ecology of the microbes once introduced into the soil and related to the target host plant and existing soil biota, toxicology, and, finally, commercial manufacture, QA and formulation. Some of this will be generated with current project funding with additional funding sought when and where required.

The first of the project outputs will be the identification of a suite (5-10) of beneficial microbes for potential commercialisation with associated data on efficacy, mode-of-action, laboratory-scale fermentation and product formulation. The principal focus of Flinders University, SARDI and CSIRO is disease suppression,

in particular the diseases *Rhizoctonia*, *Pythium* and *Fusarium* of cereals. For Murdoch U, the focus is general plant growth promotion and includes both cereals and legumes.

The second project output will be the development of tools for screening of beneficial microbes and for tracking and documenting the ecological interactions between the beneficial microbes, the target host plants, existing soil biota and the target pathogens (in the case of disease suppressive beneficial microbes). It is envisioned that the new tools will streamline the isolation of other beneficial microbes in the future and potentially provide sources of novel bio-active compounds. Activities under this output will essentially be conducted by CSIRO.

Building capacity for the study and use of beneficial microbes in Australia's grains industry through post-graduate training and strong inter-institutional collaboration within the framework of the BM Program will be the third project output. Four GRDC-funded PhD scholarships are to be associated with the project, one for each of Flinders U, SARDI, CSIRO and Murdoch University.

Two project coordination meetings were held during 2009 in which the specific project objectives, outputs, structure and budget were set. The project commenced 1st October 2009 and is due for completion 30th June 2013.

Improving soybean and nitrogen management in subtropical NSW cane systems

Project leader: Dr Natalie Moore, I&J NSW Grafton

This project, in collaborator with Professor David Herridge, and funded by the Sugar Research and Development Corporation (SRDC) through the Grower Group Innovation Program aims to (i) provide information on residual N cycling following soybean rotations on different cane soil types in subtropical NSW, (ii) use this information to produce soil-specific fertiliser recommendations following soybean to achieve more efficient use of nitrogen fertiliser in NSW cane crops, and (iii) compare different methods for dealing with soybean crop residue in terms of cost in a subtropical environment.

The benefits of using legumes such as soybean and peanut as break crops in sugar cane monoculture on the wet tropical coast of Queensland are well documented with yield increases of the following cane crop in the order of 20–30%. In addition to reducing the levels of cane pests and diseases, soybean rotations also provide economic benefits from the harvested grain and economic and environmental

benefits from the N-rich residues reducing subsequent fertiliser N inputs. However, it has been observed that some cane growers in subtropical NSW may not realise the full benefits of the soybean rotation due to over fertilisation of the following cane crop whilst, in other situations, N stress has been observed in cane following a well-grown soybean crop.

During 2009, replicated field trials were established in each of the three sugar mill areas of NSW. Residual N cycling following soybean was assessed by measuring the contribution of the soybean crops through N₂ fixation (nodule assessment, biomass, grain yield, grain protein and 15_N analysis) and soil tests to determine plant-available and total soil N. Results indicate effective soybean nodulation at all sites with soybean shoot biomass ranging from 5.7 to 8.3 t dry matter/ha, soybean grain yields of 2.7 to 4.0 t/ha and grain protein levels of 37.5 to 44.4% (dry matter basis). The soybean Ndfa (nitrogen derived from the atmosphere) values ranged from 72 to 79% with, on average, 90 kg N fixed for each tonne grain produced. Residual soil mineral-N levels (0–90 cm depth) ranged from 50 to 260 kg/ha with soil organic carbons (0–25 cm depth) ranging from 1.9 to 2.9%.



Project leader Dr Natalie Moore sampling north coast soybean for nodules.

Various fertiliser N rates were applied to all Phase 1 cane crops after sowing in October-December 2009. The fertiliser rates ranged from zero to 196 kg of N/ha. Cane leaf analysis and sugar cane yield (tonnage and sugar yield) will be assessed during the next two years. The N response curves should allow current fertiliser N recommendations, developed for cane following fallowed land, to be revised to account for the N benefits of soybean.

Livestock data link project: Solutions to feedback

Project leader: Bill McKiernan, I&I NSW, Armidale

The objectives for the Meat and Livestock Australia (MLA) Livestock Data Link (LDL) program are as follows:

- Enhanced exchange and utilisation of information by businesses in the red meat industry
- Enhanced industry capacity for monitoring, benchmarking, planning and evaluation
- Maintain existing standards for data security and confidentiality, and simplicity of access and use
- Develop value-add services and programs
- Provide education and extension programs for industry use of integrated system

In order for MLA to meet these objectives, it needs to secure technology that will allow it to add value to existing data that will be utilised through the LDL program. MLA requires a technology supplier to build, develop and possibly maintain an extensive red meat and livestock industry "library" database, used primarily by producers of livestock in order for them to make productivity improvements, therefore improving the overall productivity of the red meat and livestock industry.

Rural Greenhouse Gas Research

Agricultural management to increase soil carbon

Project leader: Professor Annette Cowie, NCRGGR

The project aims to assess the impacts of changes in management on soil carbon in NSW cropping and grazing land. It is part of the National Soil Carbon Research Project that has been established under the Climate Change Research Program. The NSW Department of Environment, Climate Change and Water (DECCW) is collaborating with UNE and I&I NSW to undertake the project.

The project will assess the potential for agricultural land management practices (including emerging land use practices) to influence soil carbon, and assess factors that influence soil carbon distribution across the landscape. 800 sites will be sampled across central and northern NSW. The samples will be processed at UNE, and analyses undertaken at UNE and by CSIRO, to determine the total soil carbon content and the contribution from the labile and recalcitrant fractions. The data generated will be made available for development of soil carbon models to guide land management, and for emissions trading and GHG inventories. The project commenced in May 2009 and will be completed in June 2012.



Gropal Rizal preparing soil samples for carbon analysis.

Initial activities focussed on refinement of the sampling protocol and identification of the major land uses and soil types in each of the regions to be sampled. A minimum of 25 replicate sites that have been under the same management for at least the last ten years will be sampled for each land-use by soil type combination. In 2009 50 sites were sampled on vertosol soils in north western NSW, representative of irrigated cropland.

Discussions were initiated with landholders undertaking 'carbon farming practises' (e.g. natural sequence farming, biological farming) to identify sampling locations for these management strategies.

The I&I group based in Tamworth have commenced identification of suitable sites to test the influence of conventional tillage and minimal tillage practices on soil carbon, and to assess the impact of tropical pasture grasses on soil carbon.

The Central team of I&I NSW and DECCW are collaborating with Lachlan CMA to identify sites in the central west for sampling in 2010.

Genetic improvement of beef cattle for greenhouse gas outcomes

Project leader: Dr Kath Donoghue, I&I NSW, Trangie

Methane is a potent greenhouse gas and has a global warming potential about 21 times that of carbon dioxide (CO₂). It is found in the air, burped and breathed out by cattle and is a major contributor to the total greenhouse gas emissions from agriculture.

Two years ago Dr Roger Hegarty and Dr Robert Herd had evidence that bulls differed in methane production and began a breeding program to produce low methane emitting cattle. Now, two years later, the sons and daughters of those bulls are "teenagers" and have just been measured for their methane production. The best group of cattle were



Roger Hegarty - breeding program for low methane emitting cattle.

producing the equivalent of 4 kg CO₂/day, about a quarter less than the worst group, who produced about 5kg CO₂/day. By comparison, a 6-cylinder family car doing 20,000 km per year produces about 12 kg CO₂/day. These differences between sires in the methane emission from their progeny provide new evidence that methane production is, in part, under genetic control.

Importantly, the project is targeting "methane yield". It is methane produced per unit of feed intake that must be reduced. Cattle must eat well and grow well, but at the same time, produce less methane. These results give real hope that it may be possible to breed cattle that produce less methane.

The research team have now gone the next step. Dr Kath Donoghue designed the matings for the next generation of cattle. She used the "best" and the "worst" new young bulls from among those measured. This is a second generation of low and high methane emitting cattle. If, as expected, they produce some truly unique low methane-emitting offspring, it will be a world-first demonstration of the opportunity to breed cattle that produce less of this greenhouse gas without sacrificing growth performance. The calves will be ready to be measured for methane late in 2011.

Mitigating nitrous oxide emissions from soils using pulses and improved nitrogen management

Project Leader: Dr Graeme Schwenke (I&I NSW)

Our project hypothesis is that increasing the ratio of pulses to cereals grown across the grains region will reduce the overall soil emissions of nitrous oxide (N₂O) associated with dryland cropping. This reduction in emissions may come about in two ways; firstly nitrogen (N) sourced from legumes may be less prone to loss from the soil, and secondly, N sourced from legumes means less fertiliser N is needed and so less greenhouse gases are produced through fertiliser manufacture.

The project involves measurement and comparison of N₂O emissions and N dynamics in three commonly practiced dryland cropping rotation systems typical of northwest NSW, namely; chickpea-wheat, chickpea-sorghum, and canola-wheat. We are also comparing emissions from soil growing chickpea with fababean and fieldpea; two other pulses commonly grown in the region. The non-legumes are grown with nitrogen fertiliser added as per budgeted crop demand, while the pulses are inoculated at sowing with species-specific rhizobium.

The GRDC-funded project officially commenced on 1st May, 2009, although funding was not available until October. Using borrowed funds, we were able to prepare the necessary infrastructure of a dedicated power line, field laboratory, and ultra high purity gas supplies in time for the commencement of the planned field trials. We began the project with a comprehensive soil sampling and characterisation of our study site; a black vertosol on the Tamworth Agricultural Institute property. Soon after, the trials were marked out and the first crops of chickpea, fababean, fieldpea and canola were sown. Concurrent with this sowing was the installation of a set of 6 automatic gas emission sampling chambers in selected plots of the rotation experiment. These chambers were loaned to us by Professor Peter Grace at QUT in Brisbane, while our own set were being constructed. Other plots in this experiment, plus those in the legume species experiment had gas emissions sampled periodically using manual chambers. During the crop's growth we sampled both soil mineral nitrogen and plant biomass nitrogen monthly. Greenhouse gas emissions were measured continuously (7.5 times per day using automatic chambers) or periodically (at least once a week with manual chambers). Kelly Baker, our project-funded technical officer commenced employment in December 2009

In the 157 days from sowing until harvest, soil under N-fertilised canola emitted a total of 293 g N₂O-N/ha. Much of this occurred in the first two months after N application in conjunction with rainfall events that would have stimulated soil nitrification after the urea had hydrolysed to ammonium. Emissions from canola plots equated to 0.37% of the N applied as urea at sowing, although we did not correct for background, i.e. nil fertiliser N. Over the same period the soil under chickpeas emitted only 28.5 g N₂O-N/ha. If we consider



Kelly Baker - collecting nitrous oxide samples.

this as the background N₂O emission then the emission factor for N fertiliser under canola during crop growth was 0.33% of that applied. This is close to the Australian emission factor used for accounting emissions from non-irrigated crops, and therefore of similar magnitude to previous research done on soil under cereals. However, those figures are based on 12 months of measurement, including both the crop and the fallow. Rainfall during the cropping period totalled 179 mm, which is approximately two-thirds of the long-term average at Tamworth. Despite this, crop growth was reasonable with canola yielding 1.7 t grain/ha and chickpea 1.3 t grain/ha, although chickpea yields were substantially depressed by insect damage during grain-filling.

