AGRICULTURAL SCIENCE
PEER-REVIEWED RESEARCH AND NEWS IN AGRICULTURE AND NATURAL RESOURCES MANAGEMENT.

FEATURED ARTICLES
> VALE: DAVID FLOYD SMITH
> THE HOWARD TRUST AND PASTURE RESEARCH IN AUSTRALIA
> THE EVOLUTION OF AGRICULTURAL EDUCATION
> ERIC BOND AND THE SHAPING OF THE BREAD RESEARCH INSTITUTE
> REMEMBERING HOW TO WRITE BEAUTIFULLY
> USING FARMLANDS FOR ELECTRICITY GENERATION
Agricultural Science is the official journal of Ag Institute Australia, the trading name of The Australian Institute of Agricultural Science and Technology (AIAST), published twice annually, in May and November.

The journal is an independent and authoritative resource for professionals engaged in agriculture and natural resource management to inform each other and the general community of significant scientific developments in relevant disciplines. It also contributes to its members’ own professional development by publishing relevant articles and promoting networking opportunities and activities conducted on their behalf.

It accepts manuscripts and papers for peer review from academic and non-academic sources, including from non-members, especially featuring applied research results, as well as invited and contributed articles, divisions’ activities and seminarCONFERENCE reports, obituaries, letters and book reviews.

The journal is currently listed in the ERA 2012 Ranked Outlet Consultation lists and it is being impact evaluated by Thomson Reuters.

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I thank Adrian Egan for his summary of the recent AIA Conference conducted jointly with the South West Science Council, and look forward to publishing some of the papers in future issues."

Like many in the Institute, I look back fondly to my time as an undergraduate in the 1970s. Amongst other things, we could develop strong and deep relationships with our teachers, and these extended into professional and personal bonds that have lasted throughout our careers. David Smith was the embodiment of such an academic. Although David had left Melbourne before I started, his influence was clear and lasting, and it was a pleasure to be able to work with him later in our respective careers. His deep interest in his students and their successes is described in his obituary published in this issue of the Journal. David was a stalwart of the Institute, and of the application of science to the practice of agriculture. His contributions as a public intellectual will continue to have an impact for many years to come. His career is a fine model for new entrants into the profession to study.

Education is also the focus of other papers in this issue, particularly the contribution by Jim Pratley and Cameron Archer that traces the evolution of agricultural education, and particularly farmer education, from the early days of settlement. Understanding our history is important for the profession and it is interesting to see the many changes in approaches, practice and policy that have occurred over the last 200 years.

Continuing a historical theme are two other contributions. First, Lindsay O’Brien traces the shaping of Australia’s Bread Research Institute by Eric Bond, and covers some important contributions made to the development of the nation’s grains industry through the application of sound science. John Radcliffe continues with a paper on the Howard Memorial Trust that has supported pasture research for the last 50 years. He touches on the contributions of Amos Howard and reminds one of the importance of observation in our practice as scientists. Observing what is happening in the field is still a very powerful and very necessary part of our role as agricultural scientists.

Development of a decision tool that farmers and advisers can use to mitigate wheat yield losses is the focus of a paper by Darshan Sharma of the WA Department of Agriculture and Food. This work developed in Western Australia has wider implications and we welcome the opportunity to publish the work here.

Always eclectic, the Journal also publishes an article by Turlough Guerin that addresses a long-standing debate on whether or not agricultural land should be used for producing energy. This paper provides a well-balanced framework and concludes that large-scale solar developments have the potential to transform rural landscapes in positive ways.

It is pleasing to publish two contributions from younger members of our profession. Caspar Roxburgh from the Queensland Alliance for Agriculture and Food Innovation readily accepted my invitation to expand on an earlier article that he had published on the RAID network (Researchers in Agriculture for International Development) on how much of the writing that we now produce in science has become clinical and sterile (my words!). It will be interesting to see how members respond. Can we, and should we, care for beautiful writing?

Emily Webb Ware, an undergraduate in the University of Melbourne, reflects on how organisations like the Institute can help students enter careers in agriculture. Again there are challenges here that we individually, and as an Institute, need consider.

The Federal Government is about to launch a national enquiry into regional development and decentralization. This is outlined in a short contribution from Cathy McGowan, the Federal Member for Indi, and a staunch supporter of agriculture in our political system.

The Australian Academy of Science has also provided a contribution on the Decadal Plan for Agriculture that is has released recently.

I trust that the Journal continues to provide a useful and valued source of information for members and for the wider readership, and I acknowledge gratefully the efforts of those who are contributing articles. I particularly acknowledge Jim Pratley who makes valuable contributions in many of our issues. However, it is not always easy to find enough contributions to make a viable issue and that is one of the reasons why the last couple of issues have been late off the press.

The Institute recognises that there are opportunities to expand the scope and the content of this publication. The Board therefore will be reviewing the Journal over the next 5 to 6 months, with a view to introducing changes that will encourage a wider contribution and serve a wider range of interests. If you have any ideas on this subject, I would welcome hearing from you.

Above all, the journal is only as good as the contents, which is dependent on the goodwill of contributors - both members and non-members.

Good reading!

Shaun Coffey
FROM THE CHAIRMAN’S DESK

Andrew Bishop, Chairman

A STRATEGIC FOCUS FOR AG INSTITUTE AUSTRALIA - RISING TO THE CHALLENGE

A challenge all organisations face is determining where and in what to invest both monies and energies to maximize benefits for the members. This really is all about strategy; continuing to progress both strategy development and implementation is something the AIA board takes very seriously. Following our Annual General Meeting in May 2017, the re-election of directors (including myself thank you members), and the appointment of two new directors from our membership, the scene is set to continue focused action in three broad areas: divisional support/membership development, accreditation and communications, including a national conference. These three broad areas are all accompanied by a healthy side of exploring additional revenue streams for the institute to continue to secure the financial base of our organisation.

Accreditation and recognition: With the board’s recent decision to focus on the development and implementation of a pilot national accreditation scheme for agricultural professionals this will first be tested for the Commonwealth Government and will be focused on water use efficiency. In tandem with that action will be the reinvigoration of our existing CPAg professional development recognition system, 2017-18 will be a defining year for our professional recognition and accreditation activities. We have established alliances with several like-minded organisations that will be watching developments and of course we will be looking to integrate and compliment other related systems. Awards and recognition of those contributing to their profession remains a very high priority. Each year when I watch our national student award finalists I know that our recognition and encouragement of our students is an activity of great importance and one that recognizes the enthusiasm of these early career professionals. Peracto’s ongoing sponsorship of these awards is also testament to industry recognition of the importance of our up and coming professionals.

Divisional support and Membership: There are several facets of membership that are the focus of key strategic actions including the imminent appointment of a divisional support officer. This extends beyond simply event assistance to the identifying of needs for divisional maintenance and strengthening, increasing membership, and also funding options. All in all, a stimulus in this area will be of direct benefit to the viability of AIA and support of its members at all levels. We will be repeating our divisional engagement workshop later this year following on from its success in 2016.

Communications: A big area but communications are occupying the board’s strategic attention over the next year. Members will have seen a survey circulated in recent times about a national conference. Our new board is certainly keen to develop such an event for later in 2018 and is keen to hear the thoughts of members. This would be a truly national event with professional organisers alleviating divisional pressure and enabling the latter to provide intellectual input. Social media will take its place as a fully utilised communications and marketing vehicle. Also standby for some new developments with respect to our journal. Our editor Shaun Coffey and sub-editor Turlough Guerin work hard to bring together the journal. We are very conscious of a constantly changing environment presenting challenges to our journal and other communications vehicles and are committed to keeping our communications contemporary through appropriate development. Speaking of the journal, I commend this edition to you and trust you will find the information it contains of great value and relevance to your professional lives.

Andrew Bishop
Chairman
chair@aginstitute.com.au
It is with sadness that we advise the passing on Saturday 22 April 2017, aged 88, of our esteemed member Dr David Smith AM, Medal of Agriculture [AIAS], FIAAS, a stalwart of Ag Institute Australia. He rose to the top in Victorian Agriculture holding the role of Director General of Agriculture, State of Victoria in the 1980’s. He had a distinguished career where he taught, worked, networked with many and championed the advancement of agriculture and agricultural education.

David started from humble beginnings on a dairy farm in the Adelaide Hills during the Depression, he was born on 27 October 1928. At that time there was no electricity, no gas, and once petrol rationing started, no car. David’s first ambition was to be a rabbiter as rabbits were the family’s main source of food and income. Despite these obstacles David finished an ag. sc. degree at Adelaide University and soon became a schoolteacher at Cummins in the Eyre Peninsula, teaching agriculture. And so began the two great passions of David Floyd Smith’s life, agriculture and education. After Cummins and a stint as a researcher in the South Australian Department of Agriculture, he became a lecturer at The University of Melbourne in 1957, teaching in the Agricultural degree, first at Dookie Agricultural College and then at Mount Derrimut Agricultural Station of that university, which David helped establish and then by coincidence closed down. He remained friends with many of his students for the rest of his life and took satisfaction in their successes. This network continued to give him insights into the changes and challenges in Agriculture.

In 1974 he began a stint as Principal of the Tasmanian College of Advanced Education at Launceston, although after some years his energies were increasingly frustrated by the North-South politics in that state and the larger movements in higher education. Whilst in Tasmania he had been on the Board of the Tasmanian Museum and Art Gallery, and the restricted publications board reading and viewing pornography!

Restless, he applied for and was appointed to the position of Director General of Agriculture in Victoria in 1979 under the Hamer Government where he directed a staff of 5000 and won the award for the best Government Department for his Department. After 6 years the Cain Government gave him a series of special assignments, the first being as Head of Community Welfare Services. But these led to a series of short term appointments and projects some official, some extra-curricular.

The Kirner Government asked him to set up a new body, The Victorian Animal Welfare Advisory Committee, where one of his achievements was to introduce the registration of domestic cats in Victoria. He was made Chair of the National Egg Industry Research and Development Board. Then he established and became Chair of the Victorian Curriculum and Assessment Board, and later acting Chair of the Victorian Post-secondary Education Commission. He was a member of the Council of The University of Melbourne from 1979 to 1986, the Board of Caulfield Grammar School from 1983 to 2000, the Australian Dairy Research Committee, the Australian Meat Research Committee, and the Victorian Land Conservation Council. These posts emphasised David’s enduring passion in education.
In 1983 the Federal Primary Industry Minister, John Kerin, asked him to be Australia’s representative on an international review of the operations of the United Nations’ Food and Agricultural Organisation, FAO. Then in 1984 Kerin asked David to set up and Chair the Cotton Research and Development Organisation. In that role he made the controversial decision to allow the cultivation of genetically modified cotton crops, which resulted in spectacular increases in productivity and a reduction in environmental impact by reducing the use of pesticides. For 3 years from 1997 he was a local councillor with the Shire of Strathbogie, where he had a farm, which he loved and developed into a sustainable and self-sufficient haven.

He was made a Member of the Order of Australia in 1995. He gained the Australian Medal in Agricultural Science in 2003 and was President of The Australian Institute of Agricultural Science. He gained numerous qualifications (B Ag Sci, M Ag Sci, Dip Ed, PhD, and M Ed Admin).

In earlier years he had been a political activist, opposing the Vietnam War and being Victorian convener of the Australia Party, the forerunner of the Australian Democrats. He was always a strong advocate for public transport, being on the Victorian Transport Advisory Board, and for bikeways including playing an active role in establishing the bike path from Flinders Street to Hawthorn along the Yarra River. In later years he was more critical of what he saw as ignorant Green attacks on agriculture and romantic nostrums about organic farming, often writing for the Quadrant magazine on these themes. He wrote two books, which gained acclaim, “Natural Gain in the Grazing Lands of Southern Australia” and “Rain and Shine”.

David made a generous donation of $20,000 to his old High School at Mount Barker to support an annual prize for an essay on “the impact of some clover and fertilisers on the productivity of agriculture in southern Australia”.

David was an active member of Ag Institute Australia and its President at a past stage. David initiated monthly luncheons with a special guest speaker, so that Institute members could be kept up to date with agriculture advances, network and maintain their friendship links. David guided this for 11 years and it was fitting that the last luncheon that David organised included Professor Tim Reeves speaking on the topic: “Major Challenges facing World Agriculture by 2050”. David had been a long-time mentor of Tim’s. Vale David, you have certainly served your passions, agriculture and education, well over your lifetime.

The University of Melbourne sent the following tribute and because of David’s association it is included in full.

The lives of Dr. David Floyd Smith, AM and the School of Agriculture at The University of Melbourne were intricately linked, from the time David commenced as a Lecturer at Dookie Agricultural College in 1958 through to the Honorary Senior Fellowship, which he carried out with exceptional intellectual energy and distinction until his death in April 2017.

An old-style agronomist-agriculturalist, David’s life-long professional passions of agriculture and education came together at The University of Melbourne, as well as, in many other fields of public service and education, nationally and internationally.

Among David Smith’s many scholarly contributions to his discipline, his book ‘Natural Gain in the Grazing Lands of Southern Australia’ in which he drew from on his whole career’s work from his early years growing up in South Australia to detail the subterranean clover and superphosphate revolution in Australia of the 1950s and 1960s – a revolution that tripled stocking rates on grazing lands - was a masterly work.

David’s deep commitment to agriculture and education motivated his well-recognized role as a public intellectual, unhesitatingly staking out cogent public positions, leading debates in defending agriculture and education when it came under ill-considered, ill-informed, unjustifiable attack from anti-science, anti-education, anti-intellectual forces.

David Smith worked ceaselessly to advance agriculture in Australia. Along the way David positively influenced people throughout society. David’s advocacy for the good and right earned him the deeply-held, genuine respect of his peers and brought much deserved credit to the School of Agriculture and The University of Melbourne.

David is survived by his companion, Pamela, his daughter, Kathryn, sons, Graham and Andrew, 8 grand-children and one great-grandson, Henri. His two wives (Marian and Susan and a son, Stephen) predeceased him.
Adrian Egan PhD FAIA FTSE, is Emeritus Professor and Honorary Professoral Research Fellow at the University of Melbourne and an Adjunct Professor at the The University of Western Australia.

Adrian and his wife Lesley returned to WA in 2004 after a 40-year interstate and international odyssey; choosing Bunbury as home base. In “retirement”, Adrian consults on environmental research and policy formulation, and has a mix of honorary activities that utilise his expertise in specialist research and research management or serving the community more widely. In 2002 he was awarded the Centenary Medal for services to Environmental Sciences, and in 2004 the Centenary of Agricultural Science Medal.

Adrian was born in Carnarvon in 1937, educated at Perth Modern School, graduated from UWA in 1958 with a BSc (Agriculture). He worked as a research officer in the WA Dept of Agriculture for 3 years, then returned to UWA completing his PhD in 1964. Since then he has held research and teaching positions at the University of California (Davis), the University of Adelaide’s Waite Agricultural Research Institute and, from 1983 until retirement in 2003, The University of Melbourne. There he served for 20 years as Professor and Head of Department of Animal Science, but was also for periods Director of the Centre for Farm Planning and Land Management, Dean of Faculty, Chair of the Australian Association of Agricultural Deans and Acting Dean of The University of Melbourne’s School of Graduate Studies. He has also held Visiting Research Fellow and Visiting Professorial positions in New Zealand, Scotland, Thailand, India, and the USA in California, Wisconsin and Ohio.

He is a co-author of the text “Agriculture in Australia”, has published more than 200 research papers, chapters in books and commissioned reports. He has supervised more than 50 successful PhD and research Masters students. Returning to an early love of literature, his writing now includes creative non-fiction, memoirs and poetry.

REPORT OF THE JOINT AIA/SWSC 2017 NATIONAL CONFERENCE
MANJIMUP WA 18-19 MAY 2017.
SCIENCE AND INNOVATION IN SOUTH WEST AGRICULTURE
Adrian Egan, Chair, South West Science Council Inc.

INTRODUCTION
All roads led to South West WA in May for a topical conference at which up to 75 participants came together to listen, discuss and ponder the wisdom and knowledge generated by a program of 17 presentations addressing the vital role of science and technology in driving vibrant agricultural and agribusiness industries in the South West region of WA.

The two-day conference held at Manjimup on Thursday 18th and Friday 19th May 2017, was jointly organized by the South West Science Council and the Ag Institute of Australia, WA division.

The exciting program also included the presentations of five divisional finalists competing for AIA’s Young Professionals in Agriculture award, as well as the AGMs of both sponsoring organisations, a dinner and a half-day tour of four local examples of innovation in practice.

Sadly, numbers had dwindled for this last event with only 15 taking part. The AIA directors used the opportunity of coming together for the AGM to also hold an in-person board meeting.

CONFERENCE OVERVIEW
The south west of Western Australia supports a wide range of agricultural industries including annual and perennial horticulture, dairying, viticulture, silviculture, sheep and cattle grazing, floriculture and aquaculture. The goods are marketed variously as niche luxury products through to bulk domestic and export commodities. Local value adding is important and the region is also widely recognised as a food and wine tourism destination.

The conference was opened by WA Chief Scientist, Professor Peter Klinken FTSE. In setting the scene he addressed the topic, “Science and the tools for continuous improvement of agricultural enterprise”. His key official State role is to provide independent advice to the Government of WA on science and innovation, broadening the economy and promoting science to build leading-edge capacity, promote science policies and raise public awareness.
In his address, Dr Klinken highlighted that although Australia has only 0.3 per cent of the world’s population, we generate 3 to 4 per cent of the world’s new knowledge. While we punch above our weight in that area, we fall well behind in converting that knowledge into implemented technologies; we rank less well (9th in the OECD) in the conversion of that knowledge into implemented technologies. Furthermore, we are way down in terms of the number of firms collaborating with academia (34/34), and in firms collaborating globally (26/34). Building political support for research and development is an urgent need. Finally, we need more people with STEM (science, technology, engineering and maths) skills, given that 40 per cent of all new jobs will require these skills.

To describe the regional setting in which the conference took place the Manjimup Shire President Cr Paul Omodei Snr outlined the Shire’s objectives in agricultural expansion, partnering with industry, the Department of Agriculture and Food WA (DAFWA) and promoting the region through assistance received from the Royalties for Regions Program, and local education providers. The 7,000-km² Shire and its industries lie inland of 140 km of rugged coastline, with significant national parks, state forests, reserves and wilderness areas, seven pristine rivers, environmentally significant wetlands, and a biodiversity hotspot (D’Entrecasteaux National Park). Within this area lies a mosaic of agricultural land, with the largest and most diverse horticultural, food production and timber production in WA. Innovation, education and skill training are supporting new entrepreneurial activity, value adding of local produce and, potentially, a new generation of agrifood specialists. Paul highlighted the work being done in all these areas by the Southern Forests Food Council, which has 400 members across the region.

HOW SUSTAINABLE IS ALL THIS?

Dr Mike Christensen (South West Catchments Council) approached this key issue speaking to the topic Farming, Landcare and Natural resource management - can they still work together under a changing climate? The evidence is that rainfall is decreasing and temperatures are rising. In catchments of mixed agricultural and non-agricultural land, the differing skillsets and the avenues of adaptation that farmers and NRM workers can share and further develop are the key to meeting these challenges.

For on-farm sustainability, Manjimup-based consultant Paul Omodei Jnr (PlanFarm) put his experience in agricultural supply chain services and consulting on whole farm planning to work, outlining, “Advice you wish clients would take on board”. He provided information from annual farm business analysis of 532 farm businesses throughout broadacre regions of WA to show that good management continues to generate very good returns, that clients receiving advice on whole farm planning understand their business better and identify needs for improvement. Overarching this and to fulfil farm business succession plans there is a basic need to lift the profile of agriculture. He stressed the importance of building managerial skills and knowledge through benchmarking and recognition that farming is essentially a “people business”.

Fig. 1 South West WA

SW WA Land Conservation Districts

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DO WE HAVE WORLD CLASS PRODUCTION SYSTEMS?

While top farmers benchmark their businesses against both domestic and global standards, consumers at home and abroad compare prices in the local market place and seek value for money. Global players with a competitive advantage can determine where our producers sit in the scale and security of their market share. The matter of global competitiveness and sustainability of WA’s agricultural industries has been the subject of a consultants’ report, “Pathways to Competitiveness”, commissioned by the DAFWA. Tim Morris, of Coriolis Research, examined the ten-year growth of total food and beverage export value for 66 nations and placed WA at the tail end of the field, performing like a small developing country. He advanced views on where global competitiveness might be increased and the full report examines several agricultural production sectors and the impact and potential of value adding.

After a 35-year career in the wine industry, Phil May is now the Manager of the West Australian Premium Food Centre, DAFWA. In his presentation, he reviewed WA’s Premium Food Sector, identifying the existing opportunities and challenges, then moving on to the emerging opportunities. Many of these lie in the horticulture sector where premium quality standards in export or domestic markets need to be met and where “not-quite-right” product, seen as waste, can be transformed by smart processing into other saleable lines.

WHAT DO OUR SW PRODUCTION SYSTEMS LOOK LIKE?

The yields and the quality of any horticultural crop, both annual/seasonal and perennial, are highly dependent on water availability. Timing of irrigation from locally accessed water resources is used to manage crop available water and crop microclimate and influences nutrient availability, its soil profile distribution and extent of leaching losses. With changing climate posing additional risk, more tools for close management of a scarce resource will be essential. Tilwin Westrup, Irrigated Agriculture Development Officer, DAFWA, discussed a range of soil moisture monitoring and direct crop monitoring technologies and telemetry for automated irrigation systems and the potential use of covered cropping.

The close interaction of scientists and producers in several regional industries was further highlighted as science and innovation were strongly coupled in new and emerging management practices supporting business success and entrepreneurship.

Avocado production was pioneered in the SW region 35 years ago and today is a major contributor to the agricultural sector of the WA economy. As we learned from Shire President Paul Omodei Snr, and subsequent speakers, the avocado industry in WA is set to quadruple in the next 5 to 8 years.

Doug Pow, who farms a Manjimup property, grazes beef cattle through his avocado orchards. He has added some innovative bio-management to his farm enterprise. Feeding biologically activated biochar to his cattle and establishing a working population of dung beetles, his story was one of biological renovation of the soil nutrient base to retrieve insoluble elements, particularly P, and assessing the economics in terms of crop productivity and savings on other farm inputs. Mixing relatively low rates (5%) of biochar to the soil beneath avocado saplings is increasing growth rates significantly. The Friday tour visited this operation.

A new industry in the region opened up in the early 1990’s, with the planting of truffle host trees inoculated with the European black truffle, *Tuber melanosporum*. Local producer and development officer for DAFWA, Anne Mitchell, a pioneer of this industry, explained the challenges and the ongoing research being undertaken to increase local knowledge of most suitable conditions and practices, develop sound biosecurity measures and increase truffle productivity of the orchards and the quality of the product. It is worth noting that about half the truffles in Australia are grown in the Manjimup area, with 90 per cent of these being exported to an appreciative market. The Friday tour visited the Mitchell truffle plantation.

With other industries, the opportunities and the challenges also highlighted the role of science and technology, not only in providing the tools and practices for economically successful production but also for quality assurance, biosecurity compliance and market access. The success factors for brands were identified earlier by Tim Morris, particularly where we need to differentiate and verify premium quality and the value added.

