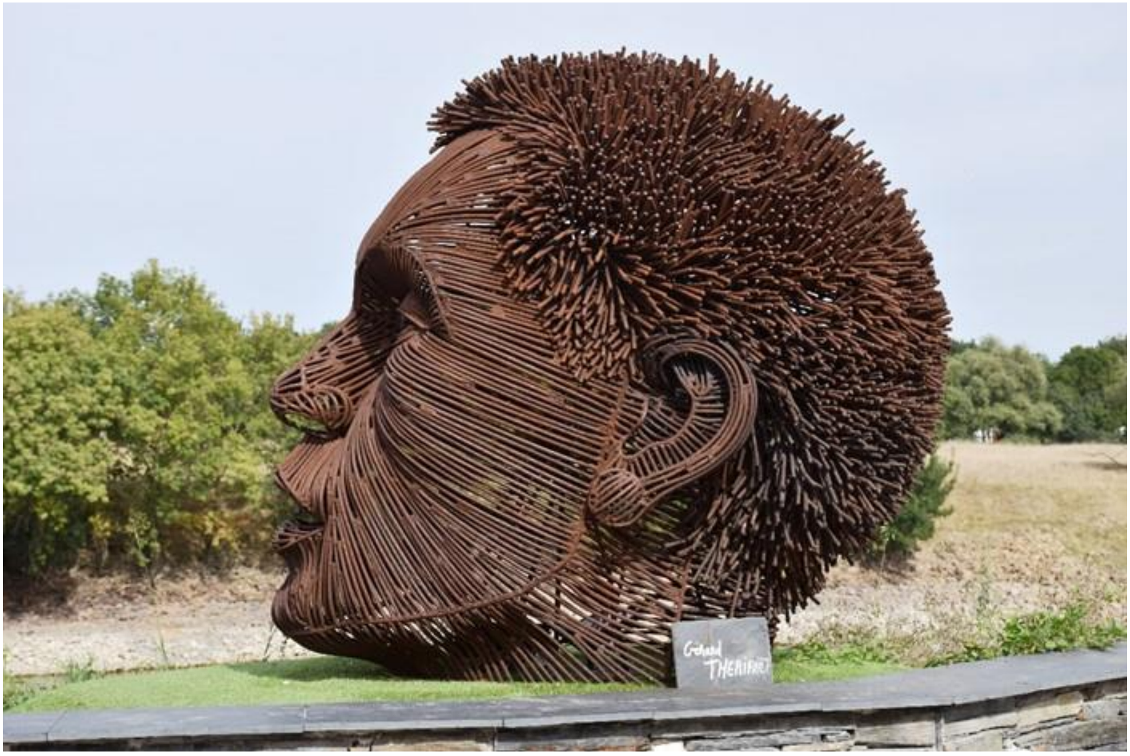
Report to Perpetual Guardian Trust

Trimble Grant Report
on
Agricultural Thinking Tour of Europe



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1 Executive Summary

This report summarises my impressions of European agricultural science from the European Society of Agronomy meeting (Geneva, Switzerland), agricultural research and teaching discussions at Montpellier and lucerne modelling and ecophysiology at INRA, Lusignan (France). The emphasis is on my interpretation and relevance to agriculture in New Zealand. Perhaps the most important contribution from this grant was that it gave me the time and space to think, investigate and discuss – unencumbered by other duties – and for that I am extremely grateful to the Trust. I embraced that opportunity and thus this report reflects those musings as well as the physical and utilitarian aspects.

In summary, European agricultural science has promoted organic production for 30+ years. The uptake has been limited, with less than 1% internationally and 6% in Europe supported through subsidies. Organic production reduces yield by ~20% across crops and this means more land is required for the same level of production. Price premiums do not compensate for the lower yield, quality and increased work that organic production requires. In Europe, farmers have continued conventional cultivation and intensification despite incentives to the contrary.

Nitrate in water has been used to reduce agricultural production in Europe with no scientific evidence of any harm to human health. Nitrate is not responsible for "blue baby syndrome" which is caused by bacteria. Nitrate is produced and retained within human bodies to fight bacterial infections and is used e.g. in canning to prevent botulism. Nitrate does lead to eutrophication in fresh water ways when phosphorous is present. NZ should avoid the entry of nitrate into closed catchments such as lakes. At current levels in NZ waterways nitrate does not promote algae blooms in the absence of other nutrients. EU (and now NZ) drinking water levels for nitrate (50 mg/l) have no scientific basis. This limit was introduced to reduce the use of nitrogen fertilizer in cropping systems in the UK because over supply of product, with CAP guaranteed prices, produced expensive butter and wine mountains. The NZ Ministry of Health adopted the same level in 2008 – it seems most likely it simply followed the EU limit without independent assessment of its validity.

The inability to combat misinformation surrounding agricultural science is leading to eco-imperialism, whereby European ideas are being forced into regions of the world (e.g. Africa, Asia) that have vastly different problems and need totally different solutions. European agricultural science is removed from producers who are still largely working with conventional agricultural production. The EU is heavily reliant on importation of grain protein (soybean) from US and Argentina to feed its livestock. EU policies have created dependence on cheap imported food but the prices achieved are failing the farmers and the consumers. There was little evidence of agronomic research, which reflects the irrelevance of the science community to EU producers.

I did find strong synergies for temperate agriculture with the INRA temperate pastures and crop research group in Lusignan. They are working on similar things to my research group in NZ and have a functioning lucerne model. Plans were initiated to exchange staff and data to test the models and to try and develop a formal workshop on lucerne and wheat/maize modelling.

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2 Introduction

I was awarded a Trimble Grant for travel to visit science institutions in Europe. I left New Zealand on 25/8/18 and returned on 22/9/18, after visiting Switzerland, Italy and France. The first week was spent in Geneva attending the European Society of Agronomy conference with over 400 delegates from across the globe. During the second week I travelled through Italy and Southern France to visit INRA Supagro at Montpellier. Here I discussed the potential for undergraduate and post-graduate student exchanges between countries with University staff. I also visited with Prof John Porter who is a member of the "Advanced Research Group" at Montpellier. The third week was spent with ecophysiologists at INRA-Lusignan hosted by retired Professor Gilles Lemaire and Dr Gaetan Louarn. During this period I also took the opportunity to investigate and discuss the reasons behind the EUs divergent agricultural policies, compared with the US and NZ.