Daily N₂O emissions ranged from -1.7 to 39.6 g N₂O-N/ha/day in the canola (+N) plots and -1.6 to 12.5 g N₂O-N/ha/day for chickpea. The higher results were recorded for both crops during a week of rainfall from 26th December 2009 that totalled 134 mm. Most daily emissions however were low, with the canola soil emitting more than the chickpea soil, which was often below detection. Both the range in our results and the low averages were of the same order as other soil N₂O emissions measured under dryland wheat crops in Australia.

This research has been presented to a range of audiences through several seminars and site visits, including; university undergraduate and post-graduate students, visiting scientists, and I&I NSW extension agronomists and specialists.

Developing ligno-cellulosic technologies for next generation biofuels in Australia.

Tony Vancov, I&I NSW, Wollongbar

The final report has been completed and submitted for a two-year Climate Action Grant project titled "Developing ligno-cellulosic technologies for next generation biofuels in Australia". Technical aspects of the work were undertaken by I&I NSW under Dr Tony Vancov's supervision at the Wollongbar Primary Industries Institute. The project investigated and evaluated a range of biochemical pre-treatment and enzyme saccharification variables for converting crop and forestry residues into fermentable sugars. Specifically, research efforts focused on identifying key conversion parameters and their relationship to each other during processing.

Extensive evaluation of bio-processing options have been undertaken to identify strategies to increase the viability of bioconversion of lignocellulosic

feedstock. As research progressed it was determined that acid and alkaline pre-treatments represented the most practical strategies for this investigation. Both treatments are receiving a great deal of focus internationally owing to their simplicity and inexpensive operating costs. Moreover, the two pre-treatment processes provided a direct comparison for evaluating selected biomass materials. Feedstocks examined in this study included three Australian native species for which there has been little or no previous research on bioconversion viability (*Eucalyptus*, Oil Mallee and *Arundo donax*).

We found that both dilute acid and or alkali with enzyme hydrolysis pre-treatments satisfy and meet some of the more important requisites for an effective pre-treatment process, namely; high sugar recovery in hydrolysate, excellent delignification, the solid fraction is acquiescent to enzyme digestion with high sugar release, and low acetate levels released during pre-treatment. Our finding also validated the belief that selecting an appropriate pre-treatment regime requires a degree of compromise between maximising glucose yield and minimising the creation of inhibitors. When comparing the two treatments it was evident that higher sugar recoveries were achieved from the acid/enzyme pre-treatment compared to the alkali/enzyme pre-treatment.

In comparing candidate feedstocks, we found that grass-type materials (wheat straw, bagasse, sorghum straw and sugarcane tops), were likely to give better fermentation characteristics when using acid/enzyme pre-treatment. The wood-based materials (oil mallee, pine, and eucalyptus) showed low levels of sugar release (and consequently ethanol production) under mild acid or alkali pre-treatment. Investigations of commercially available enzymes using several feedstocks, led to the conclusion the Novozymes

cellulase preparations were better suited under study conditions than other commercial preparations. Although endpoint hydrolysate levels were similar for those tested, the rate of saccharification differed. Novozymes cellulase treatment preps with additional β -glucosidase displayed faster rates of solid residue hydrolysis than other commercial preparations. Significant outcomes and recommendations relating to pre-treatment and development of second generation biofuels (ethanol), are in various stages of publication with up to 5 peer-reviewed journal papers, a supplementary and detailed technical report, an upcoming book chapter, 3 conference papers and a pending provisional patent.

Conversion of Eucalypt Forestry Waste Residues to Biofuels

Tony Vancov, I&I NSW, Wollongbar

Tony has been awarded a 14 month Department of Agriculture and Fisheries and Forestry (DAFF) Climate Change Research Fund project titled "Conversion of Eucalypt Forestry Waste Residues to Biofuels". The work will be undertaken by I&I NSW under Dr Tony Vancov's supervision at Wollongbar Primary Industries Institute. This project is designed to advance research and development of technologies for the production of second generation biofuels from forestry harvest and mill residues, particularly plantation



Tony Vancov - testing sugar recovery from crop residues.

eucalypts in the Northern Rivers of NSW. Specifically, the proposed research aims to develop and optimise pre-treatment platforms based on biochemical and enzyme hydrolysis that will allow conversion of forest residues to 'core' carbohydrates which may in turn be used for producing fuel ethanol and other value-added co-products. Owing to the condensed time-frame, Tony plans to initially focus the study on optimising pre-treatment conditions using *Eucalyptus dunnii* and then broaden to measure the effects of variables such as age, growth site and other selective silvicultural traits that influence wood rheology.

Post-Graduate Research Reports

Aspects of flowering and flushing of mango and macadamia

PhD Student: John Wilkie

Supervisors: Dr Trevor Olesen (I&I NSW) and Prof Margaret Sedgley (UNE).

Macadamia (*Macadamia integrifolia*, *M. tetraphylla*, and hybrids) is an evergreen, subtropical, recurrent flushing tree that is native to subtropical eastern Australia. Macadamia is induced to flower by cool temperatures, but cool temperatures do not ensure flowering because there are important interactions with vegetative growth. Interactions between the vegetative growth, flowering and yield of macadamia were investigated with the aim of developing canopy management strategies.

Characteristics of the stems were found to affect the likelihood of flowering, with short stems being more likely to flower than long stems. The stem age most likely to flower, 1- or 2-year-old,

depended on cultivar. Overall this indicated that floral behaviour of a stem was influenced by its physiological position within the canopy. The dependence of flush development on the environment was investigated. Flush development in macadamia is cyclic, the rate of flush development increased with mean temperatures between 15 and 25°C, whereas mean stem length decreased as mean temperature increased from 15 to 25°C.

The rate of bud break and the number of stems re-growing following pruning also increased with mean temperature between 15 and 25°C, but were better correlated with a composite variable, the product of mean temperature and solar radiation. These relationships were used to predict the timing and characteristics of flushes following pruning at various times of the year in four macadamia growing locations in eastern Australia. The effects of autumn and early winter pruning times on flush development, flowering and yield were investigated. Early June pruning did not affect flowering in the season of pruning but did reduce yield, probably due to decreased light interception, although the differences were not always significant.



John Wilkie (right) was PIIC's first PhD graduate. He is celebrating with his mother Ann Wilkie (centre) and PIIC Director Bob Martin (left).

Autumn pruning reduced flowering, because the developing flushes did not mature by early winter. This IV reduction in flowering led to a reduction in yield. Uniconazole applications reduced shoot elongation and canopy expansion following pruning, but did not affect raceme production or yield. Pruning time affected raceme production in the year after pruning, although the mechanisms are not well understood. The relationship between raceme density, yield efficiency and vegetative growth was investigated. Yield efficiency increased with raceme density up to a point. At low raceme densities the trees compensated by increasing fruit size and the number of fruit retained per raceme. At high raceme densities yield efficiency appeared to be limited by assimilate supply. High raceme densities and crop loads in one season inhibited raceme production in the next, consistent with a biennial bearing cycle.

Landscape ecology of the egg parasitoid *Trichogramma* (Hymenoptera) in Northern New South Wales

PhD Student: Christopher M. Carr

Supervisors: Assoc. Prof. Nick Reid (UNE), Dr Robin Gunning (I&I NSW) Dr John Stanley (UNE), Assoc. Prof. Geoff Gurr (CSU) and Dr Louise Rossiter (I&I NSW)

Trichogramma is a naturally occurring wasp egg parasitoid of the pest moth *Helicoverpa* spp. (Boll worm). A two year study was conducted on the spatial and temporal ecology of *Trichogramma* in all major crop and non-crop vegetative areas of the Liverpool Plains, North-Western NSW. Low egg parasitoid activity and abundance over winter and spring was recorded. However *Trichogramma* do overwinter on the Liverpool Plains in native vegetation refuges. Generally in the Upper Namoi *Trichogramma* parasitism is not sufficient to provide economic control roughly hovering around an average of 15% in summer. Parasitism increases in early



Christopher Carr - landscape ecology of the egg parasitoid *Trichogramma*.

January particularly in maize and sorghum. *Trichogramma pretiosum* which is the only introduced egg parasitoid species is the dominant parasitoid at this stage parasitising the majority of eggs. By February natural parasitism peaked at 70% in a single cotton crop, and 40% egg parasitism in the first year which was a drought year. This is remarkable for an area that has had little documentation of *Trichogramma*. On the whole the second summer season study saw a doubling of the *Trichogramma* spp. population, which indicates given a better season and reasonable *Helicoverpa* spp. pressure that *Trichogramma* also build up numbers comparably.

One of the main impediments for *Trichogramma* effectiveness in natural pest control on the Liverpool Plains is the slow early build up populations. A further experiment was conducted to examine the effectiveness of springtime inoculative releases of *Trichogramma* and the subsequent flow-on benefit it provides to summer crops for improved production via pest control. *Trichogramma* was inoculatively released in canola and wheat on 12 properties on the Liverpool Plains in spring to boost the natural population. A significant *Helicoverpa* laying coincided with the release of *Trichogramma*. Within the release area *Trichogramma* parasitised

up to 85% of *Helicoverpa* eggs in both crops. An additional benefit was the control of *Helicoverpa* in Canola in the release area. This was a significant finding that will require future research. Until this large experiment, no *Trichogramma* spp. had been released in Canola for the control of *Helicoverpa* spp in Australia. Summer populations of *Trichogramma* increased compared to the last two years surveyed.

