PRECISION AGRICULTURE AS BRICOLAGE: UNDERSTANDING THE SITE SPECIFIC FARMER

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ABSTRACT

There is an immediate paradox apparent in precision farming because it applies all of it 's precision and recognition of variability to the land, yet operates under the assumption of idealism and normative notions when it comes to considering the farmer. Precision Agriculture (PA) systems have often considered the farmer as an optimiser of profit, or maximiser of efficiency, and therefore replaceable with mathematical constructs, so that although at the centre of decision making they are effectively made to disappear. However if the farmer disappears then so does the farm in terms of individualism and it simply becomes a patch work of zones and problem setting strategy generates the traditional approach to linear extension models. However practicing farmers do not think or act in the same way as the model specifies they should, the models might be more idealistic rather than realistic.

This paper explores the idea that "bricolage" could make a useful contribution to explain the slow rates of adoption achieved in PA, or put another way, the lack of apparent appeal of PA even though it would appear to offer many benefits through optimisation. Even the social science that has been applied to PA would appear to be enamoured with achieving greater precision by removing the individual farmer by breaking them down into generalised categories and sub sets to explain their behaviour.

The French anthropologist Leví Struass introduced the concept of bricolage in the nineteen sixties to counter "the supposed ineptitude of 'primitive people' for abstract thought", in contrast to the highly engineered solutions driven by modern science. In essence bricolage is a cobbling together of what is at hand, (local or particular knowledge and available enabling technologies). Essentially this process is driven by on-going curiosity and an iterative trial and error development of partial solutions rather than a linear march where curiosity has been replaced by "so-called" certainty. The idea of bricolage has gone on to be developed in a number of fields relevant to

PA, such as information systems development, artificial intelligence and entrepreneurial activity, but to date it has not been applied to PA.

Case study evidence of very early adopters and the most advanced or leading edge farmers indicate that they are individuals with individual interests, skills and knowledge. What they tend to do is target their areas of improvement and build solutions based on their particular knowledge and the enabling technologies at their disposal. Essentially a bricolage, which is driven by the individual farmers on-going curiosity and producing workable precision at the individual farm level.

Keywords: adoption bricolage, innovation, decision support, farmer.

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, where it attempted to address these questions, Anon (2014). Food affordability has also been highlighted as a problem and quoted the World Bank who 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).

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.