This report provides the physical details of these visits. It also presents my reflections on the implications for New Zealand agriculture. The report covers global issues associated with drivers of agricultural research, overproduction, EU Common Agricultural Policy (CAP), origins of nitrate limits, impacts of organic agriculture, redefinition of sustainability, climate change, eco-imperialism, poverty and the decline of democracy as a symptom of lost rationale debate. I am grateful for the Trimble Grant that gave me the opportunity and time to undertake this study tour and reinvigorated my passion for NZ agriculture and our associated research.

3 European Society of Agronomy meeting – Geneva

3.1 Background on drivers of European agricultural Policy – which influences agricultural research directions.

My first objective for this study tour was to understand the divergence in policy and science between the EU and the rest of the world. I therefore spent time investigating the basis of EU policy and the science behind nitrate.

The Common Agricultural Policy (CAP) was instigated by the Rome Treaty immediately after WWII with the laudable aim to provide food security to a starving continent (Addiscott 2005). It had several other goals to stabilise markets, and generate a regular food supply at reasonable costs to consumers, while maintaining a fair standard of living to farmers. Preference was given to community members with access to imported food protected by tariffs and subsidised production.

These guaranteed prices initially fed post war Europe. However, they inevitable led to a glut of over production that had to be purchased through “intervention buying.” New Zealanders identify this period as the butter and wine mountains of the 1970s and 1980s. On-farm the reward for production also led to the overuse of nitrogen fertilizer, particularly after cheap urea and ammonium nitrate were invented and became significant contributors to the “green revolution”. The guaranteed product prices pushed the biological optimum for rates of nitrogen (N) use higher (analogous to SMPs for skinny sheep in 1980s NZ). More N leads to greater above ground biomass which encourages disease and thus greater agrochemical use. In essence the food producers became too successful – and the CAP meant this production had to be purchased which locked in the consumer expectations that their food would be available at a low price.

Overproduction linked to nitrogen fertilizer led to increasing land prices – because the guaranteed income meant more production produced more profit – so land prices rose accordingly. However, the increased land prices then also locked in the need for increased arable and livestock production, required to pay the now higher mortgage on the land – this led to even more use of nitrogen fertilizer. An “intensification loop” developed where production is rewarded by rising land values which reinforces the need for more production to pay the mortgage and provides more food required to be purchased under the CAP!

This situation is comparable to the expansion of NZ dairy farming in the last two decades. Higher international prices for dairy products ($8/kg MS/ha) led to greater use of nitrogen fertilizer (year on year increase of 8500 kg in use of urea in Canterbury) that led to greater output (Moot 2018). That greater output has led to higher land prices and therefore the need for greater output (intensification as a high input system in an inevitable production loop). In New Zealand this is now also seen in the increased use of palm kernel extract (PKE), supplementary feed crops and high stocking rates (3.8 cows/ha in Canterbury) – it was fuelled further by high demand for land from overseas buyers which produced the same intensification loop that occurred under the CAP. The consequences in both situations through market solutions has been increased pollution. The recent curbing of foreign buyers into NZ land may directly or indirectly be a politically expedient way of reducing this intensification loop. I outlined this situation in my address to ESA on 30/8/18.

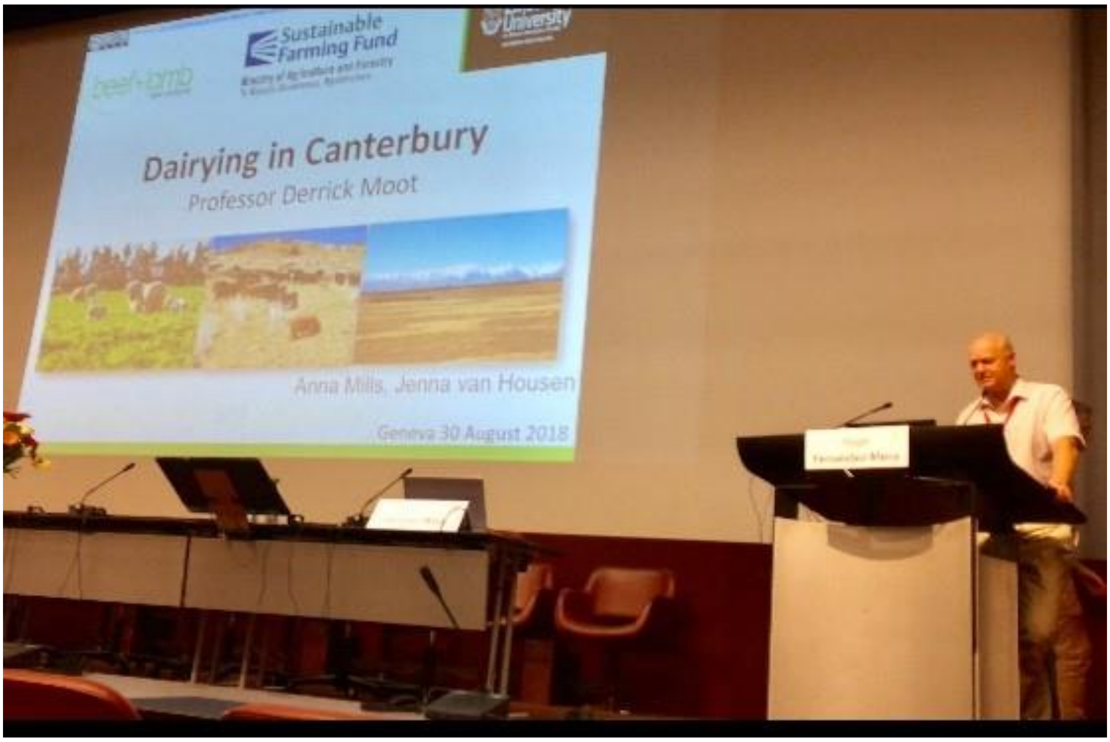

Plate 1 Presenting to the European Society of Agronomy Conference in Geneva on 30/8/2018. The video can be viewed at https://www.youtube.com/watch?v=kAzKdVEkM4U&t=4s. The presentation on the lucerne transformation at Bog Roy Station, made on 31/8/2018 can be viewed at https://www.youtube.com/watch?v=vVlXYLD7kWM.

