Fifty Years in Pursuit of Agricultural Sustainability – an ever 'Moving Target' *Donald Oration 2017*

Professor **Timothy G Reeves** FTSE

Professorial Fellow, Faculty of Veterinary and Agricultural Sciences, University of Melbourne
Chair, Agriculture Forum, Australian Academy of Technology and Engineering
Director, Timothy G Reeves and Associates P/L, Geelong, VIC 3220

Email: timothy.g.reeves@bigpond.com

Abstract
This paper provides key insights into factors important in the development of agronomists and other agricultural scientists. These include the critical people-related roles of - establishing strong, multi-disciplinary teams to conduct rigorous and accurate field and related research; strong leadership and support from senior managers; experienced mentors and role models; and the imperative of effective farmer participation in the research-development-adoption continuum. It then tracks the 'rise and demise' of some major farming systems in SE Australia, providing insights into the factors influencing their initial adoption by farmers and the factors that lead to them ultimately becoming unsustainable. Lessons learned and the current relevance of these findings is described for each system, particularly in relation to sustainability factors. It concludes that 'business as usual' is rarely, if ever, a viable sustainability option.

Sustainable intensification of agriculture is the last of the systems considered and its critical importance to future global food and nutritional security is described. The paper concludes by identifying five 'Grand Challenges' to global food and nutritional security – natural resource losses; climate change; nitrogen-use efficiency; food loss and waste; neglect of rural communities - and the measures required to successfully overcome them, including sustainable intensification. Urgent attention is recommended to better tackling nexus issues; implementing sustainable intensification in agri-food chains; establishing policies and targets for reducing food loss and waste; developing a vision and strategy for rural communities; and implementing longer-term, patient co-investment in factors critical to sustainability.

Introduction
Firstly, let me say that I am honoured, humbled and delighted by the award of the Donald Medal today. I thank my proposers and Agronomy Australia for the award and acknowledge the other outstanding candidates who could have been in my place. I have learnt much from you all, as sharing has been and always should remain, a foundation of agronomy. Thank you.

Professor Colin M Donald
I never had the privilege of meeting Professor Donald, but always lived in awe of his reputation as an agronomist and agricultural scientist. In some ways, we were a long way apart and practiced our craft in very different ways, he working in CSIRO and academia for nearly all of his career, and me located in a small country town, at the Victorian Department of Agriculture's Rutherglen Research Station, later Institute, a community where I spent the first 25 years of my working life in Australia.

And yet, I now realise that we had quite a bit in common and that our destinies were in fact to be eventually drawn together. Like Professor Donald, I was born in the UK and emigrated to Australia as a young man – he was 16 and I was 22, on our respective arrival times in this wonderful country and we were equally blessed with great opportunities in our new home land.

Looking through the excellent and detailed life history of Professor Donald, prepared by the late Professor Jim Quirk, I also noted that in 1954 Colin Donald was appointed as Professor of Agriculture and Head of the Department of Agronomy at the Waite Institute, University of Adelaide. Nearly 40 years later, in 1992, I was appointed Professor of Sustainable Agricultural Production and became Head of the Department of Agronomy and Farming Systems at the same university. Unusually, at the times of our respective appointments both of us had a Master's degree, rather than a doctorate, as our highest qualification. In a final twist of destiny, it is my understanding that the vacancy that was used to create the Foundation Chair to which I was appointed in 1992, was that of the former position held by Professor Colin Donald.

Becoming an agronomist

Like most of us here I suspect, I did not grow up wanting to be an agronomist and the truth is I did not know what one was until I left university. However, by great fortune I did become an agronomist, in 1967, and to this day I still introduce myself that way – "I am an agronomist" – and am very proud to do so.

The basis for this paper, is to record for posterity some of the important agronomic breakthroughs with which I and my colleagues were involved over the past 50 years and in so doing to note for ongoing attention, the **lessons learned** in regards to the pursuit of **sustainability**, **sustainable intensification** and in line with the theme of this conference, attempting to **'do more with less'**. My approach is to not just repeat what is already well recorded in the literature – although I will draw on this where appropriate – but to try and provide some insights into the thinking of the day; the issues that underpinned decisions at the time; and what I believe to be critical success factors, that may well have escaped formal write-ups. In most cases, I will try to draw this out to principles that have current relevance and in so doing try to help history beneficially inform current practice, an important component of sound agronomy.

But firstly, a little bit of history to help set the scene for my commencement in this noble profession of agronomy. I still have an aerogramme letter (remember them?!) from Les Hore (father of Des, for those of you who are familiar with the name), Deputy-Chief in the then Department of Agriculture, Victoria. It is dated 18 January 1967 and stated that when I arrived in Australia, I would probably be located at Longerenong College, Horsham (which was my preferred location, even though I had no idea where, or what it was, from my then very distant home in East Yorkshire, UK).

In retrospect, there were two other sentences in that letter that ultimately determined my fate and set my career as an agronomist in train. One of these read, "However, there are other possibilities, including our Research Station at Rutherglen in North-Eastern Victoria". Of course, this meant little to me at the time and I had no inkling that it could in any way be connected to the post-script in that same aerogramme letter, which read as follows. "P.S. I am sorry to tell you that we Victorians are not Rugby Union fans, but rugby players usually make good Australian Rules footballers – so here's hoping." It is now clear to me that it was this combination of ideas that settled my location, rather than any key scientific or more technical criterion! Rutherglen was indeed in need of footballers and an agronomist who could also possibly play for the 'Rutherglen Redlegs' was obviously seen as a win-win! (Thinking back, the precedent for Les's hypothesis that 'rugby players make good footballers', probably had a sample size in single digits! I did however help to reinforce his beliefs by playing around 150 senior games for Rutherglen, in the strong Ovens and Murray League. In so doing it helped my work as an agronomist, but more on that later).

Starting at the Rutherglen Research Station, NE Victoria

My first year at Rutherglen was 1967, which turned out to be one of the worst drought years on record, with less than half of the annual average rainfall received. The very harsh conditions were a both a personal and professional shock to me. It was very hard for me with my (wet, cold weather, English) background to envisage how plants could grow in such conditions and how livestock could survive. So from those earliest days, I had an understanding of the risks associated with the new environment and it has remained with me throughout my career. It was also somewhat counter-intuitive that during my ensuing 25 years at Rutherglen, the major weather risks to agricultural production generally arose from too much rain and resultant waterlogging, rather than too little rain…

The future priorities for my career as an agronomist were planted in that first year of work. Like any new recruit, I helped with everything that I was asked to do and in so doing learned a great deal. However, my very helpful, friendly and supportive first 'bosses', Ian Smith and Arthur Mann, started to direct my interests towards weeds in crops and 'chemical cultivation', the latter being part of the birth of zero tillage in Australia. I did not realise at the time what an opportunity this was to work on something from 'scratch', which would change the face of agriculture in Victoria, Australia and the world. I have been fortunate enough to since have some involvement with the development of this technology at each of these levels (Reeves and Ellington 1974; Reeves 1992; FAO 2011a; FAO 2016).

The Role of Great People

I will repeat and reinforce some of these points as I go along and one could also put the case that this section could have come towards the end of the paper, as concluding comments. However, I believe that they have been so important from the start of my career to the current day that dealing with them in the 'real time' of writing of this paper better emphasises their influence and continuing importance.

- *Good people, good teams***.** Agronomists must be team players and we have a key role to play in drawing together other specialists in order to integrate and coordinate their knowledge skills and resources and bring them to bear on the complex systems related to the challenges and opportunities which are the core business of agronomy. From the outset - initially by good fortune, but later through focused and conscious recruitment efforts - I was surrounded with excellent colleagues, each of whom brought specific expertise to the work at hand.

  There are many of those colleagues that could be named, but at Rutherglen I specifically wish to acknowledge the hard, detailed and expert soils research work of my friend and colleague, the late Tony Ellington. We both arrived at the Rutherglen Research Station from the UK within a few weeks of each other. We were both referred to as 'Poms' – sometimes affectionately, sometimes not – but we were very different people. Tony was 10 years older than me and rather than being a new graduate who knew nothing (me), he had worked at two prestigious research institutions in the UK – Cockle Park Farm, part of the University of Newcastle, and the Plant Breeding Station at Aberystwyth, Wales. As a result, he was then the only cropping scientist at Rutherglen who actually knew how to accurately work on soils and plant growth. I learned so much from Tony, particularly the importance of scientific rigour and there is no doubt in my mind, that if I had not had his example to follow and just as importantly his collaborative work with me and other colleagues (e.g. Ellington and Reeves 1978; Ellington and Reeves 1990), I would not be standing here now. Thank you Tony, RIP.

  The other Rutherglen researcher that I wish to acknowledge is Bert Brooke. He was one of the very best field researchers and technicians that I have ever worked with and his practical ingenuity and expertise underpinned many programs and projects that helped to transform farming systems in Victoria and elsewhere. Importantly, he also had a great rapport with farmers and added to our credibility. His sole academic qualification was a Dookie Diploma of Agriculture and yet he ended up as the senior or contributing author of many papers in prestigious peer-reviewed agricultural journals (e.g. Coventry et al.1993).