Based on this work publications are underway, and a review of *Trichogramma* in Australia with a focus on cotton has been submitted to the Australian Entomological Journal in collaboration with other scientists.

Mechanisms of seed coat and cotyledon adhesion that influence the dehulling and splitting quality of chickpea (*Cicer arietinum* L.) Seeds

PhD Student: Jennifer A. Wood

Supervisors: Prof. Mingan Choct (Poultry CRC, UNE), Mr Edmund Knights (I&I NSW) and Dr Grant Campbell (University of Manchester, UK)

The dehulling and splitting process, aims to isolate the two cotyledons (dhal) without chipping/abrasion of the cotyledons or contamination by the seed coat. The ease of separating the seed coat from the cotyledon, and the ease of

splitting the cotyledons impact on dhal yields. This dissociation between botanical parts of the seed is influenced by both environmental factors and varietal characteristics.

An estimated 70-90 % of desi type chickpeas are dehulled and split before consumption. Australia produces 300,000 tonnes of desi chickpea annually, yet only value adds by dehulling/splitting around 5% of the crop due to the high cost and difficulties of local processing. The ability to breed desi chickpea cultivars that are easier to dehull/split would benefit Australian processors greatly. On the other hand, such easy-to-dehull/split cultivars would exacerbate unwanted splitting of seed during harvest and handling. Farmers and grain handlers currently have trouble with some cultivars splitting during harvest and handling (especially after pre-harvest rainfall on mature crops) leading to high percentages of split seed and price penalties.

The ideal chickpea would, therefore, be one that withstands harvest/handling, maybe even pre-harvest rainfall, but would dehull and split easily during processing. Such a cultivar would be highly sought after by growers, handlers, millers and exporters alike. The challenge is to achieve both benefits from the same cultivar – obviously breeding alone cannot achieve both of these mutually exclusive outcomes. The identification of the underlying mechanism(s) of seed coat and cotyledon adhesion may enable the development of an effective process to artificially break this adhesion during processing. This would enable the breeding program to focus on chickpea that withstands harvest/handling, and the adhesion-breaking method could be used during processing to optimise dhal yields and quality.

The results of this PhD project are summarised:

1. Milling quality is a genetically controlled trait that may be manipulated in a breeding program.



Jennifer Wood - effect of seed coat and cotyledon adhesion on dehulling and splitting quality of chickpea.

2. Other factors that influence the ease of milling chickpea include seed size, seed shape and weather damage. However, seed coat/cotyledon ratio and seed coat thickness did not significantly affect dhal yields, despite affecting the theoretical maximum dhal yields obtainable.
3. The physical and chemical properties of chickpea seeds were examined using various microscopy and analytical chemistry techniques that identified potential underlying mechanism(s) responsible for the differing strength of seed coat and cotyledon adhesion in chickpea genotypes.
4. Six new methods of breaking the adhesive mechanism(s) were proposed from these results, and their effectiveness tested on a difficult-to-mill genotype. Visual quality and taste of the resulting dhal were also considered. Commercially significant improvements in dhal yield were achieved whilst retaining acceptable dhal quality, and are potentially patentable (hence commercial-in-confidence).

The thesis is due for submission in September 2011.

Development and evaluation of functional food pasta

PhD Student: Nisha Aravind

Supervisors: Dr Chris Fellows (UNE) and Dr Mike Sissons (I&I NSW)

This project addressed the potential applications of technology at different scales for developing and evaluating the functional food pasta. The project was implemented in collaboration with I&I NSW and the Australian Nuclear Scientific Organisation (ANSTO).

Major objectives of the study were: The development of functional pasta using different concentrations of selected potential functional ingredients with specific health value (targeting chronic diseases); Evaluation of the technological quality of pasta using instrumental and sensory methods; Determining the quantity, quality and functional properties of uncooked, cooked, and partially digested pasta with enzymes in vitro; Understanding the structural changes at the micro and nano-scales in uncooked, cooked and digested pasta developed from various functional ingredients using techniques like Scanning Electron Microscopy (SEM), Confocal Laser Scanning Microscopy (CSLM),

Nuclear Magnetic resonance (NMR), X-ray diffraction (XRD), Small-Angle X-ray Scattering (SAXS); Determining structure-function correlations in modified pasta through materials science characterisation.

The work involved the development of pasta as a functional food by incorporation of ingredients such as bran, pollard, inulin, guar gum (GG), carboxymethyl cellulose (CMC), Z-trim (Oat fibre), Novelose 330 resistant starch, high amylose starch, and β -glucan concentrate in pasta formulations made from durum semolina. Semolina was mixed with ingredients at various concentrations and made into spaghetti. The cooked pasta was evaluated for technological and sensory quality and enzymatic in vitro starch hydrolysis. In a sub-set of samples, a study was undertaken to investigate the effect of the enzyme, transglutaminase on gluten protein structure and quality.

The results suggest that inclusion of insoluble fibres like pollard and bran increases the reducing sugar release during in vitro digestion in pasta. SEM and CSLM images showed the clearly disrupted matrix exposing the starch granules. XRD diffractograms and SAXS curves demonstrated that crystallinity levels also decreased for pasta with insoluble fibres. Thus, a good correlation was obtained between starch crystallinity and the extent of starch hydrolysed.

Starch hydrolysis decreased continuously with increasing soluble fibers (Inulin, Guar, Resistant starches, CMC, beta-glucan) suggesting their inclusion decreases the glycaemic index of pasta. SEM and CSLM images and crystallinity data support the starch hydrolysis data.

A systematic study was also done to modify wheat proteins in semolina to improve dough rheological properties, pasta technological quality and gluten

strength by the addition of the enzyme transglutaminase (TG) at different concentrations. The use of enzyme improved the dough strength and resulted in pasta products with different cooking quality. In addition to understand the affect of protein matrix in starch digestion XRD and SAXS were done on extracted pure gluten and water soluble proteins albumin and globulin.

Results of the work have lead to the conclusion that for efficient development and use of functional food requires a comprehensive approach that extends beyond the analysis of the beneficial biological activity of a functional ingredient or nutraceutical. The research has made advances into each of these areas by utilizing the above mentioned innovative technologies for nutritionally enhanced pasta. The work has been driven by micro and nano scale analytical techniques that enabled to obtain an in depth and better understanding of the relationships between molecular structure and their macroscopic properties. The study proved to be successful in introducing these powerful characterization techniques in food science and technology area, in which their use had been quite limited.

Already one research paper is published from the work and has been presented in three major conferences. Moreover, this study has been chosen as one of the six finalists for the 2010 American Association of Cereal Chemists (AACC) International Best Student Research Paper Competition in 2010.



Nisha Aravind - development and evaluation of functional food pasta.

Biological indicators and potential amendments to improve soil health, crop productivity and profitability for cropping soils in central western NSW.

PhD Student: Anne Williams

Supervisors: Prof. Heiko Daniel (UNE), Prof. Bob Martin (PIIC), Dr Peter Lockwood (UNE) and Dr Kathy King (UNE)

Anne is continuing her work that started 2008 on her GRDC funded post-graduate studies with PIIC. She has been collecting data from farm surveys, field trials and pot experiments at UNE in an attempt to quantify the influence of cropping (especially no-till) on soil properties and whether surface applied organic amendments can improve soil health. Anne and husband Ray own a 1,420 hectare property "Magomadine", 24 kilometres east of Coonamble on which Anne has been conducting her field trials.

Collection of physical, chemical and biological data over two years has also been completed for soils on 20 paired sites in Central Western NSW to obtain a comparison between farmed and natural systems. No-till agriculture is often credited for creating more resilient and healthier soils compared to traditional practices involving cultivation. However, this survey has indicated that, on average, farmed soils, regardless of tillage system, have lower soil carbon, microbial and fungal biomass compared to soils under natural systems. Despite this difference, soil carbon and microbial biomass was higher in farmed soils where no-till had been practiced the longest but recovery of fungal biomass did not follow this trend.

The field trial set up in 2008 compared organic amendments (straw, compost, manure) with subplots of inorganic amendments (biochar, zeolite and biochar mixed with zeolite). The first year of the field trial examined the effect of long fallow on soil physical, chemical and biological properties. In the



Anne Williams - biological indicators and potential amendments to improve soil health.

second year the effect of surface applied organic amendments on wheat yield was recorded.

Application of straw at 10t/ha gave the greatest improvements in soil moisture, aggregate size, microbial biomass and activity. Biochar increased soil carbon levels. These benefits were not reflected in significant increases in wheat yield. This could have been due to the higher than normal rainfall during the crop growing season.

Pot trials have shown that differing rates of straw can influence fungal levels but this was not evident in the field trial. The interactions between microbial populations in soil are complex and are affected by differences in environment and management practices. Further research under controlled environmental conditions could lead to better management practices to improve soil health in farmed systems.

The influence of climate change on *Nezara viridula* and its parasitoid, *Trichopoda* spp.

PhD Student: Pol Chanthy

Supervisors: Dr Nigel Andrew (UNE), Dr Robin Gunning (I&I NSW) and Prof Bob Martin (PIIC).

Soybean is the most economically important legume crop in the world. In the tropics and subtropics, green vegetable bug *Nezara viridula* is a major insect pest world-wide. Serious yield losses can result from green vegetable bug (GVB) feeding as well as reduced seed germination in GVB damaged seeds. Integrated Pest Management (IPM), in which natural occurring biological control mechanisms are used in conjunction with compatible insecticides, is the preferred management strategy for GVB. Two important biological control agents of GVB are the parasitoids *Trichopoda* spp. and *Trissolcus* spp.. Pest status and density of GVB is limited by environmental temperature and winter diapause, however, climate change may exacerbate the pest status of GVB. The likely temperature increase of 2.4 – 6.4°C in Australia may shorten the life cycle of GVB allowing more generations and damaging populations on soybean

crops. GVB may also become a year round pest as increased temperature may remove its winter diapause. While GVB may adapt to climate change, predators and parasites may not be able to survive changes in temperature and rainfall and changes in the life cycle of the GVB host. The aims of this project are to measure the effect of changed temperature and moisture thresholds on GVB and *Trichopoda* spp. life cycles and the ability of the parasitoid to parasitize GVB.

