Getting Comfortable with No Seat No Cab

Preparing Growers for Driverless Machines

A report for

NUFFIELD AUSTRALIA FARMING SCHOLARS

By Boyd Carter

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Scholar Contact Details

Boyd Carter

KL Carter & Co

14336 Rabbit Proof Fence Road

Wubin 6612

Phone: 61 429643020

Email: boydfarming@live.com.au

In submitting this report, the Scholar has agreed to Nuffield Australia publishing this material in its edited form.

NUFFIELD AUSTRALIA Contact Details

Nuffield Australia

Email: enquiries@nuffield.com.au

Address: PO Box 495, Kyogle, New South Wales, 2474

Executive Summary

Farming as an industry is arguably a forward-thinking enterprise that works as efficiently as all its parts. In a time of unpredictable weather, rising input costs and a greater gap in understanding between consumers and growers, broadacre farmers are looking for innovative ways of meeting these challenges while also meeting consumer demand for developing agriculture in an environmentally sustainable way. Could Driverless Machines help in meeting these challenges and if so, what can farmers do now to make an easy transition to this automated future?

Technical efficiency in broadacre farming assumes maximum output from a carefully considered complex range of inputs. With the trialling of new technologies, farmers not only need information about the new technology and its applications in various scenarios, but they also need to know how to prepare for trials with suppliers in ways that might guarantee success for both. Furthermore, they need reassurance that legal, social, and financial considerations for themselves and their communities will not be adversely affected.

As pointed out in the Rabo Research Food & Agribusiness Podcast (June 2017), many farmers lack the necessary technological and financial infrastructures that are key to executing a smooth adoption of robotics to the farm. Knowledge of the dollars and cents for the farm are a must, along with an overview of assumptions of how the driverless products could improve efficiency and timeliness. Such information is the kind that can be shared between farmers and suppliers during trials and is crucial to their success.

Farmers' concerns also relate to the impact of the use of new technologies on their communities. Shire offices and the police have an interest in how the machines are moved around the area, for instance. There is much confusion about regulatory laws for autonomous machines in general and with the possibility of driverless machines driving on public roads, an understanding of these will have a determining factor on the type of driverless machines farmers will purchase.

This report gives farmers information about the technology and its applications and provides a guide for steps that can be done now in preparation for trials which will allow farmers to develop a greater understanding of the technology, giving them confidence in the products available today and to come. This guide contains advice on paddock mapping and current issues with mapping as this is the brains behind the operation. It considers factors around getting machines from paddock to paddock and issues of operation and assessment such as which operation suits which type of machine best. Furthermore, it suggests that there is much that is still unknown about how driverless machines will affect broadacre farming and that farmers need to look at what is important to them, the people they work with and getting the job done.

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Foreword

As a broadacre farmer in the Wheatbelt of Western Australia in a 280ml a year rainfall area, technical efficiency has always been important to my business. Over time, developments in technology have doubled the number of hectares we farm, while adding a minimal number of staff. Staffing is not an issue for us at this stage but in saying that I've noticed the ability of staff to work efficiently is falling.

At the conference *Innovation Generation* in 2014, I attended a talk by Andrew Bates about these small un-manned machines doing the labour of a seat attendant, a concept now known as SwarmFarm. I said to my fellow Liebe Group Members: *This will be the next big thing in agriculture*. With this eye-opening concept of possibilities churning away in the back of my mind, all the positives began to take shape: no compaction issues, being able to pay workers more because they are not doing mundane tasks and doing all those jobs that could be done all year round instead of what we do in just two months, such as, looking after fire breaks.

However, as the idea progressed, I began to also see the negatives of the driverless future, not so much to our business but to our community. Ours is a community that has lost two schools and where there has been a reduction of participation in golf, bowling, cricket and football clubs. The loss of more people coming into the community, I realised, could be seen as a real threat.

The solution, I decided, was to study how driverless machines could affect both the business and social aspects of broadacre farming areas (Deloitte, 2017). I also thought that perhaps if individual farmers could feel more comfortable with the idea of driverless machines, then whole communities could become early adopters leading to more people coming into the area through investment in the supply chain of robotics.

Research into the inevitability of robotics in broadacre farming poses a series of problems and questions that are rooted in financial and social unpreparedness (Gent, 2018, Ghaffarzadeh, 2018, Gray, 2017, RaboResearch Food & Agribusiness Podcast, 2017, Robotics Industries Association Blog, 2017, Wolff, 2017)) Largely the problems, as highlighted by Rabobank research in 2017 and reported in the article *Bungle in the Ag Tech Jungle*, stem from a disconnect in communication from the producer to the client. Many farmers lack the necessary technological understanding and financial infrastructures that are key to executing a smooth adoption of robotics on the farm. As a result, many farmers find the inevitable transition to autonomous technology in broadacre farming, to be daunting.

My hopes in doing this study were to alleviate some of the stress involved in tackling the transition to robotics in broadacre farming by developing a guide for action. In creating this robotics *how to* manual I hoped to achieve a platform where both farmers and developers could share a common ground of knowledge. The platform would be written for the farmer and would be easy to read and understand. It would be a step-by-step guide derived from international trials that would allow me to highlight the financial benefits, the potential pitfalls and the evolution of farming employment. Thus, the impending transition would not seem so daunting, and in many cases, proactive measures could be undertaken to improve the efficiency of adopting new robotic technologies. Alas, it would seem that for this I was on the wrong side of the curb. My research revealed that international trials were only just beginning to be implemented and that there were few results available.

Though Robotics was the hot topic, I began to see that the true nature of my research was technical efficiency in broadacre farming. As we all know, Australia is looking to agriculture for its next *boom* and I believe the only way this is possible is through ensuring the efficiency of our inputs, that is, allowing agriculture in Australia to develop the ability to adopt new technologies to control our inputs before other world growers. As for the robotics, with investment growing by 2% to 3% per year, they are coming to agriculture. Already insurance companies are using drones to do crop damage assessments and it is only a matter of time before robotics and drone technologies collaborate for broadacre weed management.

My study then evolved from just a focus on robotics to include topics such as regulatory laws and where they may be heading when automation becomes a profitable prospect and an exploration of what other institutions can do to help the adoption of automation to broadacre farming. Furthermore, it became clear during my research that trials for the farmer need to address other issues, including the issue of driverless versus robotic or whether we should have a combination of both; the issue of the significance of farm design; the issue of qualifications of employees and the issue of the importance of grower education. The trials also need to identify technology and information that is available now that will help with the transition to automation and to work towards the design of a comprehensive two-part guide of current knowledge and its application. It is also important that new trials encourage an approach to robotics that thinks *beyond the robot* and that develops new logistics and information systems as they pertain to farm operation. Such trials will build on the technical efficiency that already characterizes the business of broadacre farming in Australia (Southern Phone Blog, 2018) and not simply focus on robotics as a new technology.

Acknowledgments

I am firstly indebted to the Grains Research and Development Corporation for all their support and the opportunity to travel and undertake this project. I am also immensely grateful to my parents, Keith and Rosemary Carter, for *picking up the slack* through the time I was overseas and while I was involved in the Nuffield process.

I also want to thank all the farms and industries for their time and for sharing aspects of their new technologies with me. In particular,

- Swarmfarm, Queensland
- DoT, Canada
- Small Robotics Company, England
- Harper-Adams University, Shropshire, England
- Hoflanden, Germany
- Tesla, Australia
- Bees Wax Farms, United Kingdom.
- Seed Synk, Canada

The Liebe Group has always been a good sounding board for my ideas and its members set me on this path well before I knew about Nuffield and I am grateful to them. I also want to thank Grain Growers Australia for their encouragement and especially for their support through their Leadership Programme of which I am a graduate. Thanks also to Farmanco, especially Ben Stewart and Rob Sands for working with me on the cost effectiveness of driverless machines. Thanks go also to my neighbour and editor, Glenda McNeill, for her assistance in preparing this report for publication.

Finally, thanks to Nuffield for the opportunity to meet like-minded people from all over the world and for providing the platform for me to develop and publish my ideas. It is a great institution for promoting farmers and the industry from the ground up.