  <u>Lessons learned and current relevance</u> – *The basis of good agronomic research is the establishment of first-class experiments utilising the very best techniques so that the measurements made are indeed based on valid comparisons of the systems/treatments being evaluated. This requires the efforts of multi-skilled teams comprising specialist experts who all bring their knowledge and expertise to the work. Unfortunately, in recent years I have seen an increasing amount of field based research which has been of a very poor standard and despite the use of sophisticated monitoring and measuring equipment – often extremely costly – could not deliver accurate and meaningful results as the basic comparisons were flawed. If two systems are to be compared, then it is essential that each is established and managed using best management practices that accurately represent the situation in the best farmers' paddocks. Sophisticated digital measurements are not a substitute for the accurate and rigorous establishment of first-class experiments.*

- *Leadership and support.* This is the second people related aspect that I wish to refer to, and it is one that has had a profound impact on my career and remains an important of good management to the current time. There are two facets of leadership and support that I believe serve to provide strong lessons for today.

  My career as an agronomist has been strongly supported by the confidence that various leaders have shown in me and I believe that this remains a very important aspect of personal development for developing agronomists and others. In the Department of Agriculture, Victoria such support came from a number of leaders including, Les Hore at the start of my career and his son Dr Des Hore, who became Director General of the Department, later on in my development. The late Dr David Smith and Dr Jack Meagher were others who were tremendously supportive of my work and development. Their confidence in my abilities to achieve, became in a way, a self-fulfilling prophecy as it gave me confidence to attempt and strive to achieve greater and more complex tasks.

The Department also provided several key opportunities to carry out 'higher duties' roles when senior personnel were away and for me these opportunities were invaluable in helping me to develop management and leadership roles, as an agronomist and more generally. However, perhaps the most pivotal piece of senior leadership support for my career was provided by the late Dr Jim McLaughlin, when he provisionally promoted me to become the inaugural Director of the newly upgraded, Rutherglen Research Institute, in 1980. I was still a relatively junior agronomist at the time and Jim, at significant reputational risk to his own career, was prepared to recommend my promotion to a position six grades above my substantive classification. I had to subsequently survive a rigorous Public Service Board appeals process, before taking on the major task of upgrading Rutherglen, a challenge that was described by one senior manager as: 'you've inherited a steam train and it needs to be converted into a luxury liner'! There were many motivations to succeed, not least to repay the faith shown in me by Jim.

There were also a number of distinguished leaders from outside of the Department who were great mentors and provided excellent support for me as I developed as an agronomist. These included Dr Jim Peacock, the late Paul McGowan, the late Professor Harold Woolhouse, Dr John Gladstones and Professor Wally Falcon (former CIMMYT Board Chair). I am very grateful to all of them.

Lessons learned and current relevance – There appears today to be a much greater reluctance to invest in human 'potential' and to take a calculated gamble that 'rising stars' will grow into the job and more than reward the confidence shown in them. Quite often I have been recently involved with, or am aware of, selection processes at universities or other institutions, where an appointment is not made, or is offered at a lower level (and often as a result, not accepted) because none of the candidates were deemed to have fully satisfied the selection criteria. We are in an age where it is notoriously difficult to get good, senior people to move for a new job, but young ambitious people are much more mobile. It is therefore critical that the best of these are recruited and supported so that they can achieve at the high levels required and hopefully beyond, within a year or two of their appointment. We must again be prepared to invest in potential, if we are to get the succession that agronomy and other agricultural professions require!

- *Making time for younger agronomists.* In 1974, as a still young and 'junior' agronomist, I was working on lupin-wheat rotations (Reeves et al.1984a; Reeves 1984) and had the opportunity to visit the 'King of Lupins' Dr John Gladstones (e.g. Gladstones et al.1998), and other distinguished colleagues in Western Australia. It was my first long interstate visit – over a week - and I learned so much, it has remained with me to this day. There were many technical things that I learned due to the generosity of the excellent agricultural scientists over there at the time – Poole, Hamblin, Chatel, Francis, Walton, Pearce and Perry all come to mind for their contributions. However, perhaps the main lesson that I learned was the importance of dealing with visiting scientists graciously, efficiently and effectively. Quite frankly, I was very nervous when I arrived there, as Dr Gladstones was and remains, an iconic figure in Australian agriculture. I wondered how much of his valuable time that I would be able to access. Imagine then my absolute surprise when I found out that he had planned his whole week around my visit and drove me to important lupin sites over the course of a week away! I learned as much during the substantial car journeys as I did at the research and other sites that we visited. The next year, I made my first overseas study tour to Canada, and just as in WA, I was amazed and delighted with the reception that I received with well-planned visits, including with senior decision makers. Although I was away for around three weeks I do not recall having an evening meal by myself as I was invariably invited out to the homes of the scientists that I was visiting.

  These experiences in WA and Canada set a new standard for how we subsequently treated visitors to Rutherglen. Proper printed itineraries, good planning and generous offering of our time became a trademark for visitors to our Institute, where previously a visitor was seen as something of a distraction that had to be dealt with. My treatment as a visitor was a lesson that I have not forgotten.

Lessons learned and current relevance – I think that these are self-explanatory from the experiences described above – making time for all visitors is important, but it can have an even greater impact when a senior scientist allocates generous time to a younger agronomist/scientist. When I later went to work at CIMMYT, the treatment of visitors was already an art form and handled very professionally by a dedicated Visitors Services section. My message today is to not underestimate the importance of visiting, and being visited, both in the knowledge exchange process and in the career development of younger scientists.

- *Farmer participation.* One of the things that sets apart Australian agricultural research, development and extension from most countries worldwide, is the full participation of farmers in the continuum from priority setting through to adoption. This transformation has occurred during my lifetime as an agronomist and is of vital ongoing importance to the future success of Australian agriculture. The introduction of Landcare in the 1986 (https://landcareaustralia.org.au/about/the-landcare-story/) helped to stimulate and formalise concerted farmer participation and other, more productivity focused groups, soon followed in all of the States. Here in Victoria, The Birchip Cropping Group was one of the early pioneers.

When I first arrived at Rutherglen in 1967, we were still in the 'annual major Field Day mode', where most of the contact that researchers had with farmers was on 'that one day in October'. Even by that time, the popularity of such days was waning and field day attendances in the 1960s and early 70s fell to gatherings of around 120 people at best and only some of those were farmers.

However, from the early years at Rutherglen a feature of my work was the cooperation and participation of local and regional farmers in the agronomic research that I was conducting. This is where football, cricket, the Apex Club and school councils were all important factors – football particularly. Most of my teammates and opponents were farmers and this naturally lead to conversations around what I was doing and their ideas on what was important and needed attention. As a result, I had lots of invitations to put trial plots on their properties both on local farms and across NE Victoria. "Are you the Pom that plays footy for Rutherglen?' was a common farm gate greeting and from then on it was never difficult to get a plot site and also some buy-in to the research work.

By the mid-1970s our field day attendances started to climb markedly and peaked in 1981 when over 1000 farmers attended our field day on 'Soil Conditions and Plant Growth' where soil acidity, soil compaction and zero tillage were the main topics of the day (NLA Trove 1981). From that year onwards we had to duplicate our field days – the same program on two consecutive days – to accommodate the large attendances, which remained in the range of 700-800 for a number of years. The attractive features of these field days for farmers included an initial session on the research station to see the meticulous field plots and understand the rigour and accuracy of what we were telling them. But probably the highlight for them was the next session when we took them all to a neighbouring commercial farm that had already adopted the new technologies that we were featuring. Those local farmers were able to tell the visitors what difficulties that they had faced, how equipment needed to be modified, weed control measures etc. and this was powerful advice and information. These farmers were often football friends – around Rutherglen, that included the Baker, Tafft, Terrill and Francis families – or others met through Apex or similar. These included the Fisher, Chambers and Briggs families. They all had the confidence to take up early research findings and implement them over broadacres and it was their full participation that contributed greatly to the rapid and widespread adoption of such technologies as direct drilling/zero tillage (D'Emden et al.2008); soil liming (Coventry et al.1992) and deep ripping (Ellington 1986; Steed et al.1987) in the region.

