Seeking sustainability – an example from Australian agriculture[1]

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Abstract

Methods of 'conservation agriculture' have recently been adopted in all areas of the Australian cereal industry. This development, which involves 'zero' tillage and the use of stubble mulching of seed beds has increased yield, particularly by the more effective use of water. In these and other ways the industry is following a sustainable and productive path as it seeks to meet the rising local and world demand for grain.

Keywords

Australian agriculture, conservation agriculture, sustainability, wheat yield, soil cultivation, water use.

Introduction

One of the subjects relevant to the anxiety mentioned in the call for papers for this conference is that of the sustainability of Australia's food security system and the associated agricultural industries. Our 130,000+ farm businesses export the equivalent of 60% of what they grow and each feeds the equivalent of some 600 people (Anon, 2012). This is a significant contribution to global food supply and hence the sustainability of these industries is important both in an Australian and in a world context.

Agriculture is an industry which sits within the environment and is based (among many other things) on three natural resource inputs, viz, land, water and energy which, at a more detailed level, are also subjects of the afore-mentioned anxiety. While there are many other associated scientific and technological inputs, these three each involve engineering analysis and design which is one of the reasons for the author's interest.

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Agriculture and food security have been the subject of many analyses and assertions which suggest, in various ways, that in Australia there is a 'crisis in agriculture' or that 'our food security is under threat'. While these conclusions may have some validity, they are often drawn by generalising from what might be legitimate and specific causes for concern in other places without a nuanced explanation of their applicability to Australia.

For example, popular writers do not seem to know or understand the energetically efficient, symbiotic basis of our broad-acre, low yield, cereal / sheep industry. Nor do they recognise and acknowledge the strengths of our agriculture, which, after 150 years, continues to feed and clothe millions around the world.

In what appears to be a general assertion, one writer (Brown D. 2014) states that 'soil and its fertility is being eroded much faster than it can be replenished'. However, the only evidence offered is a quote (albeit a worrying but hardly surprising one) from Kenya that yields for 'many farmers' have dropped by 75% in 25 years 'after decades of farming using the same methods that extract nutrients from the earth but put nothing back'. What is the lay reader to conclude from that?

More generally agriculture is critiqued on the basis of ill-defined and often emotionally loaded terms such as 'chemical agriculture' or 'industrial agriculture' or 'mono-cultures' or 'harsh chemicals'. It is as if the mere words were sufficient to justify the conclusion that there is a crisis or whatever is the writer's particular political or social view-point.

It is therefore little wonder that such statements leave the lay reader with the afore-mentioned anxieties which they are unable to resolve. So, on the basis of the conclusion that 'something should be done', solutions may be offered which, while valid in principle, will not meet short or medium term community needs.

This is not to say that there are not problems with existing and new systems. However, the solutions to these will be found, not in a retreat from further research, but in a more nuanced understanding of these aspects of the industry, a more sympathetic application of technology and a more strategic use of our resources.

In the light of this fairly low level of community understanding about our agriculture and food security, the question remains as to whether this anxiety is justified. I suggest that, notwithstanding these suggestions of crisis, recent history and current research and development activity do not justify the popular conclusions.

Agricultural development

The long history of agriculture from hunting / gathering to the settled cultivation of sown crops pre-dates formal science by many thousands of years. So, in terms of the sub-title for this conference, while the suggested (or ideal?) order is: *'science – theology - action'*, the traditional and actual order is: '*action –> science –> theology* –> action –> . . .' etc.

This is dramatically illustrated by the growth in grain production which for hundreds of years was based, not on scientific research to increase yield, but on the growth in the technological capacity to bring new areas under the plough.

> From the beginning of agriculture until the mid-twentieth century, growth in the world grain harvest came almost entirely from expanding the cultivated area … It is only within the last 60 years or so that rising yields have replaced area expansion as the principal source of growth in world grain production. The transition was dramatic. Between 1950 and 1973 the world's farmers doubled the grain harvest, nearly all of it from raising yields. Stated otherwise, expansion during these 23 years equaled the growth in output from the beginning of agriculture until 1950.
>
> Brown L. 2012

So what has been the Australian experience in agricultural development?