The dairy industry in WA contributes just 4% to Australian milk production and while profitable for many producers, does face challenges and market uncertainties. The RD&E support services to the WA dairy industry was exited by DAFWA, yet there remains strong commitment to industry development and commercial thinking among the producers. Western Dairy, built up over 17 years and with Regional Manager, Esther Jones, now retains a small team dedicated to RD&E directly applied to the suite of issues identified by the dairy producers to improve
their productivity, with research into cost reduction in farming practices, better pastures and on-farm waste management.

In the beef and sheep industries, Professor Dave Pethick, Murdoch University, posed a core question: “What are the key aspects of consumer-focused meat brands?” Beef production in the SW region is growing apace, while sheep for meat is holding steady. He traced the development of Australian meat quality standards and the science and technology developed and applied in producing to meet those quality standards. Integrity and traceability, enjoyment and convenience, nutritional value, ethical production systems and value and efficiency are the watchwords in ensuring market acceptance.

In achieving triple bottom line progress through greater precision and efficiency at all levels of the agrifood supply chain, the world of farming is continuously changing. Josh Giumelli and Ben White, researchers with the Kondinin Group, are two engineers who in their entertaining presentation looked ahead to the implementation of autonomous machinery, drones and sensor technology, battery and energy storage developments, computer-aided construction equipment and communications and data transfer technology. So many of these will have applications at almost every phase of production, processing, quality assurance, market access and supply chain efficiencies.

A further issue of market access is the direction being taken by some sectors of the global market to incorporate as quality factors the environmental impacts of the specific food production system from which products come. Thus, sustainability meets climate change drivers and greenhouse gas mitigation objectives. Whether we agree with their stance on not, it will affect market access. Not only are the issues of environmental impact within a given catchment and production locality important locally but this invokes a wider issue of the environmental impact delivered at every level of the goods and services applied along the supply chain.

This topic was addressed by Alex Murray of Department of Primary Industries, NSW. Environmental “product declarations” may be used to inform or guide consumer preference or may lead to non-tariff trade barriers and denial of access to some markets. With industry funding, the environmental impacts of crop production have been assessed for the WA grains belt and the environmental impacts of WA grain production benchmark very favourably compared to those of other developed nations and our competing supplier nations.

Looking further at systems of animal protein production Susanna Morley of Grow Consultancy questioned the environmental and sustainability status of current livestock production systems. Novel methods of production of plant, animal and insect protein were presented and the environmental credentials matched to consumer trends.

Science and technology can be applied to develop new protein products but consumer culture will be a very strong influence on the nature, extent and pace of change. Jennie Franceschi, at Advance Packing and Marketing Services, aims to expand in Manjimup an already high technology core facility to assist local growers to a more profitable and sustainable future in Agrifood enterprise. Not only grading and packing horticultural products (WestFresh) for domestic and export markets, her company converts lower grade produce that would otherwise be wasted by processing into new products, testing for consumer appeal and successfully establishing market outlets. Her company’s investments in High Pressure Processing (HPP) and Individual Quick Freezing (IQF) technologies are proving a game changer in this respect. The Friday tour visited this factory complex.

Simon Cook, WA Premier’s Fellow in Agriculture and Food, who previously led CSIRO’s Precision Agriculture Research Group, explored digital agriculture as a spectrum of technologies, from robotics and drones, through precision agriculture to market analytics. An area of rapid growth into the applications of big data and locally generated data form a disruptive technology that offers huge opportunities but adoption into agricultural applications remains a challenge where obstacles and pitfalls need to be overcome. To ensure the mass of data leads to better outcomes, close integration is needed between the agricultural sciences, the data sciences and the decision sciences.

IN CONCLUSION

While all the forces of change and the trends in both consumer preferences, market access and technological developments will apply in determining the sustainability of SW Agriculture, science and technology have much to offer in enabling the decision making along the way. It will help us know our strengths, support the drive to competitiveness, help us adapt and underpin the new efficiencies and premium product range, but only if we harness data.

An objective of the conference was to explore outcomes that will contribute to increased agribusiness profitability, competitiveness and sustainability in the SW region.
Clearly there is a wealth of skills, knowledge and experience within the region’s agricultural sector. The interactions between the audience and speakers during Q&A sessions exposed many opportunities for combining ideas and fertile cross-referencing where knowledge in one field was seen as transferable or adaptable to other areas of the agrifood industries.

The need for data in evidence-based decision making in part points to a need for farmers and community members to adopt citizen science capability, measuring and monitoring with or without sophisticated digital tools. Relevance of all this in practical education in science and mathematics can be a path to increased uptake of STEM subjects in the formal education sector. The implications for jobs and growth and the attendant knowledge and skills required will lead to more skill training and a strong TAFE sector as well as within-industry research by qualified professionals as evidenced by the research content embedded in the stories of all speakers.
Jim Pratley

School of Agricultural and Wine Sciences, Charles Sturt University, Wagga Wagga, NSW 2678

Jim Pratley is Strategic Research Professor of Agriculture at Charles Sturt University, Wagga Wagga. He was Foundation Dean of Science and Agriculture at CSU for 16 years. His research interests have included selenium nutrition of grazing livestock, tillage systems, weed biology, herbicide resistance and self-weeding crops. In recent times he has published widely in agricultural education. He is a member of the NSW Primary Industries Ministerial Advisory Council, the Research Committee of the Australian Farm Institute, the National Committee on Agriculture Fisheries and Food (Australian Academy of Science), the expert panel of the Agricultural Biotechnology Council of Australia and is Secretary of the Australian Council of Deans of Agriculture.

Dr Cameron Archer AM

Conjoint Professor, Tom Farrell Institute, University of Newcastle and former Principal Tocal College.

Dr Cameron Archer grew up on a grazing property on the Southern Tablelands of NSW and has spent his career in agriculture, initially in research and extension in the Northern Territory but for most of it at Tocal College, Paterson, NSW. He has degrees in agriculture, education and in environmental history.

Cameron was Principal of the College and Director of Tocal Agricultural Centre from 1987 to 2015. His responsibilities also involved the operation of the Yanco campus in the Riverina and the delivery of state-wide and national vocational education and training programs. Cameron is involved in a number of National and State organisations and including being Chair of the Board of the Primary Industries Education Foundation, Australia. He has worked for many years to improve learning about food and fibre production in Australian Schools.

In 2013 he was made a Member of the Order of Australia for services to agricultural education and heritage conservation.

Education in agriculture has evolved in conjunction with the rest of the education system. In some ways it has a special place in the system while in other ways agriculture missed the boat in not taking advantage of opportunities available at particular times. At first settlement from 1788 there was no education system. The upper and middle classes were the only ones who could afford to pay tuition in those early days although there were no teaching standards for those who provided the tuition. McCreadie (2006) indicates that “by the 1830s, the idea that crime was the result of ignorance, ignorance was the result of a lack of education and, therefore, education would decrease crime, was seen as a means of forging the penal colony of Australia into an organised and orderly society. Opponents of this idea, however, felt that the child of a blacksmith did not need any more education than what was necessary for him to become a blacksmith, the child of a farmer only what was necessary for him to be a successful farmer”. The lower class then learned by what was handed down and by experience; this practice perpetuated in farming well into the 20th Century.

THE SCHOOL SYSTEM FOR AGRICULTURAL EDUCATION

Early formal education was largely through the various churches supported by colonial government. Control was vested in these institutions at the local level. Dissatisfaction with provision by the religions led States to enact legislation, despite religious opposition, to establish public school systems which were defined as ‘free, compulsory and secular’ (Campbell, 2014) and under the control of government ministers. All States implemented this, albeit at different times, Kempsey National School becoming the first school to join the government education system in New South Wales in 1848. The application of the components of ‘free, compulsory and secular’ were put in place progressively but varied across States (Table 1). State aid was removed around that time although it was reinstated much later by the Commonwealth Government from the mid-1960s in order to sustain the religious schools and take the pressure off state schools.
Table 1. Evolution of the public school systems across Australia

<table>
<thead>
<tr>
<th>States</th>
<th>Education Acts</th>
<th>Establishment of government departments</th>
<th>Abolition of school fees</th>
<th>Compulsory attendance laws proclaimed</th>
<th>Abolition of State aid to church schools</th>
<th>Secular curriculum established</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Australia</td>
<td>1851, 1875</td>
<td>1875</td>
<td>1892</td>
<td>1875</td>
<td>1851</td>
<td>1852</td>
</tr>
<tr>
<td>NSW</td>
<td>1866, 1880</td>
<td>1880</td>
<td>1870</td>
<td>1880</td>
<td>1882</td>
<td>1880</td>
</tr>
<tr>
<td>Victoria</td>
<td>1872</td>
<td>1873</td>
<td>1872</td>
<td>1872</td>
<td>1873</td>
<td>1872</td>
</tr>
<tr>
<td>Queensland</td>
<td>1875</td>
<td>1875</td>
<td>1870</td>
<td>1900</td>
<td>1880</td>
<td>1875</td>
</tr>
<tr>
<td>Tasmania</td>
<td>1885</td>
<td>1885</td>
<td>1908</td>
<td>1916</td>
<td>1854</td>
<td>1854</td>
</tr>
<tr>
<td>Western Australia</td>
<td>1893</td>
<td>1893</td>
<td>1901</td>
<td>1871</td>
<td>1895</td>
<td>1895</td>
</tr>
</tbody>
</table>

Many forms of schools comprised primary, secondary or combinations of both. Secondary public schools first began in late 1883 with the establishment of separate High Schools for boys and girls in Bathurst, Goulburn, Maitland and Sydney. Fort Street School however had existed, in different locations, from 1849 as did some private schools (e.g. The Kings School from 1830, SCEGS from 1845). From their inception the High Schools offered an academic course designed mainly for students intent on entering university; entrance to High School was through a competitive examination so a large proportion of children in those days did not progress beyond Year 6 – in NSW and Victoria around 1910 for example, fewer than 5% of the school population continued schooling after primary level.

Table 2. Establishment of agricultural high schools in NSW

<table>
<thead>
<tr>
<th>School</th>
<th>Date established</th>
<th>Coeducational</th>
<th>Selective</th>
<th>Residential</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW Agricultural High Schools</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hurlstone</td>
<td>1907 (at Ashfield)</td>
<td>1979</td>
<td>1907</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>1926 (at Glenfield)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2020 (at Western Sydney University)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yanco</td>
<td>1922 (Yanco)</td>
<td>1993</td>
<td>yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Farrer Memorial</td>
<td>1939 (Tamworth)</td>
<td></td>
<td>Boys only</td>
<td></td>
</tr>
<tr>
<td>James Ruse</td>
<td>1959 (Carlingford)</td>
<td>1977</td>
<td>1969</td>
<td>No</td>
</tr>
<tr>
<td>NSW Lighthouse Schools in agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colo HS, Junee HS, Kempsey HS, Mount View HS, Murrumburrah HS, Tumut HS</td>
<td>Designation from 2015</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>South Australian Agricultural High School</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urrbrae</td>
<td>1913 Agricultural high school from 1932</td>
<td>1972</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Western Australian College of Agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cunderdin, (Yrs 10, 11, 12)</td>
<td>1959</td>
<td></td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Harvey, (Yrs 10, 11, 12)</td>
<td>1953</td>
<td></td>
<td>1988</td>
<td>yes</td>
</tr>
<tr>
<td>Morawa, (Yrs 10, 11, 12)</td>
<td></td>
<td></td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Denmark, (Years 10, 11, 12)</td>
<td>1942</td>
<td></td>
<td>1991</td>
<td></td>
</tr>
<tr>
<td>Victorian Agricultural High Schools</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ballarat, Colac, Leongatha, Mansfield, Sale, Shepparton, Wangaratta, Warragul, Warmambool, Mildura</td>
<td>Established from 1907 Disestablished 1917</td>
<td>no</td>
<td>no</td>
<td></td>
</tr>
</tbody>
</table>

Training of farm boys, state wards and migrants also occurred in Catholic-run institutions in Western Australia including Tardun Agricultural School (1928-2008)
It was somewhat revolutionary then when in 1907 a new school called the Hurlstone Agricultural Continuation School was created at Ashfield in Sydney particularly to prepare boys for farm production and for admission to Hawkesbury Agricultural College. The course was only for two years and no other school in the state at the time had subjects about agriculture since “farming was considered to be something you learned at home, not in the classroom” (www.hurlstone.com.au). Hurlstone Agricultural High School, as it developed, was moved to Glenfield in 1926 due to urban encroachment and is scheduled to move again in 2020 as Glenfield has become a residential area of Sydney. It was a boarding school particularly for country students and its success generated three other schools in NSW to be designated agricultural high schools. Two are located in rural areas at Yanco (Yanco Agricultural High School) and Tamworth (Farrer Memorial Agricultural High School) and were established to train future farmers and provide education for isolated students. The fourth, James Ruse Agricultural High School, was established much later in 1959 on the outskirts of Sydney to provide training for local students from farm industries (see Table 2). With time, three of the four schools have become selective schools with high academic pursuits – James Ruse is the highest selective and highest performing school in Australia. The memorandum from the Minister in 1939 (Box 1) clearly indicates that these schools were to perform at high academic levels.

In some other States agricultural education was also given special status (Table 2). In South Australia the Urrbrae Agricultural High School came into existence in 1932 although the school itself dates from 1913 from a bequest with high academic pursuits – James Ruse is the highest selective and highest performing school in Australia. The memorandum from the Minister in 1939 (Box 1) clearly indicates that these schools were to perform at high academic levels.

Much later, in the 1940s and 1950s, the government of Western Australia enabled the development of a network of agricultural senior schools. This network, now called Western Australian College of Agriculture, comprises residential campuses at Cunderdin, Harvey, Denmark and Morawa for Years 10, 11 and 12. They are separated from the junior high schools and located on farms where instruction takes place with a focus on vocational studies but provision also exists for higher education entrance programs. A selection process requires students to demonstrate an interest in agriculture or related industries. Perhaps the most intriguing and informative of attitudes was the foray by the Government of Victoria into agricultural high schools. Agriculture was used politically to establish

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**BOX 1: DEPARTMENT OF EDUCATION**

00160 11 Jan. 1939

**AGRICULTURAL HIGH SCHOOL POLICY**

The establishment of the Farrer Memorial Agricultural High School at Tamworth will give to the State the third residential Agricultural high School geographically so placed as to provide effective training for students who wish to qualify for a degree either in Veterinary or Agricultural Science. It appears to me that with the establishment of this third school the time has arrived for the Department to seriously review the existing policy with a view to determining what is best in the interests of this branch of and of the State in the future. Agricultural High Schools, by reason of the fact that they provide residential accommodation for student who enrol, plus provision for practical husbandry, etc., are in the nature of things fairly costly to establish and maintain. It is essential, therefore, that the cost so incurred by the State should be compensated by the maximum advantage in the way of educational results of the highest possible order.

I am of the opinion that for many years to come the Department should not commit itself further to the building of such schools, but should concentrate on completion of schools which are now established, ensuring that they shall have the best possible equipment and accommodation for the maximum number of lads who can be efficiently accommodated there. Further, I am of the opinion that having regard to the fact these schools are so designed and equipped as to prepare for a University Degree, it is not in the interests of the State that boys should be admitted to these schools whose I. Q. is so low as to render it completely doubtful as to whether they will succeed in satisfactorily completing a matriculation course. Boys whose I. Q. falls below this standard should not be admitted to Agricultural High Schools unless there is a surplus of accommodation which cannot be otherwise used.

It will be noted that the real purpose of an Agricultural High School is not to provide a training farm course. Such facilities are only for the better training of the student in the application of science and a better apprehension of its teachings. For those lads of lower standard of intelligence, the obvious place is an Agricultural Farm where courses are designed to meet the requirements of a training school for lads who wish to become practical farmers. The training there is along the lines of practical work, systematic routine and a thorough knowledge of the work and implements of agriculture. This section of the work in an Agricultural High School is largely incidental, though necessary.

To place an Agricultural High School upon the level of a training farm is to incur an expenditure which cannot be justified in the final analysis. There is continuous complaint of the overcrowding of our Agricultural High Schools. And it is probable that even with the establishment of the Farrer Memorial High School at Tamworth, this overcrowding will continue unless a rigid standard of entrance is applied along the lines which will ensure, so I have already indicated, that those who commence the course will be capable of carrying it through successfully.

I desire that this policy be noted for action in the forthcoming and succeeding years.

D.H.

DRUMMOND.
secondary public schools (‘continuation schools’) in rural Victoria due to opposition from independent schools in the city. It was supported by the government’s wish for closer settlement in the country to encourage people onto the land but this created practitioners without the appropriate knowledge, leading to many failures (Martin 1977). Education into agricultural techniques was seen as ‘essential’. The courses were made up of one third culture subjects, one-third science subjects related to agriculture and one third farm work. A deficiency in the agricultural high school system was the difficulty for the students to be qualified to enter higher education. In reality they were continuation schools with agriculture in the name and their establishment in some of the smaller centres resulted in the closure of independent schools in those centres. After the failure of the agriculture courses in these schools (see Box 2) it was regulated in 1916 that agriculture should be retained as a subject. For the newly created Intermediate Certificate, all male candidates going to school in rural areas were required to study agriculture as one of their subjects. Martin (1977) reports much community apathy towards the “agriculture” in the schools and little financial support. In the end the schools had ‘agriculture’ removed from their names and they reverted to continuation schools.

More importantly, Martin’s paper was revealing in the attitudes of farmers to agricultural education – the scepticism from farmers about the needs for such a course since they had learnt by experience and had progressed without training. Further, a ‘potent factor’ described was that “farmers as a class are sceptical of men who are classed as experts”. This view is reflective of a significant proportion of farmers and pastoralists through much of the 20th Century in Australia.

So even in those early days the benefits of an education per se were being touted even though the sector tended not to embrace it readily.

BOX 2:

“The success of some of these farmers is measured in the amount of wealth accumulated… if the farmer could be convinced that …a wider education and a scientific knowledge of the principles underlying agriculture would achieve the same end…. And at the same time secure happiness in work and a fuller life because an intelligent interest in the doings of others and in the welfare of the State would be created, then our agricultural high schools become more popular”

Headmaster of Ballarat Agricultural High School 1916 (extract from Martin, 1977)

Agriculture became a subject of study at many high schools across Australia including independent and private schools. The number of secondary schools in NSW now offering agriculture is significant as shown in Figure 1 and their distribution is shown in Figure 2. Over time in some of these schools, however, it became the de facto subject for disinterested and less able students. This generated a negative attitude amongst students and teaching staff towards agriculture and so students with ability were avoiding such subjects even though their interests may have been highly compatible. Over time as fewer people were employed in agriculture on-farm and as more of the population moved to the cities a disconnection evolved between agriculture and the majority of the population and its image became tarnished.
Since 2000, there has been a change in attitude towards agriculture as issues such as global food security have gained traction. The realisation regarding the lack of young people coming into agriculture became a driver to reinvigorate agricultural education at all levels and particularly at the school level. A Ministerial Review into agricultural education and training in NSW (Pratley, 2013) led to the designation of 7 Lighthouse Schools in agriculture in 2015. These, together with the Agricultural High Schools, became part of a network of schools with responsibility for providing leadership and support for other schools that were involved to a lesser extent in agriculture. The proposed transfer of Hurlstone Agricultural High School in NSW to the campus of Western Sydney University in 2020 with a focus on STEM (science, technology, engineering and maths) education signifies a strengthening of emphasis in agricultural education for NSW.

Overall, in respect of the school system for agricultural education, there are some strong contradictions. Agriculture is one of the few industry sectors to have specialist high schools in at least three states, despite its unpopularity in the community for the last 30 years of the 1900s. These specialist schools for the most part though are very high performing schools academically whereas agriculture in many other schools is, or has been, considered an inferior study. It is also clear that through the evolution to current offerings the early provision for boys only over a long period has now largely dissipated and agriculture is seen as appropriate for girls as it is for boys.

The wider issue that influences education is that of consumers having knowledge of their food; where it comes from and how it is produced. Because the practices involved in producing agricultural products are now foreign to most people, the danger is that they learn about them from vocal activists and then may reject modern agricultural production methods and set about opposing agriculture. If these views become mainstream it will become very difficult for agricultural industries to operate and progress. Although it is important for students to be taught best practice in their agricultural subjects, this ‘preaches to the converted’ and does not address the wider issue. Clearly for best outcomes, all students, and their teachers and advisers, need to be exposed to a holistic insight of food and fibre production and consumption. This can be achieved through agricultural contexts in other subjects.

In 2009, the Australian Curriculum Assessment and Reporting Authority (ACARA) was established to execute a national curriculum in Australian schools. While this change provided an opportunity for populating the curriculum with agriculture, there needed to be a raft of agricultural teaching resources developed together with teacher and adviser professional development. The establishment of the Primary Industries Education Foundation Australia (PIEFA) in 2007 has provided for this process to occur in conjunction with other providers. There are over 3.5 million school students in Australia, 250,000 teachers and 9,500 schools and so the challenge is a major one. At the same time there is the need for industries to continue to work towards a positive image and identify career paths that are attractive to the emerging workforce.

In order to move from the school system to further education and training, academic attainment requirements needed to be met. From 1867 in NSW, and presumably in other states, these were met by senior and junior public examinations marked by the University of Sydney. In 1912 the Intermediate Certificate examination in NSW was first held – this was taken at the completion initially of two years of secondary schooling and, after 1919, three years. There followed from 1913 the Leaving Certificate (called Matriculation in some states) examination which comprised a further two years of schooling after the Intermediate Certificate. The Intermediate Certificate became the qualification of admission to tertiary colleges and the Leaving Certificate became the basis for university entrance. In the 1960s, following the Wyndham Report of 1957, which was to reshape school education in NSW and subsequently elsewhere in Australia, an extra year of schooling was included. Thus the School Certificate (replacing the Intermediate Certificate in 1965) was at the end of 4 years secondary schooling and the Higher School Certificate (replacing the Leaving Certificate in 1967) after 6 years of secondary schooling in NSW. Variants of this occur in other states.
**BOX 3: How Western Australia is dealing with the problems of agricultural education by “Martingale”**

“PROBABLY never before in the history of the world has there existed a greater need for men of trained intelligence in the ranks of agriculturists. The trend of modern life in a highly-industrialised world has forced agriculture out of the comparatively leisurely tempo at which it has been conducted throughout the centuries, for the farmer himself is not content to adopt the primitive mode of life which contented his ancestors, but wants motor cars, radios, electric light and power and all the other amenities enjoyed by his urban acquaintances.

More and more dependent upon the commercial and industrial world for his tools of trade, his tractors, trucks, artificial fertilisers, and complicated implements, he is forced to boost up production and cut down costs. To do this successfully he must overcome a host of problems of a financial, biological, chemical and mechanical nature. To grow better crops he must use better implements and study the manorial requirements of his land more closely. He must improve his stock by skilled animal husbandry, by paying more and more attention to feeding, breeding and kindred subjects, and whereas the old-time farmer had time to learn by trial and error, the farmer of today is compelled to accept the accelerated pace brought about by changing world conditions.

FARMERS are naturally averse to change. Their calling is an ancient one with its broad outlines, but little has changed throughout the ages, and past experience has taught them the dangers of being swayed by untested innovations. Even today there are practical farmers who regard agricultural education with scepticism and even hostility, despite the fact that they are taking full advantage of new techniques introduced by the agricultural scientist. I think, however that this type is in the minority in these days. Most farmers are fully cognisant of the part played by science in agriculture, and many would like to ensure that their sons commence their careers equipped with a sound foundation of scientific and technical knowledge upon which to base the practical experience of later years. Admittedly comparatively few of them really take the necessary steps to make this possible but I feel it is due partly to financial stringencies and partly to the fact that there has never been an active campaign to “sell” agricultural education to the farmers of our State. Many West Australians are quite unaware of the fact that we possess an agricultural college in this State. Others have a vague idea of its existence, but nothing more.”