Lessons learned and current relevance - The continuing participation of farmers in the research-development-extension continuum is absolutely vital to the future success of Australian agriculture. This is important for all aspects of research but essential for successful agronomic research. Researchers are now less likely to live in the communities that they serve and therefore new modalities and efforts are required to foster full farmer participation in research, including such mechanisms as steering and industry advice groups. The Rural R&D Corporations have had a mixed record on supporting effective farmer participation, with some very good and some not so. GRDC is amongst the former and has been a leader in this field from Board level to grower groups for decades. However, even GRDC from time to *time seems to suffer from 'fatigue with grower groups'. There is an ongoing need to monitor, review and evaluate current and future investments – it is a key part of best practice – however it is also important that grower groups are not left in 'limbo' and can remain as a foundation of our future programs. I once was in a small UN working group with the distinguished economist and global thought leader, Professor Jeffrey Sachs. The topic was international development assistance and he said words along these lines, ' What the Western world has to get into its mindset is that it will still need to be providing development assistance to poorer countries in 50 or 70 years time. We cannot expect that our past and current assistance will somehow make them immediately sustainable. The nature of the assistance will hopefully change, including to a greater partnership mode, but the assistance will still be required'. Well, that same principle may well apply to grower groups in agriculture, as they are unlikely to be sustainable without ongoing investment. The nature and modality of that investment may change, but it will still be required.*

A 'Golden Era' for Agronomy

There were a number of factors that combined to make the period from the beginning of the 1970s to the end of the 1990s a remarkable era for agronomy in Australia.

Firstly, in 1969 at the instigation of the industry, restrictions were placed on the quantities of wheat that could be delivered to the Australian Wheat Board, in the form of wheat delivery quotas. This was an attempt to reduce the potential for the build-up of excessive carryover stocks after the record 1968/69 harvest in Australia, and the coincident build-up of world wheat stocks. One of the industry responses to this was the initiation of new research efforts funded by the State based 'wheat research committees' (precursors of GRDC) in the category of 'Alternative Crops to Wheat'. This spawned and stimulated the first coordinated and substantial research in Australia on oilseed rape (later to become canola), lupins, chickpeas, lentils and faba beans and reinvigorated longer standing interests in field peas and vetches. Whilst the wheat delivery quotas were short lived, the momentum for research on crops other than cereals was maintained resulting in the transformation of the cropping industries in Australia and the basis of farming today. The challenges and opportunities for agronomists in growing new crop species and types for the very first time were both exciting and almost overwhelming! I well recall watching oilseed rape growing in the plots and learning something new each week as the plants developed and grew and eventually flowered! Harvest of course was another new adventure, not just for the rapeseed but also for the pulses. One is left to wonder how soon such work would have commenced had it not been for those ephemeral 'wheat quotas'.

Secondly, at around the same time, ICI the UK based company, was stimulating interest worldwide in the development of direct drilling using their new and revolutionary 'knockdown' herbicides, paraquat and diquat. We were already conducting research at Rutherglen and elsewhere in Victoria, which had commenced in 1965 on 'chemical cultivation', but all of the herbicides evaluated in those early years – I was significantly involved from 1967 onwards - were either ineffective and/or damaged the emerging wheat, due to residual soil activity. Amitrole, diuron and triazines were some of those early unsuccessful candidates. Paraquat changed the face of this work and I cover the 'direct drilling story' a little later in this paper, given its critical importance to Australian agriculture.

The birth of alternative crops to wheat and direct drilling are sufficient to create a 'golden era' in their own right, but when one adds to this the discovery and introduction of selective soil active herbicides for grassy weed control in cereals – diallate and trifluralin were particularly useful (Reeves and Tuohey 1972; Reeves and Lumb 1974); early post-emergent selective herbicides for use in cereals, firstly for broad-leaved weeds and then the 'holy grail', herbicides for selective grass control in cereals, including annual ryegrass. There is little doubt that the evaluation, demonstration and widespread adoption of these new herbicides, was at the time one of the one of the biggest technological breakthroughs for cropping farmers. As agronomists at that time we were immersed in this work, not just for the weed control and yield increases gained in conventional crops, but even more so for the opportunities that they provided to introduce disruptive new farming systems based on intensive cropping. These systems subsequently revolutionised cropping in Australia.

<u>Lessons learned and current relevance</u> – *Agronomic research was at the heart of each of these breakthroughs in cropping technologies. Every State in Australia had very good agronomists working at a range of locations and there was both a spirit of cooperation and (mainly beneficial) competition during those exciting years. At Rutherglen, we were always involved with the very good scientific team at the*

Agricultural Research Institute at Wagga, led by an outstanding agronomist, the late Eric Corbin, with whom cooperation was very good and competition pretty fierce! As groups, we sparked off of each other and in my opinion this was all to the benefit of growers in both Northern Victoria and Southern New South Wales. The message was clear, no one research team had a monopoly on good ideas and the exchange of ideas and material helped everyone and ensured greater progress was made with these exciting breakthroughs. This spirit of cooperation and healthy competition is as relevant today as it was then. Whilst the National RDE Strategy has some strong merits in terms of rationalising integration and cooperative efforts, there is still a place for rational duplication and competition, in order to emphasise urgency, disrupt uniform thinking and avoid complacency.

The other lesson learned relates to sustainability. At the time we thought that all or most of these new technologies were sustainable. The later onset of herbicide resistance (e.g. Powles and Holtum 1990) is just one further example of the 'ever moving target of sustainability', the title of this paper.

The Direct Drilling Story - a brief account

It is around 50 years since the first introduction of aspects of direct drilling technologies into Australia. To mark this important milestone, the National Library of Australia has recently completed a significant and substantial work - 'Direct drilling farming in Australia oral history project' (NLA Trove 2016). In this project, initiated by a group of former ICI Australia scientists lead by Mike Barrett, all of the key people involved with the development of direct drilling in Australia have been interviewed and their stories orally recorded – farmers, scientists and more. These interviews are now archived in the National Library and are well worth a listen. I had the privilege of having my complete life history recorded as part of this project. There are a couple of key points from those early days that I think are worth recording here as they still have great relevance to agronomy today. Firstly, the development of direct drilling was an excellent example of a 'public – private partnership' before anyone had coined that phrase or even knew what one was. ICI provided knowledge and technical support to those of us working on this revolutionary technology, often in isolation. As one example of this, I well remember when ICI brought Dr W R 'Bill' Boon the "Pioneer of Paraquat" (ICI 1973) to see our work at Rutherglen whilst I was still a very junior agronomist. The beneficial impacts are still with me today.

Secondly, is the fundamental importance of timing and message in the adoption of new technology and this was well demonstrated in the direct drilling story. When ICI brought the direct drilling concept to Australia it was to my mind a technology ahead of its time. The drivers for direct drilling as espoused by ICI did not really resonate with Australian growers at the time. These drivers included – saving on fuel costs; less labour requirement and reduced time on the tractor. Whilst each of these factors subsequently became important on-farm aspects, they were not then and in fact in some ways were counter-productive in promoting the new crop establishment methods. Fuel was a few cents a litre; labour was plentiful, as at that time most kids stayed home on the farm after (and during) schooling. 'Less time on the tractor' was also well out of line with rural community values in the 1960s and 1970s. Farming men (they were nearly all men in those days) could almost be excused anything if it was seeding time and they were out on the tractor. If he wasn't at church, or at a family gathering, or at sports training, priorities were well understood and so to actually spend less time on the tractor would have been a social no-no! When Monsanto came into the market a little later with the 'Conservation Tillage' concept and the associated Roundup CT - fuel, labour and time were already more important commodities to farmers and as the subsequent success of the Landcare movement later showed, conservation and sustainability were also coming more to the forefront of farmers' thinking.

The third point, which still resonates today, is the scientific contention at the time, around the likely development and success of direct drilling. Both scientists and farmers working on direct drilling in those early days were often the subject of ridicule and criticism from some of their peers. At the scientific level, there were the 'believers and the non-believers' and at the extremes there was a good deal of intolerance and scathing comment along the lines of 'that may work in your location, but it is totally irrelevant here and would be impossible to implement'. Some of the most strident criticism came from a relatively few researchers who were working in regions now completely dominated by direct drilling/zero tillage systems. They did not have an open mind about the new technology and when they were more or less forced to do their own experimentation, sought to 'make it fail' through site choice and other management decisions. There is and should always be the opportunity for vigorous debate in any scientific arena, but it is fair to say that the 'non-believers' of those days actually did their local farmers a disservice through their negativity.

Lessons learned and current relevance – *Good timing for the introduction of new technologies is paramount. Keeping an open, but enquiring mind about new technologies is a quality that all agronomists should try to adhere to. There may be some obvious faults with the first phases of new technology, but the good agronomist will think, 'what if we could make this work better?'*

Pursuing sustainability, 'rise and demise' – brief personal experiences

1. Ley farming

When I arrived at Rutherglen, ley farming (Donald 1965) predominated throughout SE Australia and was considered by many to be the 'perfect' sustainable farming system, whether it used clovers or medics, or whether it included a bare fallow period, as it usually did in the lower rainfall regions. For Northern Victoria and Southern NSW it appeared for all purposes to be totally sustainable, from both soil fertility and economic aspects. The late Dr Tony McGowan stated in his Masters thesis (McGowan1967) that, 'nowhere does sub clover grow better than in the Chiltern Valley' (the location of the Rutherglen Research Institute). Soil fertility was built up during the ley phase and then utilised by 2 or 3 years of cereal cropping, often wheat, wheat and then oats, undersown with subterranean clover/medic. From the viewpoint of economic risk, ley farming again appeared to be the answer with returns possible from cropping, hay, sheep and cattle production. One of the older local farmers at Rutherglen told me that his plan was always 'a third, a third and a third' meaning crops, sheep and cattle and 'you couldn't go wrong'. However, even in those halcyon days for ley farming, some warning signs were emerging as McGowan's thesis also stated that annual ryegrass in the cropping phase was "…considered a serious weed because it can rapidly build up and reduce grain yields" (McGowan 1967).