Initially the settlement of Australia was probably more to do with sustaining the British social and penal system although it soon morphed into what turned out to be, from their point of view, a very successful source of food to sustain the rising demand.

Theologically the early free settlers would, if they thought about it, have merely seen the Australian continent as part of creation although their ideas had been theologically informed (even misinformed) in ways that they neither recognised nor acknowledged. However, the new land was sparsely populated and hence the name 'terra nullis' seemed appropriate, if unwarranted. Hence it was also seen as available to be 'filled' and 'subdued' under the commands of Genesis 1.

Those hardy souls were, for the most part, practical men and women who were under pressure to grow enough food to live on and hence they had little time for considering how it might be necessary to modify the farming insights, or the machines which they had brought with them, to ensure their best chance of survival.

Agriculture therefore began under climate and soil conditions of which the settlers had little or no understanding, experience or scientific traditions. It was to be 50+ years after the Australian settlement before Rothamsted, the first agricultural research station, started in the UK. Locally it was 100 years after settlement that, with declining wheat yields, the formal study of agriculture began in South Australia at Roseworthy Agricultural College. 'Theoretical science' ran a poor second to 'practical action' in the sustainability stakes!

The understanding of 'land' that the settlers had brought was based on the stability of their home-land. Generally speaking British soils were younger, deeper, higher in organic matter and clay and not so subject to erosion. The lighter sandy soils, the lower rainfall and the presence of dispersive clays and salt in many Australian soil profiles meant that erosion and salinity were likely to be incipient problems.

Climate, and in particular winter rainfall, had the most significant influence in determining areas for cereal production; the latter is in the range of 250 to 400 mm. Historically, pressure for more land to be made available for cropping resulted in moves to lighter sandy soils in Victoria and South Australia which have, not only a lower, but also a less reliable rainfall. The suggested northern limit for cereal cropping (Goyders line) in SA was not observed and this, together with inappropriate cultivation methods, were the undoing of many farmers in the latter decades of the C19th. It proved to be a hard lesson in the search for sustainability.

The practically based need for survival and the later export driven development in the first 50 years, resulted in the 'mining' of the soil resource base. Like many failures in agriculture, in Australia the evidence appeared decades later and, however significant these failures were and still are, they hardly justify the hind-sight driven outburst by Flannery.

> For most of the past two centuries we have believed that we could remake the continent in the image of Europe – turn the rivers inland and force the truculent soils to yield. . . . . Much of this terrible history reads as a rush towards 'development', which was then – and often still is – just a soft word for the destruction of Australia's resource base.
>
> Flannery 2002

Against this background it is appropriate to seek an understanding of the present condition of our cereal growing. Wheat is taken as an example, partly because it is our most important domestic and export crop and the cereal for which most data is available. This brief review, which is limited to the more physical aspects, is consistent with in-depth biological research and reviews of agronomy and genetics by agricultural scientists such as Smith (2000), Fischer (2007), Passioura (2008) and many others in the field.

Yield

Although the varieties of wheat brought from Europe and the land in the early settlements on which to grow them were both unfavourable (Leeper 1970), as a crop, wheat soon proved to be suitable for dry-land production as one of the main staples and as a basis for an export industry.

Yields were low compared with Europe but declined from 1 T/Ha to 0.5 T/Ha in the first 50 years due to inappropriate farming practices causing nutrient exhaustion (Figure 1). However, as a result of scientific research from the 1880's this decline was partly met by the use of phosphate fertilizer and by the inclusion of introduced and native, nitrogen producing legumes (clovers and medics) in the pasture phase of the cropping rotation.