To try and reduce agricultural production (and get out of the intensification loop) the EU has come up with several production barriers. They considered taxing N fertilizer but the levels required to reduce N use were too high to make it politically viable. Therefore they introduced a nitrate leaching limit of 50 mg/l of water. The rationale was that this would limit the use of N fertilizer, reduce on-farm production and prevent potential contamination of ground water. There was, and is, no scientific basis to this limit – it was set by an unknown bureaucrat in the EU in the 1970s. Requests by scientists to understand the basis of this limit have been unanswered (Addiscott 2005). It is now broadly accepted, and in part, this limit has probably led to a reduction in the use of nitrogen fertilizer in the EU – and hence a reduction in total output. So it has achieved its goals – but the impact of this policy has been far reaching. For example, New Zealand has accepted the limits and is enforcing them for drinking water – with no scientific basis for doing so. (Note: the limits may be written as 11.3 mg/l of nitrate-N i.e. multiply by 4.4 to get to the NO_3 mg/l value).

The Ministry of Health set this guideline in 2008 and regional councils have accepted it as a mantra without questioning the validity of it. I doubt the Ministry of Health has the capacity or desire to determine the toxicological reality of nitrate in drinking water. One of the initial reasons for limiting nitrate levels was a link with "blue baby syndrome" technically known as methaemoglobinaemia. In 1985 the British Medical Officer of Health acknowledged no link between nitrate in water and blue baby syndrome. The syndrome is actually caused by nitric oxide usually induced in response to bacterial gastroenteritis. The dangers of bacterial gastroenteritis were seen in the Havelock North water contamination issue that has led to the recent chlorination of Christchurch water – the dangers of bacteria are much greater than any posed by nitrate. Indeed nitrate is known to kill many bacteria and maintain pristine water. Oral doses of 175 – 700 mg/l of nitrate to infants only caused 7.5% of haemoglobin to be converted to methaemoglobin. Nitrate in the absence of bacteria does not cause an issue (Cornblath & Hartmann 1948). The last supposed "blue baby" case in the UK that caused death was from 200 mg/l from well water – probably also contaminated with bacteria (Ewing & Mayon–White 1951) which would have been the cause of the death through the interaction with nitric oxide – not the nitrate level.

Nitrate is a common compound that dissolves in water and is used by the body in defence of bacterial infection. Its ability to kill bacteria has been known for many years including its continued use in the canning industry to kill botulism (*Clostridium botulinum*) spores – it was always added to canned food and still is. The nitrate ion is one of our oldest allies! Indeed, nitrate levels in plant leaves are often high and one of the poster paper presenters at the conference noted her work on beetroot was aimed at producing high nitrate levels (Glied-Olsen *et al*. 2018). Plants with high nitrate levels are now sought out by high performance athletes who are using them as a natural agent to reduce blood pressure (Zikeli pers comm. 2018). This is also why we use nitro-glycerine to treat heart attack patients – it is in the nitrate family and becomes nitric oxide (NO) which also reduces blood pressure.

Effectively, regional councils and central government are consciously or subconsciously using nitrate levels in water as a way to curb agricultural production. They do this by scare mongering with regard to "blue baby" syndrome or health problems associated with drinking water (e.g. CDHB – Medical Officer for Health). There is more scientific credibility in restricting nitrate, where possible, through impacts on fresh water lakes such as Taupo and native fish and aquatic life. For this we have a mean annual value of nitrate N of 6.8 mg/l or 30 mg/l nitrate. This is set at a level that 90% of fish life are expected to be protected.

The major cause of algae blooms is most related to the presence of phosphorous. Cyanobacteria is the cause of unsightly pond scum, and because it is a nitrogen fixer it does not need an external source of nitrate N. Of note, and often forgotten, is that nitrate leaching is an inevitable consequence of agricultural production systems. You cannot feed 9.0 bn people without some loss of nitrate to the environment. The political question is what level of loss is acceptable? The answer depends on whether you are feeding starving or well fed populations – and whether your economy depends on agriculture or is happy to be an importer of most of its food – so the nitrate and other production problems (water, soil, land use change) becomes someone else's issue. The EU has consciously chosen to export such problems to e.g. South America, where soybean production is reducing water tables and causing soil erosion.

Further reform of the EU to try and reduce agricultural production occurred in 2013 – at this point the aim was to reduce guaranteed payments for production and move to production for "other factors" such as reduced use of pesticides, species diversity, crop rotations and maintaining the country side through ley farming. Again the driver was a reduction in production to avoid oversupply. The consequence of a lower production driver has been the increased research on organic production, intercropping, and agroecology that has set the EU research agenda for the last 20 years. This agenda has been contrary to most Australasian and American research which maintains a production focus with an aim to reduce unnecessary inputs and environmental impacts within conventional farming systems.

Having completed substantial background reading, I approached the European Society of Agronomy meeting seeking to understand whether their desire to reduce production had been achieved and whether the non-production based incentives had led to change in farm practise. In particular I was interested to see if organic agricultural had become dominant – as it is often portrayed by its advocates in NZ as leading the way in European agriculture.

Several key papers provided answers and take home messages about the impact of the EU research agenda.

- Organic production now represents 1% of the world's total agricultural production, 6% of the EUs production (Cox *et al*. 2018) and up to 20% in some countries with a large livestock component such as Estonia (Cabilovski pers. comm. 2018).

- Organic production reduces yield by about 20% across agricultural and horticultural crops. This figures varies with individual studies but is consistent across meta-analyses that have now been possible because the EU has had such production systems and reported on them for 20 years or more. Without soil tillage (which is a major producer of greenhouse gases; GHGs) the reduction for organic agriculture is 50% (Justes *et al.* 2018) because weed control is ineffective.

- There is still a large push from some in the EU scientific community to convince farmers to produce organically – however the policy incentives are insufficient to convince many to do so. Their overriding imperative to remain profitable means conventional farming is still the norm. The scientific community is moving the debate from strict organic production to it being about crop rotations – including a legume, because the biggest impediment to production is the lack of nitrogen (Justes *et al*. 2018). This author also wanted to stop using gross margin as a measure of production – because that is what farmers do – and based on that organic production does not stack up. The implications of doing so can only be considered from a rich continent with no desire to feed a global population.

- One scientist from the UK noted Brexit could provide UK agriculture the opportunity to innovate when out of the restrictions in place under the CAP (Iannetta pers. comm. 2018). This may allow local food production at a cost that is accessible to lower income families who are currently caught having to purchase imported convenience foods of dubious health benefits leading to obesity and chronic health issues.