History now tells us that ley farming, without significant modifications, was not sustainable, as soil acidity (Coventry et al.1985; Helyar 1990; Dolling 1996); soil compaction caused by excessive cultivation and the trampling of animals' hooves (Reeves et al.1984b); cereal root diseases (Puckridge and French 1983); and weeds, particularly annual ryegrass (Reeves 1975) all took their toll. But interestingly, in NE Victoria it was economic aspects that first caused farmers to change from ley farming to more intensive cropping. In 1974 cattle prices collapsed (https://australianabattoirs.wordpress.com/tag/beef-crash/) and sheep returns were also below that of crop returns and it was this situation that began to erode ley farming systems, rather than bio-physical problems which became dominant in the ensuing years and decades.

Lessons learned and current relevance - *This was my first experience and example of the 'ever moving target of sustainability' and it was a major shock for most farmers and agronomists at the time, as most of us were very comfortable with the 'status quo' which initially appeared to have all of the answers. It is a lesson that remains important to the current day – business as usual is rarely, if ever a viable option.*

2. More intensive cropping

As indicated above, lower prices for livestock products stimulated farmers to increase the proportion and often the intensity of their cropping, but generally still within a 'ley-farming framework'. Greater areas of crops were planted at the expense of livestock production and this was nowhere more evident than in some of the higher rainfall traditional grazing areas. Amongst the first adopters of lupin production in NE Victoria were predominantly graziers around Benalla, Euroa and the Strathbogie Ranges, who had been hard hit by depressed cattle prices and were prepared to be the pioneers of high-rainfall cropping. Ewan Cameron, subsequently a Federal parliamentarian for Indi, was at the forefront of this movement and planted several paddocks to lupins in 1975 and in subsequent years. In the more traditional, medium rainfall (450-550 mm/year) cropping areas, more cereals were planted, but again there were leading growers who were prepared to experiment on broad acres with lupins and rapeseed/canola and the first commercial crops were grown there from 1975 onwards. The major technological breakthrough for lupin production in these regions was the use of simazine for weed control (Reeves and Lumb 1974). In the higher rainfall regions it worked very well on its own, but in the drier areas admixtures with diallate and trifluralin were necessary to bolster grassy weed control.

Whilst high rainfall growers were satisfied with lupins as a priority crop to provide diversification from livestock, this was not the case in the more traditional cropping regions where the stimulus for lupin production was its beneficial impacts on subsequent wheat crops. This was well illustrated at a field day held on the property of the EG Bakers and Sons at Rutherglen in 1976. We took the substantial field day crowd there to see a commercial lupin crop grown by the Bakers and although it was well grown and weed free, the growing season had been drier than average and the lupin crop was okay, but unspectacular. However, as we discussed the lupin crop, most of the farmers could hardly pay attention, as they were distracted by a wheat crop growing in the adjacent paddock, which despite the dry year was superb, with an expected yield of around 3-4 t/ha, well above the then district average. When we told them that the wheat crop was in fact a 10th cereal crop in 11 years, but that lupins had been grown in the paddock the year before, little more needed to be said as those farmers were already convinced!

Lessons learned and current relevance - *The lessons learned from those experiences are that there are different aspects of new technologies and that adoption is best stimulated when the aspects of most relevance and value to individual growers are clearly demonstrated. A good example of this in current times is auto-steer technology, where the major initial benefit espoused was the savings that would arise from unnecessary overlapping of fertiliser and spray applications. For many growers however, the subsequent personal benefits arising from better family time and thinking time, have far outweighed the material savings. I also believe that more intensive cropping within the framework of more diverse farming systems has the greatest chance of longer-term sustainability, provided that these systems are dynamic.*

3. Continuous cropping

As the economic forces that favoured cropping returns over livestock returns in mixed farming areas persisted throughout the following decades – from the1970s to the current century – more and more farmers intensified their cropping and in many cases totally disposed of livestock. The use of zero tillage, residue retention, cereals, oilseeds, pulses and widespread nitrogen fertiliser, herbicide and fungicide applications, have been the underlying 'sustainability props' for this intensification which continues to the current day. In contrast to ley farming where sustainability was rarely questioned until the systems started to collapse, intensive cropping has continually raised questions about its sustainability and those questions remain until this day. There have already been some major perturbations – herbicide resistant weeds; root diseases; nitrogen use (in)efficiency; soil health; narrow rotations – and the main question for all agronomists should be - which factors will prove to be the 'tipping points' that will overwhelm the sustainability of these systems? History tells us that this is highly likely to occur. However, there are other opinions as to the sustainability of continuous cropping systems and some quote the long-running paddy rice growing systems in Asia (e.g. Buresh and Wopereis 2014) as proof that such intensive systems can survive and remain productive. This may well be the case in some circumstances, but there are already emerging sustainability challenges to those rice systems (Cornell University 2017) and they are very, very different systems to our largely dryland winter cropping systems here. I have significant misgivings about the sustainability of the wheat-canola-wheat-canola rotations that are currently dominating Australian croplands, if significant diversification of these systems does not take place. They must be dynamic systems and include more legumes and where appropriate more livestock.

Lessons learned and current relevance – *Continuous cropping is still a current practice and the lessons to be learned will be for the future. However, if we become complacent about these systems and do not identify key 'tipping points' for sustainability, my experience is that narrow rotations such as continuous wheat-canola-wheat-canola will break down sooner rather than later.*

4. Sustainable intensification of agriculture – doing more with less

I have now reached the topic of the 18th Australian Agronomy Conference, 2017 – 'doing more with less'. I could make the case, given the first 25 years of my work were implicitly focused on sustainable farming systems, including more explicitly, during my period as Foundation Professor of Sustainable Agricultural Production at the University of Adelaide, that I have been working on 'doing more with less' from the outset. But it was not until I took up the most challenging, but most worthwhile job of my career, as Director General (DG) of CIMMYT in Mexico that I have explicitly concentrated on sustainable intensification, looking to produce 'more with less' (Foresight 2011).

When I arrived as the new CIMMYT DG in 1995, the centre was in need of re-generation and a renewal of its directions, after a distressing period of reduced resources, heavy staff cuts and strident criticism from some quarters that CIMMYT had become "arrogant" and was not prepared to face up to the 'post Green Revolution' era. I was told these things, by many important stakeholders including key investors and it was clearly important that CIMMYT responded appropriately. Whilst CIMMYT already had a strong agronomy program, headed up by one of the best agronomists that I have ever had the pleasure to work with – Dr Ken Sayre – this aspect of its work did not have a sufficiently high external profile. It was however highly valued by our partners in the countries of the South where CIMMYT worked and the agronomic work of Drs Peter Hobbs, Raj Gupta and Craig Meisner in South Asia; of Dr Pat Wall in South America; of Dr Ivan Ortiz-Monasterio in Mexico; and of Dr Ken Sayre globally, was of the very highest order. Despite this, CIMMYT was deemed by many key stakeholders 'to not be taking sustainability importantly enough'

One of my first responses to this situation was to establish a Natural Resources Group at CIMMYT, headed up by Dr Larry Harrington and provide it with modelling and GIS capabilities that could support our agronomy/sustainability research and development around the world. Importantly, this also sent a clear message to CIMMYT's stakeholders – including its critics – it was not 'business as usual' and that things were changing. I also adopted and promulgated a new paradigm for CIMMYT's work – G x E x M x P – genotype, by environment, by management, by people/participation (Reeves 1998). The clear and explicit additions of 'management' and 'people/participation' resonated favourably with stakeholders including investors.

In order to formally document this change in emphasis at CIMMYT, I published 'Sustainable Intensification of Agriculture' (Reeves 1998; Reeves 1999) which firmly placed CIMMYT's work in a new framework that was well accepted by partners and other key stakeholders. This publication was one of the first in the world on the topic and was preceded only by Professor Jules Pretty (Pretty 1997) although I was unaware of this at the time. It is interesting to note that today 'sustainable intensification' is CIMMYT's largest program, a remarkable change from the times when the wheat and maize programs dominated the budget. The latter are of course still very large and hugely important, but the framework for their implementation is now more clearly focused on sustainability.

In recent years, I have had the privilege to be heavily involved with FAO (the Food and Agriculture Organisation of the United Nations) helping them to develop and drive their program on sustainable intensification, which they have branded 'Save and Grow'. I was Technical Editor of their first publication on this topic 'Save and Grow – a Policymaker's guide to the sustainable intensification of smallholder crop production' (FAO 2011a) and Lead Author for their second publication 'Save and Grow in Practice – Maize, Rice and Wheat; a guide to sustainable production' (FAO 2016). Both of these publications are most apposite for the theme of this 18th Agronomy Conference, 'doing more with less'.