Research by Farrer and others resulted in the introduction of new varieties more suited to the dry climate. These, together with water conservation in the soil profile by appropriate fallowing and mechanisation, providing more timely field work, gave yield increases over the next century.

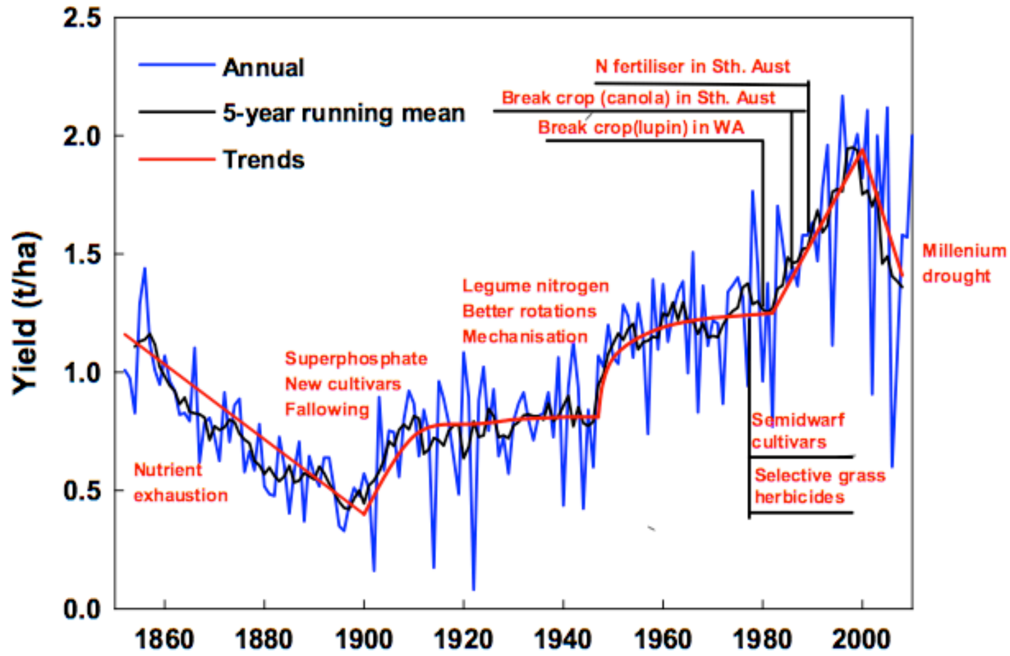

Figure 1: Australian wheat yields 1850 - 2010 (Angus, 2011)

This resulted in a symbiotic, energetically efficient, low yield - large area cereal / sheep industry that is still the mainstay of farming in the 250 to 500 mm rainfall areas.

The industry continues on this very effective and appropriate basis with a current average yield of some 2 T/Ha compared to European, nitrogen fertilizer based, yields of some 7 T/Ha. Within the very wide, year-to-year range of yields caused by rainfall variation there is no evidence for the suggestion that yields have collapsed or even peaked. However there is evidence that continuing increases are more difficult to achieve both in Australia and overseas (Fischer 2007).

Fischer also writes of continuing research in agronomy and genetics which seeks to increase production by 1.0 to1.5% pa, to keep up with world demand for food grain. The diversion of food grain to meet the ever increasing demand for automotive fuel is a legitimate cause for anxiety but one which society has the capacity to at least partly alleviate.

The natural stability and economy of the industry provided sufficient confidence to warrant efforts in the 70's to transfer the technology back to the Middle East from where some of the legumes, on which it was based, had originated (Springborg 1985).

Crop yield provides an overall measure of the condition of the industry because it integrates, in a complex way, the effect of many factors that determine the crop response. Its continuing high level suggests that we can have reasonable, if not absolute, confidence in this aspect of the sustainability of the industry. However there are many aspects which, if understood, may be eliminated or ameliorated to further increase the yield. Water supply and use is one such limiting factor.