The parasitoid flies and their hosts, green vegetable bugs were obtained from Breeza in North-Western NSW and Grafton on the North Coast of NSW. Breeza (Gunnedah) represents a dry climate (618 mm annual average rainfall) compared to Grafton (1053 mm). Grafton is also more humid with average annual 3pm relative humidity of 53% compared to 46% at Breeza (Gunnedah). Average annual maximum temperature is similar at both sites (26°C) but minimum temperature is higher at Grafton (13.6°C) compared to 10.9°C at Breeza (Gunnedah).

An experiment was conducted under controlled conditions to determine the effects of combination of two factors, temperature and humidity regimes on the developmental stages of *Trichopoda* spp. and to examine whether the two populations of *Trichopoda* spp. are different under the effects of temperature and humidity. The experiment was laid out as factorial design with two factors, temperature (25, 30, 33, and 36°C) and humidity (30-40% RH and 70-80% RH) and three replications. The temperature was considered as the main factor for this experiment. Saturated salt solution was used to maintain humidity regimes in incubators. Magnesium Chloride was used for the higher humidity regime, whereas Lithium Chloride was used for the low humidity regime. The data of this experiment is being analysed.



Pol Chantry - influence of climate change on Nezara viridula and its parasitoids.

In relation to the effects of climate change, a study of insect physiology: Discriminating temperature of green vegetable bug (GVB) was conducted. The objective of this study was to determine whether the discriminating temperature of GVBs from different climatic gradients is different between these two populations. The results of this study showed that the discriminating temperature of green vegetable bug was about -7°C under cold condition and there were no significant differences of discriminating temperature between these two populations. Similarly, there were no significant differences in discriminating temperature between two populations of green vegetable bug under hot conditions. The discriminating temperature of green vegetable bug under high temperature was about 40°C. In relation to this study, the effects of

acclimatisation temperature on discriminating temperature of GVB populations will be conducted in order to determine whether acclimatisation temperature increases or decreases survival discriminating temperature of GVB.

Nitrous oxide emissions from two contrasting systems: Fertilizer-N versus Biologically fixed-N

PhD Student: Nazma Begum

Supervisors: Dr Chris Guppy (UNE), Prof David Herridge (PIIC), Dr Graeme Schwenke (I&I NSW), Dr Guy McMullen (I&I NSW)

The main greenhouse gas produced by Australian agriculture is nitrous oxide (N₂O) (83.9%). N₂O is a significant greenhouse gas with a global warming potential of 298 times greater than CO₂ and contributes to the depletion of

the stratospheric ozone layer, which protects the biosphere from the harmful effects of solar ultraviolet radiation. The exponential increase in the use of nitrogenous fertilizers in Australia over the past 20 years has resulted in a corresponding increase in N₂O emissions attributed to agriculture. A shift towards increased use of legumes to supply N to non-leguminous crops through rotation and intercropping is being proposed as a strategy to abate N₂O emissions strongly associated with increased fertilizer use. Comparisons of N₂O emissions suggest little difference between legume and fertilizer-based agriculture. However, few studies have carefully compared N₂O fluxes during crop growth as well as during fallow periods between these two systems. The overall objective of this project is to study the magnitude of N₂O emissions for the potential use of legume-derived N as a replacement of fertilizer in cropping systems.

The main part of Nazma's PhD project involves a glasshouse pot trial, growing four different crops, wheat, canola, faba bean and chickpea under high and low N levels on vertosol. A rain simulator is being used in this experiment in order to mimic the episodic nature of rainfall. N₂O fluxes will be measured in samples being extracted from the headspace of the soil columns after sealing for 1 h using closed plastic chamber. Soil mineral N and moisture content are two of the most important factors which directly influence nitrification and denitrification processes from agricultural soils, and therefore emissions of N₂O. In this study, these two factors are being monitored in order to understand their influence on N₂O emissions. Basically, there are four issues to be addressed by this study. The first issue is whether the magnitude of N₂O emissions is similar between fertilizer-based systems (from wheat and canola pots supplied with high N) and N-fixing systems (from faba bean and chickpea pots supplied

with low N) during the whole growing season and the residue breakdown period after the grain harvest.

Studies have been attempted to quantify N₂O emission during biological N₂ fixation process or legume growing season but the contribution of biologically fixed N of legume residues is still lacking which might be useful to improve the current IPCC default emission factors for various groups of legume residues. Earlier studies tried to focus only on above-ground residues ignoring the importance of below ground N. Recent studies showed that 30-50% of legume total N is located below the ground. The ability of legumes to contribute to the total pool of N in the soil varies. We are using an ¹⁵N stable isotope shoot labelling technique to estimate the below ground plant N of faba bean and chickpea in order to assess their effect on N₂O emissions (2nd issue).

Furthermore, in theory, the algorithm model gives negative field N balances of faba bean because of high N-harvest index. But the 'spared N' effect can result from lower N uptake of faba bean primarily caused by low rooting density and rooting depth of this legume, has been reported in the literature. In order to clarify the contradictory below ground N effect of faba bean, faba bean and chickpea are being growing under high and low N levels (3rd issue).

In general, a strong relationship exists between grain protein content and N concentration of the residues. As the grain protein level increases at high N levels, the N concentration of the residues also increases. On the other hand, a large number of studies have been done on the quality and quantity of plant residues and revealed that N₂O emissions following incorporation of residues with low C:N ratio and low lignin



Nazma Begum - nitrous oxide emissions from contrasting cropping systems.

contents could be greater. Therefore, grain protein content can be used as a surrogate measure for how much N₂O is coming out of the residues, which can be a great tool for the farmers at paddock level to know the emissions from their field. To test this hypothesis, we are growing wheat, canola, faba bean and chickpea under high and low N levels to get a range of protein levels and N₂O emissions out of their residues (4th issue).

In addition to this major experiment described above, two short-term experiments will be carried out to understand the effect of pH and soil pore connectivity on N₂O emissions.

Profile dynamics of soil carbon storage and resilience under three paired land uses on a duplex soil in NSW, Australia.

PhD Student: Christine Walela

Supervisors: Prof. Heiko Daniel (UNE), A/Prof. Brian Wilson (UNE), Dr Peter Lockwood (UNE) and Prof. Annette Cowie (NCRGGR)

Terrestrial ecosystems have been identified as having the potential to offset greenhouse gas emissions through carbon sequestration. Though various authors have estimated the terrestrial sink to absorb approximately 2-4 Pg C yr⁻¹, there is still a considerable debate in literature regarding the most effective land use practice that might achieve increased soil carbon storage. In particular, knowledge of the relative quantities of soil carbon that might be stored by different land uses is lacking in Australia and particularly in NSW. Further, most work to date in Australia has been focussed on the surface layers and our knowledge of the subsurface carbon distribution and resilience is still limited. The importance of carbon (C) sequestration in subsoil is steadily growing, with increasing evidence of low turnover rate and occurrence of subsoil soil organic carbon in relatively stable form.

The objective of this research is to quantify profile (up to 1m) carbon stocks in three paired land uses which include; native woodland, native pastures and forage cropping on a duplex soil in NSW, Australia. The choice of conducting this study on a duplex was to assess the association of soil texture and C storage with increasing depth. In order to understand the resilience/stability of soil carbon stored in these systems, the size and turnover of carbon pools (active, slow and resistant) will be determined through mineralization studies and carbon dating techniques. Further, the stability of these pools will not have been fully understood without understanding the interactions between how both above (plant) and below ground (root) litter quality affects transformations of

residues into stable soil organic matter. Therefore, Christine will determine biochemical characteristics of plant and root litter and conduct litter mineralization studies in order to provide insights on how litter quality may influence C storage and resilience within a given management system.

Activities conducted so far include, completion of the first phase of field work. Christine has successfully sampled all the sites which were located around the township of Uralla on the Northern Tablelands of NSW. An extended laboratory incubation study which will last for six months has also been set up. Extended laboratory incubation utilizes the degradative enzymes of the soil biota to provide an analytical estimate of the soil C pools and fluxes. Laboratory analyses are now underway.



Christine Walela - profile dynamics of soil carbon storage under different landuses.

During this calendar year, Christine received AUD \$2000 funding from PIIC to attend and present a paper and a poster at the European Geosciences Union International Conference which was held in Vienna, Austria.

Root contributions to soil organic carbon sequestration on the Northern Tablelands of NSW

PhD Student: Giregon Olupot

Supervisors: Prof. Heiko Daniel (UNE), Dr. Peter Lockwood (UNE), Dr. Malem McLeod (I&I NSW) and Dr. Melinda McHenry (UCQ).

Giregon is evaluating the impact of three landuses: 1. Improved pasture, 2. Native pasture and 3. Woodland on: The morphology and demographics of fine roots, profile distribution of fine root biomass, rate of decomposition of the root biomass as influenced by soil quality and root litter quality and fine root activity in relation to inputting carbon to the soil. His research is supported by the University of New England (UNE) Faculty Scholarship, with supplementary funding from PIIC.