Save and Grow farming systems are based on five complementary components and their related practices (FAO 2016):

- **Conservation agriculture** (CA) through minimal soil disturbance, the use of surface mulches and crop rotation, and the integrated production of crops, livestock and trees
- **Healthy soil**, through integrated soil nutrition management, which enhances crop growth, and bolsters stress tolerance and promotes higher input-use efficiency
- **Improved crops and varieties** adapted to smallholder farming systems, with high yield potential, resistance to biotic and abiotic stresses and with higher nutritional quality
- **Efficient water management** that obtains 'more crop per drop', improves labour and energy-use efficiency, and helps reduce agricultural water pollution
- **Integrated pest management** (IPM) based on good farming practices, more resistant varieties, natural enemies, and judicious use of relatively safer pesticides when necessary

In the couple of years that have elapsed since writing this, I have made some modifications to these components/practices in my thoughts and presentations on sustainable intensification. Firstly, I am now strongly of the belief that sustainable intensification must be implemented along the whole agri-food value chain, rather than just at the farm level. It is essential that efficiencies gained in one link of that chain are not lost in another. Secondly, livestock systems need to be more explicitly included in sustainable intensification. Most of the practices shown above are also relevant to livestock based systems but rather than just "improved crops and varieties" this statement should be broadened to include 'better and more resilient and more efficient animals'. Likewise, for "efficient water management" and "IPM", where it is also desirable to make these broad enough to explicitly include livestock.

I believe that the widespread implementation of sustainable intensification 'producing more with less' is absolutely paramount if the world is to ensure future food and nutritional security. Sustainable intensification systems are scale neutral and whilst their implementation differs between larger farms in industrialised countries and smallholder farms in developing countries, the underlying principles and practices are substantially the same.

The question remains as to how we are doing both globally, and in Australia, with sustainable intensification and the challenge of achieving global food and nutritional security by 2050 and beyond? The final section of this paper addresses these issues.

Lessons learned and current relevance – Sustainable intensification is a current practice and there will no doubt be lessons to be learned but at some time in the future.

Overcoming the Grand Challenges to Global Food and Nutritional Security

In 2009, Sir John Beddington stated that the world could be facing a 'perfect storm' of global events associated with food, energy, water and the climate, which could cause major disruptions by 2030 (Beddington 2009; Foresight 2011). In the eight years that have elapsed since he made his warning, it is my opinion that the prospects of a 'perfect storm' for global food and nutritional security have become even more likely and the challenges even more complex. As affirmation of this, 2016/17 is the first time since the turn of the century that the number of hungry people in the world has increased, with both conflict and climate change implicated in the upturn (FAO 2017).

Earlier in 2017, drawing on my 50 years of experience, I presented what I consider to be the 'grand challenges' to food and nutritional security in the context of this 'perfect storm' (http://upclose.unimelb.edu.au/episode/392-feeding-9-billion-inconvenient-truths-about-global-food-security).

By 2060, the world has to double food calorie production in order to feed a global population that is still growing at around 150 people/minute and this extra production will have to come using less land, less water, and with less energy-rich inputs. Compounding this already daunting task is changing dietary preference for more consumption of meat, particularly by the growing global 'middle class' and more particularly in Asia. More people, more food, changing diets, less land, less water and less energy rich inputs, are challenging enough even when considered in isolation, but much more so when combined. And there are three other key factors that add further layers of complexity – the urgent need for enhanced nutritional security; the urgent need to reduce greenhouse gas emissions from agriculture; and the potential multiplier effect of climate change (IAASTD 2016). If ever there was a compelling case to say that 'business as usual' is not a viable option, this scenario is surely it. Sustainability remains as elusive as ever.

In terms of nutrition, the world is already faced with the 'triple burden of food and nutritional security' (Pretty and Bharucha 2014) with around 0.815 billion people chronically under-nourished; 2 billion people suffering from malnutrition due to vitamin and trace element deficiencies in their diets; and over 1 billion people suffering from over-nutrition due to excessive consumption of calorie rich foods and drinks, with resultant impacts on obesity and associated metabolic diseases.

At the Crawford Fund's Annual Parliamentary Conference in 2012, Professor Jonathan Foley (Foley 2012) made the following assessment:

> *"That makes three challenges: feed the world, feed the future, address sustainability. Each one of those challenges is daunting, and we must solve all three, and at exactly the same time, over the next 30-40 years. This new combined challenge is unprecedented in human history, and it brings in multiple disciplines and multiple outcomes.*
> *How are we doing so far? In a word, badly"*

His conclusion was mainly based on concerns for environmental degradation caused by agriculture, but could equally have been about shortcomings around nutritional security. As the great Indian icon Dr M S Swaminathan, recently stated 'It is time for a nutrition revolution' (Swaminathan 2017). The United Nations Sustainable Development Goals further reinforce this sentiment.

By effectively tackling the 'grand challenges' I believe that we can do better for food and nutritional security, both in Australia and globally.

1. GRAND CHALLENGE (GC) – LOSS AND DEGRADATION OF NATURAL RESOURCES (Land, Water, Air)

Prime agricultural land is being lost at an alarming rate around the world. Depending on which source of data one uses, the range of losses is from around 1 to 7 million hectares/year (various sources). For convenience, I have therefore settled on a figure of 3 million ha/year, which is alarming. As a result of population increase and land losses, the area of arable land per capita has decreased from almost 0.35ha/person when I started my career as an agronomist, to less than 0.2 ha/person now (World Development Indicators and World Population Statistics). In addition, of the land remaining in agriculture, much is degraded, some severely, resulting in lowered productivity (FAO 2015). More people, more food and more nutritious food required, but less land on which to produce it. This is a major challenge in its own right. Giving much greater emphasis to enhanced soil health and better soil fertility in the lands remaining is therefore of paramount importance.

At least 70% of global freshwater withdrawals are used for agriculture (OECD 2017), with around 45% of global cereal crop production coming from irrigated systems. However, the irrigation efficiency of some of these systems is less than 50%. There has also been a rapid increase in competition for water resources between agriculture and other uses including for urban, industrial and environmental purposes and this competition will only be exacerbated in coming years. On current trends, global blue water withdrawals would approximately double by 2050 compared to 2000 levels. With 'business as usual' this additional water will simply not be available. Water stress will increase in many agricultural areas by 2025 due to growing water use and higher temperatures (IPCC Scenario A1B). Agriculture must not only increase water-use efficiency but also reduce overall water consumption – a major challenge.

Lastly, in relation to GC1 on loss of natural resources, is the major issue of greenhouse gas (GHG) emissions from agriculture. It is estimated that around 24 to 30% of current global GHG emissions come from agriculture. If food production is to be doubled by 2060 and current production methods are used, then it is estimated that this figure would rise to 70% of global GHG emissions, a clearly unsustainable scenario, as it would provide almost no scope for any other sectors to achieve realistic reductions and still remain productive. GHG emissions from agriculture must therefore be reduced.

Natural Resources – what needs to be done?

- *Development of integrated policy frameworks across the water-agriculture-food-energy-environment-population nexus*
- *Increased WUE and reduced water consumption*
- *Clear policies and strategies for peri-urban and urban agri-food production and associated land use planning*
- *Increased emphasis on soil health and fertility including 'tipping points'*
- *Conservation agriculture and sustainable intensification essential*
- *Farm enterprise choices based on input-use efficiencies*
- *Mitigation of GHG emissions by use of BMP to avoid future 'right to farm' challenges*

2. GRAND CHALLENGE – ADAPTATION TO CLIMATE CHANGE

In February 2015, the Director General of FAO made the following headline statement "The impacts of climate change are no longer an anticipated threat." This seemed to be a pretty bold statement if one did not read on. His full statement was: "The impacts of climate change are no longer an anticipated threat. They are now a crystal-clear reality right before our eyes. Climate change will not only affect food production but also the availability of food and the stability of supplies. And in a global, interdependent economy, climate change makes the global market for agricultural products less predictable and more volatile."

There is no doubt that if the world is to achieve global food and nutritional security that adaptation of our farming systems to climate change is absolutely critical. Climate-smart agriculture is required and sustainable intensification can help us deliver more adaptive and more resilient production systems.

Most studies project net adverse impacts on crop yields due to climate change, and many of those adverse effects will be felt in regions that are at the forefront of both food production and food consumption, including South Asia; West Asia and North Africa; parts of East Asia; major areas of Sub-Saharan Africa; and large areas of South America (World Bank 2010).

These impacts have been confirmed from some of my own experiences working in these regions over the past couple of decades. For example, in a review that I chaired for FAO and the Government of India in 2009, on the impacts of climate change on Indian wheat production, farmers in NW India told us that the water level in their tube wells was falling by from 1 to 2 m per year, well above the overall NASA monitoring assessments of around 0.4 m per year – substantial in itself. These unsustainable water reductions were considered to have resulted from over-use of water as a consequence of two factors. Firstly, perverse policy settings that provide substantial subsidies for the costs of pumping water. Secondly, due to the changing climate whereby some aquifers are no longer being adequately replenished during the annual monsoon season (FAO 2009).