Water use

In a climate that is water limited for many species, it is not surprising that low and highly variable rainfall and droughts are seen as cause for anxiety by many people, not least because of the deleterious effect they have on rural communities.

For the wheat plant there appears to be, for a given level of water available for evapotranspiration, a yield which cannot be exceeded. This is some 20kg/ha/mm of the water available as shown in Figure 2. (Sadras and Angus, 2006) Hence one of the measures of success of the wheat breeding and husbandry processes is the degree to which, for the given level of water availability, the crop yield approaches that potential.

The gap between the actual and the potential yield is due to the effect of the other specific, local, yield limiting factors, such as weather, soil, management, etc. Although there is a wide range of yields relative to the potential for all areas, it appears that Australia achieves a somewhat better yield than other producers.

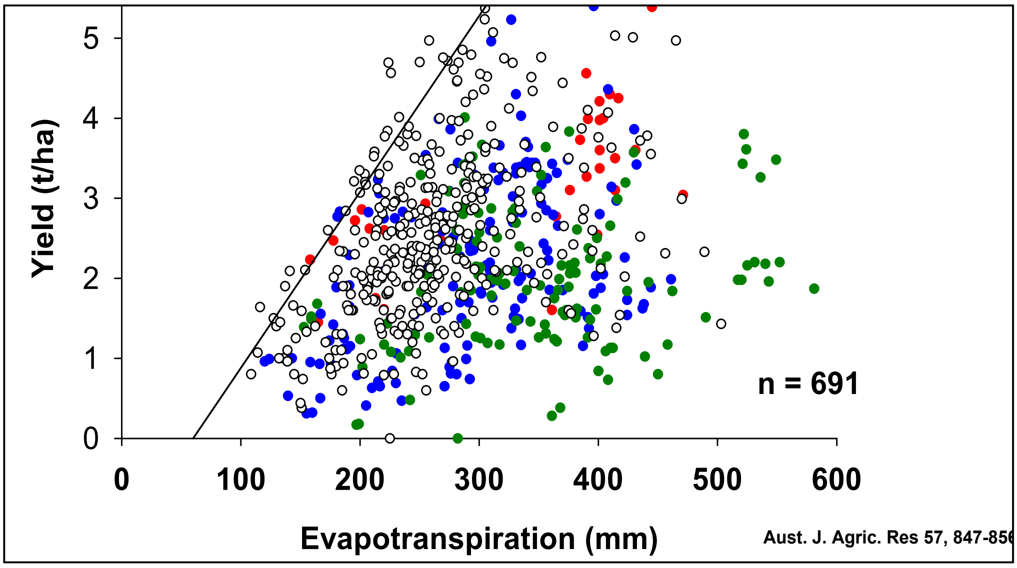

Figure 2: Wheat yield below water limited potential (line)

Australian trials – o (Sadras and Angus, 2006}

Notwithstanding this, as the graph shows, there appears to be the capacity in many areas for increasing yields by 30 to 50% with more appropriate and site-specific agronomic practices. Passioura (2008) writes of agronomic research to not only increase the water stored in the soil by better weed control and use of stubble retention (see on) but by measures to achieve an even greater extraction of that water from the soil. To understand the problem and to be able to measure one's success in seeking to overcome it, is a cause for some confidence in our science and in our practice.

Mechanisation

The mechanisation of our cereal growing, which involved the replacement of animals with tractors and other machines, brought about huge increases in the cereal production because of huge increases in work rate, more timely operations, more efficient collection and separation of grain and increases in yield associated with agronomic changes.

Several physical, soil related issues associated with maintaining and increasing cereal yield on Australia's light, sandy loams emerged in the cropping industries in the second half of the C20th. These arose from problems associated with the traditional cultivation processes that in turn were based on the *form* of the Australian tillage machines that had been developed and used over the previous decades.

