HOW DO WE TRANSFORM OUR INDUSTRY TO ACHIEVE A MODERN VISION FOR NEW ZEALAND AGRICULTURE?

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Abstract

There has probably never been a time when the tensions between achieving higher food production, environmental sustainability and the need to reduce risk created through increased climatic variance have been more acutely felt. Possibly the biggest challenge is to have a balanced debate about a path forward especially in relation to the expansion of intensive agriculture and its effect on the environment. In our case the most recent focus has been fresh water and the health of our river systems versus dairy farming.

Some global commentators are already predicting that we are past peak food, and there is a good deal of evidence to suggest that global food production is not keeping up with population growth. There is also evidence from around the world that policies designed to assist environmental sustainability are reducing food output and quality. One of the major sources of risk for farmers is lack of water. Many have made capital investments to reduce this risk but then the capital structure of their business usually leads to more intensive land use, which many argue is presently detrimental to sustainability.

Accelerated change is required, and the adoption of new methods and technologies needs to be encouraged. It will not necessarily be an orderly transition however and there will be a huge number of small incremental steps and individual solutions developed, "Rapid Incremental Improvement". One of the major failings of technology adoption at the moment is that we perhaps have an idealised or normative view of farmers and their motives.

In this paper we argue that many improvements need to come from land managers and farmers using improvisation to adapt enabling technologies to their farming systems. A concept called "bricolage" is introduced which attempts to explain how this process might work, how solutions might be developed by this "brick by brick" approach, and what it means for technologists, researchers, regulators, government, service providers and farmers.

Introduction

There have been many statements made around the need to produce more food for a growing population from a smaller area. There have also been tremendous concerns around our use of finite resources such as water and fertiliser, plus concern around the effect all of this agricultural activity is having on the environment's capacity to deal with it. Environmental legislation is having an effect on productivity. The EU is perhaps the largest example where the rate increase in cereal yield has slowed significantly when nitrogen caps have been put in place. A report produced for the Danish Government Petersen et al (2010) illustrates the problem. The UK government released "A UK Strategy for Agricultural Technologies" in July 2013, Anon (2013) where it attempted to address these questions. Food affordability has also been highlighted as a problem. The World Bank (2008) estimated that 44 million people around the world were pushed into poverty due to food price spikes in 2008. It was hardly a surprise that the most food secure were the wealthier western nations which have high earnings and a low ratio of spending on food but also a significant investment in agriculturally related R&D. The report also pointed out that some of the countries at the bottom of the food security index (in sub Saharan Africa) had the fastest growing economies and although still poor they may be in position to better address some of their food security issues in the future.

Clearly there are huge pressures to produce more from less and precision agriculture (PA) would appear to be at the nexus of this debate, with its ideas around placing the right input, at the right rate, at the right time in the right place and in the right manner. Precision Agriculture came about 25 to 30 years ago when the technology of Global Positioning Systems (GPS) allowed us to consider how we could take spatial variability into account within our farming systems. This is important because it meant for the first time that we could potentially feed a crop to its potential and not beyond it, thus increasing the efficiency with which we use inputs and reducing any adverse effect on the environment from having excess nutrients within the system. Researchers and academics became very excited about the possibilities and most focused on large complex integrated systems that they saw as necessary to achieve significant benefit.

In the thirty years since these ideas were being discussed and developed very few farmers have adopted such a complete approach. Significant progress has been made with some technologies but few have (PA) to its full extent or potential as it was originally portrayed in diagrams similar to figure 1 which emphasises the complete and linear integration of crop production processes.

As a linear model, PA has broken down production into within field or cross field zones where the variability can be managed. The paradox here is that we have put all our effort into describing the physical variability of the farm, but we do not consider the impact of the individual farmer. We actually take no account of the individual farmer, yet the farmer is generally recognised as the main decision maker. The original PA model effectively took farmers out of the equation by reducing them to efficiency maximisers who rationally managed their farms as a complex mosaic of land parcels, each of which could be treated differently from the other.

The record of widespread PA adoption by farmers is poor. Perhaps however the problem is to be found in the way they have been taken out of the equation. Perhaps we should turn to the adoption question on its head. Rather than ask why farmers are not adopting PA more quickly, perhaps we should ask how PA itself has created the problem of farmer adoption. By answering this question we may discover better, more practical ways for PA technologies to be adopted on individual farms.