Most of the indicators for climate change in Australia – including annual average temperature increases, with 2017 being Australia's warmest winter on record – an occurrence that the Climate Council reports was 60 times more likely to have been caused by climate change; greater climate variability – although a recent article disputes this (Freebairn 2017); a higher incidence of extreme events – more likely to have occurred due to climate change (Graham and Eckard 2017); and reduced run-off in many regions (BOM 2016), paint an equally concerning scenario here (Alexander et al. 2017). The paper published earlier this year by Dr Zvi Hochman and colleagues "Climate trends account for stalled wheat yields in Australia since 1990" (Hochman et al.2017), is perhaps the most clarion call for more emphasis on adaptation to climate change and that 'business as usual' is unlikely to be viable. On the positive side, the authors pointed out that whilst wheat yield potential had decreased by 26% over the study period, actual yields had generally not fallen so markedly, as technology gains – read 'adaptation' – had been able to offset the potential losses. The question remains as to whether the future rate of technology gains can keep pace with the impacts of a changing climate, where much of the Australian cropping regions are likely to get warmer and dryer. Greater, longer-term and patient research investment is urgently needed to maintain and hopefully increase, the rates of adaptation in all major crop and forage farming systems.

Adaptation to climate change – what needs to be done?

- *National adaptation strategies for agriculture where all innovation is evaluated through the 'lens' of climate change*
- *Substantial, long-term, patient co-investment in adaptation by public and private sectors*
- *Farming systems that are more resilient and adaptable and based on sustainable intensification*
- *Infrastructure that both helps adaptation and is itself adapted to climate change*

3. GRAND CHALLENGE – NITROGEN USE (IN)EFFICIENCY

Nitrogen fertilisers account for over 50% of the protein in human diets and are therefore critical to global food and nutritional security. However, the 'elephant in the room' for these fertilisers is that nitrogen-use efficiency (NUE) only averages around 50% and the economic and environmental costs of low NUE are substantial and unsustainable (The Conversation 2016). Already, some countries and regions are basing 'right to farm' challenges on environmental damage caused by losses of nitrogen from farming systems (e.g. Dairy NZ 2014).

Global nitrogen fertiliser use has increased at a rate much greater than population growth and this dependence on N fertilisers often been accompanied by less use of biologically fixed nitrogen from legumes. Legume-based cropping systems have been shown to reduce carbon and nitrogen losses in many situations (e.g. Drinkwater et al. 1998; Migliorati et al. 2015). I believe that we need to urgently review our investments in legumes, here in Australia and globally, in order to re-invigorate their usage on farms. In the global scene, the CGIAR has not yet approved and funded the 'Grain Legume and Dryland Cereals' CRP and this is a situation that needs to be rectified immediately. Here in Australia, we have conclusive evidence around the importance of pulses and forage legumes in our farming systems (e.g. Peoples et al. 2013; Seymour et al. 2012) but their uptake remains static. This also needs to be addressed and the reasons – particularly the factors influencing farmer decision-making – investigated, so that new and effective strategies can be implemented. Legumes in global and local farming systems can have major beneficial impacts on food and nutritional security; on more diverse and resilient farming systems; and on reducing nitrogen losses and environmental impacts.

Of particular concern globally, is that nitrogen-use efficiency has reduced substantially since the 1960s (Tilman et al. 2002). As a result, these increasing losses have not only resulted in economic losses on farms, but have also contributed to the “Nitrogen Cascade” and resultant environmental damage described by Professor Galloway during his visit to Melbourne in 2016 (Galloway et al. 2016). In Australia, due to our high consumption of animal products, we have one of the world’s largest per capita ‘nitrogen footprints’ – around 47 kg N /person (c.f. 28 kg N/person in the US) another indicator that ‘business as usual’ is not sustainable (The Conversation 2016).

A lesser concern expressed around nitrogen fertilisers, but still of significance, is that urea the most widely used form globally, is a product that requires the use of ‘fossil fuel’ – natural gas – in its manufacture, with around 4 barrels of ‘energy equivalent’ being required to manufacture 1tonne of urea. Given the needs to reduce GHG emissions from the sector this could be seen as counter-productive and raises the question as to the development of other forms of N fertilisers that are not based on ‘fossil fuels’ (IAASTD 2016). We know that there is plenty of work on reducing dependency on fossil fuels in the energy, automobile and housing industries but is there any progress with regards to alternative processes for N fertiliser production?

Nitrogen efficiency - what needs to be done?

- *Greater investment in energy-efficient fertilisers and better technologies*
- *Re-invigoration and re-investment in legumes RDE emphasising sustainability*
- *Real-time testing for mineralised soil nitrogen*
- *Enhanced Best Management Practices (BMP) for N use*
- *Regulatory framework for N use based on BMP*
- *Community education around our ‘N footprint’*

4. GRAND CHALLENGE – FOOD LOSS AND WASTE

FAO has estimated that of the food produced globally, 32% by weight and 24% by calories is lost or wasted! (FAO 2011b). This does not make economic or environmental sense – in fact, the complete opposite - and if we could reduce the rate of food loss and waste it would not only have substantial beneficial impacts on global food and nutritional security, but also on important sustainability issues. This is an issue that provides both huge challenges and huge opportunities for improvement.

Unsurprisingly, the extent and the sources of food loss and waste vary around the world and Figure 1 below illustrates this well. Of significant concern is the high proportion of food losses and waste at the farm level in Sub-Saharan Africa, arising from problems with both production and storage and handling. There must be even greater investment by the international community in overcoming these problems. However, levels of per capita food loss and waste are higher in Europe and Industrialised Asia, whilst North America and Oceania have the highest per capita food loss and waste by a significant margin, with around 60% of that occurring at the consumption level!

There are a number of factors that I believe are influencing and exacerbating the profligate and unsustainable levels of loss and wastage in Oceania and North America. Taking Australia as an example, conservative use-by dates and ‘over–the-top’ specifications for products in supermarkets are both significant contributors. Both result in unnecessary rejection of products and resultant wastage. However, my main hypothesis is that a major underlying cause of our extreme levels of wastage, arises because many of us in the Western world have lost our respect for food, treating it as a commodity that will always be there and that we can take as much of as we wish, regardless of cost or real needs (Reeves 2017). Such an attitude – which is in sharp contrast to the great respect for food in most developing countries – results in over-purchasing, excessive portion sizes for meals and in many cases over-consumption. When we phone up the pizza shop with our order and they say ‘We can give you two for the price of one’, there are many of us who should say ‘Why?’ rather than ‘Why not?’…

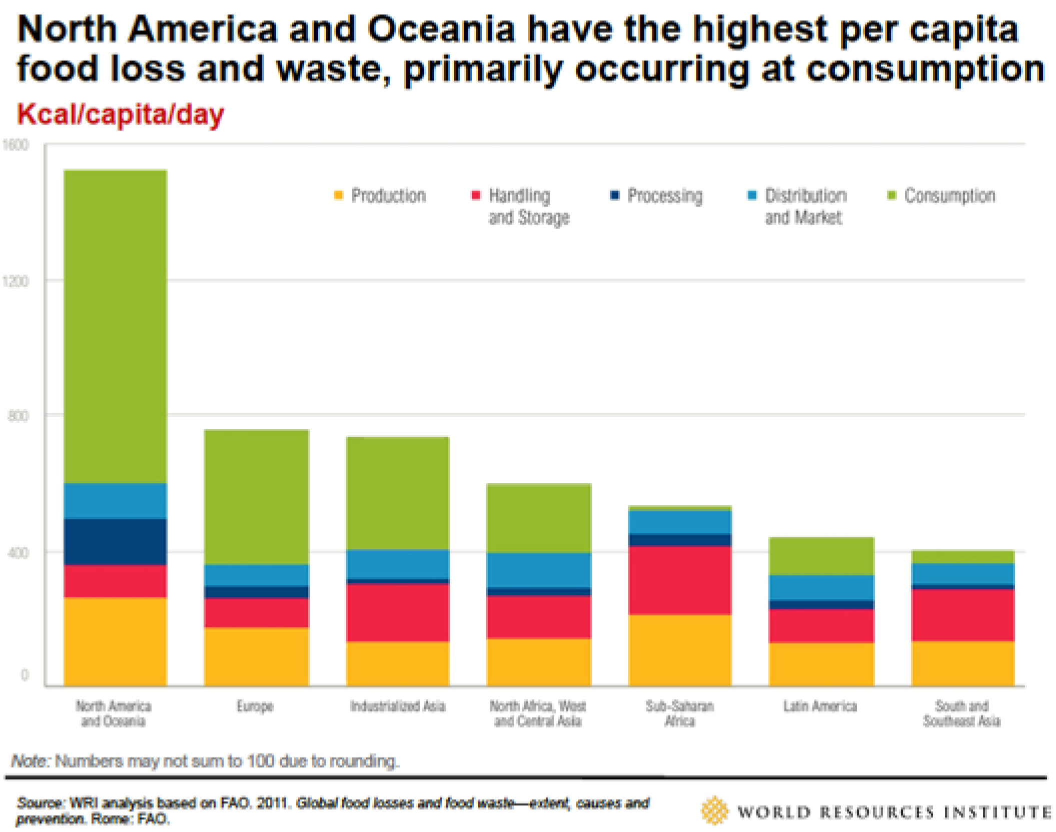

Figure 1. Variation in food loss and waste from various stages of food production and consumption around the world.