Conservation agriculture

The most significant change in the last 40 years has been the development of so called 'conservation agriculture'. This required a series of new machines that included seed drills to sow through stubble mulch into uncultivated land and precision guidance systems giving a so called 'controlled traffic' system. This uses 'road beds' for tractor and implement wheels alone and separate 'seed beds' that are not subject to wheel compaction – hence the use of the term 'zero traffic'. Australia leads the world in these technologies; some 90% of farmers have adopted them over 10 M ha.

The benefits associated with conservation agriculture and in particular zero tillage and controlled (zero) traffic may be illustrated by five comparative results for three systems reported by Tullberg (2008).

Crop yield

An increase in yield as shown in Table 1 is one of the obvious advantages of conservation agriculture over traditional systems. Conservation agriculture with controlled traffic on hard road beds allows improved traction, hence more timely operations and more uniform seed beds with resultant yield increases. Yield benefits will of course vary widely with local soil and weather conditions.

System all with stubble mulch	Crop yield	Total energy	Infiltration rate	Water content	Soil biota worms
'Normal' tillage	100	100	100	100	100
Zero tillage	105	60	170	120	400
Controlled (zero) traffic	115	35	260	185	1100

Table 1: Benefits from zero tillage and zero traffic (adapted from Tullberg, 2008)

Energy consumption

Comparison of energy consumption within cereal agriculture is highly variable and complex; it requires consideration not only of direct fuel use but energy equivalents of other inputs such as fertilizer and herbicide; Table 2.

System all with stubble mulch	Direct Fuel	Herbicide	Fertilizer
'Normal' tillage	100	100	100
Zero tillage	60	400	105
Controlled (zero) traffic	35	300	80

Table 2: Energy use for zero tillage and traffic
(adapted from Tullberg, 2008)

Compared to normal stubble mulch systems (=100), zero tillage, where soil disturbance is limited to providing a slot and soil to cover the seed, fuel energy is much lower (60). For controlled (zero) traffic, which avoids the energy consumption by machines which compact the soil and then have to cultivate it again, fuel energy consumption (35) is even lower.

Again compared to stubble mulch (=100), zero tillage and controlled traffic have much higher energy equivalents in herbicide use (400 and 300 respectively). Fertilizer is variable according to local needs.

The general adoption of conservation agriculture across Australia's agricultural industries, while generally significant for on-farm profitability, would only reduce national fuel consumption by a small amount. Clearly any significant reduction in our anxiety about the sustainability of our national fuel supply must be sought elsewhere; for example, in transport and personal travel?

Infiltration rate and water content

The early understanding of the soil / water relationship promoted cultivation (fallowing) after every fall of rain to break up the capillary paths that were thought to be the mechanism of the water loss by evaporation (Mullett 1926). This repeated cultivation was shown to be wrong and not necessary; it destroyed the soil structure and allowed the fine soil particles to be blown away in the notorious dust storms in the late C19th.

The most significant and limiting climatic factor in our cereal production is rainfall, hence the greatest agronomic benefit will be gained by promoting infiltration and conserving as much of this water as possible in the soil. To this end, the use of zero tillage and controlled traffic allows a significant increase in the infiltration rate as shown in Table 1.

The conservation of the water in the soil also requires the reduction in evaporation and this is aided by the stubble mulch residue which reduces the radiation falling on the soil surface and the soil temperature. The residue also reduces the wind velocity which is a significant factor in reducing evaporation.

The overall result is a significant increase in the water available in the soil (Table 1) and a corresponding potential to increase yield as shown in Figure 2 above. Farmers are using science and technology and, notwithstanding those 'truculent' soils', are working 'smarter' rather than just 'harder', and are maintaining sustainability.

Soil biota

One simple, obvious measure of soil biota, and presumably of soil health, is the number of earth worms in the soil. Table 1 shows the dramatic increase in their numbers with the more 'sympathetic' treatment of soil practised in conservation agriculture.