Adoption

As decision makers, farmers are seen as optimisers or maximisers of efficiency. These are also the goals of the PA system, but one big difference is that there is a lot more information around a particular farm or farming situation than a large and integration focused PA system can take into account. This fact is extremely important in the farmer centric decision making process. The farmer is essentially a problem solver and as individuals their particular knowledge of their own farm and farming system serves as a critical backdrop to decision making. Lissaman *et al* (2013) suggest that farmers adopt technologies when they can see bottom line gains in their farming system. But what counts as the bottom line for farmers? Lissaman reports work from Robinson (2009) which found that the uptake of innovation depends upon five factors: 1) relative advantage, 2) compatibility with existing values and practices, 3) simplicity and ease of use, 4) trial-ability and 5) observable results. These five farmer drivers play an important role in PA uptake, though it must be said they often seem to be ignored by PA technology developers. The 5 drivers do not appear at all for example in the 1998 'A strategy for better crop management based on yield mapping' (Figure 1).

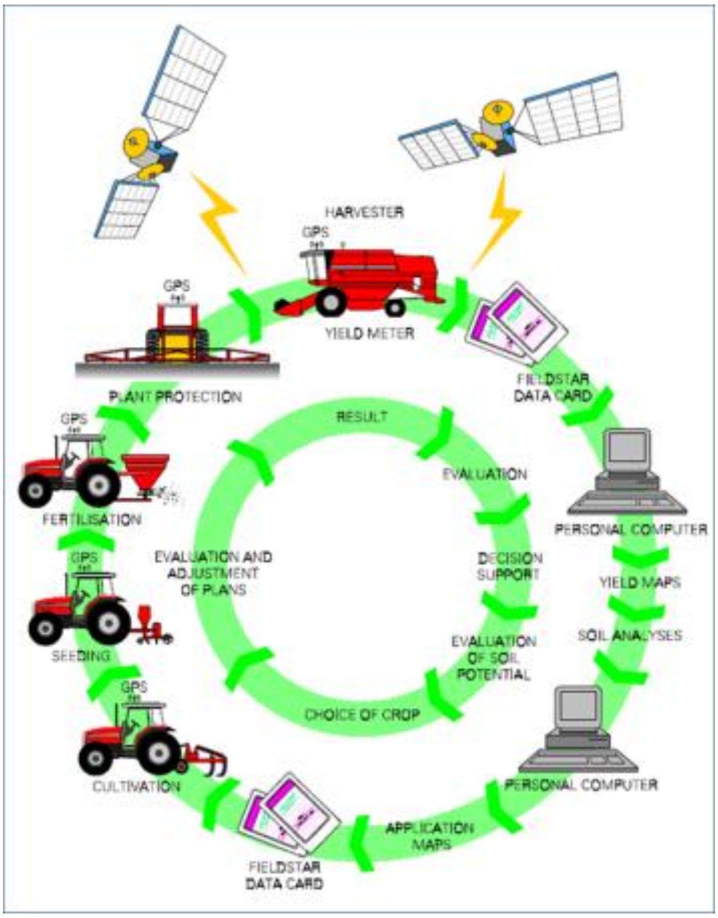

Figure 1: A nineties version of Precision Agriculture for cropping. From Mark Moore: A strategy for better crop management based on yield mapping, AGCO Ltd, Coventry England. 1998

Some farmers have adopted PA. We can expect this uptake to have been driven by the sorts of farmerly concerns identified by Robinson (2009). Batte and Arnholt (2003) analysed PA adoption in six case study farms. As these case studies clearly show, in practice PA is not a closed and integrated system. From a farmer's point of view, rather than a single, unified technology, PA is a suite of component technologies. Batte and Arnholt asked farmers to identify the single most important component and yield monitoring was chosen by 3 of the 6 respondents. Two chose geo-referenced grid or zone soil sampling and one selected GPS. None selected the variable rate application of fertiliser, which is where many PA scientists and developers started their careers.

They also reported on the work of Gelb et al (1999) who asked delegates from the European Federation for Information Technology in Agriculture (EFITA) to evaluate factors limiting farmer adoption of ICT. There were no practicing farmers in the group, their suggested factors were: 1) the cost of the technology, 2) too hard to use/unfriendly , 3) no perceived or other benefits, 4) do not understand the value of ICT, 5) lack of training. Anecdotal evidence from working with farmers in New Zealand would suggest that cost of technology is not the issue in itself if the value or cost benefit can be proved. This is especially evident in the case of using RTK Autosteer guidance systems which have seen huge growth in the number of users over the last ten years. Expensive yes, but clearly providing both direct economic benefits to farmers as well as further indirect benefits to farmers and other users.

Bricolage

Perhaps we should consider two different aspects to the problem: the size of the adoption step and the value of the adoption step. In summary, the scientist has valued an approach where the whole system as a whole was integrated, and variable rate inputs were an important part of thatintegration. However, while some technologies had a proven economic benefit this was not the case with variable rate application and moreover it was also difficult to measure its effect. By initially concentrating on the integration of the whole system, the scientist-research community have perhaps weakened or increased uncertainty in the financial return argument and introduced other difficulties associated with the introduction of ICT. It might also be fair to say that the scientist-research community has tended to look at PA in isolation whereas for the farmer it is only one component in their already complex situation.