Dietary choice can also have an important part to play in food loss and waste and the sustainability of farming systems. The following are some examples drawn from the literature:

- If the rate of food wastage is reduced by 50% by 2050 – the 'food gap' would be reduced by 22% (Lipinski et al. 2013)
- If all consumers were vegetarians and ate to nutritional guidelines it would reduce global nitrogen usage by 50% (Galloway et al.2016)
- The average daily (embedded) water consumption of a meat-eating person is twice that of a vegetarian (www.angelamorelli.com/water)

Food loss and waste – what needs to be done?

- *Value-chain nexus approaches to reducing loss and waste*
- *Setting food loss and waste reduction targets to drive strategy*
- *Investment in RDE to reduce post-harvest losses for smallholder farmers*
- *Increased food re-cycling/'second harvest' approaches and less conservative use-by dates (industrialised countries)*
- *Respect for food – purchasing, portion sizes and consumption (industrialised countries)*

5. GRAND CHALLENGE – (Benign) NEGLECT AND EROSION OF RURAL COMMUNITIES

This is a major global issue that is already having significant implications for food and nutritional security. It is estimated that 70% of the world's population will be globalised by 2050 and that figure already stands around 50%, including in some developing countries. This rapid urbanisation of communities poses some key policy dilemmas for government decision-makers. Not the least of these is the ongoing tension between affordable food costs for city-dwellers and high enough prices for farm products, that allow farmers to make a profit and stay in the business of food production. It is common to hear politicians refer to their determination to keep food affordable, but it is much less common to hear them espouse similar determination to keep farms profitable. The achievement of both is absolutely critical to future food and nutritional security.

One of the main reasons for the migration from rural areas to the cities in many countries – both developing and industrialised – is the steady erosion of infrastructure and essential services in rural areas, leading to continual rural restructuring and demographic changes. This is not a new phenomenon and the outstanding social researcher Neil Barr, has stated that in the average lifetime of an Australian farmer s/he can expect the number of local farms to halve in number (Barr 2009).

In addition, there is a range of other socio-economic issues that disproportionately affect rural communities. Alston (2011) lists some of these:

- High levels of rural poverty
- Out-migration
- Masculinisation of remote communities
- Higher unemployment
- Poorer health
- Lower levels of education
- Higher levels of ageing
- Poorer service infrastructure

I have talked to some long-standing friends who still live in rural areas in Australia and their thoughts reflect many of the points made by Professor Alston. They add additional concerns around health and safety – particularly around increased illicit drug usage; the demise of social and sporting clubs due to population decreases; and the ICT 'divide' between connectivity in metropolitan and rural areas. I have other friends who run a $20 million farming business, but who cannot get mobile phone reception or internet access at their home. Their home is not 'beyond the black stump' but less than 300 km from Melbourne! Would a business in Melbourne tolerate such poor services? We all know the answer – a resounding 'NO!'. But if you live in the country, all too often this is the type of issue that is commonplace. Technological changes and climate change have added to the uncertainties facing rural communities.

These principles and deficiencies are common to both developing countries – where the problems can be even more severe – and industrialised countries. Future food and nutritional security will only be achieved if farmers can access the services and infrastructure that they require to remain productive, profitable and sustainable. Governments and other key decision-makers must address these issues with urgency!

Rural communities – what needs to be done?

- *Development of a clear vision, strategy and investment plan for rural regions*
- *Cohesive and supportive policy framework*
- *Greater rural community participation in policy advice*
- *Immediate attention to assessing the impacts of technological changes and climate change*
- *Further decentralisation of government services to rural areas*

Conclusions and final thoughts on the pursuit of sustainable agriculture…

I have tried to capture my key thoughts and recommendations throughout the text of this paper, in the form of 'lessons learned and current relevance' and also under the headings of 'what needs to be done?' in the context of the 'Grand Challenges'. However, I believe that there are some overall priorities for agronomy and all of its related disciplines, if we are to achieve global food and nutritional security, efficiently and sustainably. We have no choice, as the feeding of humankind is the most important and fundamental challenge facing us all – food and nutrition are part of, or implicated in all of the United Nations' Sustainable Development Goals. My priorities are:

I. Tackle **nexus** issues more effectively: e.g. **Agriculture-food-water-energy-climate change. Agriculture-food-nutrition-human health**
II. Implement **Sustainable Intensification** in agri-food chains including **Conservation Agriculture** on farms
III. Develop a cohesive policy framework and strategy to reduce **food loss and waste**
IV. Develop a vision, policy framework and strategy for **rural communities**
V. Implement **better targeted, longer-term, patient co-investment** in RDE, education and infrastructure for **sustainability**

Overall, I remain optimistic about the prospects for continuing success, but not with 'business as usual'. We must tackle the 'grand challenges' and related issues effectively and with urgency. This will only occur if we embrace the opportunities for enhanced development by integrating first-class agronomy with the new and emerging technologies arising from the 'digital revolution' (the agriculture sector currently has the lowest adoption rate), genomics and advanced breeding methodologies, materials science and other disruptive and transformational developments. As agronomists and agricultural scientists we are working in a most noble profession, but the job is far from over and you must carry the baton forward with renewed vigour and determination. For me it has been a great privilege to serve as an agronomist both here in Australia and in the developing world; with apologies to A B Facey, I have had a most 'fortunate life'. Thank you again to the Australian Society of Agronomy for this great honour and to all who have had confidence in me.

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It gives me great pleasure to be able to formally acknowledge my wonderful family who have provided love and great support to me from the outset. For the first 33 years of my working life I was blessed to have my first wife Pat alongside me, from the time in 1967 that we both stepped onto the SS Oriana in Southampton, until her tragic passing in 1999 – RIP and thank you Pat for taking the chance. She and our children were 'part and parcel' of an agronomist's life and I believe that my children have probably seen (and hidden amongst!) more field research plots than many agronomists! In later post-Mexico life, I have been most fortunate since 2003 to have the love and support of my wife Patricia Lopez, who has also been an invaluable and highly professional part of our global and national consulting business.

I would also like to acknowledge and congratulate other recently 'retired' agronomists, or who are on the way there (!), whom I believe have made excellent contributions and these include (but are not limited to) - Deirdre Lemerle, John Angus, Mick Poole, Harm van Rees (still going, I know Harm!), David Coventry, and Colin Piggin (and the late John Sykes of Albury, NSW would also have been part of this list). It could easily have been one of you standing here and I salute and thank you all.

References

Alexander D, Steffen W and Hughes L (2017). Hot and dry: Australia's weird winter. Climate Council. (http://www.climatecouncil.org.au/uploads/4801d325365bccdbbb99a1ce8e8e9810.pdf).

Alston M (2011). Social implications of climate change (Powerpoint presentation). Gender, leadership and social sustainability (GLASS), Monash University. Available at (https://www.slideshare.net/ccrspi/social-implications-of-climate-change-margaret-alston?qid=5db6f221-6575-46bf-ab65-106a8026d032&v=&b=&from_search=1).

Barr N (2009). The House on the Hill: The transformation of Australia's Farming Communities, Canberra, ACT.

Beddington, J (2009). Food, energy, water and the climate: a perfect storm of global events? The Government Office for Science, London, UK.

BOM (2016). Australian Government Bureau of Meteorology 'State of the Climate 2016'. (www.bom.gov.au/state-of-the-climate).

Buresh RJ and Wopereis M (2014). Save and Grow: Rice. Paper prepared for the FAO Technical Consultation on Save and Grow: Maize, Rice and Wheat, 15-17 December 2014. FAO, Rome, Italy.

Cornell University (2017). SRI International Network and Resources Center. (http://sri.ciifad.cornell.edu).

Coventry DR, Hirth JR, Reeves TG and Burnett VF (1985). Growth and nitrogen fixation by subterranean clover in response to inoculation, molybdenum application and soil amendment with lime. Soil Biological Biochemistry 17, 791-796.

Coventry DR , Reeves TG , Brooke HD and Cann D (1993). Influence of genotype, sowing date, and seeding rate on wheat development and yield. Australian Journal of Experimental Agriculture 33, 751-757.

Coventry DR, Hirth JR and Reeves TG (1992). Interactions of tillage and lime in wheat-subterranean clover rotations on an acidic sandy clay loam in southeastern Australia. Soil and Tillage Research. 25, 53-65.

D'Emden FH, Llewellyn RS and Burton MP (2008). Factors influencing adoption of conservation tillage in Australian cropping regions. Australian Journal of Agricultural Resource Economics 52 (2), 169-182.