*Extract from Western Maim. Perth WA, 18 Dec 1941*

**TERTIARY AGRICULTURAL EDUCATION IN AUSTRALIA**

The term ‘tertiary education’, a relatively recent descriptor, refers to all education post-secondary school and is largely split between vocational education and training (VET) and higher education (largely university). The demarcation though is described by West (1998) in the Review of Higher Education and Policy:

“The submissions that our committee received supported the widespread view that VET should continue to teach competencies and maintain the strong focus on skills, and higher education should cultivate attributes. Each sector should have clearly expressed goals. There should be articulation and credit transfer between the sectors and, where possible, facilities should be shared as well in order to effect economies. The curricula, however, should be clearly defined and discrete.”

Over time this demarcation has become blurred as the TAFE sector has sought to offer degrees, (although early history had the technical colleges, such as in Perth, offering degrees where a university wasn’t available) and universities have assumed the education of some professions that were previously the bailiwick of TAFE. This questions, philosophically, the role of universities. Falvey and Bardsley (1995) in discussing the revitalisation of agricultural education in the Australian university system identified the need for distinct and high quality skills-based courses and degree courses with pathways between the two. In arguing for strengthening of vocational education nearly 25 years ago, they referred to Hall (1972) as noting that “pressure on university undergraduate training for graduates to be job-ready, has already vocationalised university education in Australia far more than is admitted”.

A traditional view is summed up by Anderson (2012 – see Box 4). Universities have moved away from the original scholarly function to a business model of qualifications and skills. In agriculture this is the case as the curriculum has little space for reflective considerations. Employers also argue for job-ready graduates. Former Australian Chief Scientist Chubb (e.g. Office of the Chief Scientist, 2012) strongly promoted universities as providing ‘employment-ready’ (prepared for the future) rather than ‘job-ready’ (focused on the present) graduates and this tension remains, particularly with agricultural employers.

**BOX 4: What is a university?**

“If we seek guidance from the past, it is better to see the ‘idea of a university’ not as a fixed set of characteristics, but as a set of tensions, permanently present, but resolved differently according to time and place. Tensions exist between:

- Teaching and research
- Autonomy and accountability
- Universities’ membership of an international scholarly community and their role in shaping national cultures and forming national identity
- The transmission of established knowledge and search for original truth
- The inevitable connection of universities with the state and the centres of economic and social power and the need to maintain critical distance
- Reproducing the existing occupational structure and renewing it from below by promoting social mobility
- Between serving the economy and providing space free from utilitarian pressures
- Teaching as the encouragement of open and critical attitudes and society’s expectations that universities will impart qualifications and skills

To come down too heavily on one side of these balances will usually mean that the aims of the university are being simplified and distorted.” Adapted from Anderson 2010
Table 3 shows the chronological relationships between components of the Australian education system as they relate to agricultural education. To some extent, there are clear blocks of activity suggesting there were political imperatives at work.

**Table 3 Chronological establishment of institutions related to agricultural education by decade**

<table>
<thead>
<tr>
<th>Decade</th>
<th>Public school Acts</th>
<th>Agricultural high schools</th>
<th>Vocational agricultural (certificate) colleges</th>
<th>Agricultural colleges*</th>
<th>Universities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1850</td>
<td>SA</td>
<td></td>
<td></td>
<td></td>
<td>U Sydney</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>U Melbourne</td>
</tr>
<tr>
<td>1860</td>
<td>NSW</td>
<td></td>
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<td></td>
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<tr>
<td>1870</td>
<td>Vic Qld</td>
<td></td>
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<td></td>
<td>U Adelaide</td>
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<tr>
<td>1880</td>
<td>Tas</td>
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<td>Roseworthy SA*</td>
<td>Dookie Vic*</td>
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<td>Longerenong Vic*</td>
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<td>Queensland*</td>
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<tr>
<td>1890</td>
<td>WA</td>
<td></td>
<td>Burnley Vic*</td>
<td>Hawkesbury NSW*</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Wagga NSW*</td>
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<tr>
<td>1900</td>
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</tr>
<tr>
<td>1990</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Agricultural colleges tended in most cases to become Colleges of Advanced Education in the early 1970s*
While Australian universities per se were established progressively from the 1850s, agricultural colleges predated faculties of agriculture in the universities. South Australia, Victoria, New South Wales and Queensland all had agricultural colleges established by their respective colonial governments in the late 1800s (Table 4) whereas the teaching of agriculture in universities did not start until early in the 1900s. Agricultural colleges are unique educational institutions and date back to the 19th Century when they were established in Europe. The first agricultural college in the English-speaking world was Cirencester (1845), now known as the Royal Agricultural College. The establishment of such institutions in Australia were heavily influenced by similar developments in the UK. These agricultural colleges were particularly for the training of farm boys to certificate or diploma level, providing also the opportunity to articulate to university entrance. Their establishment coincided with the closer settlement movement and graduates of the colleges worked both for government and on farms. The initial thrust to establish agricultural colleges in each colony was driven more by city interests than country interests. Large landholders or graziers, the descendants of the squatters, by then landed gentry, did not readily support the new colleges. Their interest in education was in sending their sons and daughters to private boarding schools in the capital cities and then anything that needed to be learnt about agriculture (more specifically grazing) could be learnt on the job.

The 1950s saw a succession of good seasons and relatively strong prices for farm commodities. The impacts of post-war research and development and the application of science and technology were becoming very apparent. The demand for training in these technologies was strong and it was felt that the jackaroo system was not adequate to train young people for a farming career. At this time there was also a rise in the discipline of farm management, principally coming from Massey and Lincoln Agricultural Colleges in New Zealand. The Australian agricultural colleges, which had now been operating for decades, did not readily embrace this emphasis on farm management. Entry from the 1960s had become the Leaving Certificate and colleges were seen as indulging in ‘academic creep’. Farmers were often critical of the colleges, their farms and courses as they had moved away from farmer training towards extension and other professional careers. As a result, in the 1960s, new agricultural colleges that focussed on farmer training were established in Queensland, NSW and Victoria to train young boys for a career on the land (Table 5). These residential colleges were based on farms and they had strong support from the farm sector.

Two of these colleges (Table 4), Marcus Oldham College and Orange Agricultural College, had particular emphasis on farm management. Special mention should be made of Marcus Oldham College, located in Geelong, which is now the only private agricultural college. Its focus was on farm management, was fully residential and required students to spend time in the industry gaining first-hand experience. It remains successfully in that paradigm although its academic standards now categorise it within higher education. Some Australian universities also established chairs of farm management around that time.

### Table 4 Establishment and evolution of agricultural colleges in Australia

<table>
<thead>
<tr>
<th>Agricultural College</th>
<th>Established</th>
<th>Co-educational</th>
<th>Evolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queensland</td>
<td>1897 (High School until 1962 and College)</td>
<td>1990 to UQ</td>
<td></td>
</tr>
<tr>
<td>Hawkesbury</td>
<td>1891</td>
<td>1974</td>
<td>1989 to WSU</td>
</tr>
<tr>
<td>Wagga</td>
<td>1896</td>
<td>1974</td>
<td>1989 to CSU</td>
</tr>
<tr>
<td>Orange</td>
<td>1973</td>
<td>1973</td>
<td>1990 to UNE - 1994 to U Sydney - 2006 to CSU</td>
</tr>
<tr>
<td>Dookie</td>
<td>1886</td>
<td>1973</td>
<td>1997 to U Melbourne</td>
</tr>
<tr>
<td>Longerenong</td>
<td>1889</td>
<td>1972</td>
<td>1997 to U Melbourne - 2006 to private VET</td>
</tr>
<tr>
<td>McMillan</td>
<td></td>
<td></td>
<td>1997 U Melbourne - VET Community College</td>
</tr>
<tr>
<td>Marcus Oldham</td>
<td>1962</td>
<td>1979</td>
<td>Ongoing private residential college</td>
</tr>
<tr>
<td>Burnley</td>
<td>1891</td>
<td>1899</td>
<td>1997 to U Melbourne</td>
</tr>
<tr>
<td>Gilbert Chandler</td>
<td>1966 (formerly School of Dairy Research 1939)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roseworthy</td>
<td>1883</td>
<td>1972</td>
<td>1991 to U Adelaide</td>
</tr>
<tr>
<td>Muresk</td>
<td>1926 (- Muresk Institute of Agriculture, 1990s)</td>
<td>1969 to WAIT/ Curtin U - 2012 VET</td>
<td></td>
</tr>
</tbody>
</table>
In the 1960s most colleges were under the auspices of state departments of agriculture. Education was largely the responsibility of the state but increasingly the Federal Government was providing funding to tertiary institutions. In 1971 most of the original colleges became Colleges of Advanced Education (CAEs) in a two tier system of higher education and gradually moved to degree offerings over succeeding years. The Dawkins Report in the late 1980s then removed the two-tier system to a unified model of universities and most colleges moved into existing universities or became new universities (Table 4).

In almost all cases, the early versions of the institutions indicate their mission as educating boys, lads or young men in the ‘practice and science of agriculture’ for profitable management of farms (Falvey and Bardsley, 1997). Clearly there was no consideration given in the early days to the possibility that females might have aspirations on farm or in industry. This was the case in agricultural high schools, agricultural colleges of all types and universities. There seems to have been an epiphany in the 1970s as many of the institutions progressively, but suddenly, became coeducational. At that time there was a strong affirmative action push and during the 1960s legislation against discrimination of sex, race and religion was adopted by various States (Gaze, 1997). It also coincided with the social reforms of the Whitlam Government although whether that played a role is a matter for debate. Universities were more liberal earlier and Burnley Horticultural College was well ahead of sister colleges admitting women part-time from 1899 and full-time from 1914. Falvey and Bardsley (1997) recount that many female students treated Burnley as a form of finishing school as it did not lead to a means of livelihood. In the 21st century women now outnumber men in higher education agriculture (Figure 4).

### Table 5 Current vocational agricultural colleges in Australia

<table>
<thead>
<tr>
<th>College</th>
<th>Date established</th>
<th>Coeducational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queensland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emerald</td>
<td>1968</td>
<td>1991</td>
</tr>
<tr>
<td>Longreach</td>
<td>1967</td>
<td>1979</td>
</tr>
<tr>
<td>NSW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CB Alexander now Tocal</td>
<td>1965</td>
<td>1972</td>
</tr>
<tr>
<td>Victoria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longerenong</td>
<td>2006 (from U Melbourne)</td>
<td>2006</td>
</tr>
</tbody>
</table>

Vocational education and training

General education establishments were in place from the early 1800s for post school learning, beginning in Hobart in 1827 and in most major centres by 1840 (Goozee, 2001). These included initially Schools of Arts, Mechanics Institutes and Technical Colleges. After Federation in 1901, these continued to be solely funded by the state governments until the 1970s. Often they were stand alone and regionally independent colleges that had strong industry and community support. Agricultural colleges evolved during the same time but were never directly associated with the technical college system.

In the early 1970s the Commonwealth Government established the Australian Technical and Further Education Commission to develop consistency in technical education across the nation. The desire for consistency continues to this day. The Kangan Report in 1974 defined what was to become the TAFE system with the acronym being adopted as the brand for the various forms of technical education in each state.

Most technical colleges had dated facilities and many were over-crowded and under-resourced. Successive Commonwealth governments poured money into the newly created TAFE system, including the more recent agricultural colleges, and this continued for both capital and recurrent funds until the early 2000s. The TAFE system was, by implication, a monopoly for tertiary, non-university, education. The only anomalies were the few agricultural colleges. TAFE grew rapidly and colleges were established throughout country towns. Courses were mostly free and ranged from recreational cooking through to sophisticated technical courses in engineering and highly skilled vocations. TAFE also became an avenue for social welfare support in the community and developed an important role in outreach and community support. During the late 1970s through to the 1990s TAFE was lavishly funded and grew to have extensive facilities and resources. Throughout its state networks it provided a wide range of agricultural and related courses at certificate and diploma levels and played a strong part in skills development in agriculture. Some TAFE campuses such as at Wagga Wagga and Dubbo in NSW became specialist primary industries campuses.

The monopoly created however was generally inflexible with a relative incapacity to respond to the needs of various industries. Responsiveness and the need for consistency across the states for transportability of qualifications thus became political imperatives. During the 1990s a TAFE revolution occurred whereby national competencies were established. This partitioned work performance into ‘bite-sized’ pieces, i.e. competency based training, which could
be taught and assessed within the institution or in the work place. A national structure was put in place through which funding could be provided and provision was made for non-TAFE organisations to deliver TAFE-type programs through the market-based concept of Registered Training Organisations (RTOs). At this time the term ‘Vocational Education and Training’ (VET) was introduced (the VET system) and it is now common parlance. The move to a user choice arrangement meant that the user was funded to take the course rather than the institution funded to provide the course, i.e. a demand funding system rather than the former supply funding model.

Demand funding has its challenges. Courses only run where the demand is strong enough to make the provision economic. Private RTOs ‘cherry pick’ those courses of high demand and profitability thus leaving TAFE to provide the difficult, expensive and low demand courses. Quality of private RTOs has been variable and this has required increased scrutiny of registration and audit.

The legislation for the operation of the VET system rests with the states including registration of RTOs although pressure existed to create a national system of registration. As a result, the Australian Skills Quality Authority (ASQA) was established for national registration in all states but Western Australia and Victoria which still run their own registration system. The funding for VET is a mix of Commonwealth and State funding although there is greater emphasis on user pays.

The training in VET varies from a full qualification to a skill set or an individual competency. An issue which hampers the effectiveness of competency-based training is that competencies are written based on industry intelligence and information at a certain time. They then need to be endorsed and ultimately adopted by RTOs. By this time they can be out of date.

In 1995, a national system of qualifications, the Australian Qualifications Framework (AQF), was established in Australia. The AQF encompassed higher education and vocational education and training and regulates qualifications (Table 6) in the Australian education and training system (AQF, 2013). The objectives of the AQF are to provide a contemporary and flexible framework that:

- accommodates the diversity of purposes of Australian education and training now and into the future;
- contributes to national economic performance by supporting contemporary, relevant and nationally consistent qualification outcomes which build confidence in qualifications;
- supports the development and maintenance of pathways which provide access to qualifications and assist people to move easily and readily between different education and training sectors and between those sectors and the labour market;
- supports individuals’ lifelong learning goals by providing the basis for individuals to progress through education and training and gain recognition for their prior learning and experiences;
- underpins national regulatory and quality assurance arrangements for education and training;
- supports and enhances the national and international mobility of graduates and workers through increased recognition of the value and comparability of Australian qualifications; and
- enables the alignment of the AQF with international qualifications frameworks.

### Table 6. Components of the Australian Qualifications Framework (AQF 2013)

<table>
<thead>
<tr>
<th>Level</th>
<th>Qualification</th>
<th>Providers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Certificate I</td>
<td>VET, schools</td>
</tr>
<tr>
<td>2</td>
<td>Certificate II</td>
<td>VET, schools</td>
</tr>
<tr>
<td>3</td>
<td>Certificate III</td>
<td>VET, schools</td>
</tr>
<tr>
<td>4</td>
<td>Certificate IV</td>
<td>VET</td>
</tr>
<tr>
<td>5</td>
<td>Diploma</td>
<td>VET</td>
</tr>
<tr>
<td>6</td>
<td>Advanced Diploma</td>
<td>VET</td>
</tr>
<tr>
<td></td>
<td>Associate Degree</td>
<td>VET, universities</td>
</tr>
<tr>
<td>7</td>
<td>Bachelor Degree</td>
<td>Universities, some VET</td>
</tr>
<tr>
<td>8</td>
<td>Bachelor Honours degree</td>
<td>Universities, some VET</td>
</tr>
<tr>
<td></td>
<td>Graduate certificate</td>
<td>Universities</td>
</tr>
<tr>
<td></td>
<td>Graduate Diploma</td>
<td>Universities, some VET</td>
</tr>
<tr>
<td>9</td>
<td>Master Degree</td>
<td>Universities</td>
</tr>
<tr>
<td>10</td>
<td>Doctoral degree</td>
<td>Universities</td>
</tr>
</tbody>
</table>

### Apprenticeships

The system of training involving a legal contract (an ‘indenture’) between an employer and employee has been in operation in Australia for over a century. Detail of the history is given by Knight (2012). Traditional apprenticeships typically run for three to four years and 80% of the apprentice’s time is spent in training on the job, with the remaining 20% spent at TAFE undertaking off-the-job training, the cost of which is borne by government. Originally, apprenticeships were only available in traditional trade occupations, and an upper age limit (23 years in most states) restricted this mode of training to young people. Young people entering a traditional apprenticeship usually left school at the Intermediate Certificate or School Certificate or earlier if they had passed the statutory minimum school-leaving age. As apprentices were
frequently minors, considerable government regulation was involved. Wages, which were specified in industrial awards, were low. In the 1980s the traditional apprenticeship model was extended to non-trade occupations under the banner of ‘traineeships’. As the skill requirements were usually much less than in traditional trades, the duration of the training contract for traineeships was much less—six months to two years but typically a year—and the level of training was lower. In other respects traineeships operated in much the same way as traditional apprenticeships, including government funding for the off-the-job training and low wages, even for older adults undertaking this form of training. Traineeship numbers were slow to grow until the Australian Government introduced incentive payments to employers of trainees in the 1990s. Knight (2012) suggests that much of the training has been at a low level of qualification giving little economic return and “neglects the general education needs of young people”.

Figure 3 Completions of apprenticeships and traineeships in horticulture and production horticulture 2008-2012 (NCVER, 2014)

Agriculture has not widely embraced the apprenticeship opportunities although there has been more interest in traineeships. An exception was the Dairy industry particularly in Victoria which led the way with farm apprenticeships in the 1970s followed by NSW Dairy Industry in 1980. The amenity horticulture sector also embraced apprenticeships and traineeships (Figure 3) but the remainder of the sector minimised involvement because of general disdain for qualifications and the resultant need to pay labour more. Interest in establishing a farm apprenticeship more generally in NSW was not progressed as the leadership of NSW Farmers at the time did not believe in any form of industrial award and would not entertain the idea of an apprenticeship even though there were significant funds for the purpose. This view was strong in the National Farmers Federation as late as a decade ago where the mantra was that ‘I didn’t have any qualifications and have done ok so why should those following need them’. Farmers occasionally saw the need for skills training (known as ‘just-in-time’ training) but without qualifications attached as this would increase the cost of the labour. Given that in the 2000s qualifications are the currency for job seeking and career progression the attitude was regressive and helps explain why careers until recently have not been sought in the sector by new players.

Agricultural Science education in higher education commenced at University of Melbourne (1905) and University of Sydney (1911) with other universities following over the next 80 years or so (Appendix 1). A similar pattern existed in New Zealand. All Australian universities were located in the metropolitan areas until the University of New England in the 1950s although agricultural education was available through the rural-based colleges. The number of ‘agricultural’ universities grew to 9 by the 1980s. Together with the CAEs in agriculture there were about 22 campuses offering higher education agriculture at the time of Dawkins reform in 1989. The McColl Report (1991) into agricultural and related education indicated inter alia that multi-disciplinary institutions were educationally more desirable than specialist agricultural institutions and that there should be fewer, stronger campuses. Further, the Report indicated that there was a shortage of agricultural graduates and this should be addressed. From that time, however, intakes to higher education started to decline and that decline continued through to 2012. In the process the number of campuses shrank to about 11, with the number of rural campuses reduced by 50%, fulfilling the recommendation of McColl et al., except that reduced numbers of students at almost all campuses had weakened all schools of agriculture. The composition of the agricultural student body at the time of the McColl Report is given in Table 7. Males dominated, indigenous students were very poorly represented and international student numbers were low. The only change has been the attainment of gender balance in recent times.

The decline in university enrolments since 2001 is shown in Figure 4. This also shows the relative decline in funding to these faculties as universities are funded on a per student basis. The decline shown represents the loss equivalence of about 100 academic staff across the nation. What is also important to note is the changeover in student gender during this time in stark contrast to earlier times of boys only and then minority proportions of women.
Figure 4. Annual enrolments of students in agriculture and their gender composition in Australian universities, 2001-2014

Table 7. Composition of participants in agricultural and related education in 1990 (McColl et al., 1991)

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>women</td>
<td>34</td>
</tr>
<tr>
<td>indigenous</td>
<td>0.2</td>
</tr>
<tr>
<td>rural</td>
<td>55</td>
</tr>
<tr>
<td>Interstate</td>
<td>11</td>
</tr>
<tr>
<td>External study</td>
<td>16</td>
</tr>
<tr>
<td>International</td>
<td>6</td>
</tr>
</tbody>
</table>

Most universities are established under State Acts and States were initially responsible for their funding. In the early days, entry to universities required the payment of fees and so was largely for the elite. Following World War II the Commonwealth made increasing contributions to the funding of universities and from 1974 assumed full funding responsibility. From 1951, the Commonwealth Scholarship Scheme was instituted whereby entry was based on merit rather than capacity to pay. Such scholarships had both fee and accommodation components, subject to a means test of the student or parents, and this provided greater scope for rural students to attend the metropolitan-based institutions. In the late 1960s and early 1970s there was a concerted effort to make higher education more available to the working classes and, on election to office, the Whitlam Government abolished fees for university study, substantially increasing participation rates. Free university education became unaffordable for governments and in the mid-1980s the Higher Education Contribution Scheme (HECS) was introduced which provided the opportunity for students to postpone their fee liabilities until employed with a threshold salary. HECS has evolved into HELP (Higher Education Loan Program) which extends the concept to VET students. Agriculture seemed to have missed most of the opportunities that have arisen through this period.

A consistent theme through many reports over time has been the commentary on the shortage of graduates in professional agriculture. It was inferred by Menzies in 1945 (Box 5), explicit in the Murray report of 1957 (Box 6) and in the McColl Report of 1991. It has been the focus of activity by the Australian Council of Deans of Agriculture in the last decade (Pratley 2012, 2016). The question is raised as to why students have not followed the employment opportunities.

A further theme has been the opposition by farmers to formal tertiary education for farmers. This is particularly so with respect to university education. Farguhar (1966) commented that “in Australia there has been comparatively
little interest in and demand for university agricultural courses for farmers”. Falvey and Bardsley (1995) record that “the image of agriculture has not been assisted by the relative neglect of farmer education. This has allowed criticism of the knowledge levels of persons charged with managing the bulk of the country’s terrestrial resources”. They cite Campbell (1980) who claimed “distressingly low levels of farmer education in Australia in the face of evidence linking education to the adoption of new practices”. In the 1960s, less than two per cent of the 6,000 to 8,000 persons entering farming in Australia each year had formal post-secondary education (Falvey and Bardsley, 1995).