Abbreviations

AI - Artificial Intelligence

Ag – Agriculture

AgBot – Agricultural Robot

AgTech - Agricultural Technology

AWS - Amazon Web Services

GPS - Global Positioning System

GRDC - Grain Research and Development Corporation

Ha - Hectares

Hr - Hours

IP - Intellectual Property

QR - Quick Response

RTK - Real-Time Kinematic

Tech-Technology

Objectives

Technical efficiency in broadacre farming assumes maximum output from a carefully considered complex range of inputs. With the trialling of new technologies, farmers not only need information about the new technology and its applications in various scenarios, but they also need to know how to prepare for trials with suppliers in ways that might guarantee success for both. Furthermore, they need reassurance that legal, social, and financial considerations for their communities will not be adversely affected.

Hence this study intends to -

- Explain to broadacre farmers the technology that is available and how it relates to driverless machines.
- Develop a guide for broadacre farmers of steps that can be taken now to be ready for the implementation of driverless machines.
- Inform those in the driverless machine supply line of the needs of broadacre farmers so they can help facilitate change.
- Step off the farm and investigate how the adoption of driverless machines might affect the life of farming communities.

Chapter 1: Introduction

Farming as an industry is arguably a forward-thinking enterprise that works as efficiently as all its parts. In a time of unpredictable weather, rising input costs and a greater gap in understanding between consumers and growers, broadacre farmers are looking for innovative ways of meeting these challenges while also meeting consumer demand for developing agriculture in an environmentally sustainable way. Could Driverless Machines help in meeting these challenges and if so, what can farmers do now to make an easy transition to this automated future?

Giving farmers information about the technology and its applications and giving them a guide for steps that can be done now in preparation for trials will allow them to develop a greater understanding of the technology, giving them confidence in the products available today and to come. This guide will need to contain advice on paddock mapping and current issues with mapping as this will be the brains behind the operation. It will need to consider factors around getting machines from paddock to paddock and additionally issues of operation and assessment such as which operation suits which type of machine best. Furthermore, it needs to include a list of technologies that will allow growers the confidence to have no operator as, all over the world, farmers are saying that the biggest risk to their business is labour.

As pointed out in the Rabo Research Food & Agribusiness Podcast (2017), many farmers lack the necessary technological and financial infrastructures that are key to executing a smooth adoption of robotics to the farm. Knowledge of the dollars and cents for the farm are a must, along with an overview of assumptions of how the driverless products could improve efficiency and timeliness. Such information is the kind that can be shared between farmers and suppliers during trials and is crucial to their success.

Farmers' concerns also relate to the impact of the use of new technologies on their communities. Shire offices and the police have an interest in how the machines are moved around the area, for instance. There is much confusion about regulatory laws for autonomous machines in general and with the possibility of driverless machine driving on public roads an understanding of these will have a determining factor on the type of driverless machines farmers will purchase. New laws are expected at the end of 2019. At this point there are no laws restricting driverless machines being operated on farms. In the future it is not inconceivable that autonomous machines could be exempt from some regulatory laws due to their lower speeds.

Chapter 2: For the Farmer

The Nuffield Scholarship allowed the author to travel all over the world to meet farmers and high- ranking officials connected to agriculture. What was heard, from Jinan in the Shandong province of China to the wide corn fields of Iowa in North America, was that finding suitable employees was of major concern. In China, even where there was high unemployment, there were employment issues, because whole community populations were moving closer to cities and working in industries. In Iowa, social change meant that younger populations were no longer interested in taking up farming and were moving to town centres.

In Africa, where labour was most unskilled, corporate solutions were being tried where two farms were established side by side to teach workers the skills which would eventually enable them to take over the second farm. In England, where farming land is closer to larger communities, the focus was on open farm weekends in acknowledgement of the *Farm to Fork* approach. Townspeople visited farming areas to buy produce and provided some casual farm work out of interest. There was something of a Disney view of farms apparent in this approach, however. For example, a teacher would not allow her students to visit farms at shearing time because she thought sheep were killed before they were shorn.

In terms of facilities, Australian farms appeared well off compared to the rest of the world. It was difficult to observe applications of new technologies anywhere in the study tour. In theory new technologies were said to be important for the future but in practice there was little that farmers were willing or able to demonstrate. Farmers and suppliers appeared secretive, unwilling to share what was being trialled or the results of trials. There were only four instances where trial work was demonstrated:

1. In England - a small robotic company used small robots to take photos in the process of building a sprayer.
2. In Szechuan, Canada – DoT seeding and spraying was observed.
3. In Queensland - Three Swarmfarm machines worked well on a local farm. Swarmfarm had sold 80 machines at this stage.
4. In Washington, D.C. – Hitachi automated mowers were observed at work.

Nevertheless, there was a great deal of information available to farmers even at this early stage about the potential of driverless machines and the new processes and technologies that accompanied them.

Swarm Vs Driverless Machines

In the driverless vehicle space, research has convinced the author that there are two main concepts to consider in broadacre farming, Swarm and Driverless, each has its pros and cons as set out in the table below.

	Pros	Cons
Swarm	Less compaction	Low hp
	Easy to repair	Need 2 to 3 times as many
	Component shipping cost cheaper	
	Attachments smaller so easy to man handle	Need to replace existing implements
	Safer due to lower weight.	Need a tech support team
	If one machine goes down there are more still working.	
	Opportunity for plant share or contract	
	Saving on getting tasks done in a timely manner.	
	Savings on labour	More loading times e.g. fuel products.
	Savings on less materials	Off set by more machines
	24 hour run time	
	Slower speed allowing for greater control of chemicals	
Driverless	Standard use of equipment	
	Time savings of getting things done in a timely manner.	
	Savings on no cab (if applicable)	Down time due to no cab (GPS dropout)
	Savings on maintenance	Higher safety risk
	Savings in fuel	
	Savings on labour	Need a tech support team
	24 hour run time	
	Can be run slower speed allowing for greater control of chemicals	Getting machine producer on board

Figure 1: A Comparison of Swarm and Driverless Vehicles – Pros and Cons (author)

The swarm concept (Ghaffarzadeh, 2018) is the idea of having multiple small machines running around doing the same task, talking to each other, and working like a swarm of insects. Having a smaller machine means less to nil compaction. With machines getting bigger, carrying more load compaction is a major soil constraint said to cost the industry $1 billion per year (Petersen, 2016) and is mostly managed today with Controlled Traffic. Being smaller, repairs to the swarm machines should be easy and can be man handled, and transport cost of the parts should be cheaper.

In this report a driverless machine refers to both retro fitting an existing machine and a pre-fitted machine such as the Case IH Cab-less prototype pictured in Figure 2. These machines allow farmers to use their existing implements. However, in saying that, there will be many sensors that will be needed to be added so the machine can operate implements correctly.

Figure 2: A driverless machine refers to both retro fitting an existing machine and a pre-fitted machine such as the Case IH Cab-less prototype (above)

There are a few people who have retro fitted machines around the world. Harper-Adams University in Shropshire, England has managed to retro fit two tractors and a plot harvester allowing them to grow and crop a hectare without a human stepping on the field (Harper-Adams University, 2016).

Figure 3: Retro fitting two tractors and a plot harvester at Harper Adams University, UK

Kyler Laird, a farmer in Indiana (USA) was the winner of the AgBot challenge in 2017 when he had three machines retro fitted, planting 1,700 acres and taking on the challenge of planting 10,000 acres to prove working this way was ten times more efficient (Bedford, 2017).

Figure 4:Kyler Laird, a farmer in Indiana (USA) was the winner of the AgBot challenge in 2017 when he had three machines retro fitted

With all these forms of Ag driverless machines, there is a common question which farmers must ask: *Will I need a command centre or can I leave the machine to work alone?*

For comparison, in the mining industry, there is a command centre where two to four people oversee many machines and systems and the control centre is not necessarily on site.

In the case of the hands - free hectare in Shropshire, the command centre was set up directly near the Ha plot which leads to the question: *Is the control centre required?* Jonathan Gill (Personal Interview), the lead researcher for Harper-Adams University, suggested that the role of the control centre is less about controlling the machines and *more about analysing the data and education for the trial*.

Figure 5: The author with Rob Sands, Farmanco

The investment

When working to develop the following figures with Rob Sands from Farmanco (Figure 5), it became obvious that, when investing in driverless machines, there are main points that farmers need to consider.