Weed control

Fallowing (repeatedly cultivating the soil) had the same purpose in Australia that it had in the old world – that of killing each batch of weeds that germinated with each rainfall event. Research proved that this was much more important in keeping water in the profile than the previously promoted effect of breaking the capillary paths by which evaporation was thought to occur. The old idea died hard and it was many years before the fact that water loss was mainly due to weeds was accepted. Seeking sustainability has to deal with human issues as well as technical ones.

The introduction of conservation agriculture, with the associated agronomic and financial benefits from reduced tillage noted above, required an alternative method for the removal of weeds. Spraying has been the main method to date and has brought a significant reduction in energy used in the field.

However, the resistance of weeds to herbicides and weed control in general is a major issue for no-till farming. The effect of herbicides on soil biota and other life forms also remains a, not unreasonable, source of unresolved anxiety for many.

Further research is underway to reduce if not eliminate herbicide use. 'Weedseeker' technology, which targets and sprays only actively growing weeds, has the potential to reduce herbicide use by up to 90%. An alternative non-chemical weeder using microwaves to kill weeds may be commercialised in the near future. (Gould 2015)

Wind erosion

The early emphasis on 'clean fallows' and associated fine tilth of the soil which was promoted as the best science of the day brought with it the disastrous history of wind erosion and dust storms in the late C19th. The roughness of the soil and the presence of residue promoted in conservation agriculture has the effect of reducing the velocity and erosive effect of the wind at the soil surface and hence the associated soil loss.

Other issues

There are other aspects of agricultural and food security systems, both technological and sociological, that for many are cause for anxiety. These include the use of genetic engineering for changing crop characteristics, the diversion of agricultural crops and land for use in the production of transport fuels, the extraction of coal seam gas from under farm land and the use of agricultural soils for carbon sequestration.

In economic terms the continued sustainability of our agricultural industries depends not only on the technical and scientific innovations noted above but also on their continued profitability. One overall measure of their profitability, and of the sustainability of our rural communities generally, is the terms of trade (prices relative to costs) of on-farm production. These have been gradually declining from some 200 in the 70's to 100 in the last decade and result in deterioration in the condition of our farms and the well-being of our farmers. Here is a socio-economic cause for anxiety that is often hidden by the price wars between the food chains and the pressure on suppliers to accept lower farm-gate prices for their product. In seeking sustainability, 'care' and 'use' applies to the farmer as well as the farm.

Conclusion

While popular writers question the sustainability of our agricultural industries they usually offer little but unsubstantiated generalisations. The author contends that, notwithstanding early, unsustainable practices based at least partly on ignorance of our climatic and soil conditions, both practical developments (action) and research (science) have contributed to an industry in which we can have confidence of sustainability for the foreseeable future.

Our agriculture has been the source of export of food and fibre for a 150 years for millions in the Old World and still is for the New. However economic and technical pressures have encouraged the widespread adoption both in Australia and overseas, of conservation agriculture. This allows significant and sustainable improvements in soil conditions, increases in yield and reductions in on-farm costs. While these developments are encouraging, it is conceded that continuing research is necessary to overcome new problems that arise with such new technologies and to meet the continuing need for increases in production to meet increasing national and world population.

The withdrawal of Government institutions from research, development and extension activities has prompted the development of regional, independent farmers' groups who engage in their own research and development activities to promote the sustainability of their industry. This 'ownership' of the research and development capacity by farmers, who are stake holders in the industry, is a good move to promote its future sustainability.

Any suggestion that we take our focus off a production objective and the scientific and technological system that drives it is technically and socially unrealistic. However, none of what has been said above would justify anything other than that focus should also be a caring one that is sympathetic to the place of agriculture in the created order.(Macmillan 2009)

The genius is to keep both the 'use' and the 'care' objectives in focus while fulfilling the command to feed even our enemies (Proverbs 25:21; Romans 12:20). We ought to obey this, even at the cost of some temporary detriment to our rural environment, while the search for sustainability goes on.

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