The paradigm that farming can be learnt on the job has been a powerful one and remnants are seen today. Why it continued this long is a matter for debate but there were contributing factors. Prior to the 1970s agriculture had a powerful voice in parliaments. The Country Party, the forerunner to the National Party, had strong leadership which protected farmers. It was able to do this because there was a higher proportion of the population in the rural areas, albeit in decline, which, with gerrymandered electorates, provided them with a strong political powerbase. Farmers benefitted from the superphosphate bounty, tariff protection, public plant breeding institutes, the single desk for wheat marketing and free extension

BOX 6: Murray Report 1957

“Primary industries have played their part. Among the many industries of the country agriculture is still the most important single source of wealth in this country and has progressed rapidly in this post-war period; wool production has increased by 44.3% between 1946-7 and 1955-6 and in the same period beef and dairy cattle production has also risen considerably. In southern Australia this expansion has been largely due to the control of the rabbit and to the application of scientific research whereby large areas of native pasture of low stock-carrying capacity can be converted to high quality sown pasture, the area of the latter having increased in the last nine years from 11 million to 33 million acres; intensive scientific investigation of similar problems in Queensland and northern Australia offer promise of no less spectacular improvement in the productivity of semi-tropical and tropical pastures in the next decade. While shortage and uncertainty of rainfall are likely to remain the most important handicaps from which Australian agriculture will suffer, scientific advances and new techniques, if continued, will extend far the physical limits of expansion in that industry.

For example the Australian Institute of Agricultural Science over the past three years has conducted a vigorous campaign to attract more undergraduates to the Faculties of Agriculture in view of the difficulty of maintaining and effecting some expansion of the present sparse agricultural advisory services of the State Governments………… in spite of the fact that all States attempt to ensure a minimum intake of both agricultural and veterinary graduates by the offer of cadetships in the several universities.”

The data for the past three decades or so provide stark evidence of the discrepancy between those in farm production and the remainder of the Australian workforce (Figure 5). It is pleasing to note that between 1984 and 2012 there has been substantial improvement in the proportion holding a degree from around 2% to nearly 12% and that improvement can be expected to continue as the age distribution reconfigures through generational change from a skewed distribution towards the higher age bracket. The increasing influence of corporate farming may also contribute. The challenging statistics however are the increasing gaps between agriculture and the rest of the population, although the relativities have narrowed (i.e. the population was 4.5 times as likely as agriculturalists to have a degree in 1984 and about 2.3 times in 2012).

Another way of considering this quandary is to look at the data for lack of post-school (largely tertiary education) qualifications (Figure 6). In 1984 more than 70% of agriculturalists had no qualifications following school relative to just over 50% of the national workforce, with these percentages declining to around 52% for agriculturalists and 34% for the Australian workforce, again a significant improvement but the gap remains.

The paradigm that farming can be learnt on the job has been a powerful one and remnants are seen today. Why
services. In 1973 with the Whitlam Government elected federally, much of this protection was removed – ‘one man one vote’, removal of subsidies and gradual tariff removal altered the power dynamic. The Australian Conservation Council came into being in the 1960s and the Greens in the 1970s. Soil erosion becoming a political issue as well as an environmental one and provided a basis for raising the profile of these activist organisations at the expense of agriculture. The suddenness of the changes caught the sector unprepared and it adopted a defensive position from which it took decades to recover. The anti-education stance meant that little advantage was taken of free education introduced by the Whitlam Government and so the sector became uneducated relative to the rest of the community. The lack of strong industry leadership allowed the sector’s image to be tarnished and the disconnection between city and country exacerbated this.

Whereas in decades past the support of government could mask the need for education other than ‘on the job’, the development of technology, the need for compliance, the environmental imperative, the biosecurity imperative, the importance of strong business acumen and the need for a positive sector image all point to the need for a well-educated and trained workforce. There has been significant change in the past decade in particular as these issues are progressively addressed and the industry has moved from the early 20th Century education paradigm to the 21st Century paradigm based on qualifications.

SUMMING UP

Education evolution in Australia has been rapid and we are fortunate that education is readily available and of a good standard that is recognised globally. Agricultural education has featured strongly and with greater emphasis than for any other industry sector, both in the school system and in post-school offering. In the specialist schools, academic excellence has been a key principle but in many other schools it has suffered until recently from disdain.

The availability of tertiary education has been strong since early days and has served the service industries well. Farmer education however had been shunned by farmers themselves until recent times but the challenges now faced have created a new imperative for education and the emerging generation is taking advantage of the vast opportunities that exist through better capability in new technologies and in business principles.

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APPENDIX 1. AUSTRALASIAN 'AGRICULTURAL' UNIVERSITIES

<table>
<thead>
<tr>
<th>University</th>
<th>Year university established</th>
<th>Year of first intake into undergraduate agriculture</th>
<th>Year of first intake of females into UG agriculture</th>
<th>Year of first PhD graduate in agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>UQ (See also Qld Agricultural College)</td>
<td>1910</td>
<td>1927</td>
<td>1969</td>
<td>1953</td>
</tr>
<tr>
<td>CQU</td>
<td>1967</td>
<td>2016</td>
<td>2016</td>
<td></td>
</tr>
<tr>
<td>U Sydney</td>
<td>1850</td>
<td>1911</td>
<td>1917</td>
<td>1929</td>
</tr>
<tr>
<td>UNSW</td>
<td>1949</td>
<td>1951 Ceased 1997</td>
<td>1960</td>
<td>1959</td>
</tr>
<tr>
<td>UNE</td>
<td>1938 (university college of U Sydney 1954 UNE)</td>
<td>1950s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSU (See also Wagga Agricultural College)</td>
<td>1989</td>
<td>1990</td>
<td>1990</td>
<td>1995</td>
</tr>
<tr>
<td>WSU (See also Hawkesbury Agricultural College)</td>
<td>1989</td>
<td>1990</td>
<td>1990</td>
<td>1993</td>
</tr>
<tr>
<td>SCU</td>
<td>1994</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U Melbourne (See also Victorian Colleges of Agriculture)</td>
<td>1853</td>
<td>1905</td>
<td>1914</td>
<td>1949</td>
</tr>
<tr>
<td>La Trobe U</td>
<td>1964</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U Tasmania</td>
<td>1890</td>
<td>1960s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U Adelaide (See also Roseworthy Agricultural College)</td>
<td>1874</td>
<td>1905 (RAC grads could articulate to BSc) 1928</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UWA</td>
<td>1911</td>
<td>1913 (chair established)</td>
<td>1923</td>
<td>1950</td>
</tr>
<tr>
<td>Curtin U (See also Muresk Agricultural College)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lincoln U NZ</td>
<td>(1878 as School of Agriculture, Canterbury College) 1990</td>
<td>1880 (Certificates until 1896) 1946</td>
<td></td>
<td>1961</td>
</tr>
<tr>
<td>Massey U NZ</td>
<td>1927 (Massey Agric College 1963 – Massey University)</td>
<td>1928</td>
<td>1938</td>
<td>1956</td>
</tr>
</tbody>
</table>
GUIDELINES FOR WHEAT YIELD LOSS

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Dr Darshan Sharma is a senior researcher at the Department of Agriculture and Food Western Australia. He has more than 30 years of research experience comprising wheat agronomy, cropping system research, crop genetics and plant breeding. Currently, Darshan is managing the Genetic Improvement portfolio in Grains R&D Transformation directorate. In addition, he is conducting pre-breeding research for wheat yield improvement on sodic dispersive soils in WA.

ABSTRACT
In most cases there is more than one constraint to dryland or rainfed crop production in the field. However, relative impact of the limiting factors varies according to nature and intensity of the constraint. In order to rank constraints according to the predicted level of potential yield loss due to given constraints present in a given season in a given field, a new decision tool named ‘MyPaddock’, has been developed and released in Western Australia. (www.agric.wa.gov.au/mypaddock). It has been primarily developed for retrospective analysis of yield loss although majority guidelines can be equally well used in making pre-season predictions. Output of this decision tool, is a colour coded display similar to a typical traffic light system. The decision tool uses a range of models and guidelines for calculating likely yield loss under the input level of biophysical variables. This paper documents such background information, guidelines, models and critical intervals used in the wheat module of this decision tool. The information contained in this paper is potentially useful for understanding and interpreting model outputs and as a teaching tool.

Key words: Wheat production constraints, MyPaddock, rules of thumb, yield loss, wheat yield, rainfed wheat, decision tool

INTRODUCTION
The average world production of wheat is about 700 million tonnes each year (Food and Agriculture Organisation 2015) from about 222 million hectares (CIMMYT 2014). Yield levels vary from about 18t/ha under irrigation to less than half a tonne under rainfed conditions in different parts of the world. The spectrum of yield levels due to rainfall and temperature across regions is large and obvious but within-region yield variations are also alarmingly high and reflect yield losses due to local constraints (DAFWA 2015a). For example, Sadras et al (2002) could attribute only 27% of yield variation observed in 75 crops to differences in the amount of rainfall and the majority of the remaining variance was attributed to soil salinity, alkalinity and root lesion nematodes. Fortunately, diagnosis followed by appropriate treatment of such constraints can help recover yield levels under most conditions (Sharma and Anderson 2014, Anderson et al 2014).

One of the key components in the diagnostic approach is the collection of information and data on biophysical variables. The ‘Focus Paddocks’ project in the Department of Agriculture and Food Western Australia (DAFWA) collected data from 180 paddocks over five years and reported large variation for a range of variables. These constraints have been previously identified in many scoping studies (for example, Anderson et al 2014). While farmers and consultants are aware of the existence of such constraints, they are more interested to compare the level of yield loss from the identified constraints so that the costs of remediation can be estimated. For example, the maximum yield loss due to stem rust (Puccinia graminis f.sp. tritici) can be as high as 90% (DAFWA 2015d) while that due to yellow spot (Pyrenophora tritici-repentis), would seldom exceed 30 percent (DAFWA 2016e).

The objective of this work was to develop a decision tool that farmers and advisors in Western Australia could use for comparing local constraints. The intended purpose of this tool was to enable retrospective analysis after the harvest when growers would be planning paddock treatments and choices for the upcoming season. However, by virtue of the nature of critical factors accounting for constraints, guidelines for many of these constraints can also be useful in making predictions. The tool was deliberately kept simple in order to provide answers using a traffic light system and was released in May 2015 under the name ‘MyPaddock’ (DAFWA 2015b). In this paper, the background information and guidelines used in the development of MyPaddock are presented. The aim is to summarise the methods used to rank constraints to crop production in Western Australia. This is seen as a prerequisite to further demonstration of
possible improved productivity through the use of tools such as MyPaddock.

**METHODS:**

*List of constraints*

A list of constraints was compiled from the results published from past research projects and fresh systematic sampling, monitoring and observations recorded on 180 paddocks across the grain belt in Western Australia over four years (French et al 2015, Harries et al 2015, Malik et al 2015, Poole et al 2015, WK Anderson, unpublished). The selected list included the following:

- **Crop management:** Inappropriate sowing time or seed rate
- **Diseases and pests:** Cereal cyst nematode, Root lesion nematode, Rhizoctonia AG8, Take all, Crown rot, Yellow spot, Septoria tritici blotch, Septoria nododum blotch, Leaf rust, Stripe rust, Stem rust
- **Soil chemistry:** Acidity, alkalinity, aluminium toxicity, boron toxicity, salinity, sodicity
- **Nutrition:** Nitrogen, Phosphorous, Potassium, Sulphur, Zinc, Copper, Boron, Manganese, Molybdenum
- **Soil physical:** Compaction
- **Weeds:** Barley grass (*Hordeum glaucum* and *H. leporinum*), Brome grass (*Bromus diandrus* and *B. rigidus*), Cape weed (*Arctotheca calendula*), Double gee (*Emex australis*), Ryegrass (*Lolium rigidum*), Wild oats (*Avena fatua* and *Avena ludoviciana*), Wild radish (*Raphanus raphanistrum*)

*The process for generating critical limits*

The relevant knowledge base comprised published scientific literature, unpublished reports and personal communications with local scientists. Preference was given to data generated locally and articles published in refereed scientific publications or peer reviewed miscellaneous publications. Constraints for which the available information was conflicting or was not available at all, were resolved by organising discussion sessions among relevant scientists to reach knowledge and experience based consensus. While doing so, as argued by Miller (2013), caution was observed to distinguish between shared knowledge and mere agreement.

‘Guidelines’ for estimating yield loss for some constraints were straightforward lookups while some were complex and required some level of modelling using the magnitude of key influencing factors. Constraints for which models were already available and in use, were adopted using assumptions and protocols underlying those models. Where pre-existing models were not available, simple models were developed and adopted after discussion with experts.

*Phases in development of the decision-tool*

The decision tool was developed in two steps. At first, a test version was developed using Shiny application for R platform (RStudio 2016). This was made available to knowledge contributors, project colleagues, selected farm advisors, grower groups and relevant scientists from other organisations. Feedback and queries were addressed and the final version was then produced as a hard-wired, web-based tool and launched in open access public domain under the name ‘MyPaddock’.

*Adoption of the decision tool*

Critical limits employed in MyPaddock were used for interpreting and producing annual reports over three years for the 180 paddocks adopted under the state wide Focus Paddocks project. This was achieved by imposing a traffic light system on an oracle database and was made available to respective growers. The MyPaddock decision tool is a legacy of this Focus Paddocks project released for general use by the farming community and advisors.

*Display*

MyPaddock displays the likely level of yield loss for each considered constraint as a colour code. The colour codes and corresponding interpretations are given in the Table 1 below:

A screenshot of the output part of the decision tool is shown in Figure 1. The display allows users to input their levels of the biophysical variables. For example, in the example shown in Figure 1, the user has to make three input selections: i) select from the drop list for the part of the crop cycle when leaf rust was actually seen; ii) select using slider or enter the severity of disease observed in the upper part of crop canopy and, iii) select using slider or enter the number of relevant fungicide sprays applied on the crop. The pointer on the colour coded dial changes with change in each input. The dial in Figure 1 shows that the yield loss in this case was 5-15% and hence, coded yellow. The colour code is also written in words considering usability by colour blind users.

*Location on web*

The MyPaddock decision tool is open access and available at https://www.agric.wa.gov.au/mypaddock.
GUIDELINES USED IN MYPADDOCK

Time of sowing

Sowing at the right time is critical for maximising yield potential and there is large variation of optimum sowing time for wheat yield in Western Australia (Sharma et al 2008). In the typical Mediterranean type climate, frost events in spring and terminal heat or drought stress dictate that crops must flower in location specific periods or ‘windows’ in order to set up adequate sink size and allow enough time to fill grains (Anderson et al 1994; Anderson and Garlinge 2000, Sharma et al 2016). Given the diversity of phenotypic responses of phenology genes to the environmental factors, the optimum sowing time is different for different varieties in different regions.

MyPaddock uses flowering date outputs from the DM model (Sharma and D’Antuono 2011) available on-line at the Flower Power decision tool webpage (DAFWA 2016a). MyPaddock looks up for predicted flowering date of the given variety sown on the given date at the given location and compares it with Table 2 for determining the extent of deviation from optimum flowering time. The guidelines for yield loss (Table 3) and region specific optimum flowering periods are based on a range of published data from Western Australia (Shackley and Anderson 1995, Garlinge 2005, Zaicou-Kunesch et al 2005, Sharma et al 2008).

Seed rate

Optimum seed rate can be determined by considering the estimated minimum plant population required to achieve the target yield. The establishment percentage of a given sown seed rate will be determined by the moisture, temperature and physical conditions in the seed bed. The optimum plant population for wheat increases with increasing target yield by a factor of about 40 plants per ton of targeted yield (Anderson et al 2004, 2011). The calculation of estimated actual plant density includes inputs on target yield, quantity of seed used, average seed weight, germination percentage and seed bed conditions. Seed bed conditions refer to pre-emergent plant loss due to soil crusting and post-emergent seedling death due to lethal water deficit. Three levels namely, nil, 10% and 30% plant reduction, have been allowed to account for nil, unfavourable and highly unfavourable seed bed conditions, respectively. An additional establishment factor related to targeted plant density has also been included to vary as given in Table 4. The assumption on this factor is based on author’s own unpublished data and is little harsher compared to Anderson (1986) and Del Cima et al (2004).

The ratio of used seed rate to the estimated seed rate required to achieve the target yield is calculated for determining the yield loss category according to the rule of thumb in Table 5.

Root Cyst Nematode

Cereal Cyst (Heterodera sp.) and Root Lesion (Pratylenchus sp) nematodes commonly referred to as CCN and RLN, respectively, are the most prevalent soil borne pests in Western Australian grain belt. Guidelines for assessing yield loss to these nematodes were developed in consultation with local nematologists (Vivien Vanstone and Sarah Collins, personal communication) and SARDI manual (McKay et al 2008).

Cereal Cyst Nematode

Two methods of assessing the impact of cereal cyst nematode on wheat grain yield are available to farmers in Western Australia (Table 6). These are DNA based PreDictaB developed by SARDI (McKay et al 2008) and actual root analysis available at the Agwest Plant Labs (Sarah Collins, personal communication). PreDicta B quantifies nematode DNA and reports results in equivalence to number of eggs per gram of soil. The actual root analysis requires manual assessment of symptoms on a 0-3 scale following SARDI TOPCROP brochure as reproduced at DAFWA (2016b).

Root Lesion Nematode

Like CCN, both PreDictaB and actual root analysis tests are in use (Table 6). PreDicta B results are presented in equivalence of number of nematodes per gram of soil. The actual root analysis for this pest involves manual extraction and microscopic counting of nematodes.

Root diseases

Three most common root diseases in WA are: Rhizoctonia AG8 root rot caused by Rhizoctonia solani, Take-all caused by Gaeumannomyces graminis var. tritici and Crown rot caused by Fusarium pseudograminearum. Both Predicta B and actual disease scores (Daniel Huberli, Geoff Thomas, Shahajahan Myyan, personal communication) can be used for assessing disease level and assigning yield loss category (Table 7). For all the three pathogens, Predicta B test reports results as log (DNA) while actual root analysis involves observations on disease incidence and mean severity score on a 0-3 scale following SARDI TOPCROP brochure as reproduced at DAFWA (2016b).

Foliar diseases

Common foliar diseases in WA are: Yellow spot (Pyrenophora tritici-repentis), Septoria nodorum blotch (Parastagonospora nodorum), Septoria tritici blotch (Mycosphaerella graminicola), Leaf rust (Puccinia tritici), Stripe rust (Puccinia striiformis f. sp. tritici) and Stem rust (Puccinia graminis f. sp. tritici).
The traffic light colour in MyPaddock appears according to yield loss estimated by discounting an assumed maximum loss (Table 8) adjusted for disease severity (as percentage of leaf area damaged in the top 3 leaves), crop cycle duration when the disease was actually present (only before-, only after- or both before- and after- anthesis) and the number of effective fungicide spray applications after the appearance of disease (Bhathal et al. 2003, DAFWA 2015c, DAFWA 2015d, DAFWA 2016c, DAFWA 2016d, DAFWA 2016e, Geoff Thomas, personal communication).

**Nutrients**

Except Molybdenum and Manganese that do not have a reliable soil test, all nutrient elements may be gauged for inadequacy using both soil and tissue tests. Guidelines on yield loss estimates in Table 9 are based on applicable soil or tissue tests for all nutrients except the soil test for nitrogen (Brennan and Boland 2006, Anderson et al. 2013, Bell et al. 2013, Brennan and Bell 2013, GRDC 2014, Craig Scanlan, Geoff Anderson, Ross Brennan and Bill Bowden, personal communication). The reason for not using soil N results is that although they provide a more relevant estimate of the nitrate and ammonium concentration at a given time, it is seldom useful in determining the amount of nitrogen that is available to the crop over the entire growing season. Hence an alternative approach using paddock history as advanced by Bowden and Burgess (1993) was followed. Components of this approach are reproduced below.

Quantity of required N is calculated assuming 40kg N/ha for each ton of target grain yield.

Quantity of available N is estimated as the sum of the amount of applied fertiliser N, estimate of the stable organic nitrogen (SON) and estimate of the residue organic matter (RON).

**N from SON:** The estimate of N from SON is based on the proportion of stable organic component that is available for mineralisation. That is,

\[ N_{\text{from SON}} = \text{SON\_pool\_size} \times \text{SON\_availability\_factor} \]

where,

\[ \text{SON\_availability\_factor} \text{ in this equation is assumed to be 2.5\%.} \]

\[ \text{SON\_pool\_size} = \text{oc} \times 10000 / (\text{cn} / 2.5) \times (1 - \text{gravel} / 100) \]

where, \( \text{oc} \) = % organic carbon in the top 10cm; \( \text{cn} \) = C:N ratio in the soil; and, \( \text{gravel} \) = percentage of gravel in top soil. The C:N ratio is assumed to be 15 for most Western Australian soils, 20 for forest soils in high rainfall area and 10 for heavy soils in low rainfall area.

**N from RON:** The estimate of N from RON is based on the quantity and N percentage of leguminous stubble in previous two years. That is,

\[ N_{\text{from RON}} = \text{RON\_pool\_size} \times \text{RON\_availability\_factor} \]

where,

\[ \text{RON\_availability\_factor} \text{ is assumed to be 0.43.} \]

\[ \text{RON\_pool\_size} = (\text{ron\_last\_year}) + (\text{ron\_year\_before} \times \text{carry-over\_factor}) \]

where,

\[ \text{carry-over\_factor} \text{ has been assumed to be 0.5 for legumes and 0.67 for pastures;} \]

\[ \text{ron\_last\_year} \text{ and ron\_year\_before nitrogen fixed in the last and in the year before last year, respectively and its estimation varies with the crop.} \]

**Canola and cereals:** This value for cereals and canola, being non-leguminous, is zero.

**Legumes:**

\[ \text{ron\_from\_an\_year\_for\_seed\_crop} = (\text{sy} \times \text{hi} \times 1000 \times \text{Nb}) - (\text{sy} \times 1000 \times \text{Ns} / 100) \]

where,

\[ \text{sy} = \text{seed yield of that crop;} \]

\[ \text{hi} = \text{harvest index;} \]

\[ \text{Nb} = \text{N\% of the plant biomass and is assumed to be 2.75\% for lupins and 2.5\% for other legumes;} \]

\[ \text{Ns} = \text{N\% of the harvested seed and is assumed to be 5.0\% for lupins and 4.0\% for other legumes} \]

**Pasture:**

\[ \text{ron\_from\_an\_year\_for\_pasture} = ((\text{lp} / 100 \times \text{tdm} \times 1000 \times 2.5 / 100) + ((100 - \text{lp}) / 100 \times \text{tdm} \times 1000 \times 1.4 / 100) \times \text{f} \]

where,

\[ \text{lp} = \text{legume percentage in the pasture} \]

\[ \text{tdm} = \text{total top biomass grown (kg/ha)} \]

\[ \text{f} = \text{fraction of biomass remaining after grazing} \]

**Soil Physical factors**

Soil compaction (Hunt and Gilkes 1992, Hamza and Anderson 2005, Isbister et al. 2013, DAFWA 2016f) and sodicity (Boucher 2011, DAFWA 2015e, David Hall, personal communication) are the two major physical constraints in Western Australia. Soil compaction is usually measured with a hand held penetrometer while sodicity is expressed as exchangeable sodium percentage in soil solution. Table 10 shows consensus limits for yield loss in WA grain belt.
**Weeds**

Determination of yield loss due to weeds is complex given the variance in competitive ability of varieties, seasonal conditions, crop nutrition and yield potential. The two largest factors, nonetheless, are timing of weed emergence and duration of their presence (Sally Peltzer, personal communication). Critical intervals given in Table 11 correspond to weed numbers present early in the season and presumed to stay for at least one month (Gilbey 1974, Gill et al 1974, Martin et al 1987, Medd et al 1985, Pathan et al 2006, DAFWA 2015f, DAFWA2016g, Moore and Moore 2007, Abul Hashem, John Moore, Sally Peltzer, personal communication). Although weed pressure in a season is highly influenced by paddock history factors such as crop rotation, herbicide treatment and residue management but for a retrospective analysis, it is the actual weed numbers present in the said crop that matters in gauging the resulting yield constraint.