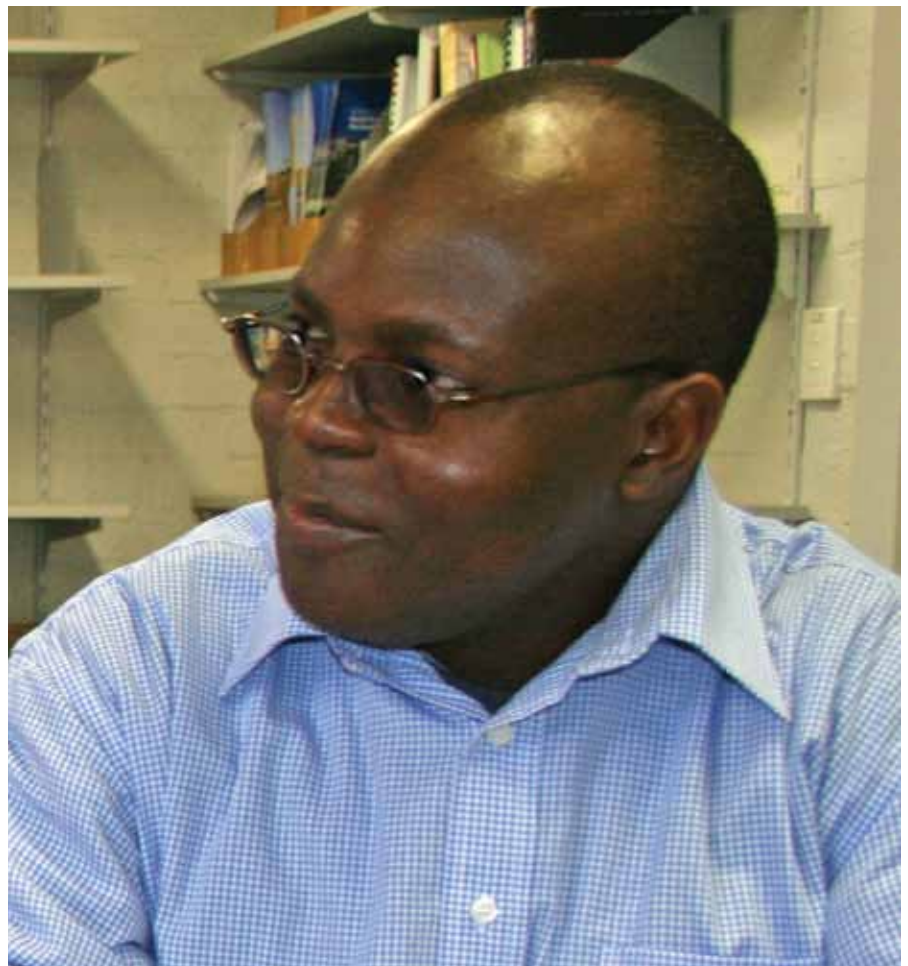
Three quarters of terrestrial carbon is stored in the soil as soil organic matter about 50% of which originates from plant roots. Soil carbon budgets are therefore incomplete without a thorough understanding of roots inputs and longevity of this carbon in the soil. It has been postulated that the depth to which roots descend and decay, ultimately determine the fate of root carbon. In addition, root-derived carbon stays longer in the soil than carbon originating from the shoots. This has been attributed to a number of factors. First, roots are more lignified and suberised than shoots and therefore, have lower decomposition rates than shoots. Secondly, roots undergo "seasoning" in the soil right from the time they are formed, which makes them less degradable than shoot biomass. Thirdly, roots continuously release carbon-rich compounds into the soil that help boost microbial activity.

As these microbes break down the organic materials in the soil, they form polysaccharide gels and exo-polymers that help "glue" and stabilise soil aggregates. Stable aggregates are more likely to protect and store carbon for longer periods than fragile aggregates. Last and most importantly, it has been shown that roots may actually initiate the formation and stabilisation of soil aggregates into which carbon gets nucleated for long-term sequestration.

Giregon is extracting intact soil cores to a depth of one metre to extract roots for determination of morphological properties (length and diameter), biomass and the rate of decomposition. He has already collected data from one out of four sites within the Northern Tablelands of NSW and is progressing into the fourth out of six sampling intervals for a controlled field experiment in which he is disaggregating species-induced differences in rooting characteristics and

decay rates for three selected grasses native to NSW. Fine root samples have been stained and Giregon will process the stained images of roots for morphological properties as soon as WinRHIZO (the software to use is operationalised).

Giregon has already synthesized the preliminary results from the work accomplished into conference papers. From the field survey of the impact of landuse on profile distribution of fine root biomass, he has shown that improved pastures produce the highest fine root biomass but about 80% of this biomass is in the top 30 cm of soil. The rate of decomposition of this biomass should shed more light on its potential for loss into the atmosphere. From the field experiment, there are significant differences among the species in terms of fine root biomass production. The interaction between species and soil depth as well as the level of shading are all significant, with all species



Giregon Olupot - root contributions to soil organic carbon sequestration.

yielding significantly higher fine root biomass in the open sun than under shade, regardless of whether a species is sun-loving or shade-loving.

Giregon hypothesises that wide-ranging environmental stresses common on the Northern Tablelands of NSW have conditioned native landuses to place relatively higher fine root biomass in deep soil horizons than improved landuses. Native landuses are, therefore, more effective in sequestering soil carbon than improved landuses. He hopes that his study will generate information that may help inform future changes to the existing landuses in NSW, with a view to improving productivity of the landuses, while ensuring better sequestration of carbon.

Stabilization of organic carbon in soil aggregates under contrasting land uses

PhD Student: Fazle Rabbi

Supervisors: Prof. Heiko Daniel (UNE); Dr Peter Lockwood (UNE), A/Prof. Brian Wilson (UNE) and Prof. Iain Young (UNE)

Micro-aggregates (<250µm) play a key role in protecting soil organic carbon (SOC) from microbial decomposition. The concept of physically protected organic matter is widespread in the literature, but relatively little is known about how organic matter interacts with soil surfaces in three dimensions (3D). Rabbi is studying the effect of land use change on SOC storage in micro-aggregates and the role of physical and physico-chemical protection mechanisms on SOC stabilization. He has selected contrasting land uses [native pasture (NP); crop/pasture rotation (CP); woodland (WL)] on a Dermosol on the Northern Tablelands of NSW, Australia.

Soil aggregate stability was determined with low energy shaking prior to wet sieving. Total SOC (TOC) and SOC pools associated with 4000-250 µm, 250-53 µm and <53 µm aggregates were determined. Light fraction carbon (<1.6 g

cm⁻³) (LF-C) was determined by density fractionation by NaI. Intra-particulate organic carbon (iPOC) and mineral associated carbon (mSOC) of heavy fraction (>1.6 g cm⁻³) was determined by complete dispersion with 0.5% sodium hexametaphosphate.

Carbon analyses were undertaken with a LECO carbon analyser (TruSpec CN) and Carlo Erba NA1500 micro-analyser depending on the amount of organic carbon recovered. The basal respiration rates of the separated aggregates were also determined to assess the decomposition rates of SOC associated with each aggregate size groups. Soil aggregates of 4000-250 µm, 250-53 µm and <53 µm obtained by wet sieving were incubated with KOH trap at 25°C for 30 days at moisture content of 70% of field capacity. The amount of CO₂-C produced during incubation was then determined by TIM 850 Titration Manager.

Pore size distribution and pore connectivity of aggregates were determined using microfocuss X-ray computed tomography (µCT) (v|tome|x|s 240, Phoenix|X-ray). Aggregate stability decreased from NP (0.81±0.06 mm)>WL(0.6±0.054 mm)>CP(0.39±0.02 mm). In NP and WL 63.21% and 53.87% of water stable aggregates

respectively, were in the 4000 to 250 µm size range, whereas in CP 46.28% of aggregates were in 4000-250 µm size range. The percentages of aggregates in the 250-53 µm size range were 23.45%, 15.96% and 21.5% in CP, NP and WL, respectively. For NP, CP and WL the 4000-250 µm aggregates contained higher TOC than aggregate fractions of 250-53µm and <53µm. TOC in 4000-250 µm and <53 µm aggregates decreased in the order of WL>CP>NP while TOC in 250-53 µm aggregates was in the order NP>WL>CP.

These data indicate rapid turnover of SOC in 250-53 µm and <53 µm aggregates under crop/pasture rotation. The µCT analysis revealed that pore connectivity was significantly higher in >500 µm aggregates. We believe that the presence of small pores in micro-aggregates drive the considerably higher respiration rates of smaller aggregates but more detailed work is needed to confirm this conclusion.

Rabbi will study stabilisation of soil organic carbon in soil micro-aggregates under different organic inputs, tillage and cropping patterns. Soil organic matter is one of the major pools of the global carbon cycle. Soil micro-aggregates (<250 µm) have unique capacity to



Fazle Rabbi - stabilization of organic carbon in soil aggregates.

protect organic matter from decomposition. The overall objective of the research is to evaluate the effects of organic inputs and agricultural land use under conventional and no-tillage on the amount and nature of carbon associated with soil micro-aggregates in Vertosol, Chromosol and Ferrosol soils.

The aggregate stability and mineralization rate of organic carbon associated with aggregate size fractions will be determined. The dispersion ratio and pore geometry of soil aggregates will be determined to relate these parameters with the amount of organic matter in micro-aggregates. Pore geometry will be determined by computerized micro-tomography. The light fraction, particulate and stable organic matter associated with each aggregate size class especially with micro-aggregate will be determined by density fractionation and chemical methods. The chemical nature of micro-aggregate organic carbon will be determined by solid state ^{13}C NMR. A theoretical study based on linear regression modelling will be conducted to evaluate the capacity of soil to protect organic matter.

Simulation of soil organic carbon dynamics under different land use and crop management practices.

PhD Student: Nimai Senapati

Supervisors: Prof. Heiko Daniel (UNE), A/Prof. Brian Wilson (UNE), Dr Peter Lockwood (UNE) and Dr Subhadip Ghosh (CUGU)

As a major part of his PhD research, Nimai is trying to calibrate soil organic matter (SOM) models, particularly RothC and CENTURY in northern NSW under different land use change and management practices for future prediction of change in soil organic carbon (SOC) stock due to changes in land use, management practices and climatic conditions. Nimai's research title is simulation of soil organic carbon dynamics under different land use and crop

management practices. He has chosen this topic as modelling is a cheap and easy alternative tool for predicting the change in SOC stock compared to costly and very time consuming field and laboratory measurements. Large scale field sampling across the vast Australian continent would be an impossible and time consuming task. However, estimation of carbon stocks across the Australian landscape is a national research priority for the Australian Government. We are proposing to use a new approach of model calibration i.e. using paired site data and Bayesian theorem. Nimai's research objectives are a) validation and subsequent calibration of RothC and CENTURY models, b) comparison of model performance, c) sensitivity analysis and d) future prediction of changes in SOC stocks under changing environmental factors, land use, management practices and climatic conditions.

A pilot study is being carried out using a Chromosol from Warialda in North-Western NSW. One uncleared remnant eucalypt woodland site and three adjacent paired cultivated sites were sampled in 2009. Cropping sites were cleared in the early 1950s and regularly cropped with winter wheat. The cropping system was simulated using APSIM (Agricultural Production Systems Simulator). Soil organic C pools were determined on composite soil samples from each of the uncleared woodland and cultivated pairs. The paired set was modelled using the RothC 26.3 model, initialized using the SOC pool structure for the woodland site and compared with the measured data for the cultivated pairs, assuming the woodland systems had reached equilibrium at the time of soil sampling.