Cost

Investing in any new plant must be well thought out but in the case of purchasing a driverless machine, growers are not only purchasing the plant but also a driver. The term *driver* is more appropriate in this instance rather than *employee*, as I will explain later. For comparison, if you take the example of a sprayer that doubles as a swather it adds an incentive but if farmers have no reason for swathing, then what is the point.

Savings

Here are some averages from Farmanco's 750 client base to get a costing breakdown.

Conventional Vs Autonomous **Tractor Costs**

FARMANCO

Power (HP)	Configuration	Opportunity Cost Interest Rate	
4WD Tractor		5%	5%

Machine		Conventional	Dot Power Platform	Small Swarm (2 Units)
Power	hp	**500**	**173**	**70x2**
Own Use (engine hrs/yr)		500	1,000	1,000
Total Hours Used/yr		500	1,000	1,000
Fixed Costs				
Market Value		**$400,000**	**$329,907**	**$450,000**
Ownership Period (yrs)		15	15	3
Engine Hours at Resale (hrs)		7,500	15,000	3,000
Litres of Fuel/hr		40	40	20
Total Use (Engine hrs/yr)		**500**	**1,000**	**1,000**
Shelter and Insurance	1.00%	$2,200	$1,900	$2,250
Resale Value		**$40,000**	**$50,000**	
Annual Ownership Cost	$/Yr	$37,200	$30,058	$152,250
	$/Hr	**$74.40**	**$30.06**	**$152.25**
Variable Costs				
Repairs and Maintenance Labour		$3,000	$3,000	$3,000
Repairs and Maintenance Parts		$3,000	$5,000	
Fuel (net cost)	$1.00	$20,000	$40,000	$20,000
Oil (% of Fuel)	10%	$2,000	$4,000	$2,000
Labour Cost ($/engine hr)	$30.00	$15,000		
IT Support, Data Connection Costs			$1,500	$1,500
Annual Variable Costs	$/Yr	$43,000	$53,500	$26,500
	$/Hr	**$86.00**	**$53.50**	**$26.50**
Total Annual Costs	$/Yr	$80,200	$83,558	$178,750
	$/hr	**$160.40**	**$83.56**	**$178.75**

Figure 6: A Cost Comparison Between Conventional and Autonomous Tractors

Some assumptions need to be made for Timeliness Cost/Efficiency Cost. A price rise in these two chemicals from four leaf to eight leaf has been considered to demonstrate the cost of timeliness.

Chemical	Rate	$/Ha	Weed Growth Stage	Rate	$/Ha	Weed Growth Stage
Jaguar	500	$6.25	4 leaf no bigger than 120mm	1000	$12.50	8 leaf no bigger than 180mm
Precept	1000	$16.05	2 to 4 leaf	2000	$32.10	up to 8 leaf
Combined $/Ha		$22.30			$44.60	
Ave Difference $/ha		$11.15				

Figure 7: Chemical Cost Comparison Early vs Late

A saving of $11.15/ha but for this let's assume the farm would at least get half the program done with the early timing giving $5.57.

Conventional Vs Autonomous

Spraying Costs

FARMANCO

Type of Implement	Interest Rate
Sprayer	8%

Tractor			Conventional	Mid Range Platform	Swarm (2 Units)
Machine			**Towed Boom 36m**	**Boom 36m**	**Boom 8m**
Own Area (ha)			20,000	20,000	20,000
Total Area Covered			20,000	20,000	20,000
Field Efficiency			60%	70%	80%
Ha per engine hour			47.52	27.72	12.80
Effective Hours per Day			10.00	18.00	24.00
Days/Year			42.09	40.08	65.10
Fixed Costs					
Market Value			**$180,000**	**$195,000**	**$140,000**
Ownership Period (yrs)			10	10	10
Hours at Resale (hrs)			4209	7215	15625
Total Use (hrs/yr)			**421**	**722**	**1,563**
Shelter and Insurance		1.00%	$990	$1,035	$770
Resale Value			**$18,000**	**$12,000**	**$14,000**
Implement Only	$/Yr		$25,110	$27,615	$19,530
Annual Ownership Cost	$/Hr		$59.66	$38.27	$12.50
	$/Ha		**$1.26**	**$1.38**	**$0.98**
Variable Costs					
Repairs and Maintenance	($/ha)		$0.50	$0.50	$0.50
	Total		$10,000	$10,000	$10,000
Labour Cost -Don't Include Tractor Driver ($/hr					
Other running costs					
Implement Only	$/Yr		$10,000	$10,000	$10,000
Annual Variable Costs	$/Hr		$23.76	$13.86	$6.40
	$/Ha		**$0.50**	**$0.50**	**$0.50**
Total Annual Costs	$/Yr		$35,110	$37,615	$29,530
	$/hr		$83.42	$52.13	$18.90
	$/ha		**$1.76**	**$1.88**	**$1.48**

Tractor & Implement & Supporting Eq.		**Conventional**	**lid Range Platform**	**warm (2 Units)**
Annual Ownership Cost	$/Yr	$56,423	$47,476	$257,421
	$/Hr	$134.06	$65.80	$164.75
	$/Ha	**$2.82**	**$2.37**	**$12.87**
Annual Variable Costs	$/Yr	$46,195	$48,600	$51,406
	$/Hr	$109.76	$67.36	$32.90
	$/Ha	**$2.31**	**$2.43**	**$2.57**
Total Annual Costs	$/Yr	$102,618	$96,077	$308,827
	$/Hr	$243.82	$133.16	$197.65
	$/Ha	**$5.13**	**$4.80**	**$15.44**

Figure 8. Comparison of Conventional and Autonomous Spraying Costs

The problem with assuming 24 hours per day of spraying is that farmers should not be spraying with an inversion so they would probably lose at least a couple hours per day. They may also lose an hour or two with a heavy dew. In addition, mixes that contain Brodal should not be sprayed at night. So, the above analysis is being generous to the Swarm alternative assuming 24hours at 80% field efficiency but with many of these machines looking at non-chemical options, it is worth mentioning. Speed of operation for trailed boom is assumed to be 22 km/hr at 60% efficiency. Mid-Range Platform assumed 22km/hr at 80% efficiency. Swarm assumed 10km/hr at 80% efficiency.

Conventional Vs Autonomous

Seeding

FARMANCO

Type of Implement	Interest Rate
Seeder	5%

Tractor			Conventional	Mid Range Platform	Swarm (2 Units)
Machine			**18m Bar & Box**	**9m Seeder**	**4m Seeder*2**
Own Area (ha)			3,900	3900	3900
Total Area Covered			4,000	4,000	4,000
Ha per engine hour			16.20	8.10	8.00
Fixed Costs					
Market Value			**$480,000**	**$300,000**	**$200,000**
Ownership Period (yrs)			10	10	10
Hours at Resale (hrs)			2407	4815	4875
Total Use (hrs/yr)			**241**	**481**	**488**
Hours per Day			**16**	**24**	**24**
Days of Seeding			**15**	**20**	**20**
Shelter and Insurance		1.00%	$3,600	$2,250	$1,500
Resale Value			**$240,000**	**$150,000**	**$100,000**
Implement Only	$/Yr		$45,600	$28,500	$19,000
Annual Ownership Cost	$/Hr		$189.42	$59.19	$38.97
	$/Ha		**$11.40**	**$7.13**	**$4.75**
Variable Costs					
Repairs and Maintenance	($/ha)		$3.00	$3.00	$3.00
	Total		$12,000	$12,000	$12,000
Labour Cost -Not Tractor Driver, But Gopher at 1/2 time might be $15/hr		$15.00	$3,611		
Other running costs Bins, Loaders, Augers, Trucks Etc			$20,000	$20,000	$20,000
Implement Only	$/Yr		$35,611	$32,000	$32,000
Annual Variable Costs	$/Hr		$147.92	$66.46	$65.64
	$/Ha		**$8.90**	**$8.00**	**$8.00**
Total Annual Costs	$/Yr		$81,211	$60,500	$51,000
	$/hr		$337.34	$125.65	$104.62
	$/ha		**$20.30**	**$15.13**	**$12.75**
Tractor & Implement & Supporting Eq.					
Annual Ownership Cost	$/Yr		$63,511	$41,754	$93,222
	$/Hr		$263.82	$86.72	$191.22
	$/Ha		**$15.88**	**$10.44**	**$23.31**
Annual Variable Costs	$/Yr		$56,315	$57,759	$44,919
	$/Hr		$233.92	$119.96	$92.14
	$/Ha		**$14.08**	**$14.44**	**$11.23**
Total Annual Costs	$/Yr		$119,826	$99,513	$138,141
	$/Hr		$497.74	$206.68	$283.37
	$/Ha		**$29.96**	**$24.88**	**$34.54**

Figure 9: A comparison of Conventional and Autonomous Seeding Operations

Assumptions have been made for the seeding operation to allow for the same speed which is 9km per hour. For the 175 platform soils these would be non-compacted and possibly wet for heavier soils to run a 9m seeder depending on tine configuration. This would also apply to the 4m Swarm Machine.