**Soil toxicity**

Soil pH, salinity and elemental toxicities of Aluminium and Boron are the predominant soil factors affecting root growth in WA. Guidelines on their risk to grain yield are given in Table 12.

**Soil pH**

The effect of soil acidity and alkalinity is indirect. Low pH tends to prune roots thus intensifying the impact of drought (Upjohn et al 2005, Gazey et al 2014, DAFWA 2015g). On the other hand, alkalinity reduces yield in limited phosphorous soils as it tends to increase precipitation of phosphorous in soil solution (Craig Scanlan, personal communication).

Given the water limited rainfed environment of WA, moisture in the top soil (0-10cm) is seldom enough past stem elongation. Thus the pH effects on grain yield relate more directly with sub-soil (10-30cm) chemistry. As such, the net interpretation should be drawn on the basis of soil pH in both top and sub soil layers. Often, a high level of constraint in the sub soil especially if the root zone is shallow (i.e.10-30 cm), can be detrimental to crop growth even when the topsoil layer appears normal (Chris Gazey, personal communication).

**Aluminium**

Aluminium is detrimental only when occurring in the free state in soil solution. Because top soil generally contains enough organic matter to keep Aluminium bound (Chris Gazey, personal communication), critical limits provided in Table 12 (DAFWA 2015g) are relevant only for the sub-soil.

**Boron**

Boron is a micro nutrient but at higher concentrations, it can seriously inhibit root growth and reduce photosynthetic leaf area by producing necrotic patches as a consequence of accumulation in leaves leading to retardation of many cellular processes (Reid et al 2004, Hall 2014, DAFWA 2016h).

**Salinity**

High salt concentration in the soil solution reduces water uptake by increasing osmotic strength. As such, crop growth reduction is a function of the concentration of salt in the soil solution rather than just its quantity in the soil. With less water in the topsoil, the soil solution will be more concentrated, which may cause higher yield loss even with a low salinity reading. It is hard to assign salinity limits to yield loss categories (Barrett-Lennard et al 2008, DAFWA 2015h, Ed Barrett-Lennard, personal communication). Instead, the critical limits shown in Table 12 correspond to severe, very high, high and low risk of yield decline due to salt.

**DISCUSSION**

Guidelines presented above cover majority of constraints to wheat yield in Western Australia although not comprehensive for other states in Australia let alone elsewhere in the world. This list was purposely kept restrictive to WA keeping in mind the brevity and simplicity of the decision making approach that it is intended to underpin. Nonetheless, the concept and information lodged in these guidelines can be used in constituting region specific decision tool for anywhere in the world.

In adopting these Western Australian guidelines elsewhere, a review of locally applicable research may be required. It appears while constraints involving soil organic matter and sowing time may require parameter adjustment, limits for most constraints should stay the same.

While the decision tool is simple enough for use by farmers, it is likely that farm consultants, agronomists and farm advisors will use it routinely. The background information presented in this paper and critical limits published online provide them with clarity and confidence in terms of local relevance. Short interviews prior to initiation of this compilation exercise revealed that many such practitioners often remain confused with the diverse level of critical limits evident from research papers arising from different regions of the world.

The ultimate benefit of the information and models compiled in MyPaddock will depend upon a range of factors such as feasibility, ease of adoption, life of the intended benefit and the benefit cost ratio of the relevant remedial. The net return on investment may follow the law of diminishing returns and possible interactions among constraints. Sharma and Anderson (2014) reported both additive and interactive examples of the application of multiple remedial measures.
CONCLUSION

This paper documents critical limits of parameters for determining level of yield loss due to a range of constraints prevalent in grain growing areas of Western Australia. The concept and information presented in this paper is portable to other parts of the world although parameters used in some models might require review and adjustment according to local agronomy experiments, environmental conditions and cropping system.

REFERENCES


Hunt N, Gilkes B (1992) Farm monitoring handbook- A practical down-to-earth manual for farmers and other land users. The University of Western Australia


ACKNOWLEDGEMENTS

The critical limits used in MyPaddock draw on knowledge and experience of many local scientists and extensive data collected from 184 paddocks over five years as part of DAFWA’s Focus Paddocks project. The project was funded by the Grains Research and Development Corporation.

Following scientists provided local information, validation or contributed significantly in discussions for determining locally applicable critical limits:

Soils: Bill Bowden, Chris Gazey, Craig Scanlan, David Hall, Doug Abrecht, Geoff Anderson, Mohammad Hamza, Ross Brennan, Paul Blackwell, Stephen Davies, and Ed Barrett-Lennard

Plant Diseases: Sarah Collins, Geoff Thomas, Daniel Huberli, Shahajahan Miyan, Bill MacLeod, Sanjiv Gupta and Vivien Vanstone

Weeds: John Moore, Abul Hashem, Sally Peltzer and Harmohinder Dhammu

Management: Wal Anderson, Mohammad Amjad and Glen Riethmuller

Table 1. Colour codes used for distinguishing levels of yield loss in the ‘MyPaddock’ decision tool

<table>
<thead>
<tr>
<th>Estimated yield loss</th>
<th>Colour code</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 5%</td>
<td>Green</td>
<td>Not a constraint</td>
</tr>
<tr>
<td>5 to 15%</td>
<td>Yellow</td>
<td>Watch it - potential risk of loss</td>
</tr>
<tr>
<td>15 to 25%</td>
<td>Orange</td>
<td>Fix it - high risk of loss</td>
</tr>
<tr>
<td>More than 25%</td>
<td>Red</td>
<td>STOP and think about how to address this constraint</td>
</tr>
</tbody>
</table>
Table 2. Optimum flowering periods for the cropping regions in Western Australia

<table>
<thead>
<tr>
<th>Region</th>
<th>Optimum flowering ‘window’</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start</td>
</tr>
<tr>
<td>North east</td>
<td>25 Aug</td>
</tr>
<tr>
<td>Eastern</td>
<td>1 Sep</td>
</tr>
<tr>
<td>Lakes</td>
<td>1 Sep</td>
</tr>
<tr>
<td>North west</td>
<td>3 Sep</td>
</tr>
<tr>
<td>South coast</td>
<td>3 Sep</td>
</tr>
<tr>
<td>Central</td>
<td>5 Sep</td>
</tr>
<tr>
<td>Great Southern</td>
<td>16 Sep</td>
</tr>
</tbody>
</table>

Source: Garlinge (2005)

Table 3. Estimates of likely yield loss with crop flowering outside the optimum flowering ‘window’

<table>
<thead>
<tr>
<th>Timing of flowering date</th>
<th>Likely yield loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop flowering more than 14 days outside the flowering window</td>
<td>&gt;25%</td>
</tr>
<tr>
<td>Crop flowering 7-14 days outside the flowering window</td>
<td>15-25%</td>
</tr>
<tr>
<td>Crop flowering 7 days outside the flowering window</td>
<td>5-15%</td>
</tr>
</tbody>
</table>

Table 4. Assumed seedling establishment rate with increasing target plant density

<table>
<thead>
<tr>
<th>Target plant density (plants/m²)</th>
<th>Assumed Establishment (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>90</td>
</tr>
<tr>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>120</td>
<td>70</td>
</tr>
<tr>
<td>160</td>
<td>60</td>
</tr>
<tr>
<td>200</td>
<td>55</td>
</tr>
<tr>
<td>240</td>
<td>50</td>
</tr>
<tr>
<td>300</td>
<td>45</td>
</tr>
</tbody>
</table>

Table 5. Estimated yield loss due to inadequate plant population

<table>
<thead>
<tr>
<th>Seed rate used</th>
<th>Yield loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 55% of the required seed rate</td>
<td>&gt;25%</td>
</tr>
<tr>
<td>55-70% of the required seed rate</td>
<td>15-25%</td>
</tr>
<tr>
<td>70-90% of the required seed rate</td>
<td>5-15%</td>
</tr>
<tr>
<td>More than 90% of the required seed rate</td>
<td>&lt;5%</td>
</tr>
</tbody>
</table>

Table 6. Estimated levels of PreDicta-B data and actual root analysis data for Cereal Cyst Nematode and Root Lesion Nematode corresponding to different levels of grain yield loss

<table>
<thead>
<tr>
<th>Pest</th>
<th>Type of test</th>
<th>Unit</th>
<th>Estimated level of indicator parameter corresponding to yield loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal cyst nematode</td>
<td>PreDicta-B¹</td>
<td>egg/g of soil</td>
<td>&gt;5</td>
</tr>
<tr>
<td>Root lesion nematode</td>
<td>Actual root analysis</td>
<td>Mean score (0-3 scale)</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td></td>
<td>PreDicta-B¹</td>
<td>Number of RLN/g of soil</td>
<td>&gt;7.7</td>
</tr>
</tbody>
</table>

Table 7. Criteria for estimating levels of wheat yield loss according to PreDicta-B and actual root disease scores

<table>
<thead>
<tr>
<th>a. Predicta B test for Root disease</th>
<th>Root disease</th>
<th>Incidence parameter (%)</th>
<th>Severity parameter: Description (first row) and assumed yield loss (%) (second row) corresponding to severity disease scores¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt;100</td>
</tr>
<tr>
<td>Rhizoctonia AG8 root rot</td>
<td>Number of plants in the population</td>
<td>Lesions on more than 50% of the roots, up to 50% of roots shortened</td>
<td>Lesions on 26 – 50% of the roots, up to 25% of roots shortened</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Take-all</td>
<td>Number of plants in the population</td>
<td>5 or more roots black, stem bases often blackened</td>
<td>3 or 4 roots black</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Crown rot</td>
<td>Number of tillers in the population</td>
<td>Infection visible upto 3rd node</td>
<td>Infection visible upto 2nd node</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

¹Deduced using standardisation done in South Australia

*Estimated yield loss= Incidence x Assumed yield loss for mean severity level

*Severity scores for Rhizoctonia and Take-all according to SARDI TOPCROP brochure as reproduced at DAFWA (2016b); for Crown rot devised in DAFWA in consultation with Daniel Huberli
### Table 8. Estimates of the effect of influencing factors on yield loss due to foliar diseases in wheat

<table>
<thead>
<tr>
<th>Foliar disease</th>
<th>Assumed maximum yield loss when disease prevalent&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Only after flag leaf</th>
<th>Only before flag leaf</th>
<th>Throughout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow spot</td>
<td>20, 20, 30</td>
<td>20</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Septoria nodorum blotch</td>
<td>20, 20, 30</td>
<td>20</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Septoria tritici blotch</td>
<td>20, 20, 30</td>
<td>20</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Leaf rust</td>
<td>20, 20, 40</td>
<td>20</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Stripe rust</td>
<td>40, 40, 80</td>
<td>40</td>
<td>40</td>
<td>80</td>
</tr>
</tbody>
</table>

<sup>a</sup>Maximum yield loss according to duration of disease prevalence x (100 - Reduction in potential loss with fungicide application) / 100

Effective fungicide application is assumed to reduce these estimates by 60%, 75% and 95% with 1, 2 or 3 sprays.

### Table 9. Estimated level of nutrient indicator corresponding to different levels of yield loss in wheat

<table>
<thead>
<tr>
<th>Element</th>
<th>Type of test</th>
<th>Major soil factor</th>
<th>Estimated level of indicator parameter corresponding to yield loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Soil available Nitrogen (Supply as %age of Demand)</td>
<td>&lt; 50%</td>
<td>50-70%</td>
</tr>
<tr>
<td></td>
<td>Tissue N concentration (%)</td>
<td>&lt; 4.5%</td>
<td>4.5-5.0%</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>Soil Phosphorous test Grey sands</td>
<td>&lt; 11ppm</td>
<td>11-13ppm</td>
</tr>
<tr>
<td></td>
<td>Soils other than grey sands</td>
<td>&lt;17ppm</td>
<td>17-21ppm</td>
</tr>
<tr>
<td>Potassium</td>
<td>Soil Potassium test Yellow sands</td>
<td>&lt; 31ppm</td>
<td>31-39ppm</td>
</tr>
<tr>
<td></td>
<td>Loams</td>
<td>&lt; 35ppm</td>
<td>35-43ppm</td>
</tr>
<tr>
<td></td>
<td>Duplexes</td>
<td>&lt; 29ppm</td>
<td>29-36ppm</td>
</tr>
<tr>
<td></td>
<td>Tissue K concentration (%)</td>
<td>&lt; 3.0%</td>
<td>3.0-3.5%</td>
</tr>
<tr>
<td>Sulphur</td>
<td>Soil Sulphur test</td>
<td>&lt; 2.6ppm</td>
<td>2.6-3.9ppm</td>
</tr>
<tr>
<td></td>
<td>Tissue S concentration (%)&lt;sup&gt;i&lt;/sup&gt;</td>
<td>&lt; 0.18%</td>
<td>0.18-0.25%</td>
</tr>
<tr>
<td>Zinc</td>
<td>Soil Zinc test Alkaline clay</td>
<td>&lt; 0.19ppm</td>
<td>0.19-0.31ppm</td>
</tr>
<tr>
<td></td>
<td>Soils other than alkaline clay</td>
<td>&lt; 0.15ppm</td>
<td>0.15-0.25ppm</td>
</tr>
<tr>
<td></td>
<td>Tissue Zn concentration (ppm)&lt;sup&gt;i&lt;/sup&gt;</td>
<td>&lt; 12ppm</td>
<td>12-15ppm</td>
</tr>
<tr>
<td>Copper</td>
<td>Soil Copper test</td>
<td>&lt; 0.15ppm</td>
<td>0.15-0.25ppm</td>
</tr>
<tr>
<td></td>
<td>Tissue Cu concentration (ppm)&lt;sup&gt;i&lt;/sup&gt;</td>
<td>&lt; 1.5ppm</td>
<td>1.5-2.0ppm</td>
</tr>
<tr>
<td>Boron&lt;sup&gt;ii&lt;/sup&gt;</td>
<td>Soil Boron test</td>
<td>&lt; 0.2ppm</td>
<td>0.2-1.0ppm</td>
</tr>
<tr>
<td>Manganese</td>
<td>Soil Manganese test</td>
<td>&lt; 10ppm</td>
<td>10-18ppm</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Soil Molybdenum test</td>
<td>&lt; 0.04ppm</td>
<td>0.04-0.06ppm</td>
</tr>
</tbody>
</table>

<sup>i</sup>Tissue test is provided as a cross check although it is not always a true indicator of the extent of deficiency. It can be used to differentiate crop with an adequate supply from that with a deficient supply. Samples collected on whole tops at Z-31 (stem elongation, 1st node visible)

<sup>ii</sup>Excess of boron is toxic. See Table 12.
Table 10. Severity of soil compaction and soil sodicity corresponding to different levels of yield loss in wheat

<table>
<thead>
<tr>
<th>Element</th>
<th>Measure</th>
<th>Major soil factor</th>
<th>Estimated level of indicator parameter corresponding to yield loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil compaction</td>
<td>Maximum penetrometer reading (Mega Pascals)</td>
<td>Sands and sandy loams</td>
<td>&gt; 2.2 Mpa 1.9-2.2 Mpa 1.6-1.9 Mpa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duplex with sandy or loamy A-horizon greater than 30 cm</td>
<td>&gt; 2.6 Mpa 2.2-2.6 Mpa 1.7-2.2 Mpa</td>
</tr>
<tr>
<td>Sodicity</td>
<td>Exchangeable sodium percentage¹</td>
<td>Clays</td>
<td>&gt; 4.5 Mpa 3.8-4.5 Mpa 3.0-3.8 Mpa</td>
</tr>
</tbody>
</table>

¹ESP (%) = Exchangeable Sodium meq per 100g of soil / Cation Exchange Capacity meq per 100g of soil x 100; where, Cation Exchange Capacity = 1.05 * (sum of Ca++, Mg++, K+, Na+)

Table 11. Estimated weed plant density corresponding to different levels of grain yield loss in wheat in Western Australia

<table>
<thead>
<tr>
<th>Weed²</th>
<th>Number of weed plants corresponding to estimated yield loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt;25% 15-25% 5-15% &lt;5%</td>
</tr>
<tr>
<td>Barley grass</td>
<td>&gt; 200 75-200 15-75 &lt; 15</td>
</tr>
<tr>
<td>Brome grass</td>
<td>&gt; 75 25-75 10-25 &lt; 10</td>
</tr>
<tr>
<td>Cape weed</td>
<td>&gt; 45 20-45 5-20 &lt; 5</td>
</tr>
<tr>
<td>Double gee</td>
<td>&gt; 45 20-45 5-20 &lt; 5</td>
</tr>
<tr>
<td>Ryegrass</td>
<td>&gt; 150 50-150 15-50 &lt; 15</td>
</tr>
<tr>
<td>Wild oats</td>
<td>&gt; 50 15-50 5-15 &lt; 5</td>
</tr>
<tr>
<td>Wild radish</td>
<td>&gt; 10 1-10 0.1-1 &lt; 0.1</td>
</tr>
</tbody>
</table>

¹Number of plants/m²
²Weeds present early in the season and stayed for at least one month

Table 12. Estimated level of soil elemental toxicity levels corresponding to different levels of yield loss in wheat

<table>
<thead>
<tr>
<th>Soil toxicity factor</th>
<th>Unit</th>
<th>Estimated level of indicator parameter corresponding to yield loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&gt;25% 15-25% 5-15% &lt;5%</td>
</tr>
<tr>
<td>Soil Acidity</td>
<td>pH</td>
<td>&gt; 4.5 4.5-5.0 5.0-5.5 &lt; 5.5</td>
</tr>
<tr>
<td>Soil Alkalinity</td>
<td>pH</td>
<td>&lt; 8.5 8.5-8.0 8.0-7.5 &lt; 7.5</td>
</tr>
<tr>
<td>Soil Aluminium</td>
<td>ppm</td>
<td>&gt; 5.0 5.0-4.0 4.0-2.0 &lt; 2.0</td>
</tr>
<tr>
<td>Soil Boron</td>
<td>ppm</td>
<td>&gt; 25 25-18 18-12 &lt; 12</td>
</tr>
<tr>
<td>Soil Salinity</td>
<td>dS/m</td>
<td>&gt; 1.0 0.75-1.0 0.75-0.5 &lt; 0.5</td>
</tr>
</tbody>
</table>
Figure 1. Screenshot of the output part of the MyPaddock decision tool
ABSTRACT

With the renewable energy sector in Australia experiencing unprecedented levels of investment, now is a unique opportunity for the national economy and for the communities in regional Australia. Environmental impacts are minimal and community benefits can accrue from both large- and utility-scale solar projects, such as jobs and regional investment. But there are questions for the agricultural sector to consider as these opportunities open up: To what extent is the concern of energy generation versus food production warranted? Should large-scale solar power stations even be built on agricultural land? The author uses a case study from the Central West of NSW to explore these issues.

INTRODUCTION

There has been a long-standing debate on whether or not agricultural land should be used for producing energy. This debate emerged in recent decades with the prospect of biologically-derived liquid fuels being produced from agricultural grain crops. However, agriculture has for centuries been a producer of energy, albeit indirectly through feeding of animals used to power land-based transport. In recent times, the question of energy versus food emerges again as large-scale and utility-sized solar photovoltaic (PV) projects secure approvals across Australia. Solar PV technology has become an increasingly important energy supply option globally. At the end of 2016, installed capacity worldwide exceeded 300 GW. A substantial decline in the cost of solar PV panels (or modules) has improved solar PV’s competitiveness, reducing the need for subsidies and enabling solar to compete with other traditional power generation options in some markets. A recent estimate reveals that these price reductions have been as high as 80% from the period of 2006 to 2015 (Anonymous 2016).

While the majority of operating solar PV projects are in developed economies, the drop in prices coupled with unreliable grid power and the high cost of diesel generation has driven interest in solar PV technology in emerging economies as well. Assuming that solar PV technology prices continue to fall relative to competing sources of electricity, the market penetration rate of utility-scale solar energy power projects can be expected to continue growing rapidly, including in emerging markets. Grid parity for solar PV is expected globally during the period 2018-2020. In some applications in Australia, it has already been reached.

Overall, Australia is a small contributor to global solar PV generation (Figures 1 and 2). Solar PV installations have, nevertheless, increased significantly in recent years in Australia. Although Australia represented only 2% of the global market share of solar PV in 2015, in the same year this represented a total installation of just over 1 GW of installed capacity.

While distributed (rooftop) solar PV is increasing, commercial and utility-scale installations are also on the rise. Large-scale projects are going to be required to ensure supply to large customers such as smelters, manufacturing plants, etc., that require large power inputs, and for the country to meet its renewable energy target. Constructing large scale solar PV plants, that is, 5 megawatts (MW) or more, requires considerable areas of land and these are not available nor economically viable in cities, and therefore will need to be constructed in less expensive regional and rural areas. This construction is also leading to employment growth (Figure 3) (Anonymous 2017).

While not considered as primary stakeholders in this emerging sector and debate, farmers and their advisors, have an important role to play to ensure the growth trajectory of large-scale solar reaps benefits for rural and regional Australia.

PURPOSE

This article compares the benefits of constructing large-scale renewable energy projects in regional areas of Australia, over continued agricultural use of land. Specifically, a case study site in Central West NSW (dry land wheat and sheep) is used to illustrate these impacts and benefits. It gives a flavour of the mechanics of what solar PV construction means, and raises questions that the industry should be asking as the sector emerges and grows.

METHOD

Location

The case study site is located in Nyngan in Central West NSW, Australia. The power plant has an installed capacity...
of approximately 102 MW. The project was constructed on entirely rural land and located on one land parcel. Approximately 250 ha of land on a larger 400 ha paddock was required for the plant and infrastructure (Figure 4).

**Utility-scale Solar PV Infrastructure**

Along with the solar plant, the development included the installation and operation of a 132 kV transmission line, approximately 4 km long x 40 m (wide) to the main network interconnection. The solar plant consists of more than one million photovoltaic (PV) modules. The modules were mounted on steel post and rail (table) support structures. Supporting infrastructure includes the installation of above and underground electrical conduits, construction of a substation, inverters, site office and maintenance building, provision of perimeter fencing, unsealed access road and the transmission line (Figure 5).

**Approvals Process**

The planning and approvals process required the preparation of an environmental impact statement (EIS), and the consent conditions, approved by the state government, were based on this documentation and extensive consultation as required under the Environmental Planning and Assessment (EP&A) Act 1979 (Lyster, Lipman et al. 2012). An assessment was made of the government requirements impacting upon construction of new renewable energy infrastructure specifically in NSW, Australia. This included local and State government requirements. A comprehensive assessment of all the operational health, safety and environment, and community (HSEC) risks were identified prior to construction, based on EIS and documents collected and or prepared during the planning stage, as well as knowledge gained from initial works at the site and the expertise of the newly assembled project team members. Figure 6 illustrates some of the early stage structural works and the final arrays when completed.

**Soil and Landscape**

Soil at the site is mapped as the Summervale soil landscape. The Summervale landscape is part of the colluvial slopes and plains and flow lines associated with Girilambone Beds. The soils in the region contain red and brown chromosols, red kandosols and sodosols and commonly called red loams or heavy cracking clays, indicative of extensive oxidation. The NSW Natural Resources Atlas indicates the soils are relatively stable and have some resilience to disturbance. Rural land capability mapping indicates that the site is not subject to severe limitations, and is generally suitable for cultivation. Soil properties were determined by field observations and assessment, and a commercial laboratory assessing soil fractionation, metal concentrations and other properties such as organic matter and propensity to erosion. Soil classification and tests were conducted using conventional soil assessment methods previously described. From a practical construction perspective, the soil was prone to bogging after 20 mm or more of rain, and was prone to dust erosion which was evident during the construction stage. Previous discussions with the former land owner indicated that the soil was typical of much of the most productive soil in the region.