- In Switzerland organic production is high because the local communities are supportive of heavy farm subsidies and agriculture is about cottage industries maintaining the countryside – producing cheese from housed cows that walk to meadows for summer grazing and are removed completely to the lowland for winter. Switzerland wants to maintain some of its own food production as a security measure but is now a long way from self-sufficient. (Field day and subsequent discussions).
- A specific problem for organic farmers has been their inability to increase grain protein content to maintain adequate baking quality in bread. Research to apply late N has not been successful and organic bread is thus considered inferior by bakers and producers (Degan *et al*. 2018).
- In contrast, in barley – the lower yield from organic systems means barley grain N is too high in protein (not as diluted across the grain) so intercropping is being used to mop up N that is mineralized late in the year and would otherwise end up in the grain (Trautz *et al*. 2018).
- There are currently reductions in grain protein content of all the major crops (wheat, maize), because of increased CHO to N ratios. This will continue in the future which has implications for human nutrition- especially in warmer regions (Asseng *et al*. 2018). This will further limit the potential of organic agriculture.
- A concept not considered by EU scientists is that the 20% reduction in yield actually means that globally to produce the same amount of food to feed 7.5 bn people, 20% more land is required. This land is likely to be coming from developing nations where native vegetative clearance and poorer production potential are the norm. The yield gap is at the core of debate about sustainable intensification – and less developed countries suffer from a technology gap, whereas western agriculture is more affected by an efficiency gap (Silva *et al*. 2018).
- A question not considered is how much of the yield reduction in the EU is leading to global degradation of forests in Asia, Africa and South America? Would higher yields in Europe from conventional production increase food security and reduce global environmental damage? At the moment the focus is solely on the outcomes for the EU. How the well intentioned CAP subsidies have affected global environmental outcomes is an issue that has not been considered.
- Much of European science is now wedded to lowering production under the guise of environmental protection. A track that NZ is fast following. The implications for our respective economies are diametrically opposite. Reduced production in NZ directly affects export receipts and the nation's economic well-being. In the EU it reduces overproduction. In both cases metrics of production per unit environmental cost need to be developed further and the consequences for other parts of the world of not producing should also be factored in. (Is NZ PKE use leading to the destruction of forests or is that more

likely the consequence of a global thirst for palm oil created by the EU not producing as much canola and sunflower oil as it could?).

- The desire to reduce production is leading to “eco-imperialism” where the ideas that generate less food are being exported to developing nations that struggle to feed their population. For example, Africa is an old continent that needs inputs of potassium, phosphorous and nitrogen – more so than most EU soils. However, training and extension from EU scientists and funding organizations often prevents research on the use of inorganic fertilizers. The transfer of low yielding practices to Africa (organic production) is adding to the inability of Africa to feed itself. When African farmers do produce well they may also be affected by American or EU production surpluses being dumped into African markets – these collapse prices and undermine the subsistence farmers. In the main EU agronomists are blind to such realities – NZ should be wary of importing these ideas.
- When comparisons of organic and conventional farming were made it was apparent that for a total system impact (nitrate leaching, greenhouse gas emissions), conventional agriculture was the most productive and no til conventional agriculture had the lowest environmental footprint. No til organic agriculture is considered impossible due to weed burdens (van der Heijden *et al*. 2018).
- My highlighting of this outcome to presenters left them bewildered. When I simply asked “so if you are paid for production and environmental outcomes no til not organic is the best option” A reluctant yes was the scientific answer they struggled to articulate (van der Heijden *et al*. 2018).
- There was a general acceptance that “pesticides cause health risks” (e.g. Malezieu 2018) but no evidence presented to support this. There was a failure to discriminate toxicological measurement from real risk. For example, coleslaw contains 42 biopesticides, most of which farmers would not be allowed to use (Addiscott 2005) because they are carcinogenic but are consumed daily because they are common. (Many pesticides are derived and refined from plant based naturally occurring compounds). However, people perceive no risk in eating it because it is familiar.
- *Any ban on glyphosate in Europe is therefore also likely to reduce agricultural production and may be another way that policy makers curb the overproduction they are obliged to purchase in one guise or another. It will also lead to increased environmental outputs (GHGs and nitrate) from the need to plough and cultivate more often to control weeds.*
- The world use of N fertilizer has risen from 100 – 180 M tonnes/yr and shows no sign of reducing – as we increase resource use efficiency then the resource becomes comparatively cheaper to use so you actually end up using more of it (White 2018 - no paper). The population of the planet cannot be sustained without increased use of N fertilizer.
- The development of “organic fertilizers” has led to testing of these to determine plant yield responses (Cabilovski *et al*. 2018). Surprisingly the fact

that all forms of applied N (organic and inorganic) are converted to nitrate in the soil for uptake did not seem to occur to the researchers. Plants take up nitrate. Without it they are unproductive and die – unless they are legumes.

- Sustainable production needs different definitions at an ecosystem versus a production level. These definitions require different outcomes. A sustainable ecosystem is in a steady state and outputs of e.g. nitrate should be minimal (plants will take up all of the nitrate available and only large organic N molecules are released).
- A sustainable production system will have some nitrate leached – should that be judged on an absolute or relative scale? Currently NZ is using an absolute scale when a relative scale would appear more appropriate for global comparisons.
- US agronomists attending the conference were bemused by the EU stance on a number of non science based decisions (e.g. GMOs). However they also cautioned that their own celebratory culture (Meryl Streep/ Ralph Nader) had caused the demise of a $250M apple industry and ruined farmers lives when ALAR was needlessly banned.
- Production agriculture to feed the world or drive an economy requires nitrogen inputs and there is twice as much N circulating in the world as there was before urea was invented. This will remain so unless population growth is curbed. This aspect is seldom discussed and feeding the world is the agronomists burden, but it cannot be done in isolation. With Europe's agronomists focussed on reductions in production the real potential of developing sustainable rotations that include legumes is being over looked (Lemaire pers. comm.).
- Sustainable production in this context should then be based on production per unit output. e.g. kg MS/kg N leached or kg meat/kg N leached or kg MS/kg CO_{2equiv} emitted. Absolute values are meaningless in a production sense (but are being used (e.g. Overseer) to reduce production in our efficient agricultural systems). The use of Overseer in our Farm Environmental Plans and Best Management Practices is likely to produce perverse outcomes, particularly because it only concentrates on nitrate.
- When metrics such as these are used NZ production systems are efficient. African systems are not. Slow growing animals on poor quality feed (because of low fertilizer inputs) are major contributors to the total agriculture environmental footprint for global warming and EU attitudes towards organic and low input systems in developing countries is exacerbating the problem (eco-imperialism from a first world with a full belly). Assistance to grow high quality pastures and crops with optimal fertilizer inputs is required in Africa but not promoted by EU policy and science contributions.
- It is ironic that a continent that requires large inputs of fertilizer is mined by NZ companies for its phosphorous (Morocco) which cannot then be used by the continent that most needs it. But NZ purchasing it is helping sustain an economy in Morocco. The consequences of environmental pressure groups to

prevent seabed mining of phosphorous off the Canterbury coast needs to be put in the context of the consequences of not mining (Current NZ debate of where we get our P from?).