A driverless machine, it can be assumed, can do more hours (no shift change) leading to 20% more grain planted in the correct seeding window. Average losses have been recorded between 28kg/ha/day to 13kg/ha/day for wheat.

Will it save time or cost?

This is hard to answer as with most new technology there are always teething issues but working through and understanding the technology that is available today will put farmers on the best footing. In saying this, if the supply line support is not there, minor issues could be very time costly.

Some Apps out today which are used for recording information can be time consuming, especially if farmers need to transfer information from multiple platforms. There were many times farmers said: *It's just easier and faster to write it on paper*. No doubt, the up-and-coming generation which is more tech savvy will find this easier. The point is that the time recording information must be weighed against the fluent sharing of information between all parties involved.

At this time of driverless machines entering broadacre farming, there is a lot of support for clients with setup, mapping, and ongoing support, as businesses are keen to protect their brand and product. Although this statement must be read with caution as the support network is not there outside of the main product base. The issue concerning time won't come from the driverless machine working on the farm that has been tested to death, the issue will come getting the technology onto the implements which communicate with the machine brain.

Technology Available Today

Auto steer

It is commonplace in broadacre farming, saving fatigue on the drive and freeing up the operator to concentrate on doing the job correctly. Having the run lines, boundaries and outside round guidance setup correctly and proficiently now will save time and money as farmers transition to driverless. Farmers have setup boundaries in one of two ways, either from the fence line or from the edge of the workings. Looking forward the better way will be from the edge of the workings so a consistent distance from the boundary for the first lap can be set and conveyed to all machines. There is an issue with doing this if farmers want to spray outside the workings because the boom will shut off. One solution for this is to have two sets of boundaries, one on the fence line, one on the edge of the workings. Having both will also save time in the future as the driverless machine will be able to do fire breaks.

Blockage indicators

These go onto the down tubes of the seeder. Head blockage sensors have been around for tens of years allowing the operator to know when the primary and secondary hose is blocked. With an indicator light leading the operator straight to the issue. Indicator lights will be important in new technology that comes along so the manager can head straight to the issue. Now blockage indicators can be on every down tube providing information about the percentage of product per head and flow over the whole machine. If the operator is no longer in the machine, new blockage indicator technology needs to be available for not only the seeding implements but for sprayer nozzles and spreaders.

Mapping data

This is another common place tool these days not that it is being utilized to its best benefit as farmers are yet to see the full extent of what is available and how it may be applied to future technology. In one pass a harvester has recorded location, date/time, yield, moisture, fuel consumption, slippage, elevation, GPS signal strength and lots more. Farmers do not have the time to go through all this data, but they do need an understanding of how this relates to their land. A yield map can relate to a soil type, a compaction layer or one of those unintentional trials. A fuel consumption map related to elevation and slippage can indicate high stubble loads. Combine this with the yield and it can demonstrate frost or weed burden or assess added cost of a variety due to higher thrashing. Some of this data is recorded for the seeding operation. As more of these data maps are processed and, combined with the process of taking the operator out of the equation, developing the system behind the driverless machine will be essential. Take a fuel consumption map for example, a variable time pressure map could be made to save wear on points allowing the implement to work at its optimal efficiency.

Line find /row finding

Row finding technology has been investigated for decades now both mechanically and more recently digitally. This is rather important as driverless machines at this point are using a form of this in combination with GPS. This is done by patent recognition of the crop type with a camera, meaning the onboard brain has to have learnt what shape the crop looks like at different stages of growth. It appears to be a more reliable system and accurate than GPS.

Drones

Drones are a great piece of technology with their main use being for observation. There are insurance companies using drones to assess crop damage allowing a speedy overview of the affected area. There are many creative ways farmers have come up with to use drones. Some of these include checking over stock without disturbing them, picking where a problem animal may be, allowing the farmer to go directly to a point, watching at the top of silo while standing safely on the ground, looking for weeds in crop to get a bird’s eye view of the area and even just having a bit of fun showing what farming is about on social media.

Smartfirmer

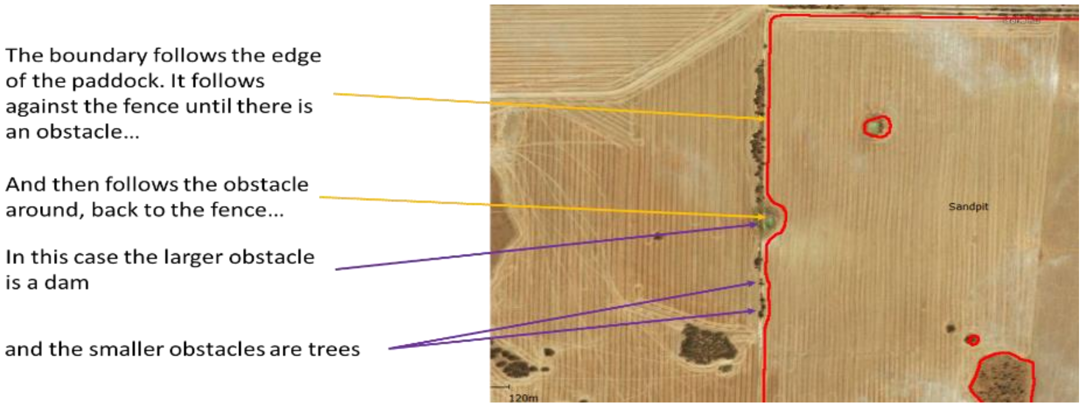
This is a new product released in collaboration with John Deere that measures temperature, moisture, and residue in the seed furrow. Smartfirmer can control seeding rate and fertilizer rate based on organic matter (Precision Planting, 2017).

Scenes from the Study Tour

Problems with Tech of Today

Some of the issues in technology today in relation to driverless machines revolve mostly around mapping. Here are unpublished scenarios set out by Ben Stewart from Farmanco and given to demonstrate what is needed before stepping into automation.

Scenario 1 – Straight fence line with obstacles on the fence line



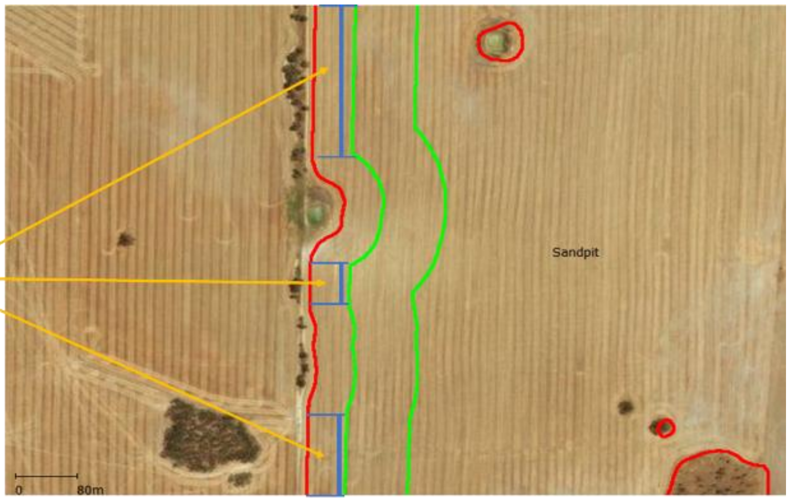
Method 1 – Map the external boundary as it lies in the paddock

The (green) headland guidance line is created by *offsetting* the (red) boundary line. That is, copying the boundary line and moving each point of the line a set distance inside the original, creating a concentric shape.