**Productivity Capability**

The output from the solar power station was 102 MW and this was from an area of 250 ha (of flat plate panels). Various parameters that impacted on the agricultural, environmental and community values for the land parcel in the case study were assessed as part of the approvals process but also during construction (Table 1). For example, as part of the construction, 10 ha of native vegetation was removed and the impacted area offset with a biodiversity area.

In terms of agricultural productivity, average yield data for the site’s district varies between 3-4 tonnes per ha for wheat. It is noted here that quantitative life cycle analyses to compare agricultural production versus energy and other outputs (e.g. community benefits) from large-scale solar PV were not conducted as part of the development work for the approval of the current project.

**RESULTS & DISCUSSION**

**General Issues**

The approvals process for the project led to a total of approximately 300 consent conditions being applied to the project and the related facilities including the construction and decommissioning of the bespoke accommodation camp. A construction environmental management plan for the project was prepared which included all the necessary subplans to address each of the consent conditions stipulated to be followed during construction. Logistics, fauna and flora management, visual impact, fire risks, soil, water and dust management and waste management and resource use impacts, were the key impact areas and are discussed in further detail in a previous publication (Guerin 2017). A summary of the targets and actual environmental and community outcomes during construction of the case study project is given in Table 1.

**Impact on Agricultural Activities**

The current article focuses on the agricultural aspects of large-scale solar power station construction. The project did not trigger Commonwealth Government legislation for disrupting significant species or any other...
environmental requirements. The state government requirements were driven by commitments required under the Environmental Planning & Assessment Act (1979). These are described in Table 2 and by their nature, large- or utility-scale solar PV projects will usually meet these thresholds for impact and or contribution in many agricultural and as well as non-arable land contexts.

A typical local environmental plan from regional NSW, states the consent authority must have regard to the objectives for development in a zone when determining a development application. The objectives of these zones, which are primarily agricultural, are:

- to encourage sustainable primary industry production by maintaining and enhancing the natural resource base;
- to encourage diversity in primary industry enterprises and systems appropriate for the area;
- to minimise the fragmentation and alienation of productive lands;
- to minimise conflict between landuses within this zone and land uses within adjoining zones.

As in the case of the State government requirements, these requirements were readily met in the case study development. While the project has had impact on land availability for primary production, the new land use meets objects b) and c) as identified above; it allows for diversity in land use, appropriate to the area and does not fragment resource lands. Being fully reversible, it will not remove the potential to use the land for primary production in the medium to long term (i.e. after decommissioning).

A qualitative evaluation of the comparative benefits and the negative impacts of construction of large-scale solar with existing agriculture activities are given in Tables 3 and 4. While these lists are not exhaustive, they highlight the extent of issues impacting farmers and rural communities.

**Benefits of Large-Scale Solar**

In the case study, the location selected for the installation considered the local, state and federal government planning requirements, as well as the productivity potential of the land for grazing and crop production.

The overall benefits of the project were compelling. With the exception of road preparation, the project did not require large-scale earthworks. The project has delivered significant social and environmental benefits on a local, state and federal level and has global environmental benefits on the basis that the development will lower greenhouse gas emissions created in the production of electricity. The project also did not significantly affect the conservation values nor agricultural output of the locality. The development has provided indirect benefits as it will decrease costs to the community as a result of a reduction in the externalities involved with burning fossil fuels, such as those resulting from particulate air pollution and emissions from burning coal.

The solar plant in the current case study avoids approximately 200 kt CO2 equivalent per annum by replacing fossil fuel-based energy. The low emission intensity of the project is therefore compliant with The National Greenhouse Strategy in Australia which aims to lower the emissions intensity associated with electricity production, as well as the COP21 commitment to contain rising global atmospheric temperatures to under two degrees. The solar plant will also result in the avoidance of the ongoing consumption of water that would otherwise have been used in coal or other fossil fuel fired power stations for cooling purposes.

The solar plant generates approximately 233 GWh of renewable energy each year and this is expected over the operating life of the plant (25 years). This equates to approximately 1.3% of the country’s large-scale renewable energy target (LRET) for the first year of targeted operation (2015) and 0.6% of the total LRET target to 2020. To put this number in perspective, the solar plant generates enough renewable energy to power up to the equivalent of 33,000 average Australian homes.

Co-benefits can occur when existing agricultural land is co-located with solar PV generation. With potential minimal risks to food security, co-location schemes can reduce land deficits for food and fibre production. This is a relatively new area for research and the practical experience of this in Australia has been variable and inconclusive based on the author’s experience in construction of large-scale solar power plants across Australia. This is discussed in the future research section. Researchers in Europe have also shown through modelling that trade-offs between agricultural productivity of land, environmental sensitivities and solar irradiance should be made in order to find the optimum location for the construction of solar PV installations (Sacchelli, Garegnani et al. 2016).

**Negative Impacts from Large-Scale Solar**

Since construction, the site of the solar plant can no longer be used for grazing (in the medium to long term), however grazing and cropping would be possible within the transmission line easement and outside of the immediate array area (an area limited to 250 ha) within the site boundary; a larger area of 400 ha (a net area of approximately 100 ha). Grazing co-benefits have been achieved on other projects with minimal damage to solar PV panels. The coexistence of grazing habitat for livestock, such as sheep and goats, may curtail the need for vegetation removal and maintenance, or both, and
limit erosion, while supporting both energy and food/fibre production (Hernandez, Easter et al. 2014). For example, Japan announced a co-location plan to diversify their grid by integrating 30 MW of solar PV in the unoccupied spaces adjacent to and on top of livestock sheds, agricultural distribution centres, and parking lots (Hernandez, Easter et al. 2014). While only a small investment at that time, it is likely that this will expand over time, and dramatically so because of that country’s energy shortages.

Overall there has been a loss of approximately 0.02% of available agricultural land within the local government area (out of a total of 1.2 million ha of land dedicated to broad-acre agriculture in the region). Therefore, there has only been a small reduction in land available for agriculture. However, this reduction was negligible and unlikely to impact on the agricultural production capacity of the region. This loss of area is equivalent to approximately 1500 tonnes of wheat per year.

The solar PV plant will be decommissioned after approximately 25 years, which will enable the entire site to be returned to grazing and/or cropping, if required. At this time, all above ground infrastructure would be removed, with the site left in as good or better condition, in terms of vegetation cover. Some compaction of the soil could be expected from the roads and driving on the internal alleys within the arrays.

From a longer term perspective the impacts of dis-used solar panels and related infrastructure are important and should be considered in the overall equation of risk and benefits (Dubey, Jadhav et al. 2013). This is particularly the case as such waste streams are generally sent off shore, often to developing countries where controls for the protection of people and the environment can be lax. This is an aspect of the technology that will require ongoing monitoring to ensure compliance and sustainable end of life management of materials. The potential negative impacts lie particularly in the cumulative impacts with other sources of e-waste. The author notes that in the current study, the disused panels were returned to the supplier for reuse.

**Comparisons of Energy Versus Non-Energy Productivity**

There are inherent difficulties in comparing electricity production with other land uses in an agricultural context. For example, how do you compare electricity production from solar PV with grain production when that grain is sold off farm for non-biofuel purposes? How much supply chain and embodied energy should be included in the comparison?

Terrestrial ecosystems vary in their net primary productivity (for example using rate of accumulation of organic C in plants as a measure), from tropical forests (1 to 3.2 kg/m²/yr) to deserts (up to 0.6 kg/m²/yr), and in their ability to sequester C in soil (Hernandez, Easter et al. 2014). As energy systems, such as the large-scale solar PV system in the current case study, may impact land through materials exploration, materials extraction and acquisition, processing, manufacture, construction, production, operation and maintenance, refinement, distribution, decommissioning, and disposal, energy footprints can become incrementally high. Some of this land may be utilised for energy in such a way that returning to a pre-disturbed state necessitates energy input or time, or both, whereas other uses are so dramatic that incurred changes are irreversible. In the current case study, it is expected impacts will be reversible. Irreversibility cost assessments can be employed to monetise restoration and irreversibility; a function of the original land cover type and properties of the land-use and land-cover change incurred. Studies evaluating landuse characteristics of large-scale solar PV systems are relatively recent, and have a narrow focus geographically and are of limited value for comparison here.

Previous researchers have described the complete energy conversion chain of large-scale solar PV systems, which necessitates materials acquisition, infrastructure and module manufacture, construction, operation and maintenance, material disposal, and decommissioning (Hernandez, Easter et al. 2014). Indirect land impacts related to materials (e.g., manufacturing modules and infrastructure) and energy for solar PV is negligible i.e. between 22.5 and 25.9 m²/GWh, compared to direct land use (Hernandez, Easter et al. 2014).

The current article has not attempted to compare quantitatively the various options for the site, such as through life cycle analysis. Rather it has considered the costs and benefits in a qualitative manner to highlight key issues with utility-scale solar projects in regional areas.

**Land Access and Ownership**

One legal issue of relevance to construction of large-scale renewable energy projects in Australia has been in relation to land access. Investors and developers seeking to secure land rights for a project site need to be aware of the potential application of Australia’s foreign investment regime that may apply to the acquisition of land interests, including options to lease and long-term leases, and the potential need for subdivision if the lease term is over a certain period (Currie, Lou et al. 2016).

From March 2015, a new Australian government regime for the acquisition of agricultural land and agribusiness by foreign investors has been in operation. The screening threshold for agricultural land was substantially reduced from that date from A$252m to A$15m, calculated on a cumulative basis.
This regime is centred around the national concern of “selling the farm”, including the potential impact on food security and competition in Australia. The application of the new regime also has the consequence of catching most solar and wind renewable development projects in Australia due to the need of those projects to acquire rights to use small parcels of land which are themselves part of much larger rural holdings.

Agricultural land is defined broadly under the foreign investment regime as it captures most of the land that would usually make up the development site required for solar or wind renewable projects. Accordingly, the developer should be aware that if one or both of the following circumstances apply, it will need to obtain prior approval from the Foreign Investment Review Board (FIRB) before entering into any long-term leases with the landowners:

- if the developer is a foreign government investor, then any acquisition of interests in Australian land irrespective of value, will require prior approval, and
- if the developer is a non-foreign government investor (i.e. a privately funded foreign investor), then the A$15m cumulative threshold for the acquisition of interests in agricultural land will apply.

The most problematic aspect of the agricultural land regime is how the value of the lease arrangements (being both the options to lease and the long-term leases themselves) should be calculated in determining whether the A$15m threshold is reached.

As most leases for renewable projects run for 20 to 25 years, with one or more extension options, this can add up very quickly to reach the A$15m threshold. For example, a single lease with an annual rent of A$10,000 can be deemed to have an acquisition value of up to A$750,000 under the foreign investment regime. Based on this, most land programmes for mid-scale and all large-scale solar and wind development projects will exceed the A$15m threshold and therefore trigger the requirement for prior approval from FIRB.

**Other Legal Issues**

Other legal issues relate to the approvals, and ensuring requirements are met during construction and operations. The owner and operator of the solar farm has responsibility for ensuring operational environment and community requirements are met. Of interest to landowners during operation of neighbouring solar farms, is the need to ensure animals and dust does not migrate into the solar plant next door. Though not an issue as far as the author is aware, neighbouring farmers should recognise this as a risk.

**Future Research**

An opportunity for future research and business process improvement would be to allow for animal grazing on site as a mechanism for safe and effective control of vegetative growth. This would, however, require revisions to current designs for utility-scale solar power stations. This could include determining the feasibility and costs of raising the height of the lower edge of the panel above the average height of sheep, and improving the design to enable their co-existence with grazing animals. Future projects should address this by factoring in co-uses. Such modifications would need to more than offset the increased capital costs.

Other researchers have recently shown the potential in the US of including solar PV in lettuce production systems (Dinesh and Pearce 2015). Their modelling, though not directly relevant to the majority of agricultural systems here in Australia, has estimated a potential increase of 40-70 GW capacity in that country alone through co-benefits.

From an Australian farmer perspective, the construction of large-scale solar PV power stations may or may not be of concern or an issue. Why is that? New infrastructure for a regional area will generally be seen as positive as it will stimulate local business (Figure 7). Of course farmers are also consumers and are already adopting solar PV technology for their own household and operational use e.g. irrigation, pumps, etc. The key issues for farmers are security of energy supply, price transparency and keeping energy costs low (Table 5). So it depends on whether large- and utility-scale solar PV investments impact upon these existing concerns. If utility-scale solar (like other technologies), doesn’t support on farm objectives, then farmers are unlikely to get behind the industry expansion (Guerin 2001).

Future research should include how to better enhance the integration of multiple energy sources to optimise on-farm energy supply (which could include biomass in particular regions), for a range of technical and policy reasons, is currently under-utilised as an energy source in Australia.

**CONCLUSIONS**

It is evident that the opportunities for utility-scale solar are greater where the prospective land area is of low productivity potential. However, this is the case in any land use setting where a new renewable energy project is proposed [not just agricultural]. The benefits versus negative impacts will vary case-by-case and from site-to-site depending on local soil type, water availability, topography, access to the electricity grid, number of sunny days expected each year, the soil’s cropping or stocking potential, among other factors. The overall contribution
and impact of any proposed utility-scale solar farm on the wider regional community should be considered. It ought not to focus on the immediate loss of potentially productive agricultural land it is making unavailable [temporarily] for agricultural production.

Whether or not agricultural land should be used for solar PV will depend not only on the presence of a good solar resource, access to the grid and a market for the electricity generated, but on the specific business case for the land and property in question. Further, the law requires that particular issues are addressed e.g. foreign ownership, construction consent conditions, and that the project’s overall sustainability and contribution to the region is considered and is materially important. Both energy and land productivity need to be assessed when selecting locations for new, large- and utility-scale solar PV projects. Nevertheless, large-scale solar has the potential to transform Australia’s rural landscape in a positive way.

REFERENCES
Table 1. Selected Outcomes, Measures and Targets Related to Environmental and Community Impacts from the Case Study

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
<th>Target</th>
<th>Actual</th>
<th>Actual Measure/Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rehabilitation of impacted areas during transmission line installation (%)</td>
<td>Land was cleared of native vegetation for array and transmission line installation</td>
<td>100%</td>
<td>100%</td>
<td>10 ha</td>
</tr>
<tr>
<td>Total construction footprint</td>
<td>Area was formerly dryland cropping and sheep grazing</td>
<td>100%</td>
<td>100%</td>
<td>250 ha</td>
</tr>
<tr>
<td>No of Noise complaints Emanating from construction activities on the site and at the residential camp</td>
<td></td>
<td>0</td>
<td>0</td>
<td>No formal complaints received (re project)</td>
</tr>
<tr>
<td>No environmental related incidents</td>
<td>Zero reportable incidents. This data was extracted from the HSE incident register.</td>
<td>0</td>
<td>3</td>
<td>Note: numerous environmental issues were raised as hazard observations</td>
</tr>
<tr>
<td>Community complaints</td>
<td>Complaints related to any aspect of the project construction stage.</td>
<td>0</td>
<td>2</td>
<td>Complaints related to industrial relations</td>
</tr>
<tr>
<td>Number of Hollow Bearing Trees (HBT) protected</td>
<td>Hollow bearing trees (HBTs) were expected to be disturbed during the construction stage.</td>
<td>100%</td>
<td>100%</td>
<td>~50 habitats were impacted. These were offset by &gt;150 nest boxes and hollows</td>
</tr>
<tr>
<td>Waste to landfill</td>
<td>Waste generated from office activity including food scraps</td>
<td>0</td>
<td>15-20 t</td>
<td>No council pickup service</td>
</tr>
<tr>
<td>% panels/modules returned to manufacturer</td>
<td>1.36 million solar PV panels/modules were installed</td>
<td>100%</td>
<td>100%</td>
<td>3000</td>
</tr>
<tr>
<td>Fauna relocations and release</td>
<td>Snakes and reptiles were to be relocated to less hazardous i.e. non-work areas</td>
<td>100%</td>
<td>95%</td>
<td>Approximately 20 snake releases occurred</td>
</tr>
<tr>
<td>Nest sites of the Grey-crowned babbler (GCB) protected</td>
<td>These were the only endangered species identified as living in the construction area</td>
<td>100%</td>
<td>100%</td>
<td>3 potential nests (of GCBs) were identified</td>
</tr>
</tbody>
</table>
Table 2. State-level development regulations impacting on the construction of renewable energy infrastructure (a)

<table>
<thead>
<tr>
<th>Regulatory requirement</th>
<th>Explanation of how regulation is achieved on large scale solar PV projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper management, development and conservation of natural and artificial resources</td>
<td>It has as its principal purposes the provision of clean energy for use by Australian consumers. There is wide global acknowledgement that there is a need for reduced emissions of greenhouse gases if the planet’s climate change is to be slowed. In Australia stationery energy is the major emitter of GHGs nationally, and a shift to clean energy is wholly concerned with better use of national natural and artificial resources, and a “better environment”. The case study has manageable environmental impacts and brings significant social and economic effects to the local and wider community.</td>
</tr>
<tr>
<td>Promotion and co-ordination of the orderly and economic use and development of land</td>
<td>It provides for an alternative orderly and economic use of agricultural land consistent with local and regional strategies aimed at providing increased economic diversity as a means of addressing long term community interests</td>
</tr>
<tr>
<td>Protection, provision and coordination of communication and utility services</td>
<td>It has a direct implication for the provision of clean energy to the State and nation</td>
</tr>
<tr>
<td>Protection of the environment(b)</td>
<td>Where environmental impacts do occur, mitigation can be achieved including through biodiversity and other required offsets</td>
</tr>
<tr>
<td>Ecologically sustainable development</td>
<td>The principles of ecologically sustainable development (ESD) are concerned with the integration of economic and environmental considerations as planning and development decisions are made. These type of projects achieve these principles at both a practical and strategic level</td>
</tr>
</tbody>
</table>

Notes:


b) This includes the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats.

Table 3. Benefits from the expansion of renewable energy developments into Australian farming land

- New leases with renewable energy developers means new revenue streams from on-farm activity
- Encouraging local and regional investment, such as new jobs
- Gives farmers and landowner an opportunity to be agents of change in contributing to new, non-fossil fuel infrastructure
- Stimulation of new industry sectors and encouraging new avenues for trades and employment

Table 4. Potential negative implications from the expansion of large-scale renewable energy developments into farming land

- Replacement of productive farming land with energy generation infrastructure leaving the land (or at least tracts of it) inaccessible and unusable for alternative uses
- Main benefits are largely temporary in nature to local regional communities eg employment boost during construction stage
- Inconvenience and disruption during construction phase eg dust, reduced land access
- Perception by wider community (outside of rural areas) is that power generation is more important than agricultural production
- Potential concerns about unknown risks from emerging renewable energy technologies (a)

Notes: a). This has been the case with wind turbines but not with solar PV.
Table 5. Expectations and needs of farmers in relation to on-farm energy use and supply of energy to farms

Need for low cost energy, but mostly agnostic about its source
As price-takers, they cannot readily pass the costs on into the supply chain
Concerned about lack of transparency in pricing and advocate for competitive market reform
Expect bioenergy sources to be incorporated into a broader renewable and conventional energy mix offering
Concerned about under investment in the power distribution system given farmers are often towards the edge of these electricity distribution networks
Expect greater government support for on-farm energy efficiency investments as is available in other sectors
Recognise that energy security is vital for agricultural production but expect productive farming land to remain productive in agricultural sense

Figure 1. Cumulative solar PV installed in Australia as a proportion of world total (Source: IEA PVPS 2017)

Figure 2. The size of business of the PV market as a proportion of country GDP (Source: IEA PVPS 2017)

Figure 3. Employment in large scale renewable energy in Australia (Source: ABS 2017)

Figure 4. Case study aerial view: (top) 400 ha site (centre left) relative to nearest town and other rural land holdings; (bottom) The site prior to installation of tables and solar panels (top left hand corner of image is due south and bottom right hand corner is due north).
Figure 5. An outline of the construction process for large scale solar PV projects. Note: PCS = power conditioning system; PVCS = Photovoltaic Combining Switchgear.

Figure 6 (top) Tables on posts prior to placement of solar panels (referred to as flat plate solar); (bottom) installed solar panels with heavy grass growth within and around alleys (spaces between rows of solar arrays).

Figure 7. (top) Local employment during the construction phase is a significant benefit to local regional communities; (bottom) technology transfer through field and community days increased the awareness and wider ownership of the project.
ERIC BOND AND THE GRAINS INDUSTRY – SHAPING AUSTRALIA’S BREAD RESEARCH INSTITUTE

By Lindsay O’Brien

Dr Lindsay O’Brien

Dr Lindsay O’Brien was appointed wheat breeder at the Victorian Crops Research Institute in 1968 and from 1982 to 1988 led the wheat breeding and cereal chemistry programs. From 1988 until 2001 he was Director of the University of Sydney’s research centre in Narrabri. From 1968 to 2001 he was involved with the breeding of 16 wheat varieties. In 2001 he was engaged by LongReach Plant Breeders to design their national wheat breeding program which since has developed 27 varieties. Dr O’Brien has published widely on wheat breeding and grain chemistry and in 1997 was awarded the F B Guthrie Medal for contributions in those fields.

Affiliations:
Sofheimar Pty Ltd and University of Sydney Plant Breeding Institute, Narrabri, NSW.

This is an abridged version of an address given by Ag Institute member, Dr Lindsay O’Brien on receipt of the Australasian Grain Science Associations Eric E Bond medal for Grain Science and Technology at the Association’s annual conference in Tamworth in September 2016. He chose to cover the career of Eric Bond as his topic.

ERIC ERNEST BOND (MBE), AMTC, FRACI, FAIFST.

Eric Bond was an outstanding cereal chemist, industry leader, instigator and participant in learned societies. This year marks 70 years since the Bread Research Institute of Australia (BRI) was established with Eric Bond and its founding director. Under his leadership the BRI became a leading international grains research centre and provider of innovation and services to the wheat and baking industries.

Some background events that shaped the industry in which Bond was to spend his career

In 1822, The NSW Royal Agricultural Society was formed. Show societies have and continue to play an important role in the development of the wheat industry through the introduction of new varieties and crop and grain sample judging competitions.

F B Guthrie was appointed Chemist with the Department of Agriculture in the Colony of NSW in 1893 and around this time Thomas Burr Osborne was undertaking his pioneering research on protein fractionation in the USA arguably the beginning of modern cereal chemistry as we know it today.

From 1893 to 1906, F B Guthrie and William Farrer collaborated on the testing of breeding lines until Farrer’s death in 1906. During this period, Farrer collected wheat materials and began cross-breeding on his property “Lambrigg” and in 1901 he released Federation which became the leading variety in Australia from 1910 to 1925. The impact of Federation extended to the USA where it was grown in the Pacific North West region. Federation became the source of the null allele for granule bound starch synthase in Australian varieties and in the Pacific North West, which was much later shown to be the basis for the high starch paste viscosity critical to the preferred texture and eating quality of white salted and Japanese Udon noodles which are major export targets for Australia and the USA.