In summary, the ESA meeting had over 400 delegates from all over the world. The presentations could be split into three distinct groups. Those trying to solve a local technical problem, those trying to support less intensive agricultural systems and those using models to try and address national and international issues. The outputs of those models are only as good as the experimental and measured data that informs them. My overwhelming impression was that the course of European science is not a course that NZ should be looking to follow. It is arrogant, indoctrinated and lacking in basic science because emotion has taken over rational debate. However, in my personal opinion our own agricultural science community has been silenced (e.g. CRI reforms), and is now devoid of the expertise required to combat the pressure groups.

4 Teaching and collaboration opportunities at Supragro Montpellier

4.1.1 Visit to Supragro at Montpellier:

Objectives; to gauge the potential for collaborative research, teaching and student exchanges. During this visit I discussed the potential for French Masters students to take an online course in crop physiology that we have developed at Lincoln University. One of the co-developers at Lincoln (Dr Amber Parker) has had previous contact with academic staff at Montpellier to try and initiate student exchanges.

A meeting with Dr Lydie Guillioni and Dr Dominique This discussed the potential for their students to undertake this online course while they are doing an internship anywhere in the world. The option of studying at Lincoln was discussed and a reciprocal course taught in English course at Montpellier described. This course would equate to a substantial training in plant science for our students and will be further discussed with academic advisors at Lincoln. The logistics of exchanges and internships were discussed with international programme co-ordinator Jean-Marc Depierre who formerly ran the secondary school French language competition in New Zealand. He has a strong desire to increase the linkages. These will be followed up in coming months. There appeared to be little research of direct interest to me at Montpellier but there were definitely opportunities worth following for student interactions.

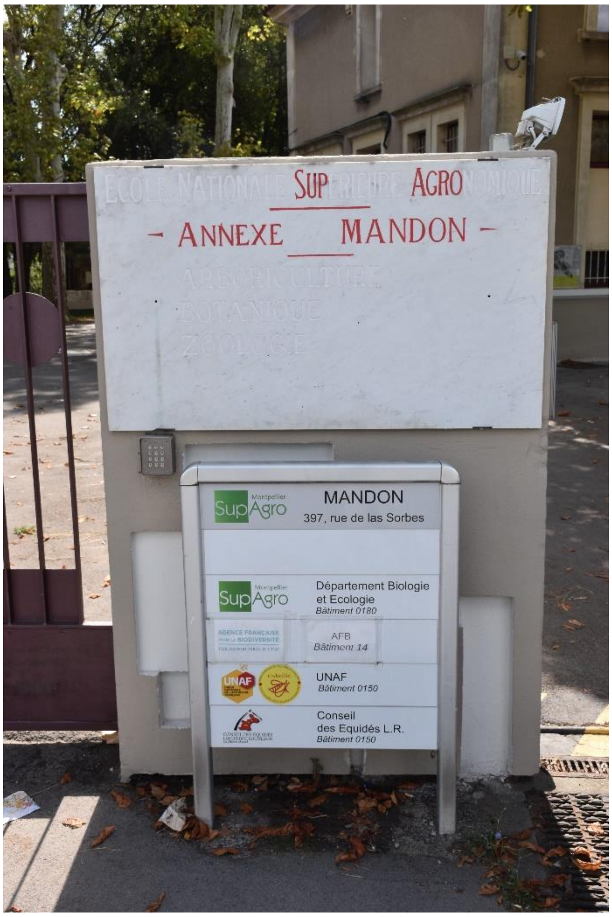

Plate 2 SupAgro campus Montpellier

4.2 The role of science in an age of non-reason.

One of the aims of my research visit was to compare the state of New Zealand science with Europe. The visit allowed me the time to debate ideas with Prof John Porter while at Montpellier.

- We discussed "that rationale debate has become a rare commodity in the age of pressure groups and this actually threatens democracy." The consequence of uninformed pressure groups holding sway over public policy are a return to tribalism that leads to autocratic leadership (e.g. Putin/Trump). These are most self-evident in ecological groups, animal welfare advocates and GMO protestors.
- Policy decisions based on emotion and poor science have consequences. For example, banning glyphosate would greatly increase GHG emissions, reduce efficiency in no til systems and stop an inert chemical that has been used for 40 years being used in production systems.
- The need for informed science to combat social media and populist opinions is at its highest at the same time as scientists are under the most pressure to act in the interests of business and are restricted from making public comment (e.g. NZ CRIs).
- The issues I raised resonated with Prof Porter who directed me to a chapter he had recently written (Porter & Wollenweber 2017) that encapsulates some of our discussion and my own thoughts in response.
- We both feel that society is seeing scientists as an unnecessary luxury at a time when they are needed the most to maintain rationale debate and avoid the consequences of "fake news." In NZ this has been shown by the continued loss of science staff in CRIs (and at LU) and a proliferation of non core managerial staff.
- At some point society must allow scientists the freedom to think, create and investigate simply for the sake of doing so – this is the basis of the Princeton Centre for Advanced Thinking (Flexner 1939) that is now being replicated at Montpellier where Prof Porter is one of the visiting fellows. It is one reason that Universities offer sabbaticals – but the ability of staff to take them is often undermined by managerial constraints.
- Science and its basis are effectively summarised through Mertonian norms (Merton 1942) that provide a framework in which to discuss current science debates. I use it here with emphasis on my own discipline of crop physiology/agronomy and its role in global issues of climate change and food security. These norms are summarised as **CUDOS.**
- **C**ommunality: *all scientists should have common ownership of scientific knowledge because all science is collaborative*. The failing of this first norm began for NZ science with the introduction of market driven reforms of science in the 1980s. The legacy of that ideological shift is reflected in the lack of public comment by CRI scientists, shackled by managers and bureaucrats. Also, the

movement of science funding to a more technoscience basis that attempts to solve short term problems for financial reward as patents, protection and secrecy.