The model predicted that conversion of woodland to



Nimai Senapati - simulation of soil carbon dynamics under different land uses and management practices.

cropping would result in decreased total SOC stock in the top 30 cm soil layer from 18.54 t ha⁻¹ to 6.7 t ha⁻¹ after 60 years of continuous cropping. Similarly, RothC predicted decreased resistant plant material (RPM) C and humified organic matter (HUM) C from 7.96 to 1.4 t ha⁻¹ and from 10.1 to 4.8 t ha⁻¹, respectively. The measured total SOC stocks in the three paired cropping sites were 5.4 t ha⁻¹, 7.4 t ha⁻¹ and 6.6 t ha⁻¹, respectively. Similarly, measured RPM carbon was 1.52 t ha⁻¹, 1.82 t ha⁻¹ and 1.58 t ha⁻¹ and HUM carbon was 3.4 t ha⁻¹, 5.1 t ha⁻¹ and 4.5 t ha⁻¹, respectively. Modelled and measured data were statistically similar with root mean square error (RMSE) of 12%, 5% and 16% for TOC, RPM and HUM, respectively. The t-test values also showed that the differences between the simulated and observed data were not statistically significant at the level of significance P = 0.05. On the basis of the result of the study, RothC represents a promising tool for estimating SOC change due to land use change. Further work will validate the utility of RothC and CENTURY for SOC estimation across a range of soil types and land-uses in northern NSW.

Effect of alternative cropping management on soil organic carbon

PhD Student: Yadunath Bajgai

Supervisors: Dr Paul Kristiansen (UNE), Dr Nilantha Hulugalle (I&I NSW), and Dr Melinda McHenry, (UQC)

Yadunath Bajgai is working on the "Effect of alternative cropping management on soil organic carbon" for his PhD research which began in July 2009. He is a recipient of Australian Government's prestigious and internationally competitive Endeavour Postgraduate Award for his PhD study. Yadu graduated in 1998 with BSc (Hons) in Agriculture from the University of Wales, Bangor in the UK and completed a MSc from Chiang Mai University, Thailand in 2006.

His MSc thesis was entitled "Assessment of soil fertility status in the agricultural land of Guma block in West-central Bhutan".

Yadu has well over a decade of professional experience in the various departments in the Bhutanese Ministry of Agriculture and Forest (MOAF). He has served in various positions concentrating on rural agricultural development and extension and working as Deputy Chief Agriculture Officer since January 2009 in the Pemagatshel district administration, eastern Bhutan.

In his research project, he is simulating the organic practices in a corn (summer)-cabbage (winter) rotation alongside plots using conventional vegetable growing methods at two UNE farms in the Armidale area. The trial is investigating the effects of key organic practices - tillage and corn residues incorporation - on soil carbon dynamics. He has already made headway through his field trial with a summer corn crop harvested and the residues incorporated in May 2010. A cabbage crop was planted shortly after and is now growing well.

His investigation is expected to improve understanding of some the short term effects of tillage and incorporating corn residue in terms of changes in soil physical properties, soil organic carbon capture and corn-cabbage yields in the New England conditions.

Alternative energy sources in regional NSW – understanding sustainable biomass energy systems

PhD Student: Brendan George

Supervisors: Prof. Annette Cowie (NCRGGR), Prof. Paul Martin (UNE)

There is a clear and growing need for diversifying our energy supply. Energy from biomass is one part of the solution but there is little information regarding the long-term feasibility and sustainability of production from multiple sources, especially for so-called 'second generation' systems. Some fundamental questions with direct policy implications for NSW Department of Industry and Investment and NSW Government include:



Yadu Bajgai - effects of alternative cropping management on soil carbon.

- What are some of the critical supply-chain issues (such as Greenhouse Gas Balance) for sustainable production of biomass based in energy from primary industries in NSW?
- How do we plan for a large-scale biomass energy system for NSW (Australia?)
- What is a feasible contribution of biomass energy to the overall stationary and transport energy mix?

There are two key methodologies available for research on renewable bioenergy systems.

1. The preferred approach is to utilise a scenario planning process based on known quantitative modelling systems. Through direct contact with Canadian developers (WhatIf Technologies) and interaction with CSIRO there is potential to utilise and develop simulation models for policy and scenario analysis.
2. The alternative is to utilise Life Cycle Assessment (LCA) procedures and techniques to estimate the GHG and energy balance of potential biomass energy generation pathways.

Following definition of key systems this would involve an initial inventory step and then an impact assessment of the options. The selection of the optimum methodology is yet to be completed and will be an initial focus of the research work.

There are significant research needs and requirements leading to better efficiency and utilisation of existing energy sources. This research, however, aims to identify the significant issues and in meeting some of the energy demand through utilisation of biomass material. We need to have some understanding and confidence that the proposed changes are socially, economically and environmentally robust and have the capacity to deliver on the expected benefits (e.g., such as actually delivering a GHG saving). This research aims to elucidate and answer some of the critical questions regarding the capacity for biomass energy to meet society's requirements through sustained production systems.

The information generated will have direct linkages to the I&I Framework for Action 2009-12

and policy outcomes sought by the NSW Government through the Biofuels Act 2007. Within the recent amendments to the act sustainability is a critical issue that will be addressed via regulations. It is expected that specific research will address some of the key parameters associated with determining sustainability such as Greenhouse gas balances.

Ionic liquids in the pre-treatment of biomass for bio-ethanol production

PhD Student: Amy-Sue Alston

Supervisors: A/Prof. Trevor Brown (UNE), Dr Tony Vancov (I&I NSW).

Second-generation biofuels have moved away from biomass sources that compete with food sources by using inedible plant material that can be grown on unused land, or even better, from plant or organic waste. A promising feedstock for second generation biofuels is lignocellulosic materials. Lignocellulose materials refer to plant biomass that is composed of cellulose, hemicellulose, and lignin and includes wood residues, municipal paper waste, agricultural residues, and dedicated energy crops. Lignocellulosic materials are of interest as raw materials for bio-energy production since they are available in large amounts and are relatively cheap. The current challenge with using lignocellulosic biomass as a feedstock is the technology to economically convert it into liquid fuels.

The production of biofuels from lignocellulosic biomass typically involves three steps: (1) Pre-treatment of lignocellulosic materials to enhance enzymatic/microbial/chemical hydrolysis; (2) hydrolysis of cellulose and hemicellulose to fermentable reducing sugars; and (3) fermentation of the sugars to liquid fuels or other fermentation products. Unfortunately, nature provides us lignocellulosic materials with physiochemical, structural and compositional



Brendan George - I&I Tamworth: PhD studies on alternative sources of energy in regional NSW.

features that confer a notorious resistance to hydrolysis. This biomass recalcitrance property holds back a cost effective technology to convert lignocellulose materials to sugars.

The key to unlocking lignocelluloses recalcitrance is an effective pretreatment process. Hydrolysis of lignocellulose to monosaccharides is usually catalyzed by enzymes. Enzymatic hydrolysis of lignocellulosic materials without pretreatment is generally known to be less than 20% of theoretical maximum. The two main causes of the recalcitrance of lignocellulose to enzymatic hydrolysis are believed to be (1) low accessibility of micro-crystalline cellulose fibres, which prevents cellulase from working effectively, and (2) the presence of lignin and hemicellulose on the surface of cellulose, which prevents cellulase from accessing the substrate efficiently.

A promising new pretreatment method for lignocellulosic materials is the use of ionic liquids (ILs). Ionic liquids are liquids at or below 100°C that are comprised entirely of cations and anions. The cations and anions can be varied to tune chemical and physical properties, including polarity, viscosity and melting point. ILs unique array of physio-chemical properties make them suitable in numerous applications in which conventional organic solvents are not sufficiently effective or not applicable. Today, ILs are recognized as one of the most promising green chemical solvents. Notable characteristics of ILs are their thermal stability, wide liquid temperature range, and good solvating properties for various kinds of materials.

The aims of Amy-Sue's project are to:

- Characterize and process a broad range of biomass sources, including barley, wheat, mustard, and sorghum straw, and also woody biomass samples such as salt bush;



PhD student Amy-Sue Alston (centre) with supervisors Dr Tony Vancov (I&J NSW) on left and A/Prof. Trevor Brown (UNE) on the right.

- Test biomass solubility in ionic liquids;
- Optimize pretreatment conditions- ionic liquid type, sonication intensity, temperature and time;
- Optimize enzymatic hydrolysis- concentration, cellulase/ β -glucosidase/ xylanase ratio, time;
- Profile the hydrolysis products and proof-test them as feed-stocks for fermentation;
- Investigate ionic liquid recycling.

An assessment of the relationship between organisation structure and innovation

Professional Doctorate Student: Darren Keegan

Supervisors: Dr Philip Thomas (UNE), Dr Lou Conway (UNE).

Darren's hypotheses are: that there is an identifiable relationship between organisational structure and innovation; and that organisation that are innovative have an identifiable capacity to adapt to a rapidly changing environment.

Aims

- The development of assessment criteria and the identification of the structuring

of organisations in a sample Australian context according to H. Mintzberg's templates.

- The identification of the key characteristics of a design of an innovative/ adaptive organisation.

Many organisations competing in global markets have organisational structures based on the experience of earlier periods of the industrial revolution when the intensity of communications and globalisation was influenced by the rising emergence of the assembly line, decolonisation and the dominance of Western industry. Western management practices heavily influence the structuring of organisations, commonly expressed by the work of H. Mintzberg as: machine, bureaucratic, entrepreneurial, political, missionary, diversified, innovative and professional structures.

In the past twenty years the emergence of information and communication technology and climate change has created new challenges for the traditional organisation. The rise of the internet as a tool for business to business and business to customer transactions and the emergence of social networking are changing the demands placed on the work place. Open

source development and on-line collaboration are changing how products are being designed and created. The expectations of workers and customers have changed with information on organisations and their products are discussed in chat-rooms and marketing and brand management is specifically targeted at the internet.

Climate change and corporate social responsibility is beginning to influence business practices and business planning and reporting. Pending legislation, national and international, will influence strategic planning and innovation within organisations. Low carbon technology will replace fossil fuel systems within structures and this will influence supply chains and how we view the workplace in the organisation and the community.

Other influences such as demographic change, the shift into cities, the rise of tribalism, globalisation, work-life balance and informed and discretionary consumerism place further strain on the 20th century structures of organisations.

However, the term "innovation" is commonly associated with new product development. In this thesis it is suggested that innovation also includes decisions and ideas designed to help the organisation adapt to an internal or external influence. Even the process of product design needs to consider the macro-environment context which is an extension of the design stage that traditionally seeks functional use and productive replication economies towards a true product life-cycle analysis.



Darren Keegan - I&J Tamowrth, Professional Doctorate Student.