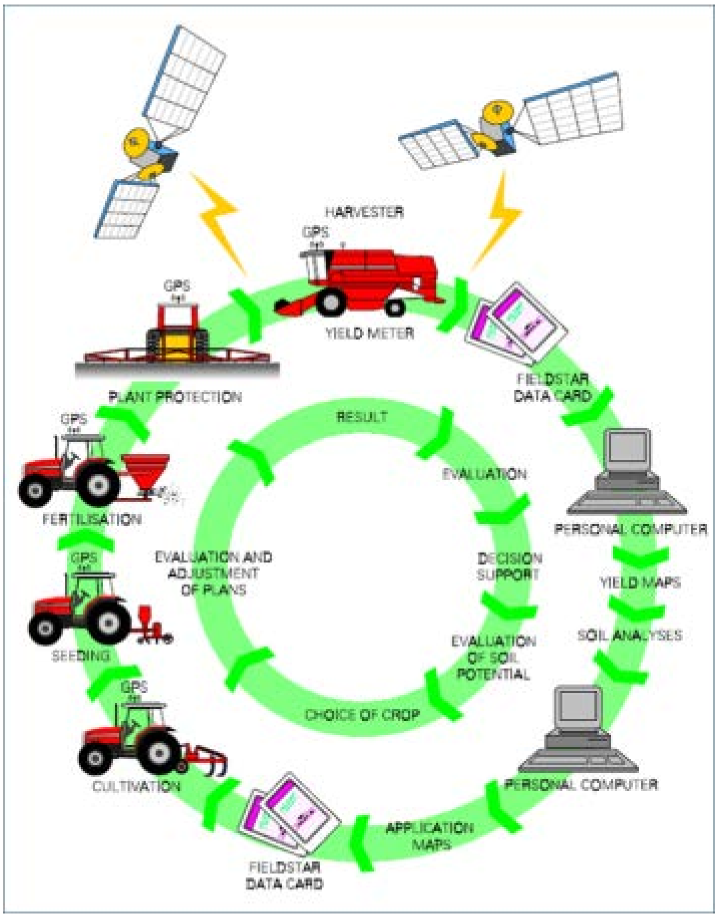

Figure 1: A nineties version of Precision Agriculture for cropping. From Mark Moore:
A strategy for better crop management based on yield mapping, AGCO Ltd, Coventry England. 1998

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 that integration. 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 emphasised 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 were 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.

Levi Strauss draws a strong contrast between the bricoleur and those we have called system builders (he uses the term *ingenieur* for the latter, a French expression with a more general meaning than "engineer"). In essence, bricolage is a "DIY" tinkering that iteratively solves problems at hand by cobbling together the resources available at the time. This adaptive approach is in stark contrast to the systematic problem-solving favoured by expertise-based scientists and technology developers. Levi Strauss points out that DIY is often seen as an inferior form of knowledge. He rejects this claim, arguing instead that bricolage and formal expertise are "two distinct modes of scientific thought" with their own specific forms of validity. In contrast to abstract science, Levi Strauss calls bricolage "the science of the concrete". This idea of bricolage has proved a useful guide for recent technological developments, including in fields related to PA such as artificial intelligence and enterprise-based IT. To date however, the concept has not been applied to PA, whose approach to problem solving has tended instead to focus on the building of integrated systems. We believe that such system building may limit farmer adoption because it makes too little of how farmers farm. As Nowak (1997) points out, "farmers understand and learn about soil in a fashion different than soil science". As formal, science-based knowledge is too abstract to solve the complexities of actual farm situations, farmers develop their own "evolving indigenous knowledge system". McBratney et al (2005) similarly argues that to make the most of PA's future we need to 'keep the farmer's perspective as the central focus".

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 expresses 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 pattern was common among the other case study farmers.

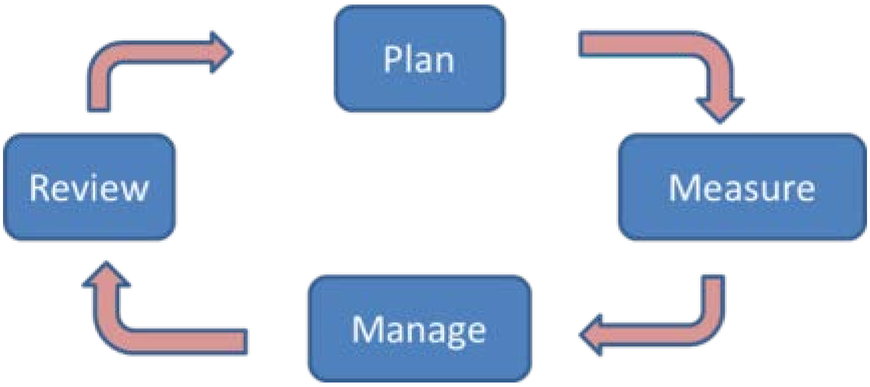

Figure 2. Management approach taken by Hayden Lawrence Niaruo Dairies, Taranaki.

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.

Case Study examples.

Three case studies are used to attempt to illustrate how enabling technologies can be adopted to significantly improve farm performance and profitability.

Dairy Farming.