Scientists working on the development of specialised and isolated systems is a familiar model of innovation. However, this is not how farmers tend to innovate. Arguably, farmers tend to innovate by improvising and improvisation is usually seen in a less positive light than the system-building aspirations of scientific researchers. For a farmer, improvisation is something that takes place within actual farming process and we suggest that it should not be seen as a less lofty practice or ambition than science-led innovation. Farmers will to a large extent adapt a technology to their own situation. Indeed, McBratney et al (2005) describe farmers as being engaged in adaptive management. Adaptation is a very strong driver. Farmers will tend to look at enabling technologies to examine how they can help their business. On these terms then, PA might have been better served if the offerings had been portrayed as a series of enabling technologies which farmers could pick and choose and get benefit from partial adoption. Fully integrated systems, on the other hand, are designed to be most effective when fully adoped, and such wholehearted adoption was emphasise in PA’s early years.

We have investigated the case of 3 farmers to illustrate how farmers make use of PA. All three are seen as leaders in the field of technology adoption and farm performance in New Zealand, yet all 3 had done completely different things and adopted the enabling technologies in a different order of priority. These orders of priority wwere driven by each farmer’s particular knowledge of their own farming system, a richly contextualised knowledge that led to the development of solutions which were quite different across the cases. The strongest similarities are perhaps that all three have a very strong knowledge base in the scientific sense and, have an excellent understanding of their own farming system. All three are fuelled by a very well developed sense of curiosity and a desire to improve their farming system. None have attempted to integrate the whole PA system, Instead, they have identified enabling technologies that can help them directly in their business and see the adaptation of these technologies as a continuing process.

Conceptually, the farmers' approach could be described as "bricolage". The term bricolage comes from the field of anthropology, and was first talked about by Levi-Strauss in the 1960s. It has gone on to be used in the fields of business entrepreneurship, cognitive psychology and artificial intelligence. Levi-Strauss (1962) described it as a "brick by brick" approach or DIY tinkering and cobbling together. He also went on to characterise the differences between the bricoleur and the system builder as illustrated in Table 1.

Table 1. The Bricoleur versus the System Builder, adapted from Strauss. Ref

The Bricoleur	The System Builder
Cyclical, iterative, detours, diversions, real-world time.	Linear, abstract time marching from means to ends.
Intimate knowledge and deep familiarity with the world based in ongoing hands-on experience.	Distant knowledge based on abstract representations of the world
Versatility and ongoing adaptation, building improvised assemblies through the substitution and shuffling of bits and pieces.	Specialization and standardisation, following the rules of prior specifications, building seamless integrated systems, everything in its proper place.

Many of the characteristics of the bricoleur describe the behaviour of the farmers. Farmer bricoleurs live in a real time world. They are constantly adapting and this means taking detours and diverting from the one path that leads to an integrated system. The nature of their business is cyclical and extra knowledge is developed with each iteration. They possess the intimate knowledge that comes from deep familiarity with the world around them and from regularly dealing with it in a hands-on way. They are versatile and adaptable and emphasise tactics as well as in longer term strategy.

Levis-Strauss' characterisation of the "System Builder" in Table 1 can just as readily be taken as describing the scientific and research communities' approach to the development of PA. Arguably, a similar mentality is often evidenced by many policy-making regulators, who also wish to develop system specifications and rules to be followed.

A more fluid concept of system relationships is illustrated by one of the case study farmers. He used the approach of Plan, Measure, Manage and Review (see Figure 2). He used this approach to reflect on the progress of the day-to-day business, but also to inform his strategic decision making. In essence, this is a continually informed iterative approach. Through this approach and the discipline of measurement, he has improved his farm system and been successful in increasing output while reducing inputs, markedly improving both farm efficiency and profitability. This farmer has adopted components of PA but only by adapting them to meet his own needs. In this way he has adopted the philosophy of PA and built his own unique technological solutions. This patter was common among the other case study farmers.

Essentially the philosophy of PA is an easy sell. Measuring performance, getting better control of inputs, farming to optimal efficiency, all this makes perfect sense to farmers. It is perhaps worth remembering that PA basically came out of one farming system, mainly cropping in the USA. PA thus has had to be adapted to cropping in other parts of the world and similar adaptations are now taking place among dairy and other forms of pasture farming in New Zealand and around the world. The adaptation of PA is thus still very much an on-going process.