Dairy NZ (2014). Canterbury Environmental Policy. (https://www.dairynz.co.nz/environment/in-your-region/canterbury-environmental-policy/).

Dolling PJ (1996). Effect of legume cereal rotation on soil acidification in Western Australian Soils. In: Proceedings of the IV International Symposium on Plant and Soil Interactions at low pH. Belo Horizonte, March 1996. Brazil. Pp. 17-24. P2.

Donald CM (1965). The progress of Australian agriculture and the role of pastures in environmental change. The Australian Journal of Science 27 (7), 187-198.

Drinkwater LE, Wagoner P and Sarrantonio M (1998). Legume-based cropping systems have reduced carbon and nitrogen losses. Nature 396, 262-265.

Ellington A (1986). Effects of deep ripping, direct drilling, gypsum and lime on soils, wheat growth and yield. Soil and Tillage Research 8, 29-49.

Ellington A and Reeves TG (1978). Minimum cultivation saves soil, time and energy. Journal of Agriculture, Victoria. April 1978.

Ellington A and Reeves TG (1990). Regulation of soil nitrogen release for wheat, by direct drilling following clover pasture. Soil and Tillage Research 17, 125-142.

FAO (2009). A report of the impacts of climate change on wheat production in India. Rome, Italy.

FAO (2011a). Save and Grow: A policymaker's guide to the sustainable intensification of smallholder crop production. Rome, Italy.

FAO (2011b). The State of the World's Land and Water Resources for Food and Agriculture (SOLAW). (http://www.fao.org/nr/solaw/solaw-home/en/).

FAO (2015). Agriculture must change. FAO News Article. (http://www.fao.org/news/story/en/item/278(192/icode/).

FAO (2016). Save and Grow in Practice. Maize, Rice, Wheat – a guide to sustainable cereal production. Rome, Italy.

FAO (2017). After years of decline, world hunger is on increase. Jose Graciano da Silva, FAO Biennial Conference 2017, Rome, Italy.

Foley J (2012). Can we feed a growing world and sustain the planet? Keynote Address. Proceedings of the Crawford Fund 2012 Annual Parliamentary Conference, Canberra, ACT.

Foresight (2011). The Future of Food and Farming - Final Project Report. The Government Office for Science, London, UK.

Freebairn D (2017). Is climate variability really on the rise? (https://www.graincentral.com/weather/is-climate-variability-really-on-the-rise/).

Galloway JN, Leach AM, Erisman JW and Bleeker A (2016). Moving from nitrogen ignorance to knowledge over time. In: Proceedings of the 2016 International Nitrogen Initiative Conference Solutions to improve nitrogen use efficiency for the world, 4-8 December 2016, Melbourne, Australia.

Gladstones JS, Atkins CA and Hamblin J (1998). Lupins as crop plants: biology, production, and utilization. In: JS Gladstones, CA Atkins and J Hamblin Eds. CAB International Wallingford, Oxon, UK; New York, NY, USA.

Graham AM and Eckard R (2017). Extreme weather: Why the impact will be felt more widely. Agriculture. (https://pursuit.unimelb.edu.au/articles/extreme-weather-why-the-impact-will-be-felt-more-widely).

Helyar KR (1990). Soil acidity in NSW, current pH values and estimates of acidification rates. Australian Journal of Soil Research 28, 523-537.

Hochman Z, Gobbett DL and Horan H (2017). Climate trends account for stalled wheat yields in Australia since 1990. Global Change Biology 23, 2071–2081. (doi:10.1111/gcb.13604).

IAASTD (2016). Agriculture at a crossroads. (http://www.globalagriculture.org/fileadmin/files/weltagrarbericht/EnglishBrochure/BrochureIAASTD_en_web_small.pdf).

ICI (1973). Dr W.R. 'Bill' Boon, Pioneer of Paraquat. ICI Magazine, Museum of English Rural Life, UK.

Lipinski B, Hanson C, Waite R, Searchinger T, Lomax J and Kitinoja L (2013). Reducing Food Loss and Waste. Working Paper, Instalment 2 of Creating a Sustainable Food Future. Washington, DC. World Resources Institute. (http://www.wri.org/sites/default/files/reducing_food_loss_and_waste.pdf).

McGowan AA (1967). Ecological studies of Wimmera ryegrass and associated annual grasses in the clover ley rotation in NE Victoria. M Agr Sc Thesis, University of Melbourne, Melbourne VIC.

Migliorati M, Bell M, Grace P, Scheera C, Rowling DW and Liuc S (2015). Legume pastures can reduce N2O emissions intensity in subtropical cereal cropping systems. Agriculture, Ecosystems and Environment 204, 27-39.

NLA Trove (1981). Soil conditions and plant growth: annual field day 22 October 1981, Rutherglen Research Institute. (http://trove.nla.gov.au/work/25998827?q&versionId=31328246).

NLA Trove (2016). Direct drilling farming in Australia, oral history project. (http://trove.nla.gov.au/version/232100088).

OECD (2017) Water use in agriculture. (http://www.oecd.org/agriculture/water-use-in-agriculture.htm).

Peoples M, Hunt J, Swan T, Watson L, Li G, Lowrie R, Breust P, Browne C and Craig S (2013). Doing the numbers – The role and contribution of break crops in cropping systems, GRDC updates 2013.

Powles SB and Holtum JAM (1990). Herbicide Resistance Weeds in Australia. In: Proceedings of the 9th Australian Weeds Conference, 6-10 August 1990. Adelaide, South Australia.

Pretty J and Bharucha ZP (2014). Sustainable intensification in agricultural systems, Annals of Botany 114 (8), 1571–1596. (https://doi.org/10.1093/aob/mcu205).

Pretty JN (1997). The sustainable intensification of agriculture. Natural Resources Forum 21, 247–256.

Puckridge DW and French RJ (1983) The annual legume pasture in cereal—Ley farming systems of southern Australia: A review. Agriculture, Ecosystems and Environment 9 (3), 229-267.

Reeves TG (1975). Changes in composition of the weed flora in successive wheat crops as influenced by cultivation and herbicide. In: Proceedings of the Fifth Asian-Pacific Weed Science Society Conference pp. 325-329. 9-11 October 1975, Tokyo, Japan.

Reeves TG (1984) Lupins in crop rotations. Technical Report Series No 97, October 1984, Department of Agriculture Victoria.

Reeves TG (1992). Farming systems research: a national perspective. Australian Journal of Experimental Agriculture 32, A3-A9.

Reeves TG (1998). Sustainable Intensification of Agriculture. Mexico DF, CIMMYT.

Reeves TG (1999). Intensification for the nine billion. Nature Biotechnology 17, BV33 - BV34.

Reeves TG (2017). Meeting the Challenges of Global Food and Nutritional Security. In: Our Changing Climate. Climate change mitigation and adaptation: Managing our climate and society. ATSE Focus issue 202 June 2017 pp. 37-40.

Reeves TG and Tuohey CL (1972). The selective chemical control of Wimmera ryegrass in wheat with di-allate and tri-allate. Australian Journal of Experimental Agriculture 12, 55-59.

Reeves TG and Ellington A (1974). Direct drilling experiments with wheat. Australian Journal of Experimental Agriculture and Animal Husbandry 14, April 1974.

Reeves TG and Lumb JM (1974). Selective chemical control of annual ryegrass (*Lolium rigidum*) in oilseed rape, field peas and lupins. Australian Journal of Experimental Agriculture 14, 771-776.

Reeves TG, Ellington A and Brooke HD (1984a). Effects of lupin-wheat rotations on soil fertility, crop disease and crop yields. Australian Journal of Experimental Agriculture and Animal Husbandry 24, 595-600.

Reeves TG, Haines PJ and Coventry DR (1984b). Growth of wheat and subterranean clover on soil artificially compacted at various depths. Plant and Soil 80 (1), 135-138.

Seymour M, Kirkegaard JA, Peoples MB, White PF and French RJ (2012). Break-crop benefits to wheat in Western Australia – insights from over three decades of research. Crop and Pasture Science 63, 1-16.

Steed GR, Reeves TG and Willatt ST (1987). Effects of deep ripping and liming on soil water deficits, sorptivity and penetrometer resistance. Australian Journal of Experimental Agriculture 27, 701-705.

Swaminathan MS (2017). Time ripe for a nutrition revolution: MS Swaminathan. (http://economictimes.indiatimes.com/news/economy/agriculture/time-ripe-for-a-nutrition-revolution-ms-swaminathan/articleshow/59992144.cms).

The Conversation (2016). Nitrogen pollution: the forgotten element of climate change. (http://theconversation.com/nitrogen-pollution-the-forgotten-element-of-climate-change-69348).

Tilman D, Cassman KG, Matson PA, Naylor R and Polasky S (2002). Agricultural sustainability and intensive production practices. Nature 418, 671-677.

World Bank (2010). World Development Report 010: Development and Climate Change. Washington, DC © World Bank (https://openknowledge.worldbank.org/handle/10986/4387). License CC BY 3.0 IGO.