- Scientists in the main are driven by curiosity and culture with a desire to do things just because they can – in a similar way that artists operate, with less regard for financial reward. Society reaps the rewards of their efforts and businesses seek financial gain from them but in the main scientists are less concerned with these things. This often makes the conversation between business and science difficult and politicians and business people are often uncomfortable speaking with scientists.
- My visit to France and discussions with Dr Lemaire highlighted how different the environment is. Open collaboration is encouraged through the common CORE funding provided to INRA. To return NZ to a similar level of co-operation will take more than building joint facilities. It will require a major change to the competitive funding model and a return to long term public funding of public good science.
- **U**niversalism: *science work should be evaluated independently, free of socio political interference* .This is why we have a blind peer review process – often criticised but not yet replaced.
- **D**isinterested: *science work should remain uncorrupted by self-interest and independent of financial gain.* This calls into question how appropriate it is for publically funded scientists to be applying for patents for private gain from research funded in part through public provision. We have a current NZ situation with regard to patenting plantain that falls in to this category.
- **O**rganized **S**cepticism: *science is presented transparently so it can be judged by society using accepted norms*.
- The continued negative consequences for individuals and populations from the false reporting of an MMR autism link, for society is evidence of what happens when poor science is corrupted by the loss of universalism or disinterest.
- Academic freedom is enshrined in our University system and it is from within this system that I personally prefer to operate. However, post-academic freedom in CRIs is constrained by companies funding, patents, and managers which means **C**ommunality no longer applies. **C**ommunication is now seen as more important. This enables organizations to promote themselves before the full implications of the work have been realised through the science community assessing the published work. Media frequently want instant responses to newly published science papers in much the same way they interview athletes post-match. This thirst for instantaneous soundbites prevents the maturing of ideas.
- H-indices, QR rankings, PBRF and journal Impact Factors are metrics being used to pigeonhole scientists. This reduces the **C**ommunality that led them to their discipline in the first place. The general malaise of CRI scientists (in e.g.

AgResearch) highlights the inevitable consequence of this “managed approach to science.”

- At the other extreme IP licencing and confidential documents provide an impediment to communality and frequently fail to recognise the public contribution to the invention. We have split **C**ommunality into **C**ommunication through “self-promotion or legal patent-protect”.
- **U**niversalism has been replaced by **U**tilitarianisms whereby sponsored work and grants lead to a desire for successful outcomes of research in the narrow sense. Science needs to produce something. This is not always possible and, at times, science just needs to discover.
- In an academic sense **D**isinterestedness applies but with funded work this can lead to conflicts of interest. If we do not get a favourable result will we continue to receive funding? This is paramount in much of the funding applications that MBIE receive each year.
- Equally, **O**rganized **S**cepticism has been lost in contracted research whereby fierce competition for funds can lead to nepotism, plagiarism and conflicts of interest. A common complaint within (my own experience as a young researcher) and across NZ organizations (my own experience as a mid-career researcher) when compelled to jointly discuss competitive research bids, and in some cases, was restricted from submitting bids by managers for political rather than scientific reasons. The “research office” and business managers that have infused themselves into science across organizations have restricted all aspects of **CUDOS** and made the science community poorer for it.
- The blurring of science into extension has also coloured the types of science that are funded and the outputs expected. The demand that NZ science (except Marsden Fund) has a commercial co-funder or support has moved science to practical application. Thus, the process has lost sight of the fundamental role of science to simply explain. While appropriate for technoscience it has become the default position of the political community with science relegated to inform policy when required but not required to advise (e.g. lack of science representation on the primary production ministerial group).
- Climate change was an academic science which has subsequently become highly politicised. The anthropogenic causes, predominantly associated with burning fossil fuel, are inconvenient to powerful lobby groups that influence policy makers. The consequence is that agriculture is now seen as a major contributor to GHG emissions but this appears uncoupled from food production, or the reality that 70% of global emissions come from burning fossil fuels.
- The effective rebuttal by pressure groups is to use other scientists to debate science or more recently to simply ignore evidence because it doesn’t fit your own opinion. The Trump/Putin legacy may well be further disdain for experts, or more optimistically the reverse, highlighting of the need for the

independence and rationality they provide (my optimism fades with each tweet).

- Equally, ill-informed pressure groups that prevent the use of GMOs provide a strong political lobby that, for no rational reason, have kept GMOs from the food chain in Europe (and NZ) despite the EU importing millions of tonnes of GM soy for livestock.
- The public appear willing to accept gene editing for GMOs in medicine where the benefits for an individual may accrue, but they fail to allow food with a low environmental footprint to be available to a population.
- The backlash against GMOs is possible a sub conscious distrust of large multi nationals that see profit in patenting the genes. If there was no patent law there may be less resistance?
- The concept that GMOs will address climate change and global food security is false. They can only contribute in a Genotype x Environment x Management (GxExM) environment where management is highly likely to be the dominant factor. However, the fact that the agronomy does not have a product to sell can make it the poor relation of plant breeding (cultivars) and soil science (fertilizer use). However, at a global level only agronomy as part of an interdisciplinary approach can solve food security and reduce environmental impacts. Excellent plant science only happens in the field!
- The thought that -omics can solve any of these problems is false and the continued comparison of modified plants with non-modified plants is evidence that, in the main, plant breeders fail to understand that production is a multifaceted thing. Genotype is only a small component of GxExM interaction.
- "Genomics, proteomics and metabolomics may increase our understanding of the regulation of different physiological processes and mechanisms of resistance to stress, but they do not show us the bigger picture."
- "The capital-driven focus on –omics and genes has led to losing two generations of young researchers who know about how whole plants grow and develop in populations in the field "where the best agricultural science has and always will be performed." This is a national and international issue that needs addressing and rebalancing.
- We have had 30 years of promises and more promises from genetic engineers with herbicide resistance and single gene resistance as the only outcomes. This will not solve a growing world food shortage which can only occur through GxExM. The lucerne example from NZ has solely been driven by changes in M. The G and E were already present but the lack of people working in M is producing unbalanced production systems based on overuse of agrichemicals through a poor understanding of agronomy. I believe the lack of a saleable product has devalued agronomists and this has been accelerated through the technoscience funding model used.