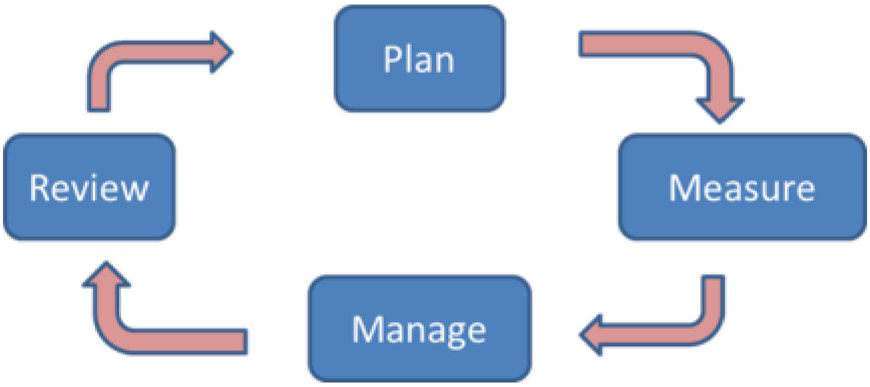

Figure 2. Management approach taken by Hayden Lawrence Niaruo Dairies, Taranaki.

Future measurement technologies

An important field of innovation in PA today is the use of remote sensing and drones in particular. In keeping with PA philosophy, it makes perfect sense to use these technologies to measure field performance more fully than in the past. Remote sensing would appear to offer great potential, but it is a technology that has been around for a similar time as PA and is still not widely adopted. A number of sensing platforms can be used: ground-based sensors, multi-rotor and fixed wing UAV's or drones the preferred term from the Civil Aviation Authority (CAA) is Remotely Piloted Automated System (RPAS), Drones certainly have some negative connotations for such authorities, while UAV gives the impression of there being no one in control. Aircraft based systems are available with some very powerful but expensive technologies. Satellite systems are being continually updated and improved with greater spectral and spatial resolution. The main difficulty in New Zealand is our climate and cloud cover. RPAS would appear to have much to offer and we know that many of the sensors work and can give us valuable information. The key question is how we can make them work within our farming systems.

A number of questions need to be answered:

Where do the different systems fit in?

How can we ensure they are safe to use?

How can we ensure they are cost effective?

Questions around safety are being addressed by the CAA. Requirements around the control of airspace mean that manned aircraft will always take precedence over unmanned. This has led to an approach that makes it likely that systems will have to be used within line of sight, something that may limit the scope of use. Fixed wing systems will have to be used with an observer and a pilot on the ground, which leads to a higher level of cost than many users may have imagined. One of the main thrusts of the development of RPAS is the automation and control of flight and this is likely to be an iterative development process. Assuming success, regulation is likely to lag behind in the interests of safety. Cost effectiveness is likely to be driven as much by operating cost as capital costs, as labour will still be a significant part of the resourcing needed.

One important concern is that our ability to collect information at ever finer spatial and spectral resolution may outstrip our ability to deal with that information at the individual farm level. We need to better define what information farmers want so that we can deliver good management information to them in near real-time. The ability to collect information does not necessarily mean that it can be delivered in a cost effective way. A great deal of potential complication has been added and robust processing systems need to be built. Automation of sensor information processing is a priority. The rapid turnaround of information or near real-time processing is an absolute necessity.

While these sensor applications require terabytes of data, there may be a series of simpler, less technical applications that could be utilised by farmers to provide cost effect solutions for observing stock, stock water, general field scouting and farm observation. As opportunities are being identified, solutions will be developed. We can already observe a bricolage process at work in which farmers are developing potential solutions for their particular problems which may have synergies with the problems faced by others. We should not ignore this brocolaging as a legitimate development pathway.

Conclusions

This paper has argued that PA would do well to focus as much on the development of enabling technologies as on their system integration. The adaptive potential of **enabling** technologies should lead to a fast moving, diverse future with lots of different possibilities, a future arrived at through an iterative rather than linear approach. There will be no single answer and lots of ideas will be brought to the market. Some will be culled fairly quickly while others will endure and develop. A bricolage approach should help bring about more rapid development than a well-controlled and highly integrated linear model carefully thought out by well-meaning scientists and engineers. It would certainly seem to offer advantages when it comes to having greater synergies with the thought processes of those who farm on the ground.

Creating large-scale, whole-farm integrated systems seems to have caused problems in getting farmers to adopt new technology. While we recognise the farmer as the main decision maker, in effect we often try to eliminate them from the decision making process, as if they serve the technology rather than the other way around. This is surely counter-productive. In contrast, the approach suggested by Levi-Strauss' bricolage would appear to offer a rational explanation of the behaviour of the farmer, which is inevitably and strongly influenced by particular and practical knowledge. It is the farmers who attempt to improve performance. They have ownership of the problem and we must put in place enabling technologies to help them. We need to be more cognisant of this in the future, in the way we develop new technologies and the size and complexity of the steps we introduce. The idea of bricolage offers many useful suggestions about how we should interact with end users in order to take greater account of the way they behave. Taking stock of farmers' particular knowledge and iterative practices will become increasingly important as the capabilities and complexity of PA technologies develop. We must be extremely careful not to repeat past mistakes.

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