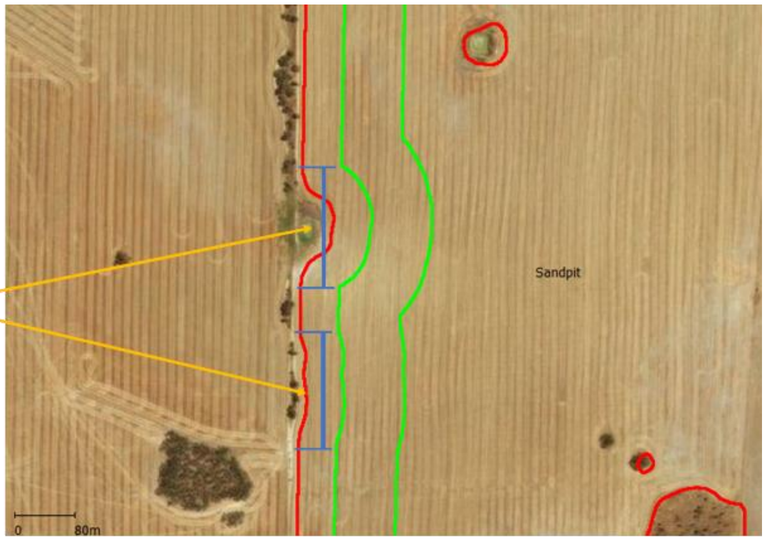
The “outer” headland guidance line is the one closest to the boundary. It is created half (0.5) of an implement width from the boundary

The “inner” headland guidance line is the one closest to the centre of the paddock. It is created one and a half (1.5) implement widths from the boundary

When the machine travels along the straight segments of the headland line here, the machine is engaged in autosteer..

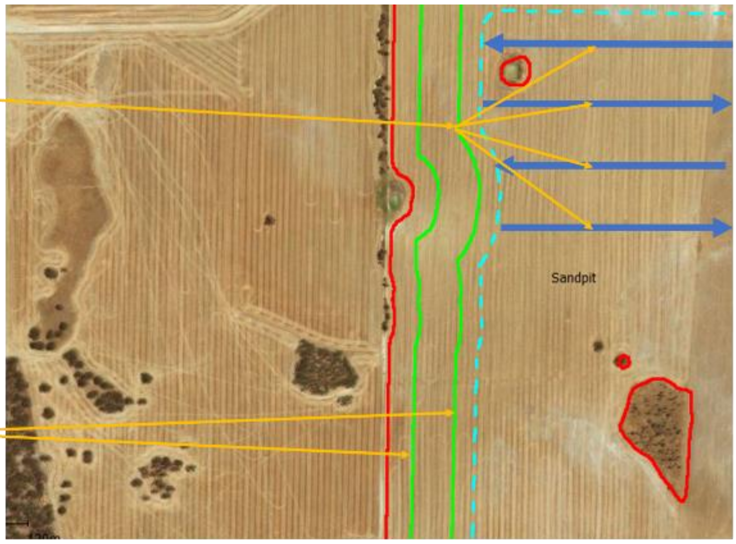


When the machine travels along the curved segments of the headland line around the obstacles here, the machine is engaged in autosteer if the curve is gentle. If the curve is too sharp, the implement will leave a gap or too much overlap when engaged on autosteer so the operator has to take over and steer manually. The machine, not the implement follows the line.



The **seeder** completes its AB passes to start the paddock. When it reaches the dotted blue line at the end of each pass it shuts off product and turns around. The dotted blue line is called the *headland indicator* and its located approx. 2 implement widths from the boundary

The seeder then follows the headland lines to finish the paddock once all of the straight passes have been completed.



Method 2 – Map the external boundary to ignore obstacles on straight sections of fence.

This is the same paddock. This time the obstacles here on the fenceline have been ignored by the external boundary. The red boundary line goes straight through the obstacles, rather than following around the edge of them...

The headland guidance lines are now straight too- this is a positive because the operator wont need to disengage autosteer and steer manually along the inner headland lap.

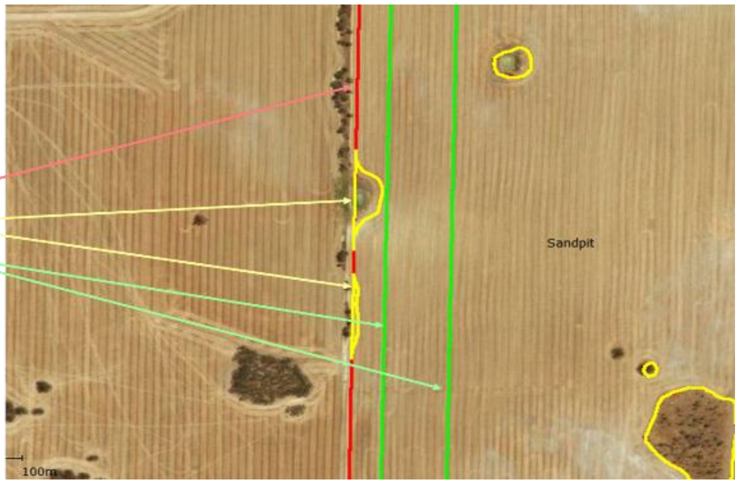
The operator will have to steer manually around the obstacles on the outer headland lap. This is usually considered a minor negative- often the curves are too sharp to leave the machine engaged in autosteer anyway

The trade-off is the headland indicator line for the seeder is now inaccurate where the obstacles have been removed from the external boundary. The blue dotted line is where the indicator should be. The pink line is the new one, created from the new external boundary.

This means the seeder will shut off product late when finishing each AB pass, resulting in excessive overlap (indicated by the shaded area)

Method 3 – Map the external boundary to ignore obstacles on straight sections of fence *then,* map the obstacles as internal boundaries.

Red: external boundary
Yellow: internal boundaries
Green: headland guidance lines offset from external boundaries



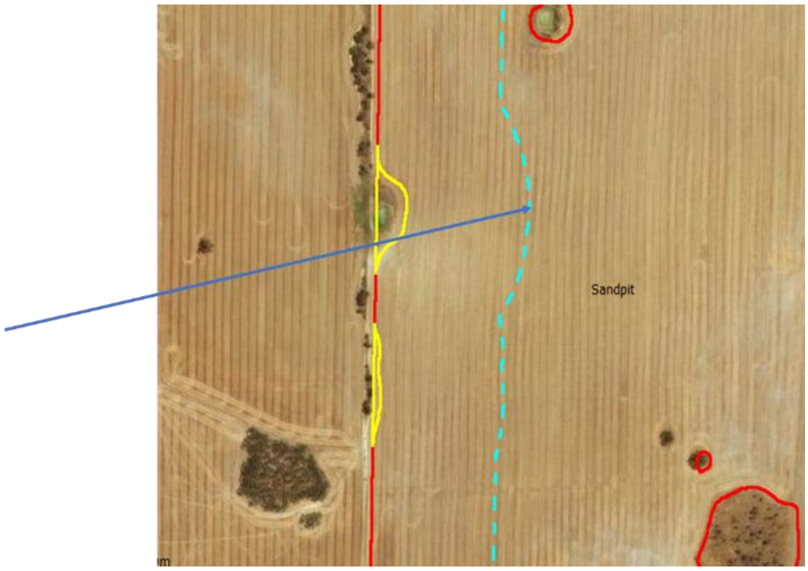
We can create a headland offset around internal boundaries as well… (if we define the internal boundary as *impassable*)

Internal boundaries

Headland indicator around internal boundaries

Now putting together the headland indicators from both the external and internal boundaries.

The headland offsets from both the internal and external boundaries effectively acts as a composite- putting the indicator always in the right place and achieving the minimum overlap of product from the seeder.



The headland guidance lines and the headland indicator lines are now both in their optimum position for current technology. This 3rd. method of boundary placement is the most effective method I've developed so far.