- In reality technoscience and its administration leads scientists to do as little as possible to meet objectives and squirrel the money away to allow them to do something useful with it. There is a need to trust the scientists with funding and stop supporting incompetent bureaucracy. Allow science to identify and criticise pseudo-science, claims related to faith, religion, climate change deniers, biodynamics, homeopathy, intelligent design etc. Without science emotion wins and the control of emotion is frequently an autocratic leader.
- After these discussions Prof Porter and I proposed to write an article or paper about these issues when he visits Australia in November. I will endeavour to meet him in Tasmania to progress our ideas.
- One direct output of these discussions is that I now have a framework with which to approach the Minister of Primary Industries to stop “Overseer” being used for nutrient budgeting on dryland farms. It fails all the basic components of **CUDOS**. My call for an independent review will be based on explaining how it fails this basic premise.

5 Lucerne model development and Collaboration with Scientists at Lusignan.

My visit to INRA - Lusingan was hosted by Dr Gaeten Louarn and retired scientist Dr Gilles Lemaire. This was three days of visiting scientists and determining the potential for collaboration. Several key contacts were established and plans for future collaboration confirmed. I presented for two hours on the second day of my visit to outline the scope of my work at LU and more broadly in research across New Zealand. This enabled some useful synergies to be identified.

Plate 3 Prof Gilles Lemaire hosts me at INRA Lusignan

- Unknown to me, and the most important technical outcome from the visit, INRA have just developed a mechanistic lucerne model based on several French data sets, including published material from our research programme. They showed me the outputs of the model and will send me details once the model is published. This will be of immense use to me and the APISM model we have working on this with my PhD student.
- I will endeavour to take the mechanistic components and also create empirical models that are appropriate for use on farm in NZ (e.g. a pasture growth forecaster).
- Lucerne is seen as pivotal in Europe to break the monoculture dominance of conventional farming with wheat or barley monocultures. The testing of a functioning lucerne model is of great interest to colleagues at INRA and we agreed to formalize a workshop visit of interested scientists at Lincoln in 2019 (Collaboration with Gaetan Louarn).

- Lucerne in Europe is predominantly seen as a cut and carry option where maximizing the quality of hay produced is essential for uptake by livestock farmers. The concept of grazing lucerne directly was not seen as viable in France, predominantly because the skill set required to do so is unavailable within their farming community.
- Of use to me personally was the dataset they produced showing N transfer to associated plants of soil during lucerne growing was only 10% compared with 50% for white clover (Louarn *et al*. 2015). This reduces the risk of N leaching from lucerne compared with white clover but white clover is the model plant used falsely in "Overseer". (Annual clovers release 100% of their N to associated plants when their lifecycle ends).
- Farmers in the region are becoming more specialist with less diversity in the landscape as a result. It is anticipated that integration of livestock farming with cropping farming is required to break the monoculture or continuous cereals production cycle. Mixed farms are becoming scarce because it is easier to farm crops with one man able to crop 250 ha by himself. The cost of labour prohibits small areas of livestock within that farm.
- My presentation on the links between on-farm research and extension being negatively correlated with relevance to farmers was well received. There was no expectation that scientists work with farmers at INRA and although there is pressure for funding the base funding for research is set. This enables long term planning and appointments to investigate science questions.
- My visit to the 25 year long term pasture crop rotation experiment showed how secure funding allows planning and thinking on a longer cycle than that dictated by political priorities in NZ (Field day with Gilles Lemaire). There are no milestones, reports or outputs specified but these eventuate from the will of the scientists involved.

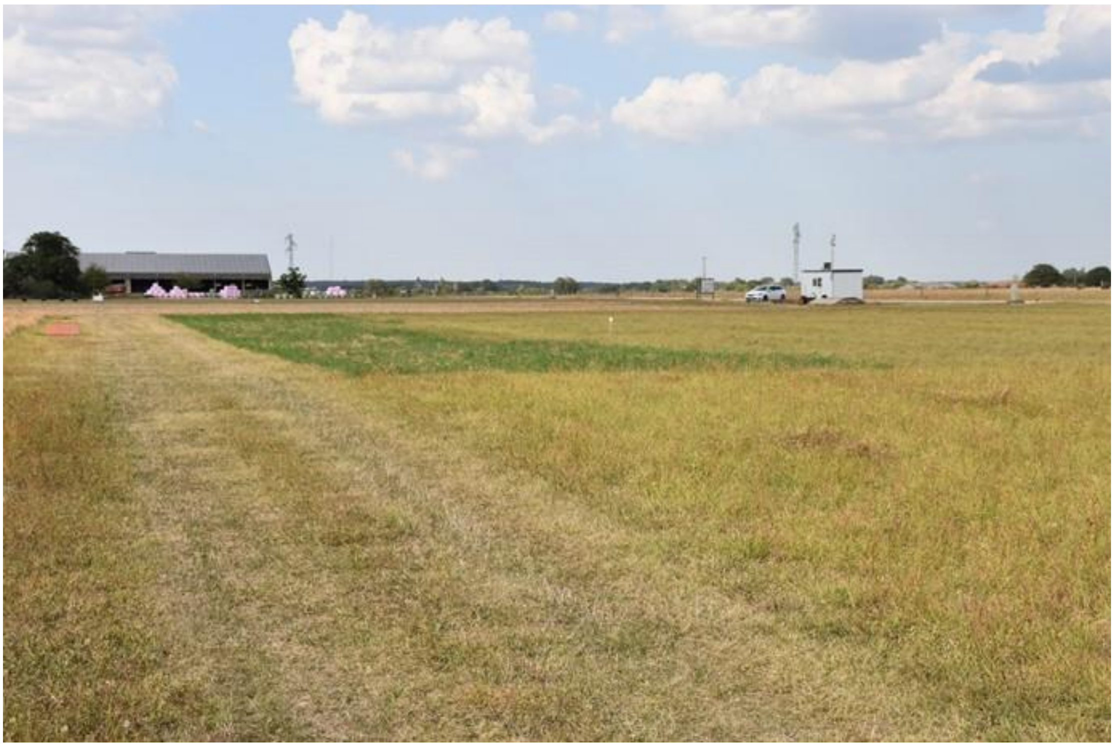
Plate 4 25 year long term pasture and crop experiment at Lusignan