In 1895, F B Guthrie and E H Gurney were invited to assist with judging wheats at the Grenfell show and they milled samples with a small hand operated roller mill and Guthrie reported favourably on the quality of Farrer’s crosses and (1897 and 1898).

Disquiet about the pooling of all wheat into one grade, the Fair Average Quality (FAQ) grade resulted in a Royal Commission into the wheat industry in South Australia in 1908 which was critical of the process.

In 1909, Dr O E Nycander left London for Australia with capital of 1000 pounds to establish the Australian Yeast Co. Ltd and in 1910 the first compressed yeast was made at the Shamrock Brewery in Abbotsford, Victoria.

G L Sutton who had succeeded Farrer as Experimentalist in NSW was appointed Commissioner for the Wheat Belt in Western Australia in 1911. Sutton, who produced the significant variety Nabawa was a strong advocate for segregation based on quality and abandonment of the FAQ system. Sutton later served as Director of Agriculture in Western Australia from 1921 until his retirement in 1937 and along with Bond became one of the strong voices for change to the pooling and selling of Australian wheat.

The first automated bakery was established in 1914, the “Brisbane Automatic Bakery”.

A Conference of State Ministers of Agriculture in 1923 determined that the States should use their efforts to discourage the growing of red grained wheats. It was decided that no red wheat would be distributed from State farms and the Royal Agricultural Societies were asked to eliminate red varieties from their competitions. This was the momentous decision that established Australia as a “white grain only milling wheat producer”.

W L Waterhouse began his pioneering research on the cereal rusts at the University of Sydney in 1921. The high yielding, poor quality variety Free Gallipoli was released in 1926 and quickly became the dominant variety in Australia with dire consequences for the domestic industry with its effects extending to export flour millers and bakers. Its release sparked a new round of debate about the FAQ system of grain handling and marketing.
In 1926, Swanson and Working in the USA reported that dough could be developed by mixing, thereby doing away with the fermentation stage of bread manufacture. This discovery was later to revolutionise commercial high throughput bread production.

In the 1930’s, the poor baking quality of Australian wheat spawned the growth of gluten extraction to produce vital gluten to improve bread quality with gluten production remaining a high value industry to this day.

Enter Eric Ernest Bond into the Australian wheat industry

Bond completed his matriculation at night school and his career started as a laboratory assistant in 1934 for Nycanders who manufactured compressed yeast. While working he undertook evening studies and nearing completion of his diploma in 1938 he was appointed cereal chemist at the State Chemistry Laboratories in Melbourne.

In 1940, Bond was appointed chief chemist at Brunton and Co. in Sydney a move that resulted in him making contact with and developing a close working relationship with the University of Sydney wheat breeding program.

Right from the start of Bond’s career the quality of Australian wheat was poor, with the dominant varieties in production being soft-grained, lacking milling quality and the dough strength and baking quality to make the quality of bread desired by consumers. This ultimately led to a number of enquiries, including the Gepp Royal Commission of 1934-36 into the wheat, flour and bread industries including the bulk handling of grain and what to do about the grading of Australian wheat which was all binned together as Fair Average Quality (FAQ).

Establishment of the Bread Research Institute

The failure of home grown wheat to meet the needs of processors and consumers resulted in the NSW Industrial Commission enquiry in 1945 which produced a report by Justice Kinsella recommending the establishment of a wheat and flour institute. The NSW bread manufacturers advanced this proposal by inviting Dr D W Kent-Jones from the Flour Milling and Baking Research Institute in the UK who recommended a baking research centre be established. The Bread Research Institute (BRI) was established in 1946 by agreement between the industry and the Commonwealth to jointly fund the centre based on a mix of Commonwealth funds and a levy on bread manufacturers. Eric Bond was appointed as the foundation director in 1947.

Relationship with the University of Sydney wheat breeding program

Collaboration with the University of Sydney started in 1941 when the manager of Brunton’s mill at Gunnedah suggested to Waterhouse during a visit to the University field testing site that the company’s cereal chemist (Eric Bond) may be able to help with quality assessment. Later in the season Bond visited with Waterhouse and offered his services to the program. His relationship with the University was to have a transformative impact on the Australian wheat industry. At the time Bond would not have realised the key role he would have in the improvement of Australia’s hard wheat varieties over the next 30-40 years.

Brunton’s mill at Granville in Sydney became the headquarters for the assessment of quality for the University’s wheat breeding program, and Bond backed by the resources of Bruntons became an indispensable member of the team. When he moved to become director of the BRI in 1947 he agreed to continue the quality testing of all of the Universities breeding lines which resulted in the release of a series of high quality hard wheat varieties that quality wise changed the industry forever.

The first, “Gabo” had excellent milling and baking quality and with its rust resistance at the time of its release rapidly rose to become the most widely grown variety in the country, transforming the industry with all in the value chain from growers to consumers benefitting. Growers got increased yield and protection from the ravages of rust, the milling industry got better milling quality due to its hard grain and free milling attributes and the baking industry now had access to flour that performed in the bakery and produced a quality loaf of bread demanded and appreciated by consumers.

The collaboration for testing University breeding lines continued right up to when wheat breeding was commercialised by the Grains Research and Development Corporation in the late 1990’s to early 2000’s.

The industry wide impact of the release of Gabo

The flow on effects on the wheat industry in Australia of the release of Gabo were wide ranging. “The extension of wheat growing into the north western areas of New South Wales and the success of Dr. Macindoe and Professor Waterhouse in breeding hard wheat varieties high in protein and of good baking quality for this region gave rise to the first break in the f.a.q. and the development of the premium wheat system whereby millers dealt directly with wheat growers through licensed receivers and paid premiums for specified varieties (Bond, 1971)”.

The new buying arrangements with the different prices on offer soon caused discontent in the grower community so growers banded together to demand equal pricing for grain of equal quality, eventually resulting in the formation of grower groups. One of the first was the Prime Wheat Association (PWA) based in Narrabri, the founders of which became industry leaders instrumental in the establishment of the first in Narrabri of a number of grower initiated
research centres in Australia following the introduction of the Wheat Research Act in 1957 which collected a production based levy for research.

Advocacy about the inadequacies of the FAQ grading system by Bond and others like Sutton, and the influence of the PWA and other grower groups around Australia were instrumental in changing the grading and payments system to one based on grain physical measures, quality specifications, variety and protein content optimum for different major end-uses. These changes evolved into the grain receival, segregation and quality based marketing system the industry utilises to this day.

Quality control and the role and development of approved testing methods

As chief chemist running quality control for a flour mill and later for the research institute servicing the baking industry, Bond knew the value of standard methods for measuring those quality parameters that delivered consistency in the mill and the bakery.

Correspondence and discussions between Bond and chemists employed in State and flour mill laboratories over a two year period up to 1951 resulted in the formation of a group that was later to become the Cereal Chemistry Division of the Royal Australian Chemical Institute. The Cereal Chemistry Division grew and prospered, holding annual conferences which became the primary technology transfer mechanism for the grains industry. The Division developed and published standard methods, ran short courses and workshops for staff employed in the industry, published books about and for the industry, provided a valuable forum for instrument manufacturers to showcase their products, and a platform for postgraduates to showcase their research and to network with potential employers. Bond served as founding chairman of the Cereal Chemistry Group in 1951 and later as chairman of the Division in 1962.

Impact of the Bread Research Institute, globally and nationally

Bond built the BRI to become an internationally respected research and service organisation. Initially their expertise was in baking research, but his activities as a member of various Australian trade missions and as the senior technical advisor to the Australian Wheat Board (AWB) involved visits to major customers around the world and exposed him to the diverse range of products they made using Australian wheat. The BRI was instrumental in establishing bakeries in India and South-east Asia using Australian baking technology.

The recognition of the importance of end-products other than bread by the AWB resulted in them financing the construction and staffing of the Central Grain Research Laboratory at the BRI which resulted in the BRI becoming a leading international research centre on the quality of a diverse range of food products, such as Asian noodles and middle-eastern flat breads. Staff at the BRI became the world leading authorities on the quality requirements for these end-products and visiting scientists were invited from Japan to work with BRI staff. The first reports and publications on noodle flour quality requirements were at Australian Cereal Chemistry conferences.

Bond’s role as a senior technical advisor to the AWB and his many visits to their major markets confirmed his belief that the lack of focus on quality and the Australian FAQ grading system did not meet the needs of customers. In his 1971 Farrer Memorial Oration he said, “The f.a.q. system, a misleading description because it in no way relates to quality, has encouraged a lack of quality consciousness which persisted until the decade or so”. … “In my view an ever-long adherence to the f.a.q. system of marketing has reacted to the disadvantage of the wheat industry by clouding the whole issue of quality improvement”. … “Much yet remains to be done both in the production of quality wheats to suit market requirements and in the adoption of a more effective system of wheat classification. Certainly we can do more to offer buyers a range of different classes of wheat today, but strangely we still maintain an f.a.q. standard, which comprises the major part of the crop, in all States (Bond, 1971)”.

Establishment of the CSIRO Wheat Research Unit

In 1957, the CSIRO established the Wheat Research Unit (WRU) and based their new unit at the BRI with Eric Bond as the foundation Officer in Charge. This resulted in a rapid expansion of basic and applied research on wheat and flour and wheat based products and the WRU rapidly established itself as a world leading research centre and the Unit’s staff international experts.

Changing work, industrial conditions and technology drive change in the industry

In the post-war era the BRI responded to changing industrial conditions, where a shorter working week, higher pay and the cessation of night baking meant a greater emphasis was needed on bread keeping quality. Changes implemented were the use of a higher protein flour, additives such as milk, fats, soya and sugars all of which demanded increased quality control. However, the greatest change was not in the formulation, but in the whole baking system.

Bread has been made for centuries using six basic steps of mixing, fermentation, dividing, moulding, fermentation and baking. Research by Swanson and Working in the United States and much later in the UK demonstrated that dough could be developed using high speed mixing or chemically by using oxidising and reducing agents. This led to the BRI
developing the Australian no-time dough baking system, which is still the industry norm in modern plant bakeries. Advances in milling technology resulted in millers using least-cost grists where wheats are blended to produce flour of the required quality at the lowest cost and the building of higher capacity mills that produced flour of acceptable quality at higher extraction rates. These changes demanded action by breeders to produce new better milling and baking varieties as summarised by Bond (1971). “Price, milling value, protein content and quality are all considered in the assessment of the value of a wheat by the buyer”.

Eric Bond’s professional and scientific society roles
Bond engaged in many work related activities during his career. He was one of the founders of the Cereal Chemistry Division Royal Australian Chemical Institute and was elected its foundation Chairman in 1951 and served again as Chairman in 1962. He was appointed Chairman of the Chemical Testing Advisory Committee of the National Association of Testing Authorities (NATA) in 1960, and was Chairman of NATA from 1979-1982.

He was a Fellow of the Royal Australian Chemical Institute; a Fellow of Australian Institute of Food Science and Technology; and a Fellow of the Academy of the International Association of Cereal Science and Technology (ICC). He was a life member of the American Association of Cereal Chemists and of the American Society of Bakery Engineers. He was President of the Nutrition Research Foundation of the University of Sydney from 1985 to 1992 and was an Honorary Governor of the Foundation.

CONCLUSIONS
The Bread Research Institute became a major centre for research and development for the industry and the expertise of staff at the BRI became mill and bakery managers and industry leaders. Bond’s role at BRI was seen by the industry as major source of the highly skilled staff they needed for their businesses.

In rounding off his 1971 Farrer Memorial Medal Oration, Bond laid out a six point plan for the future which covered the following areas:

- A critical re-appraisal of the methods of receiving, handling and marketing of wheat.
- A review of the f.a.q. system and the evolving classification and segregation system to take advantage of the range of wheat quality types produced in Australia. “The re-naming and classification of the wheats in the f.a.q. from which much of the hard wheat has already been segregated might well be made under the descriptions of Australian Standard and Soft Whites with suitable protein and variety segregations”.
- Increase the production of high protein content hard wheat by increasing our understanding of the protein potential of wheat production regions.
- The increased production of hard wheat will provide a wider range of hard and prime hard qualities and that in turn will demand a more rigorous application of protein classification over a range of protein levels.
- There will be a need to have some control over the varieties that are grown so that quality is at least maintained and quality standards improved.
- The development of a segregation system based on variety and protein content at the point of receival.

Most of Bond’s six point plan are now part of the everyday landscape in which the Australian Wheat Industry operates.

Further information can be obtained in the following sources.


Footnote: The Australasian Grain Science Association Inc. was formed in 2005 to advance the theory and practice of grain science by conducting grain science conferences; holding scientific meetings, workshops, symposia and seminars for its members and the community; by providing awards that recognise excellence in grain science and that recognise service to the Australasian grains industry and/or to the Association; by promoting, advancing and safeguarding the scientific and professional interest of its members; by organising educational activities and supporting the education of grain scientists of the future through scholarships and travel grants; and as the industry requires, provide advice or samples for the standardisation of instruments or methods.
Dr John Radcliffe
Honorary Fellow, CSIRO
john.radcliffe@csiro.au

Dr John Radcliffe AM, FTSE, FIAIST, FASAP, has had a professional association with Australian Agriculture over five decades. Originally a dairy scientist, he was Director-General of Agriculture in South Australia and later Deputy Chief Executive of CSIRO, subsequently becoming a Commissioner of the National Water Commission. He has been associated with the AW Howard Memorial Trust for many years, becoming its Chair during the later 1980s and early 1990s and again was asked to assume the role from 2015. John has an agricultural science degree from the University of Adelaide and a PhD from Oregon State University. He was awarded the Institute’s Australian Medal of Agricultural Science in 2009.

Amos William Howard (Figure 1) was born in Hertfordshire, UK, in 1848, migrated to Australia in 1876 and by 1889 was growing nursery plants and garden shrubs on a small farm in the Adelaide Hills near Blakiston. In a neighbouring farm, where he is supposed to have gone to buy a cow, he spotted a plant growing prolifically with unusual habit (Lewis, 2012). Recognising its potential as a pasture plant, he started to collect and select from the material. That plant was Trifolium subterraneum, L., subterranean clover, a self-regenerating annual.

Howard released his first ecotype, Mount Barker, in 1906, and as others were identified, became “unceasing in his efforts to gain recognition for the species” (Symon 1961, Figure 2). He initially sold seeds through E. W. Hackett, a Rundle Street, Adelaide, nurseryman. After World War II, subterranean clover with its nitrogen-fixing capacity when effectively nodulated with Rhizobia and used in conjunction with superphosphate, had become widespread in pasture development. Such pastures also became integrated into the “ley farming system” with cereal cropping. Agricultural science students were taught to differentiate the cultivars, principally by leaf morphology and markings, a skill now largely lost. Donald and Williams (1954) observed that “it would not be unreasonable to nominate it as the most important agricultural plant in Australia”, though it was not without blemishes through high levels of oestrogenicity in cultivars such as Yarloop, Dwalganup, Geraldton and Dinninup. Sub-clover now occupies 29 million hectares. Fifty-three cultivars have been registered (Nichols 2016).

On October 3 1963, the then Premier of South Australia, the Honourable Sir Thomas Playford, GCMG, unveiled a memorial on the Littlehampton – Nairne Road (then part of the main route between Adelaide and Melbourne, but now bypassed by a freeway). The plaque commemorated the unique contribution of Amos Howard in developing the use of subterranean clover as a pasture plant in Australia. The memorial was erected by the South Australian Branch of the then Australian Institute of Agricultural Science (AIAS) (Figures 3, 4).

At the ceremony, the A. W. Howard Subterranean Clover Memorial Appeal was launched. It was hoped to raise £25,000 ($50,000) to fund a trust for the development of pasture research in Australia. Chairman of the appeal was Professor Colin Donald, Professor of Agronomy in the University of Adelaide. Secretary was Mr Jack Mertin from the South Australian Farmers’ Cooperative Union (SAFU). Mertin was the first agricultural graduate to be employed by a stock firm in South Australia. In the event, $27,226 was raised, most of it from industry, the South Australian Government, private individuals and South Australian Agricultural Bureau branches.

The Appeal Committee established the incorporated Trust under the South Australian Associations Incorporations Act 1956-63 on 8 September 1964. The objective was to encourage and promote scientific research and investigation relating to pastures and their development, management and utilisation. The initial Trust committee
membership comprised the Federal President of the AIAS, the President of the SA Branch of the AIAS, the Director of the Waite Agricultural Research Institute, the Director of the Department of Agriculture South Australia, a nominee of the Federal Committee of the Australian Agricultural Economics Society resident in South Australia, the Principal of Roseworthy Agricultural College, and the Secretary and Treasurer of the Trust. There was provision for the Federal President of the AIAS to appoint others subject to the total membership not exceeding twelve. Members were to elect a Chairman from amongst their number. By-laws provided rules governing AW Howard Memorial Research Fellowships, Study Awards and Grants-in-Aid. The Trust was recognised as an “approved research institute” as defined under section 73a(6) of the Income Tax Assessment Act.

The first award by the Trust was of $1,000 made in 1967 to Dr Ron Knight who became a long standing staff member of the Department of Agronomy in the University of Adelaide. In the following two years, the Trust supported a research program entitled “Factors affecting persistence and production of Trifolium subterraneum” being undertaken by Mr Bill Collins towards a PhD at the University of Melbourne.

In 1970, the Trust awarded travel grants to 26 scientists to attend the 11th International Grasslands Congress (IGC) in Surfers Paradise, Queensland, to present and discuss their research. It has provided grants for attendance at every International Grasslands Congress held since then (Figure 5), the most recent being the 23rd IGC held in New Delhi in 2015.

Over the fifty years to June 2017, the AW Howard Trust had supported awards to 365 scientists from across Australia for conference and study tour participation.

In recent years, the Trust has also awarded Howard Fellowships in the form of “top-up” stipends which can be spent at the discretion of awardee post-graduate students who already hold Australian Post-Graduate Awards or equivalent. However, the Trust does not allow candidates to accept a second “top-up” stipend, but may allow a similar sum to be contributed to the institutional operating costs incurred in undertaking a higher degree by research.

Twenty three such Fellowships have been awarded, initially at $5,000 per year, but now funded at $10,000 per year for a maximum of up to 3½ years after the award is made, to allow the completion of a PhD.

The Trust offers in alternate years, awards of up to $20,000 for either a Pastoral Industry Extension Study Award or an Australian Graziers or Rangeland Pastoralists Study Award and also offers annually Grants-in-Aid of up to $5,000. Several research programs and industry organisations have benefitted from these grants.

A research sub-committee makes recommendations on awards to the full Trust Committee.

In 2011, the Howard Memorial Medal and Oration was established, modelled to a degree on the similar Farrer Memorial Medal and Oration which had been instituted in 1936 and is managed by the Farrer Memorial Trust through the NSW Department of Primary Industries. Howard Medallists have been Dr James Ridsdill-Smith (2011), Professor Ted Wolfe (2013) and Mr Bob Reid (2015). The 2017 Medal presentation and Oration will be delivered in Ballarat at the Australian Agronomy Conference on September 25 2017.

The opportunity for the Trust to make these awards from a small base has been due to the careful husbanding and investment of its resources and through having an experienced financial adviser making recommendations to the Board. Initially this was done by Mr Alf Adamson who had in 1946 jointly founded the listed investment company Argo Investments, chaired for 30 years by Sir Donald Bradman. Adamson was followed for many years by Mr Brian Cole, a company director also associated with Argo Investments, until his retirement in 1999. Three advisers have followed, two still being on the committee.

Some additional funds have been attracted to the Trust, for example from surpluses from events including Australian IGCs. In 2014, the Trust was invited to establish and manage the Tim Healey Legacy Scholarship with surplus funds from the Cooperative Research Centre for Future Farm Industries (CRCFFE). The late Tim Healey had been a much respected member of the Board of the CRCFFE. This Scholarship takes the form of a “top-up” stipend similar to that of a Howard Fellowship, The Healey Scholarship is awarded annually to a deserving post-graduate student studying in a field that benefits the future of Australian farming. Study areas include pastures, livestock management, woody crops, on-farm biodiversity and socio-economic aspects of farming.

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To encourage young graduates to prepare for a career in pasture science, in 2017 the Trust initiated scholarships for Honours students, offering a $5,000 stipend and $3,000 towards the operating costs of their research project.

Following the acceptance of responsibility for the Tim Healey Scholarship, the Trust committee had its constitution and by-laws professionally reviewed. The current objectives read “ to encourage and promote research and investigation in the fields of natural science and social science (including economics) which relate to the development, management and use of pastures.” Changes
approved in December 2016 included bringing the titles of office-holders up to date as they have changed a number of times since 1964. The Trust Committee now comprises

- The Chairman of the Board, Australian Institute of Agricultural Science and Technology (AIAST), (now informally known as the Ag Institute Australia) or nominee;
- The President, South Australian Branch, AIAST;
- The Dean of Waite Campus, University of Adelaide or equivalent;
- The Dean of Roseworthy Campus, University of Adelaide or equivalent;
- Executive Director of SARDI or the equivalent officer within the South Australian Public Service;
- A nominee of the Federal Committee of the Australian Agricultural and Resource Economics Society, who is resident in South Australia;
- A person skilled in tropical grassland science;
- A person skilled in perennial crop and pasture science;
- A previous recipient of support by the AW Howard Memorial Trust;
- The Secretary for the time being of the Association; and
- The Financial Adviser for the time being of the Association Committee

The Committee may include any person appointed to the Management Committee by unanimous resolution of the Management Committee. The Management Committee must have no more than 14 members at any time. The Committee will from time to time elect one Member to be Chairperson. Support is provided by the South Australian Research and Development Institute (SARDI).

The Trust has contributed to the career development of almost all of the pasture researchers working in Australia. However, it is cognisant that the opportunities for pasture research and the number of researchers employed in pastures is much reduced over the halcyon days of the 1960s to 1980s. At a time when demand for Australia’s livestock products is again strong, the Trust is committed to ensuring that a retiring generation of pasture scientists has a replacement generation with new skills coming along to maintain Australia’s pre-eminence in pasture science.

Details of the Howard trust may be found at http://pir.sa.gov.au/top_menu/pirsa_careers/aw_howard_memorial_trust

REFERENCES


Figure 2 Amos Howard shows a swath of subterranean clover (State Library of SA B 13311)
GUIDELINES FOR INTENDING CONTRIBUTORS

1. *Agricultural Science* accepts contributions which help inform its readers in the domains of agriculture and natural resource management. Contributions can be refereed scientific papers, non-refereed general articles, opinions, obituaries, letters, division reports and book reviews.

2. Refereed scientific papers are submitted on the understanding that they are either original manuscripts or are proposed as re-publication of work which deserves added attention within the domain covered by *Agricultural Science*. An example of the latter case could be re-publication of a conference paper which was published in a conference proceeding. In such proposals, both justification for re-publication and approval from the original publisher are required at the date of submission.

3. Contributed (non-refereed) articles are published at the discretion of the journal editor, but can be reviewed at the request of the author(s).

4. Along with the article, authors/principle authors are to submit:
   i. An abstract of 100-150 words
   ii. A biographical note (no more than 100 words) on their present position and career history, together with a head-and-shoulders photo in JPG format at 300 DPI resolution and 4cm x 4cm size;
   iii. Complete contact details, including postal and email address along with telephone and fax numbers.
   iv. Clear indication of whether they want the paper to be refereed (blind peer reviewed by at least two specialist reviewers in Australia or overseas). If there is no indication, the paper will be considered as a non-refereed contribution.