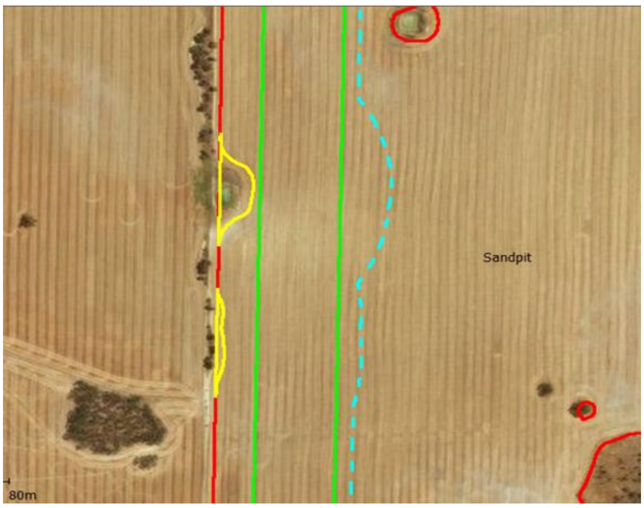


Figure 10: Boundary Set Up Shared by Ben Stewart

As you can see this is no simple task and then times that over 100 paddocks. By looking at this one aspect of mapping you can see why the companies releasing the machines would want to map a farm, they have an invested interest in their product doing well. Ben Stewart also makes some assumptions about driverless machines (Personal Interview) including:

1. New automated machines will require external and internal boundaries to define arable land to operate within. Existing GPS data (RTK or similar level) that I've gathered/manipulated will be compatible.
2. They will also require sensors to identify obstacles that aren't mapped i.e., fallen trees, fresh washouts, flooded land, vehicles.
3. They will use a similar system of straight and curved guidance lines with predominantly pre-planned routes to navigate while operating.

Technology for the future

These are technologies to watch. They demand investment and opportunities to trial them.

Weed identification

This is the way an autonomous system can tell the difference between weed and crop. This technology has the potential to change the spraying game, allowing less chemical to be used and in some cases, no chemical at all, with the use of lasers to burn the weeds and air pressure and steal to rip the weeds out. These have only been seen in wide row spacing at this point, but a small robotics company is working on high resolution image observation and is running it through image identification in the hope it can identify different weeds in pasture. CSIRO is doing 3D mapping of every stage of the plant growth stage creating a digital 3D model of the plant (CSIRO, 2016). Image identification is already well trusted in the sorting process for vegetables and fruit. Seeing this in action gets the mind churning at the possibilities for in-paddock use. The issue with images in the paddock is the multitude of changing conditions. Artificial Intelligence (AI) must identify a plant every time it needs to know what the plant looks like, at every growth stage, at every point of the day, and in every weather condition, then take into account that plants look different when stressed. For every one of these situations the AI needs at least 10,000 reference photos for accuracy. This is not the only place AI image recognition will be used. It will not only allow the driverless machine to navigate but also to identify spray drift.

Microwave technology

This is being tested as a replacement for using chemicals. So far, these instruments are big and blocky and require slow movement application to kill weeds. According to Andrew Bates, through his own research (Personal Interview), initially the microwaves kill the bug in the soil, but the bugs are back and thriving within an hour of application. The use of this tool is a perfect fit for driverless machines because of the slow speed of application.

Smart depth

This was recently released for a few farmers to trial in the USA. It allows the farmer to make depth adjustments quickly and easily.

Laser weed killing

Seen as a prototype at Harper-Adams University uses a laser to cook the weeds. This technology uses plant recognition, selecting the weed from the plant directing a high intense laser to cook the weed. There are issues with high energy use and the height distance from the target.

Virtual Reality

This is here but not so much in agriculture. This technology could allow the manager to step into any driverless machine and view it as an operator would today. This could also extend to the public bringing people closer to their food. It is not inconceivable to have a virtual mechanic solving the issue of an extensive supply chain.

Investing in driverless machines will bring these products to farm equipment that does not use the driverless system, allowing the option to go driverless to become more palatable.

The Wish List

Ability to know the most efficient way to the paddock

As farming moves to an autonomous future, it will not only be driverless machines doing tasks on the farm. If the mining industry is anything to go by some of the biggest savings, other than safety, is in the precision of loading where every machine is accurately aligned to the other. This results in savings in time and wastage of product. If this is to work in the broadacre situation the machine will need to know the most efficient way to perform its task is to be close to the filling station (automated batching unit or automated product dispenser). In other words, to know it’s not going to finish the next two runs with the product on board.

Automatic equipment adaption (fuel map wear and tear)

This would work much the same as variable rate but would save money on the wear and tear of the implement. In mining drilling rigs work on pressure and the type of soil/rock to get the most out of the drill tip, leading to greater than 20% life span in the drill tip.

Chemical digital identification

For automatic loading to be possible there needs to be a way for recognising the products in drums. QR codes are used on some products these days but this should only be a first step, as labels can be damaged. My studies in the Grain Growers Leadership Programme suggest that if each drum was imbedded with a wireless chip, it would alleviate this issue. From this comes many more benefits to safety, retail, and documentation for farmers. Within the transporting of these goods, if an accident occurs the embedded chip would allow quick and easy information to the Hazard crew just by reading the chips in each drum. As for retail, if these chips sent an alert when the drum was empty, retailers of the products could anticipate when more products would be needed. If the chip had location service with it these chemical drums could be traced and collected allowing for reuse leading to less plastics and chemical in the environment.

Chapter 3: 10 Steps to Preparing for Tech

Paddock Maps

As we take the driver out of the equation, the digital accuracy of farmers' paddock maps becomes ever more important. Boundary accuracy is the starting point for this. As discussed previously, two boundaries need to be set up, one at the edge of the crop and the other on the fence line. These boundaries should be driven and recorded as marking by hand on the computer can be suspect. From these boundaries the first run and outside laps will be generated. Keeping a record of the process you used to do this is essential because the companies supplying the machines will want to have the utmost confidence in the setup as they are protecting their brand. If contracting this work out to someone consider getting farm tracks marked out as well (for the reasons given in section 4).

Connectivity Assessment

This is important to get an understanding of where the black spot areas are on the property (Ware, 2015). So, when buying a Driverless machine, you know whether to invest in the real time data technology or alternatively invest in an existing network. How to do a connectivity assessment - the simple way of doing this is going out in the paddock and marking down where you have black spots in mobile phone coverage. From all reports it is best to invest in an existing connectivity system such as Soracom. Soracom has payment cards for doing small farm trials on connectivity giving the grower the option to scale up in a system similar to pay as you go. Founded by Amazon AWS veterans and Telco engineers, Soracom is a global team of technologists, strategists, builders, and storytellers dedicated to creating a more connected world. They live and work in Tokyo, Seattle, Palo Alto and Paris.

Paddock Assessment

Assess each paddock on an individual basis checking that the environment driverless machine can guide itself around or stop because of obstacles above crop and in crop but it will struggle with below ground level obstacles at this point such as crab holes (sink holes). Understanding the paddocks will also allow a glimpse into the machine that best fits. If it is a boggy environment a smaller machine may be required and the same can be said if you have high compacting soils. The vastness of the paddocks will also give you an understanding of how many machines to buy and the logistics of filling those machines and keeping them running daily. No one wants to get the point where it takes more people to keep the driverless machines running than to drive them.

Create Pathways

Consider putting in pathways for the autonomous machines to return to home base and even to move from paddock to paddock. This is where public roads become an issue.

Consider the Type of Machine

Swarm, small autonomous or autonomous. Take into consideration the environment of the property, labour requirements, amount of time the machine will be on public roads etc.

Check the Labour Force

Check the labour force (Piddock, 2018). This also includes the owner. At times, would an additional person mean other operations would get done in a timely manner? Is the work overly dependent on contractors? Could the driverless machines be doing these tasks when they need to be done? Are decisions on scaling up put off because of half a machine or half a worker?

Implement a Start-Up Check Regime

If the business can, get into the habit of pre-checking as this will become a must not only at the start of the day but many times during an operation with driverless machines. This is not only to make certain the operation is done right but it is also a record of safety, a fall back if something goes wrong.

Assess the Operation that Best Fits Each Machine

The assessment should include machine size and horsepower required, whether an implement change will make better use of the slowing down of the operation and an estimate of the current hours per season and the dollars spent on labour which directly converts to savings. Optional inclusions in the assessment are questions around timeliness such as: is the operation timing compromised for other important operations, is the current task compromised by logistics and can the task of the operation be done 24hrs a day?

Operation Assessment for Driverless						
Operation	Machine/HP		Savings Implement Change	Hr/current	Simple tasks	$ of Labour
	Small	Large				$30
Fence Line Control (fire Breaks)			Mower Spot sprayer	672		$20,160
Summer Spot Spraying			Laser Microwave	720		$21,600
Harvest			N/A	2352		$70,560
Planting			Air or liquid injection	1190		$35,700

Figure 11. An Example of an Operation Assessment for Driverless

Inquire about Insurance for the Driverless Machine

Work on automation of the system rather than taking out the driver because it is harder for farmers to find workers that can setup and run machine. Driverless vehicles are easy to set up if the tech is there, but you need to find an insurance company to insure it. Look at the car industry they're not talking about the 500 that worked before only the one that went wrong.