Outcomes

- Identification of key trends between innovation and the structuring of organisations in Australia.
- An assessment tool and a graphical representation(s) of the relationships identified above.
- Organisational leaders and policy makers with data on the capacity of Australian organisations to adapt to change through innovation that will influence future organisational design and policy development.

Undergraduate Research Reports

Woody plant regeneration in grazing landscapes

Scott Keelan

Scott Keelan completed his Bachelor of Science undergraduate degree in 2005 as a mature aged student. From here he gained fulltime employment with the NSW Rural Fire Service as a Fire Prevention Officer in the southern riverina area of NSW. Some of the units of study which Scott enjoyed while at UNE focused on fire ecology and plant responses to disturbance. He says he can apply some of his skills and interests in his current position while determining long term bush fire management plans and working closely with government land management agencies.

The current partnership with PIIC is providing an opportunity for further studies relevant to the rural sector. This has

led to the development of an Honours project entitled "Woody plant regeneration in grazing landscapes in the NSW wheat sheep belt: climatic contrasts and carbon futures".

This project will use a number of different techniques in an attempt to identify the precise combination of factors that have lead to the contrasting regeneration patterns of woody plants in north and south NSW. Whilst woody plant regeneration occurs en masse in northern and central NSW and is often a nuisance for landholders, the same tree species are now in decline in southern NSW, with some trees and communities now listed as endangered. Given that trees often represent the most substantial contribution to site total carbon stores, identifying processes that govern tree regeneration in rural landscapes is now especially important. This project will quantify site carbon stores across grazing landscapes in the wheat sheep belt which will assist in landscape planning and future participation in emissions trading schemes.

Post-anthesis contribution of leaves and stem to wheat yield in the northern cropping region of new south wales

Alan Bowring

Bachelor of Rural Science

In Australia, the current industry used contribution values for various plant components such as leaves, stems and heads to grain yield in wheat have been based on estimates which originate from north-western Europe. These contribution values often form the basis of foliar disease management strategies. A number of studies have been conducted assessing these relative values using a variety of methods but limited studies have been conducted of a field based nature in the northern cropping region of NSW. In the 2008 and 2009, three trials investigated the contribution of the flag leaf, penultimate leaf and stem for contribution to grain yield in the period from anthesis to maturity. Methods of assessment included defoliation of leaves and desiccation of leaf tissue with a solution of potassium iodide. Assessment of the remobilisation of stem assimilate in the form water soluble carbohydrate (WSC) was also conducted. Defoliation methods were considered to alter the radiation interception properties of the canopy, potentially leading to compensatory adjustment of other components. Grain yield differed significantly between treatments for both years. The average contribution of the flag leaf to grain yield was found to be 23%, while the penultimate leaf was not assessed due to treatment structure. Although WSC was not significantly affected by treatment, it was found to contribute between 16-21% of the final grain yield. Grain number differed significantly across all trials. Due to the early anthesis treatment timing, reduction in grain yield was



Scott Keelan (left) received a PIIC honours bursary in support of this important project. Scott is supervised by Dr. Melinda McHenry (right).

thought to be a response to reduction in the source capacity of the plant (leaf loss), leading to a corresponding reduction in sink size (grain number) through floret loss at fertilisation or cell division. Contribution values widely differed from the current values commonly used by industry. This was not surprising given the vastly different environment and varieties utilised in northern NSW compared to north-western Europe. This study forms a preliminary basis for investigation of component contribution values for wheat yield in the northern grains region of Australia.



Alan Bowring - I&J Tamworth: foliar disease management strategies.

Undergraduate Teaching

Pasture agronomy

Clare Edwards and Carol Harris

Clare Edwards has been the District Agronomist with I&J NSW for the Armidale district for 13 years. She has worked with producers on regional issues and national based projects. In 2009, Clare and Carol Harris delivered pasture lectures to third year UNE Agronomy students. Currently Clare is working on the Trevenna project which is a joint I&J NSW and UNE project funded by the Department of Agriculture, Fisheries and Forestry and Meat and Livestock Australia. The Trevenna site was set up for replicated monitoring of methane, nitrous oxide and carbon dioxide fluxes from two sheep grazing systems (naturalised pasture v highly improved pasture systems). It is hoped the results will lead to practical on-farm greenhouse gas management strategies.



Clare Edwards - District Agronomist, I&J Armidale. Carol Harris - Pasture Researcher, I&J Glen Innes.

I&I NSW Honorary Appointments at UNE (as at July 2010)

Dr Bert Collard, Adjunct Senior Research Fellow

Dr Robin Dobos, Adjunct Senior Lecturer

Dr Garry Griffith, Adjunct Professor

Dr Ron Hacker, Adjunct Professor

Dr Robert Herd, Adjunct Associate Professor

Dr Nilantha Hulugalle, Adjunct Associate Professor

Dr Malcolm McPhee, Adjunct Senior Lecturer

Dr Malem McLeod, Adjunct Research Fellow

Dr Robert Mensah, Adjunct Associate Professor

Dr Sean Murphy, Adjunct Senior Lecturer

Dr Adrian Nicholas, Adjunct Research Fellow

Dr Dorothy Robinson, Adjunct Associate Professor

Mr Mark Shephard, Junior Research Fellow

Dr Graeme Schwenke, Adjunct Research Fellow

Dr Tony Vancov, Adjunct Senior Research Fellow

Dr Barbara Vanselow, Adjunct Associate Professor

Dr Lukas Van Zwieten, Adjunct Professor

Funds received from external grants in 2009

Funds received from external grants in 2009 totalled \$2,023,147

ACIAR: ASEM/2006/130

"Enhancing production and marketing of maize and soybean in north-western Cambodia and production of summer crops in north-eastern Australia" - **\$342,447**

ACIAR: CSE/2006/040

"Diversification and intensification of rainfed lowland cropping systems in Cambodia" (University of Queensland commissioned organisation) - **\$36,250**

ACIAR: SMCN/2006/013

"Increasing food security and farmer livelihoods through enhanced legume cultivation in the Central Dry Zone of Myanmar" - **\$50,664**

ACIAR: John Allwright Fellowship

"Development of Integrated Management Systems for control of insect pests of soybean" (Mr Pol Chanthy). - **\$50,286**

DAFF: From source to sink:

A national initiative of biochar research \$430K: (A. Cowie, L. Van Zwieten, BP Singh) - **\$51,000**

DAFF/GRDC:

The potential for agricultural management to increase soil carbon in NSW: Project funded by DAFF SCRIP (\$1.05M) and GRDC \$400K: (A Cowie, H Daniel, W Badgery, G Schwenke, M. McLeod,.) - **\$400,000**

DAFF/GRDC:

Measuring and mitigating nitrous oxide emissions in dryland cropping systems. DAFF CCRP funded by GRDC (G Schwenke, C Guppy, D Herridge, G McMullen). **\$300,000**

DAFF/MLA:

Genetic Improvement of Beef Cattle for GHG Outcomes (K Donoghue, R Herd) - **\$400,000**

DAFF/MLA:

Investigate techniques to reduce methane production in ruminants by eliminating protozoa from the rumen and through the use of dietary supplements (R Hegarty, J Nolan) - **\$200,000**

GRDC, MLA, BRG CMA:

Grain & graze – Border Rivers Region I. (C Guppy, S Murphy, C Harris) - **\$180,000**

GRDC:

PDH00001 "Beneficial Microbes Program - progressing new microbial products for Australian grain production to commercialisation" - **\$12,500**

International Outreach

Annette Cowie

United Nations Convention to Combat Desertification (UNCCD) Committee on Science and Technology

Annette provided input to the UNCCD's Committee on Science and Technology Working Group on indicators for monitoring and assessment of sustainable land management. She participated in a meeting of experts in Bonn, 2-3 July, and coordinated development of a chapter on "Connections between monitoring and assessment of sustainable land management and the Climate Change and Biodiversity Conventions" for 'Understanding Desertification and Land Degradation Trends', White Papers for the First UNCCD Scientific Conference. Annette subsequently led the drafting of a journal paper based on the chapter, for submission to a special issue of the journal *Land Degradation and Development*.

International Energy Agency (IEA)

Annette participated in the 3rd annual joint Forum on 'Sustainable development of biofuels', 7-8 September, Bangkok, hosted by The Thai Ministry of Energy (MoEN) and the International Energy Agency (IEA). She presented a paper on "Global challenges for sustainability of biofuels: life cycle assessment of GHG emissions", summarising the methodology and findings of IEA Bioenergy Task 38.

IEA Bioenergy

As Co-task leader IEA Bioenergy Task 38 Greenhouse Gas Balances of Biomass and Bioenergy Systems, Annette assists in managing this collaborative program involving researchers from Australia, Austria, Brazil, Belgium, Germany, Finland, Sweden, the Netherlands and USA. The task develops and demonstrates methodology

for assessing the climate change benefit of bioenergy and sequestration projects, and contributes to climate change policy development. Annette assisted in organising and delivering the following international workshops :

- Helsinki, Finland, 30 March–1 April, 2009, on the topic "Land Use Changes due to Bioenergy Quantifying and Managing Climate Change and Other Environmental Impacts" Annette presented a paper on "Direct effects of bioenergy systems on soil carbon".
- Graz, 26-27 October, Task 38 plus "Graz Group" Expert Meeting, considering the topics: Dealing with Non-Permanence in LULUCF and REDD; Development of NAMA guidelines for Land-use and Bioenergy; and Accounting for Emissions from Bioenergy. Annette contributed to drafting policy briefs on these topics.

International Biochar Initiative (IBI)

Lukas Van Zwieten and Annette Cowie are members of the science advisory panel of the IBI. In 2009 they contributed to development of fact sheets and policy guidance aimed at ensuring the safety and sustainability of the emerging biochar industry.

ANZ Biochar Researcher's Network

Lukas Van Zwieten and Annette Cowie are members of the committee that founded and now manages the ANZ Biochar Researcher's Network, which organised the Asia Pacific Biochar Conference Gold Coast Australia 17 – 20 May, 2009 and established the ANZ Biochar researcher's network web site:

<http://www.anzbiochar.org/>

International Standards Organisation (ISO)

Annette Cowie is a member of the ISO committee (TC 207 SC 7 GHG management WG 2) that is developing an international standard for calculating and communicating the carbon footprint of a product. The working group met in Vienna 19-21

October to consider comments submitted on the second Working Draft. A revised draft was subsequently released for further comment. It was originally intended that the standard be published in early 2011 though it is likely to be delayed to allow for consensus-building on several complex issues, including accounting for timing of emissions, indirect land use change, and suitable methods for communicating the result.