Case Study Farm 1, is a dairy farm, the farmer started his adoption of PA by realising that he needed to feed his cows more consistently within a typical New Zealand pasture system in order that they perform. He was particularly concerned about the lack of ability to measure his pasture inputs. He is one of the co-inventors of the C-Dax Pasturemeter and has used it on his own farm to increase pasture utilisation. He is able to calculate just how much pasture is available and what other feed needs to be given. Cows have EID and are fed according to individual production. The main advantages he derived from this are that he can better utilise his pasture and he can be consistent in what the cows are being fed. Further advantages include a far greater ability to forecast pasture growth rates and analyse the yearly production of each pasture paddock. This allows him to target areas of improvement and make sound financial decision around pasture replacement. The system also allows him to evaluate the performance of new cultivars for example because pasture growth rate is measured every week of the year in every paddock. He take 1.5 hours per week to complete his pasture measurement and feed budgeting and rates it as being the highest rate of return for his efforts every week.

He further decided to investigate the fertility of the farm, rather than use the standard practice of using few soil samples, he produced a distinct soil sampling regime for each paddock. Although this increased cost by $35 per ha, he realised that he could make significant savings in fertiliser costs. He reduced his annual fertiliser costs by around $150 per ha for the first four years of using this system.

During this period his farm has gone from being an average performer, producing just under 1000 kg of milk solids per ha to just over 1500 kg of milk solids per ha. He used to grow around 13 tonnes of pasture dry matter per ha, he now grows 18 tonnes with significantly reduced fertiliser inputs.

Cropping

Case Study Farm 2, is a large mainly irrigated cropping farm. The first investment in PA technology was yield mapping on the harvester. What this revealed to him was the extent to which large areas of the farm were adversely affected by water logging and poor drainage and just what that was costing him. The information from the yield mapping encouraged the farmer to look at draining and re-contouring parts of his farm. Although this is a very expensive exercise the farm had the benefit of large machinery such as excavators and further scraper buckets and levelling equipment was purchased. Every season the farmer re-contours part of the farm in an on-going programme. The farm is on highly variable soils and the farmer has also invested in variable rate irrigation (VRI) or precision irrigation (PI) as it is sometimes described. The value of VRI is that the farm is on a fixed water consent and a larger area can be effectively irrigated with the same amount of water. In his case it means the ability to operate 20 centre pivot irrigators rather than 16.

The other major investment on the farm has been Autosteer, six tractors are now fitted with RTK Autosteer and this has allowed simple savings in fuel and other expenses as output has typically increased by 10 to 12%. More importantly it has allowed him to use other tillage techniques such as strip till for a range of crops. This system was difficult to work with conventional equipment but the RTK GPS enables a successful implementation. The sprayer tractor has also been fitted with Autosteer so that the operator has a greater opportunity to observe the spraying equipment and boom control has also become a reality. At this stage there appear to be no plans to use VRA technologies with fertiliser in the crops although crop sensors have generated some interest.

High Value Cropping and Dairy.

Case Study 3, is a mixed farmer with both dairying and cropping with high value seed production being one of the main arable activities. This farmer perhaps has a more environmental focus than most while at the same time the farming performance is exceptionally good. His PA activities on his dairy farm have been around utilising dairy effluent much more effectively, using crop sensors to variably apply N fertiliser to take account of the pasture response to effluent. He has also taken to more intensive soil sampling and again demonstrated that significant savings can be made in base fertiliser application. He is extremely careful with his irrigation management to eliminate drainage events and surface run off, he again uses VRI.

The cropping operations are run with a lot of attention paid to VRA application of fertilisers with significant investment in modern equipment to ensure high quality performance. In recent years VRI has been used and significant savings in water made while reducing or eliminating problems from over watering on parts of the farm. He has also been involved in the re-design of irrigation systems to enhance the performance of irrigation on his farm.

Although it is difficult to illustrate the scale of effort and change achieved on these farms in a snapshot, they have all made a very significant difference to the way they farm, but they have used the enabling technologies available to them in completely different ways with different priorities which reflect their own particular knowledge of their own farming system. They are all three fired by a tremendous sense of wanting to improve and realisation that they can improve. They have also invested in the measurement technologies that will allow them to validate what they have done.

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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