Consider Sharing

Ask neighbours in the community if there is a chance of sharing in a driverless machine. A crowd share model might work, or the community can secure a contractor. This would be one way of getting the suppliers involved to make certain there is a support network there.

Chapter 4: For the Inventor

There are a lot of companies with a solution looking for a problem. This is fine, allowing technology to be utilised from other industries but without consultation with farms, a lot of money is being wasted in the initial stages of development.

Damien Lepoutre (2017) has importantly said:

> *Technology is easy, agronomy is hard.*
> *Through the years, I have attended many conferences on satellite technology and software, and I would also wear a special tie – either one with ears of wheat or sugar beets. When my counterparts would speak about how complicated their technology was, I'd simply point to my tie and remind them plant life is a thousand times more complex than anything they launch into space.*

Ag Tech takes longer to develop than other technology and that derives from the first two letters in Ag Tech, but is *agriculture* really understood? Agriculture is an industry completely controlled by the weather or more accurately by the seasons. Humans are now able to manipulate the weather through, for example, hydroponics, irrigation and vertical farming but every plant still needs a season. That is, there is one opportunity per season to test, trial and get results. Something farmers understand all too well.

Ag Tech has an advantage over the farmer, however. Although it may be difficult and costly, Ag Tech can take advantage of the northern hemisphere season then move to the southern hemisphere season, thus literally doubling the trial data it collects as well as being able to test in a wider consumer area. Farmers and Tech groups need to connect and stop being so secretive. There are issues that already have solutions.

Protecting the brand

Everyone wants to protect their reputation and the companies working on driverless machines are no different. Conversations based on *What's the next step?* to, what I was confronted with, *I can't talk about it yet* suggest that brands are keen to protect their products. Understanding IP protection, these comments were brushed off but looking deeper, IP is not the only issue or reason. When asking to get local trials the issue for companies of not having a support crew if something went wrong may lead to a damaged image. This is a fair and valid reason for caution. However, the issue here is not with the companies being cautious but with societies not letting them fail. Farmers, for the most part, are willing to see issues occur, especially if they can see why it occurred, and that it has led to improvements.

The role of the start-up

Start-up in the dictionary is defined as: the action or process of setting something in motion (https://www.dictionary.com/browse/startup). Wikipedia defines start-up as: a start-up or start-up is started by individual founders or entrepreneurs to search for a repeatable and scalable business model. More specifically, a start-up is a newly emerged business venture that aims to develop a viable business model to meet a marketplace need or problem, and others define a start-up more loosely. Shontell (2014) in Business Insider says:

> *Perhaps the most precise definition of a start-up is that there isn't one. A lot of founders believe being a start-up is a state of mind. It's not a word that is restricted by the number of years a company has been in business, or the amount of revenue a business pulls in.*

With this becoming the way technology solutions are born, farmers need to understand how this works if they are to get solutions to issues as efficiently as possible. This is evident by a company like AgriStart that was started to bridge the gap between farmers and start-ups.

In a recent conversation with Dr Natasha Teakle, managing director and co-founder of AgriStart, she said:

> *You see a lot of solutions looking for a problem. Start-ups are looking for ways to connect with farmers. If farmers want the best out of the millions of dollars invested in start-ups, these connections need to be researched. These relationships could be helped along by better ways to do trials and this should not only be limited to farmers*. (Personal Interview, 2018)

She advised farmers to invest in start-ups to drive the technology that is important to them and drive off-farm income. When you have companies such as Google investing 14.9% of profits into research and development, are farmers investing enough in their own future? Even though, it could be argued, every season for a farmer is an investment in Research and Development.

Chapter 5: For the Investor

Where is the scaling up?

With Ag Tech industry looking to track their machines for safety and moral reasons there will be a lot of new business models that will need to be navigated, for example, subscription to the product with the guarantee of technology updates and replacement of the machine as new models are released (Parvan, 2011). Farmers will benefit as they constantly update their technology but the business will not build capital with a machine purchase. Farmers can invest in Tech companies as a way of being involved at the forefront of research and development and as a way of building off farm investments.

The drive towards robotics is trending in a similar way to the internet .com wave of 2010. With investment growing by 2-3%, 40% of manufacturing is now done by robotics and it is rising. Fast adopters have reaped gains on their competition allowing them to invest more. Some areas may be slowing but drones, for example, are maturing rapidly. There are opportunities in AI, mobile Robotics, social robotics and Industrial robotics (Bertalan, 2016, Bo and Wang, 2011, Frost & Sullivan and Hitachi, n.d.). The biggest markets in this segment are defence, agriculture and logistics. There are and will continue to be many opportunities for investment.

Chapter 6: Laws and Regulations

Most confusion around the laws pertaining to driverless machines surrounds who is liable when something goes wrong. This is coming from on road vehicles. There are no laws, no specific laws stopping the use of unmanned machines on broadacre or private property in general. When it comes to who is liable if something goes wrong and someone is injured, if the manager has recorded all safety steps and followed safe workplace practices, only on-road laws can be considered relevant.

Before proceeding, it is necessary to understand the six levels of automation. In January 2014, the Society of Automotive Engineers (SAE) issued Standard J-3016 (SAE, 2014) which provides a common taxonomy and agreed definitions for automated driving.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
Human driver **monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
Automated driving system **("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

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Figure 12 The Society of Automotive Engineers Standard J-3016 (SAE, 2014) which provides a common taxonomy and agreed definitions for automated driving

Some examples of these are:

- level 1: Early auto steer or cruise control
- level 2: Headland turning
- level 3: Park assist
- level 4/5: Driverless tractors

On-road safety laws, as they stand, are clear up until the point that a vehicle is in autonomous operation, for example, Park assist, and has an accident. Then it is the autonomous system that is at fault, unless the operator is prompted by the vehicle to take action or disengage the autonomous operation (Jones, 2017).

An example of a situation happened in March 2018. Walter Huang died in California when his Tesla Model X crashed into a highway median barrier that was missing its crash guard). Huang's family said that he had made several complaints to Tesla's service department about Autopilot steering his car on multiple occasions towards the barrier he eventually crashed into. The National Transport and Safety Board investigated the crash. After recovering the logs and reviewing them, Tesla acknowledged that Autopilot was on, with the adaptive cruise control following distance set to a minimum. Tesla has also stated that the driver did not have his hands on the steering wheel and had not responded to several visual and one audible warning to re-take control (Hawkins, 2019).

Huang's family have hired a San Francisco-based law firm, whose preliminary *review indicates that the navigation system of the Tesla may have misread the lane lines on the roadway, failed to detect the concrete median, failed to brake the car, and drove the car into the median*, (Minami Tamaki, 2018). The Huang family has said that they intend to file a wrongful death lawsuit against Tesla and, possibly, the subcontractors involved in the design and construction of the Autopilot system, and possibly also the California Department of Transportation for dangerous condition of public property.

Tesla has issued a statement which purports to attribute fault to Huang, alleging that he was aware that autopilot was not perfect, and especially that it was not reliable at the crash location. Furthermore, he did not follow directions to remain alert and have hands on the wheel while autopilot was engaged and did not follow warnings to do so.

This incident demonstrates an instance where the software/hardware was at fault but in this case the driver was found to be at fault due to his not responding to alerts from the system and otherwise using the vehicle in an incorrect manner.

Laws in Australia for fully autonomous vehicles are still being worked out. At this time for driverless agricultural machines to go from property to property it is recommended that they be driven, towed or transported until the laws become clearer. As for going between paddocks or on farm roads, most systems can be set with present path or/and the ability to follow a hand-held device.