5. Submission of an article as an attachment in Word format and UK/Aust. English to an email is preferred. PDF format is not acceptable.

6. Authors are to follow the Journal style guide in preparation of manuscripts – see the web site.

7. The refereed papers should not exceed 5000 words in length. Contributed articles should not exceed 3000 words in length. Book reviews of around 800 words are welcome.

8. Any complex tables, figures and diagrams should be referred to in the text and should be supplied in Excel spreadsheet on a separate sheet with an indication of the appropriate location in the text. Photos should be in JPG format at 300 DPI.
REMEMBERING HOW TO WRITE BEAUTIFULLY

By Caspar Roxburgh

I’ve always loved reading. As a young boy, I read books for grown-ups. Ones so heavy that they rested in my lap. My arms weren’t strong enough yet to hold them up while reading. In middle-school I asked to be allowed into literature class. There I studied the satire of Ben Eltham and Tom Sharpe. By the time I reached high school, I was reading Plato, Sartre and Kuhn in my philosophy class. Camus and Sartre (in their original language) both featured in French studies. I devoured them. However, at university I made a pragmatic move. Rather than the arts degree I knew I would enjoy, I enrolled to study agricultural science. Unlike most people, I could see a link between this scientific endeavour and the beauty and humanism that those philosophers had described. I wanted to do something virtuous with my life. And here was a field where I could fight not one, but two great injustices. Hunger and poverty.

But at university I discovered that scientific writing is not like philosophy. Though perhaps it once had been. When Darwin wrote his Origin of Species, he began by discussing his feelings about the work. His second sentence referred to the writing of philosophers. Darwin’s work had impact because people read it and understood it. And they did so because it was beautifully written. When I went to university, scientific writing was an act of othering. More likely to alienate the uninitiated than communicate discoveries with the wider world. A style of writing that reinforces control of the learned. In my science classes, we were not asked to write essays. There were no lessons in argument and logic. A formulaic structure was given, and as long as you followed it you were writing properly. As far as expression went, jargon was the order of the day. At first, I too was ‘othered’ by this style and language. After all, I hadn’t studied science in years. But over time I learned how to read and speak it. Just like in French class I began to understand and wield it. And I no longer used my analytical energy to look for literary subtext, I used it to search for meaning.

On the way home from a work trip earlier this year, I bought a copy of the New Philosopher magazine. Each edition is themed, and this one happened to be about Food (May 2017). As I began reading, I had a growing sense of clarity. One of bittersweet despair. I was suddenly reminded that it is philosophers, not scientists, who give meaning to my work. It is they who communicate its inherent virtue and beauty. I may understand at great depth the mechanisms of food insecurity (be they biophysical or socioeconomic). But what good is that knowledge, if the only way I share it is through language and media accessible by only a minute fraction of academics?

After ten years at university, I fear I have lost my ability to write. A decade of writing lab reports, academic papers, and more recently books, has changed the way I think about expression, meaning and, yes, even beauty. Now I worry I can no longer communicate beyond the academic. My doctoral thesis was lauded by my friends and family, though it was several months before anyone read it. And in reviewing my favourite chapter, I had to wonder: who could blame them? While I, the learned scholar and “expert”, found the discussion charming for its relative lack of jargon, stepping away from my academic lens, it was nauseatingly technical. I could say the same for my other written work (which even my partner is not recommended to read).

And in this regard, it seems my work is unexceptional. After discussing this issue publicly, a friend still doing his PhD confided something similar. “My supervisor says my writing is too flowery”. It reminded me of similar comments I’d received. The volume of criticism endured during a four-year doctoral degree is substantial. And this kind of attack on stylistic writing can be debilitating. Even since graduating, I’ve been scolded for writing “as if I’m talking to a child”. But isn’t that our litmus test? If we can’t explain our work to a child, then it begs the question: who does understand? What level of public misconception is acceptable? What can be achieved if everything science produces is couched in indecipherable language?

For agricultural scientists, is it any wonder that farmers are still failing to follow even our most basic research? My own work uncovered evidence that crops yields among farmers are primarily limited by incorrect planting times. This was the case for smallholders in Mozambique, and cutting-edge producers in Australia. It was true, despite timely planting being considered a “principle of agronomy”. It appears basic messages are struggling to make themselves clear to key audiences.
Instead, everything is framed in buzzwords that lack meaning outside of institutional circles. ‘Climate Smart Agriculture’, ‘Sustainable intensification’, ‘Conservation Agriculture’, ‘Innovation Platforms’, ‘Recommendation Domains’. The uninitiated would be forgiven for thinking these phrases are beyond their comprehension. In reality, they often represent nothing more than a reiteration or recycling of older theories of development. Yet this is the language we use. It is the language that is taught. It is the language we expect. The price of admission.

Science no longer cares for beautiful writing. But in abdicating our responsibility for communication, we have fundamentally eroded our ability to succeed. We do not work in a vacuum. Our efforts can’t succeed without public appreciation. We need public support and even their input. By failing to humanise our work, we give up our voice in a human conversation. We leave the debate to others, then bemoan their lack of support. Our budgets are cut and our recommendations ignored, yet we press on regardless. All the while assuming someone else will take care of it. As we know, this had led to disastrous consequences. What lessons can be drawn from the communication catastrophe of climate science? By insisting on inaccessible writing, we’ve neutered our language. In doing so we’ve lost the power to shape our message.

It then falls to these few philosophers to act as our translators, to make our work moving and human. In his article *Hunger as a weapon*, Nigel Warburton writes “It is easy to kid ourselves that extreme hunger is a rarity. But the terrible truth that we must also know, at some level, is that hundreds of millions of people go to bed hungry each night, perhaps more than 800 million – mostly in the developing world.” And there, in two sentences, Warburton captures the raw humanity of something described in every journal article I can remember reading. His words are a reminder of why I work. The give me a feeling I’ve long forgotten. Like I’m doing something virtuous. Maybe even something beautiful.

*This piece was adapted from an earlier blog post with the same title published by Researchers in Agriculture for International Development (RAID). It can be found at www.raidaustralia.net.*
Emily Webb Ware
Emily is currently studying the Bachelor of Agriculture at the University of Melbourne, Majoring in Production Animal Health. She grew up on her family’s farm, running crossbred ewes and Angus cattle, near Yea in country Victoria. Although she is currently unsure of what exact direction she would like to take in her career within agriculture, she has a passion for livestock production side of things.

INTRODUCTION/ABSTRACT
With increasing demand for graduates trained in agriculture, and a huge range of career options, it seems there has never been a better time for young people to get into a career in agriculture. As a student just beginning in the industry, it can be hard to know where to start when trying to decide what direction to follow, and how to get to where you would like to be. Ag Institute Australia may be able to offer some support to young people keen to get involved in the industry.

SNAPSHOT INTO LIFE AS AN UNDERGRADUATE:
My own undergraduate course cohort seems to be a diverse group of people. We have a similar amount of males to females, and interestingly, a significant number of international students. Coming from a farming background, I will admit I was surprised to find that most students were from urban or suburban areas, and had little to no experience on farms. Despite this, the level of enthusiasm and readiness to learn these students bring to the course constantly amazes me. It excites me to see that studying agriculture at university is not just a last resort, but something people are choosing to get into, whether they come from a rural background or not. Most of all, I am so grateful to be surrounded by an incredible group of people who are driven and passionate about Agriculture.

As a current agricultural undergraduate student, my classmates and I are frequently presented with a wide and diverse range of career options, each very different, but as interesting as the next. The challenge for most is finding what field they are most passionate about; through in-class surveys I know less than 10% of my cohort are certain of which direction they want to follow. Of these, most are unsure of what specific job they might actually want to do within their field of interest, while some are hoping to pursue the Diploma of Veterinary Medicine. I have found this trend to be the same with the majority of young people in agriculture that I have met outside of my own course. However, I think it is important to note that this is a view from a person studying at university, and may not represent those entering the industry without tertiary education.

HOW CAN ORGANISATIONS LIKE THE AIA HELP?
For my cohort at least, what we would love most is the opportunity to speak to industry professionals about their career and how they got to where they are. Furthermore, in an industry where it is often not just what you know, but who you know, the chance to network with those already in the industry, is invaluable. Personally, I have found that as I talk to more people in the industry, I learn more about the opportunities and options that are out there, and ultimately I am able to gain a better understanding of what I want to do with my career. The contacts I have made through networking events have been such an incredible source of guidance, and have become people I feel comfortable asking for help. I have been astounded by the kind advice and support people have offered me, and cannot express how valuable it has been to talk to these people about their experiences.

This support could be offered in a variety of ways, including networking events, access to work experience, seminars, or setting up a way for students to contact industry professionals that they may gain value from, or find mentors that can advise them through the early stages of their career. This contact in itself could benefit the industry as a whole; by sharing knowledge and experience we can hopefully work together towards improving the industry as a whole.

Once available, it is up to the students to make the most of the opportunities that are presented to them. However, from the connections I have made so far and the agriculture students I have met at various events, I know I am part of a group of people that are truly passionate, wanting to learn, willing to take every opportunity, and make the most of what we are given. We are all keen to get involved, and with a little bit of support from those already in the industry and with some experience to share, our generation can do great things in an industry with a promising future ahead of it.

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FROM THE EYES OF AN UNDERGRADUATE; ENTERING AND EXPLORING THE AGRICULTURAL INDUSTRIES.
Emily Webb Ware
2nd year Bachelor of Agriculture at the University of Melbourne.
Something wonderful happened in the Federal Parliament on 1 June. The months of controversy over the legitimacy of a Senate inquiry into decentralisation were eclipsed by bipartisan agreement for a House of Representatives committee to look into the same.

The Government answered “yes” to my call to establish a national inquiry into regional development and decentralisation.

This will be a visionary committee that will not only look at the role of decentralisation of Commonwealth entities as a mechanism to increase growth and prosperity in regional areas. It will take a wider look and report on best practice approaches to regional development, and the ways in which Government can encourage greater corporate decentralisation.

I believe this is an incredible opportunity for the agricultural sector to set the scene for putting regional Australia at the heart of the nation’s future.

Thanks to its resilience and adaptability, agriculture and associated agribusiness is well positioned to provide Australia’s next economic boom. The gross value of Australian agriculture increased by $2.8 billion to $53.6 billion in 2014-15, and employment in the sector is growing.

Clearly, our farmers, agribusinesses, associated industries and researchers are doing a lot right.

Equally important, agricultural professionals have an intrinsic understanding of the interdependency of the sector locally on education, employment, infrastructure, and healthy communities. Businesses understand the complexity of relying on freight and transport including airports, internet-based technology, mobile telecommunications, and access to market information.

This connectedness is the key to thriving regions. For too long the policy approach to regional Australia has been disjointed and implemented by departmental silos. Government policy has been developed on a “one size fits all” approach based on population density rather than economic impact, and long term investment to leverage innovation. Regional infrastructure investment has been limited by a grants-based approach, and the impact of government decisions on the regions has been given cursory attention.

The establishment of this national inquiry is a welcome signal the government acknowledges the need to take a more sophisticated and coordinated approach to regional planning.

Education must be central to the conversation, across the range of higher education including vocational and trade training, diplomas, and tertiary qualifications. People under 21 are sadly one of the biggest exports from rural communities. Exciting opportunities unfold for young people when regional universities, TAFEs and secondary schools are able to engage with agribusiness locally to provide meaningful pathways to employment.

The government has much to learn from local examples, such as the Alpine Valleys Dairy Pathways Project (AVDPP) in North East Victoria. Through this program, the local dairy industry, farmers and local government are working with Charles Sturt University and local TAFEs to link with secondary school students to encourage a career in the dairy industry.

Agricultural scientists and researchers will play a vital role in the inquiry. Peak bodies such as the Agricultural Institute of Australia have an opportunity on a national stage to put their case for funding and research and development priorities for the CSIRO, universities and industry.

Australian farmers know they have to be effective business people, and there is a wealth of business-savvy experience for the inquiry to draw on. Winemakers in the North East have been able to leverage their impact on local tourism to secure federal funding for cellar door activities, and this could easily be taken up by the burgeoning paddock-to-plate industry that pulls visitors from the city to the country.

There are so many opportunities that could be opened up by this inquiry. To be an effective part of it and the ongoing conversation, agricultural Australia needs to establish a strong presence at the policy table. As well as continuing its leadership in business, science, educational and community leadership, the sector is going to have to get political and find its voice in Parliament.
The Inquiry will be calling for examples of best practice. In Indi, the dairy industry (AVDPP) is again an example of how a local collaboration can provide the insight and industry expertise necessary to effect national change. In the midst of the dairy crisis, the community was able to develop a holistic and long term plan to double milk production in the region by 2050. A delegation from the AVDPP worked with my office to meet with ministers, senior departmental personnel and opposition members to get their vision on the national agenda. It was best practice in leadership as well as community engagement.

As a rural representative with a strong farming roots and experience in economics, agribusiness, research, extension and community development, I hope to play a significant part in enabling the wider regional voice to be heard. To make sure that happens, I call on all facets of the agricultural industry to take a strategic approach to this opportunity. Develop a plan, identify the challenges and the local solutions that can inform the bigger picture, and speak up.

I am looking forward to working with Australians in agriculture to bring their wisdom, energy, and connectedness government processes. Here is an opportunity to be part of nation building that acknowledges the national value of the sector – let’s grab it with both hands!

Details of the inquiry will be released in the first week of September.
AUSTRALIAN ACADEMY OF SCIENCE LAUNCHES DECADAL PLAN FOR AGRICULTURAL SCIENCES

Provided by the Australian Academy of Science.

Australia’s leading agricultural scientists are calling on industry and government to establish a $100 million agricultural translation fund to boost productivity and profitability, future-proofing Australian farmers against looming shocks like climate variability or major disease outbreaks.

The ten-year strategic plan for Australian Agricultural Sciences developed by the Australian Academy of Science recommends:

- giving strategic direction to Australia’s future investment in agricultural sciences by identifying relative strengths and shortfalls in scientific capacity that need to be developed or maintained to ensure Australia is strong, prosperous, healthy and food secure
- enhancing the value of Australia’s research investment by providing a strategic framework with which researchers can align and coordinate their efforts to leverage greater impacts
- identifying workforce needs and strategies that enhance career pathways for graduate and postgraduate scientists from all fields that contribute to the agricultural sciences.

The decadal plan for Australian agricultural sciences 2017-26 was prepared by the National Committee for Agriculture, Fisheries and Food. The plan introduces agricultural research as a confluence of many disciplines, applied to a range of enterprises to improve profitability, productivity and sustainability. It covers terrestrial systems, excluding production forestry, aquaculture and fisheries, and identifies responses that will position Australia to take advantage of the likely scientific and technological advances occurring in the next decade.

The Australian agricultural sector has a keystone position in the structure and functioning of the country as a whole. Producers have stewardship of more than 60% of Australia’s land mass, and the industry directly employs more than 307,000 workers—the biggest employer in rural and regional Australia. About 1.6 million Australians are employed in the complete agricultural supply chain including food manufacturing and processing, distribution and retail. Agriculture supports population decentralisation, provides the ‘life-blood’ and social fabric of inland Australian settlement, and the industry acts as a source of skilled labour for mining and other industries. Ensuring its future strength means ensuring Australia’s future strength.

Dr Jeremy Burdon, Chair of the Academy’s National Committee for Agriculture, Fisheries and Food, noted that a new research translation fund supported by public and private equity would fast-track investment in the development of applications for the most promising Australian research and boost Australia’s economy through new and improved agricultural products and services in domestic and international markets.

The plan also outlines strategies to improve the strength and efficiency of agricultural research in Australia in ways that will increase the ability of governments and producers to maintain productivity and efficiency in the face of evolving natural challenges.

“There remains a distinct lack of coordination of agricultural sciences.

The Decadal Plan’s first recommendation urges the federal government to establish a National Agricultural Research Translation Fund, to invest in promising agricultural discoveries and fast-track their commercialisation into new and improved Australian products and services in domestic and international markets. Such a fund could be modelled on the Biomedical Translation Fund; selecting appropriately qualified and experienced fund managers to stimulate private sector investment at the early stages of agricultural research translation.

The fund would be governed by a priority-setting cycle that keeps pace with the rate of change in the sector while providing the stability necessary to undertake large-scale endeavours. It would address the most pressing gaps in the innovation system that present barriers to uptake at the time. This arrangement would not diminish the essential roles of existing research agencies or reduce the need for them, but rather reinforce them all by strengthening the system in which they all operate. Stable funding arrangements should align with the long-term, complex nature of research translation, commercialisation and uptake.

A further recommendation supports greater cooperation between academic, industry and government sectors to create a doctoral training and early career support centre for the agricultural sciences.
research and innovation in Australia and a culture of competition over collaboration,” Dr Burdon said.

“The scientific and research community must form stronger partnerships across sectors and industries, focusing on better-integrated global data, modelling and analytical capacities, to better respond to new opportunities and prepare for major threats to agricultural production.

The plan recommends the agricultural research community engages meaningfully with infrastructure planning processes at all levels to enable agricultural research to benefit from, and contribute to, shared national capabilities, including emerging data-infrastructure and maintaining the pool of skilled technicians that unlock value from national infrastructure capability.

Finally, the plan recommends that the Australian Government review and update its national coordination of agricultural research and innovation in Australia. One option would be to establish an organisation that provides a central point of coordination for agricultural research and its applications. This organisation would coordinate Australia’s involvement in international research programs, align programs where appropriate, and to address any fragmentation of international engagement that may be found. Australia would benefit from a national perspective of the whole agricultural sector and its research needs.

The development of the plan included an extended consultation process with broad representation of researchers from across agricultural sciences. The consultation helped identify research areas that should be prioritised in Australia over the next 10 years—successfully identifying, developing and deploying the next generation of game-changing scientific advances remains an active and ongoing challenge. Research priorities are outlined in table 2.1 of the plan at the end of this article, but in no order of priority:

The Australian Academy of Science decadal plan for Australian Agricultural Sciences was launched at Parliament House in June by the Hon Luke Hartsuyker MP, Assistant Minister to the Deputy Prime Minister.

FULL LIST OF RECOMMENDATIONS:

To ensure ongoing innovation, coordination and efficiency in Australia’s agricultural sector, it is recommended that:

■ The Australian Government establish a national agricultural research translation and commercialisation fund, to invest in promising agricultural discoveries and fast-track their commercialisation into new and improved Australian products and services in domestic and international markets. It is suggested that this fund be modelled on the Biomedical Translation Fund: selecting appropriately qualified and experienced fund managers to stimulate private sector investment at the early stage of agricultural research translation. The fund should be managed according to the following principles:
  ■ The fund must be governed by a priority-setting cycle that keeps pace with the rate of change in the sector, but that provides the stability necessary to undertake large-scale endeavours. Triennial reporting from a national agricultural research and innovation body such as that proposed in recommendation 4 would be a suitable information base for such priority-setting over the medium to long term.
  ■ The fund should address the most pressing gaps in the innovation system that present barriers to uptake at the time. It will not diminish the essential existing roles of current research agencies or reduce the need for them, but rather reinforce them all by strengthening the system in which they all operate.
  ■ Stable funding arrangements must be aligned with the long-term, complex nature of research translation, commercialisation and uptake.
  ■ The academic, industry and government sectors partner to create a doctoral training and early career support centre for the agricultural sciences. Its functions should be to:
    ■ administer a substantial and targeted PhD top-up scholarships program that can compete with other options available to professional agricultural scientists. This would partially reduce the current financial barrier that prevents professionals from returning to study or bringing on-farm experience back to the research sector.
    ■ run an agricultural enterprise engagement program to provide graduate students with ongoing exposure to the working farm systems that are relevant to their research, and to encourage research towards nationally important challenges that are on the horizon.
    ■ manage an early- and mid-career support network to maintain connections between PhD cohorts and provide opportunities for early- and mid-career researchers to connect with mentors, each other, and a wider range of agricultural systems than would otherwise be possible.
    ■ The agricultural research community engage strongly with infrastructure planning processes at all levels to enable agricultural research to benefit from, and
contribute to, shared national capabilities, including emerging data-infrastructure and maintaining the pool of skilled technicians that unlock value from national infrastructure capability.

- The Australian Government consider reviewing and updating arrangements for national coordination of agricultural research and innovation in Australia. One option would be to establish an organisation that provides a central point of coordination for agricultural research and its applications. Its functions should be to:
  - coordinate the priority-setting exercises of all publicly funded research organisations and funding agencies and to strongly urge public research organisations towards simplified and transparent funding interactions between them.
  - directly manage a modest but influential collaboration incentives program with the intention of filling strategic research gaps (currently outlined in Table 2.1) and forming teams around nationally important challenges or unexpected shocks that unite the most suitable experts regardless of their location, and over timeframes that are commensurate with the research challenges.
  - conduct rolling identification of national agricultural research priorities (reporting triennially) and assessment and forecasting of Australia’s research capacity requirements (offset reporting at a similar frequency), including both human and infrastructural capabilities.
  - coordinate Australia’s involvement in international research programs, to align programs where appropriate, and to address any fragmentation of international engagement effort that may be found.

The organisation could take the form of a national agricultural research and innovation council or any equivalent body with a national perspective of the whole agricultural sector and its research needs.

- All organisations in the agricultural sector do more to understand and effectively engage with the public on social acceptance of agricultural science and the enterprises it supports. This also applies to understanding that agriculture reaches far beyond the farm gate.

**LEADERSHIP**

The plan was prepared by:

*National Committee for Agriculture, Fisheries and Forestry*
- Dr Jeremy Burdon FAA FTSE, Chair Professor
- Jim Pratley
- Professor Bob Gibson
- Associate Professor Ros Gleadow
- Professor Bronwyn Gillanders
- Dr Sue Hatcher

*Review panel for the Decadal Plan for Agricultural Sciences*
- Dr TJ Higgins AO FAA FTSE
- Prof Snow Barlow FTSE
- Prof Graham Farquhar AO FAA FRS
- Dr Anna Koltunow FAA
- Dr Oliver Mayo FAA FTSE
- Dr John Passioura FAA
- Prof Mick Poole AM FTSE
Table 2.1: Specific research frontiers and theme areas identified as being major areas of focus and contributors to agriculture in the coming decade.

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<tr>
<th>Specific research areas</th>
<th>Outcome and implementation areas</th>
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<td>Increased productivity through integrated farming systems</td>
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<td>Biosecurity</td>
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<td>Sustainable resource base</td>
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<td>Increased value through quality &amp; market advantage</td>
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<td>Development and exploration of genomics</td>
<td>Genomic prediction&lt;br&gt;Targeted genetics&lt;br&gt;Novel crops and livestock&lt;br&gt;Manipulating the soil and gut biome</td>
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<td>Agr-intelligent technology</td>
<td>Remote sensing and real-time monitoring&lt;br&gt;Harvest scheduling&lt;br&gt;Pesticide application</td>
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<td>Big data analysis</td>
<td>Integrated management&lt;br&gt;Soil microbiome functional analysis</td>
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<td>Clever chemistry</td>
<td>Novel fertilisers&lt;br&gt;Novel pesticides and herbicides&lt;br&gt;Biopolymers&lt;br&gt;Real-time nutrient</td>
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<td>Coping with climate</td>
<td>Seasonal forecasting&lt;br&gt;Managing extreme events&lt;br&gt;Carbon capture&lt;br&gt;Water storage&lt;br&gt;Managing CO₂ responses</td>
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<tr>
<td>Metabolic engineering / synthetic biology</td>
<td>Biofuels and industrial feedstocks</td>
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