- This facility has scientists visit from all over the world to take measurements on different crops, soils, air fluxes, inputs and outputs and therefore create widespread understanding. The collaboration of one experiment provides resources to many researchers – not a model used in NZ anymore- where grazed experiments outside of University are now rare (**C**ommunality and **U**niversalism in action).
- Conversations with plant breeders noted their reluctance to consider animal traits other than nutritionally in their breeding programmes. There was little interest in creating plants that would deal with NZ issues namely; aluminium tolerance, reducing incidence of bloat and the link between the phytoestrogen coumesterol with leaf fungal diseases which was new for them (Dr Bernadette Julier).
- Exchanging datasets was not possible with INRA to speed up our model development because some of their datasets were from outside organizations but I did get a commitment from them to assist with model parameters which is of greater benefit (Meeting with Nicolas Beaudoin).
- Other projects of mutual interest were identified. They have a student who has just started looking at perennial ryegrass phenology. I have also started a PhD student doing this (Richard Chynoweth) so independently we have identified this as an area needing further research and collaboration.
- The concept of pasture mixes with legumes is receiving great attention in Lusignan (different cultivars of the same species may have more, or less,

compatibility with cultivars of another species). This is being used to set breeding objectives for mutual benefit of both plants. Replacement series work is ongoing to try and create multi-species mixes. My NZ colleague Dr Alistair Black has recently started similar work and the sharing of results will facilitate interpretation of the mechanisms responsible, particularly if there are any differences between cut and grazed pastures.

- The concept of patenting plant traits was discussed with the director of the institute. He has submitted a paper to the INRA science board and the French Government that plant variety rights should be allowed but not patenting of traits. These are publically owned and should not be owned for profit. (Meeting with Jean-Louis Durant).

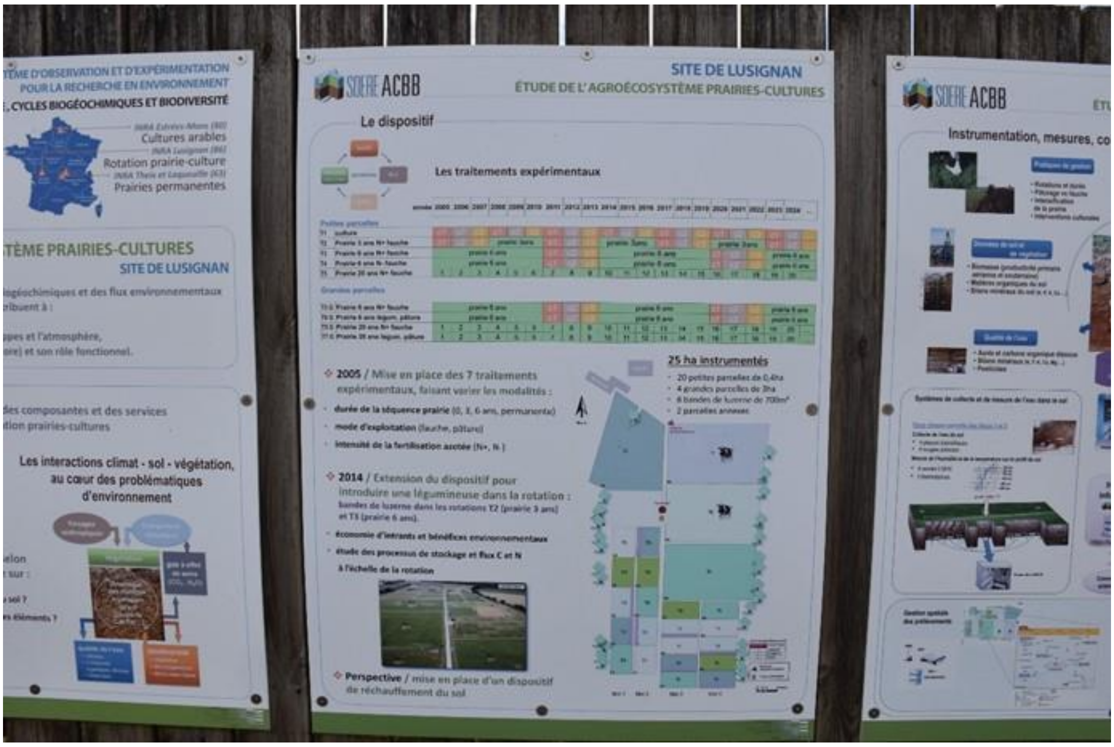

Plate 5 Treatments and info board of long term experiment at Lusignan

6 Conclusions

- The opportunity for me to reflect, discuss and debate topics of wide scientific interest was unique and appreciated. These conclusions represent the tangible outcomes but the more intangible are the growth in my own thinking that has occurred from this research tour.
- The EU has adopted a deliberate policy to reduce agricultural production to prevent large payments to farmers. To implement this policy a nitrate limit of drinking water of 50 mg/l water has been imposed. There is no scientific basis for this limit.
- NZ has accepted this limit and falsely promoted “blue baby syndrome” as being caused by nitrate in drinking water. ECAN has used this to try and limit the expansion of dairy farming on the Canterbury Plains. More accurately a reduction in nitrate to prevent eutrophication from the association with phosphorous in Te Waihora is appropriate.
- Rising agricultural production leads to increased land values which leads to rising N use in an intensification loop. This happened in the EU with the production of urea and has been replicated by dairy production in Canterbury.
- A 20% reduction in production is expected from switching to organics and this means additional production must come elsewhere in the world to feed a growing population. This is usually at greater environmental cost than if the production came from the EU.
- Montpellier provides an opportunity with synergies to explore for teaching.
- The loss of scientific rigour is leading society down a dangerous path where lobby groups and emotion lead to autocratic societies and tribalism.
- **CUDOS** is paramount to maintaining rational thought and discourse for scientists and a move to technoscience is stifling innovation and creativity.
- GMOs are a part of the solution to feeding the 9 bn but GxExM is required with agronomy at the centre of redesigning farming systems. They have delivered little more than single gene resistance but this has allowed no til agriculture to thrive and reduce GHG emissions.
- Current NZ science funding and policy is anathema to the collaborative, creative, multidisciplinary teams required to solve global food security while reducing environmental footprints.
- INRA has a funding model that is conducive to scientific discovery and at Lusignan they have a lucerne model that can be helpful in the creation of APSIM_Lucerne at Lincoln.
- The best science is always a linking of many ideas for which the individual scientist who stimulated them is frequently not rewarded and *does not aim to be so*.

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