Subhadip Ghosh

Subhadip received PIIC support for travel to Colorado USA to attend the International Symposium on Soil Organic Matter Dynamics: Land use, Management and Climate Change. The aim of the symposium was to present the latest research on soil organic matter (SOM) across the globe and highlight future research directions. Subhadip's presentation was titled:

- "Impact of land use variation on soil C change in different agricultural soils in NW New South Wales, Australia (S Gosh).

David Herridge

David Herridge is involved in ACIAR Project SMCN/2006/013 'Increasing food security and farmer livelihoods through enhanced legume cultivation in the Central Dry Zone of Myanmar'. Activities and outcomes:

- Visited with Professor Bob Martin to Khon Kaen University and Suranaree University of Technology, Thailand, for discussions on rhizobial inoculants for legumes and their potential supply to Cambodia.
- Reviewed progress by the Rhizobium/inoculant production group at DAR, Yezin, in adoption of laboratory practices from the 2007 and 2008 training programs in Thailand and 2007 and 2008 site visits

- Reviewed development of the laboratory facilities of the Rhizobium/inoculant production group against a set of objectives;
- Reviewed in conjunction with Dr GV Ranga Rao and Mr AG Surender Reddy of ICRISAT, India, the groundnut, pigeonpea and chickpea varietal improvement and village seed bank programs at DAR, Yezin.

Malem McLeod

Malem is involved in ACIAR Project SMCN 2007/040 "Building more profitable and resilient farming systems in Nanggroe Aceh Darussalam and New South Wales". Malem received a travel grant from PIIC to present a paper at an international seminar in Indonesia in 2009. Activities and outcomes:

- Synchronised protocols for biochar experiments in Aceh and Australia
- Presentation of a keynote paper at an International Seminar at the University of Jenderal Soedirman and public lecturers at University of Jenderal Soedirman (UNSOED) and University of Gajah Mada (UGM)
- Mr. Slamet Supriyadi to undertake PhD studies on biochar at UNE funded by the Indonesian Government
- The Trunojoyo University Madura has also sought collaboration with PIIC in other fields of research such as Food Science.
- Increased opportunities to develop collaboration with various Indonesian Universities, particularly on biochar research.

Bob Martin

Bob travelled to Cambodia three times in 2009 as leader of the ACIAR Project ASEM/2006/130 "Enhancing production and marketing of maize and soybean in north-western Cambodia and production of summer crops in north-eastern Australia". Activities and outcomes:

- In north-west Cambodia, we found that production costs exceed income for smallholder farmers. The project has demonstrated that improved production techniques can profitably increase yields of maize, soybean, peanut and mungbean.
- Three John Allwright Fellowships for PhD/Masters study in Australia: Mr Pol Chanthy, IPM in soybean (UNE); Mr Chea Sareth, PhD studies at the University of Queensland; Ms Srey Sinath, masters studies (University of Melbourne).
- Three publications in the ACIAR monograph series.

Mike Sissons

Mike attended and presented two papers at the 10th International Gluten Conference (IGC) at Clermont-Ferrand, France, September 7-9. He also visited Dr Joel Abecassis, INRA, Montpellier, toured facilities and discussed experimental plans with Dr Abecassis and Dr Valérie Lullien for a GRDC Senior Research Fellowship study trip in July 2010. The aim is to discuss improved methods to select for increased milling yield in early generation breeding. Currently, there has been little progress in the Australian program with milling yield and this could be related to lack of appropriate testing methods. This issue was highlighted at the 2008 Northern Durum Industry Advisory Meeting where ADWIP is expected to address this issue. Plans were developed for the forthcoming visit in 2010 with INRA scientists in September.

Publications

Refereed journals

Allen DE, Mendham DS, Bhupinderpal-Singh, Cowie A, Wang W, Dalal RC, Raison RJ (2009) Nitrous oxide and methane emissions from soil are reduced following afforestation of pasture lands in three contrasting climatic zones. *Australian Journal of Soil Research*, **47**: 443-458.

Chan P, Martin R, Farquharson R, Ung S, Pol C and Pin T (2009). Farmer's challenge in improving upland farming systems in Cambodia. *Cambodian Journal of Agriculture*, **9**: 8-23.

Cherubini F, Bird ND, Cowie A, Jungmeier G, Schlamadinger B, Woess-Gallasch S (2009) Energy- and greenhouse gas-based LCA of biofuel and bioenergy systems: Key issues, ranges and recommendations. *Resources Conservation & Recycling*, **53**:434-447

Peoples MB, Brockwell J, Herridge DF, Rochester IJ, Alves BJR, Urquiaga S, Boddey RM, Dakora FD, Bhattarai S, Maskey SL, Sampet C, Rerkasem B, Khan DF, Hauggaard-Nielsen H, Jensen ES (2009) The contributions of nitrogen-fixing crop legumes to the productivity of agricultural systems. *Symbiosis*, **48**: 1-17.

Pin T, Martin R, Ung S, Elias N and McCorkell B (2009). Rhizobial inoculation versus nitrogen fertiliser for mungbean, peanut and soybean in rainfed upland areas of Cambodia. *Cambodian Journal of Agriculture*, **9**: 54-61.

Vancov, T., Keen, B., 2009. Amplification of soil fungal community DNA using the ITS86F and ITS4 primers. *Fems Microbiology Letters*, **296**: 91-96.

Vancov, T., Keen, B., 2009. Rapid isolation and high-throughput determination of cellulase and laminarinase activity in soils. *Journal of Microbiological Methods* **79**: 174-177.

Wilkie JD, Sedgley M, Morris S, Muldoon S, Olesen T (2009a) Raceme position in macadamia. *The Journal of Horticultural Science & Biotechnology*, **84**: 387-392.

Wilkie JD, Sedgley M, Olesen T (2009b) A model of vegetative flush development and its potential use managing macadamia tree canopies. *Crop & Pasture Science*, **60**: 420-426.

Books and monographs

Belfield S and Brown C (2009). A guide to upland cropping in Cambodia: maize. ACIAR Monograph MN140. ISBN: 978 1 921531 59 0 (online). This manual, previously published in English, was re-published in Khmer language and is currently being distributed.

Martin B and White D (2009). Jorani and the green vegetable bugs. ACIAR Monograph MN137. ISBN: 978 1 921531 04 0. This book was published in English and Khmer. Negotiations are now underway to publish a Lao version of the book in collaboration with the Lao/Japanese NGO "Action with Lao Children."

Martin R and Pol C (2009). Weeds of upland crops in Cambodia. ACIAR Monograph MN141. ISBN: ISBN 978 1 921531 65 1 (online).

O'Connell D, Braid A Raison J Handberg K Cowie A Rodriguez L and George B. (2009) Sustainable production of bioenergy: A review of global bioenergy sustainability frameworks and assessment systems. Rural Industries Research and Development Corporation 134pp.

Book chapters

Gaunt J and Cowie A (2009) Biochar, greenhouse gas accounting and emissions trading. Ch 18 pp 317-340 *Biochar for Environmental Management: Science and Technology* Ed J Lehmann, S Joseph. Earthscan.

Peoples MB, Unkovich MJ, Herridge DF (2009) Measuring symbiotic nitrogen fixation by legumes. In: *Nitrogen Fixation in Crop Production* (D.W. Emerich and H.B. Krishnan, Eds), *Agronomy Monograph* 52, American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, U.S. Pp 125-170.

Vancov, T. and Jury, K. 2009. Chapter 11: Atrazine degradation using alginate encapsulated *Rhodococcus erythropolis* NI86/21 in *Advances in Environmental Research*, Volume 6. Nova Science Publishers, Inc. (chapter accepted, ISBN: 978-1-61728-163-1).

Van Zwieten L, Bhupinderpal-Singh, Joseph S, Kimber S, Cowie A, Chan Y (2009) Biochar reduces emissions of non-CO₂ greenhouse gases from soil. Chapter 13 *Biochar for Environmental Management: Science and Technology* Ed J Lehmann, S Joseph. Earthscan.

Conference proceedings

Aravind N, Sissons MJ and Fellows CM (2009). Effects of microbial transglutaminase on semolina rheological properties and spaghetti cooking quality. *International Gluten Workshop*, Clermont Ferrand, France, Aug 2009.

Cato L and Sissons MJ (2009). Durum semolina and pasta assessment using the 'Mixolab®'. *Australian Cereal Chemistry Conference* Wagga Wagga.

Cowie A. Greenhouse gas mitigation benefits of biochar as a soil amendment *Asia-Pacific Conference of the International Biochar Initiative*, Gold Coast, May 2009.

Cowie A. Direct effects of bioenergy systems on soil carbon: implications for climate change benefits of bioenergy *Land Use Changes due to Bioenergy Quantifying and Managing Climate Change and Other Environmental Impacts* IEA Bioenergy Task 38 Workshop, Helsinki March 2009.

Cowie A. Is Bioenergy Really Carbon Neutral? *IEA Bioenergy Task 38 Greenhouse Gas Balances of Biomass and Bioenergy Systems*. Bioenergy Australia Conference, Gold Coast, December 2009.

McIntosh, S. and Vancov, T. Dilute Alkaline Pretreatment of agricultural waste residues. *Bioenergy Australia 2009 Conference*, Radisson Resort Gold Coast, Qld, Australia.

McLeod MK and Rachnianna A (2009). Upland crop production in Indonesia: Constraints and potential. Presented as a keynote paper at the *International Seminar Upland for Food Security*. Universitas Jenderal Soedirman, Purwokerto, Jawa Tengah, Indonesia 7-8 November 2009.

McLeod MK, Slavich P, Rachman A, Gani A, Husen E, Tinning G, and Lines-Kelly R (2009). Developing collaborative biochar research in Aceh, Indonesia. *Proceedings of: 1st Asia Pacific Biochar Conference*. Gold Coast Australia 17-20 May 2009. pp.94-95.

Sissons M, Aravind N and Fellows CM (2009). Quality of Durum Wheat Spaghetti with added Microbial Transglutaminase. Can this Enzyme Restore Product Quality in Spaghetti with added Fibre? *Australian Cereal Chemistry Conference* Wagga Wagga.

Vancov, T. and McIntosh, S. Dilute Acid Pretreatment of agricultural waste residues. *Bioenergy Australia 2009 Conference*, Radisson Resort Gold Coast, Qld, Australia.

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