The driving of the machine is not the only law that is relevant. Chemical application laws need to be taken into consideration. In the UK, as the law currently stands, you are not allowed to apply chemical with a drone. In Australia, chemical applications with a drone are permitted provided that you have completed the accredited Remote Pilot License course. With the recent changes to the label for the use of *ester* (larger droplet size, slower speeds and a tighter weather condition window), it is not down to the automated system to follow this legislation. This lies with the person in control of the operation. In the case of a driverless machine, it is the person who sets the task. If we look further into the operation of chemical application, there is a case to be made for out of label contracts for autonomous machines. Some of the reasons are as follows:

- The machine can be set with parameters to stop/shut down when weather conditions fall outside label recommendations.
- With no driver, the operation is cheaper allowing slower speeds hence changing the way the droplet falls to the target allowing a change in droplet size. Slower speeds also cancel out the air movement caused by the machine and dissemination of the droplet effected by wind.
- With slower speeds come better coverage allowing for lower water volumes to achieve the same result. With slower speeds the fall of the droplet has a straighter decent with less machine turbulence.

The development of laws and regulations governing driverless vehicles is constantly changing and will continue to be an issue into the future.

Chapter 7: Social Impacts

How is taking all these operators out of machinery going to affect local communities? As I mentioned before, it appears people do not want to work on farms anymore. They are looking for the job in the big tower close to the amenities for an easy life. This make sense, earning the money where it will have the biggest effect, similar to what CBH is doing making strategic sites. Are we taking jobs away from people? With comments from farmers around the world the issue is not about taking jobs from people but where the workers are going to come from.

Job Losses or Gains

If people take the view that not going to driverless machines is going to keep more people in country towns, the issue is only going to get greater. From discussions with students, they have seen the hype around autonomy and want to be involved in this technology. By working towards driverless machines, we are bringing an interest back to the farm and in some ways it is breaking the stigma of the straw hat and checked shirt. In the short term, as automation flows into other industries, there may be an increase in available employees bringing new skills to agriculture. During this transitional period the agriculture industry needs to work on firstly retaining these transient workers not only with an enjoyable workplace but a community atmosphere of inclusion.

This could go the other way where the machines are not exactly driverless, but the driver is hundreds of kilometres away from the paddock, much like the mining industry with their main control centre in the major city. In 2018 the video game Farm Simulator (Farming Simulator, 2018) was played by hundreds of gamers in a competition. What if it wasn't just a game and these competitors were controlling your machines and paying you for the privilege? On November 26th 2018, Japan had a café that employed Robotic waiters that were controlled by the eye movements of paralysed patients from their hospital beds. The patients were paid for their work and so robots were responsible for providing jobs for the previously unemployed (Dawn of a New Era, 2018).

Good management and forward thinking can provide opportunities to bring younger people into farming communities and with fewer people driving machines, there will be opportunities for higher skilled workers to be employed. Farming communities are being encouraged to think of innovative ways of bringing people in.

Figure 13: Johannas at Hofladen in Germany explains how they combat lack of labour by getting customers to purchase a part of the plot to pick their own strawberries.

Chapter 8: Robots Build Rural Communities

As mentioned in Chapter 4, Ag Tech has an opportunity to double its trial data and Australia is perfectly situated to facilitate this. Imagine you are a tech company in Europe and the planting season is about to finish. The results from the trials have not yielded enough data. The board is telling the head researcher *We can't wait another year for these results*.

The head researcher replies: *How about we look at doing a season in the southern hemisphere?* After a quick internet search: *There is an AG Tech tourism agent in Australia. Let's give them a call.*
Ring Ring. Hello, how can I help you?
Head researcher: *Our company is looking to do trials for our new seeding implement. I've emailed through our requirements to do the trial, staff descriptions, and specs of our equipment to be transported.*
Tourism agent replies: *Ah yes, I see it here… We have the perfect farm for your requirements, and I will send through 2 other options. For this first option, the farmer is interested in your technology and has a grower group that has the facilities to do video conferencing. The town also has great accommodation. Would you like to take advantage of our university exchange? This will allow you to only bring the essential members of your team, reducing costs while the students get practical experience. Doing this will also allow you to take full advantage of our government exemptions.*
To which the head researcher answers: *Send through the details and I'll talk it over with the board.*

This is a simplistic look at a complex Idea. The main points are if farmers are to get the technology they require to produce in a healthier and environmentally beneficial way, then it should concern vegan to environmentalist, couch potato to fitness fanatic, young and old. Ag Tech Tourism would build on ideas from Agritourism (Ecker, S, Clarke, R, et al., 2010) which focuses mainly on food. An Ag Tech focus brings new ideas and strategies into consideration. To have an engaging process that cuts adoption time of new technologies in half allowing education and practical experience to the next generation of Tech producers, while building and keeping rural communities thriving, and which adds to the mental stability of those who grow the food, this would be something the whole of Australia could get behind and even the world.

Breaking this down further, this would require:

- a database of farmers willing to have on farm trials and the crop types, soils, connectivity situations.
- The local shire would need to provide an assessment of facilities that can be of use to an Ag Tech company, for example, Video Conferencing, Fabrication Facilities.

- Government incentives for the experience of students. Incentive enough to offset the risk of IP sharing and flying over the companies own team. It may even be wise to send the student over there for training before the action starts here.
- As for the first point of call the ‘Ag Tech tourism agent’ it would be great to see this as not for profit/ government owned agency to stop playing favourites and give farmers and shires confidence in the system and to especially protect private information within this current environment. Eventually agencies could switch to be privately owned.
- By having this Ag Tech company come to rural areas it will help produce a better understanding of getting the supply chain for their product in place. This is one of the main reasons for a slower adoption by farmers.

Ag Tech Tourism: Growing a healthier mind, body and planet. It’s got a nice sound to it!

Conclusion

There is much that is still unknown about how driverless machines will affect broadacre farming, not only for those who take on the technology but for those technologies that spin off the driverless machines. This will lead to better efficiencies, ease of management tasks and the ability to have inexperienced operators on machines. Driverless machines are the same as any new technology adopted in the past e.g. No-till, auto steer. In other words, do not be intimidated by the technology, just remember driverless machines will only do what they are told to do, they are very predictable.

What is important to the farmer? Farmers need to look at what is important to them the people they work with and getting the job done. Driverless machines should not be taken on to replace the workforce that is already there but to add to them and the existing plant.

What is holding back the adoption of driverless machines is the supply chain? This hold off is coming from both sides. The farmer is reluctant to adopt the technology if the down time is going to be too great and the support network is not there. The supplier of the technology is averse to supplying their machines to an area that has no support. Add to this the unwillingness to put the support without a significant number of machines in the area (in terms of state-to-state, country to country).

Are farmers automating the wrong part of their operation? The driving of a machine is relatively easy and with the technology that will come from driverless machines there will be fewer responsibilities for the driver. Why not go for automated filling stations allowing for accuracy and freeing up the manager further?

If it is well thought out, the community could grow along with the adoption of driverless machines. By taking advantage of all the industry offers within the community, there is no reason why AgTech tourism could not become an Australia wide opportunity.

Recommendations

- Farmers should not be intimidated by this technology but think of it as any other technology that has been adopted in the last 20 years and apply the same principles as when those technologies were introduced.

- Farmers’ investment in AgTech will bring rewards above the driverless future. With swarm machines/driverless machines AgTech are researching ways of keeping weight down and using less power. It makes sense that these technologies will come into non-driverless products. This means that investing in driverless technology is investing in agricultural tools, whether implementing the driverless technology or not.

- Think of driverless machines not as replacing existing equipment but as machines to get operations done in a timely manner. The true advantage of driverless machines is their ability to do tasks while the main workforce is doing other tasks, such as spraying after harvest. Even spraying the headlands before a paddock is seeded, allowing the trifluralin to not go off but still having other chemicals for plant contact before the seeder wheels cover the weeds.

- Protecting the brand is understandable but farmers, who are the end users, understand what can come out of presumed failure. They deal with it all the time and adapt to it. By explaining the issues and the next steps, a brand will build trust.

- Governments should remember agricultural machines will be on public roads and should be thought about when making autonomous laws. Whether it be using follow technology or controlled by humans during transport it needs to be considered so Driverless machines developers have a clear path to development.

- Insurance companies need to be looking at what it is going to cost to insure a driverless machine. With the interest in this technology, more growers are going to start asking the question.

- Making AgTech communities through AgTech tourism is a way of bringing technologies to real areas to allow farmers to get a first-hand look at how the technology works. It would also allow AgTech companies the ability to test their products in two seasons and have farmers to raise foreseeable issues with the product, allowing greater speed to an end product. It would also allow the technology to look globally rather than locally. This could bring new revenue streams to local rural communities, supply training and education to students along with closing the gap between grower and consumer. Breaking this down further, this would require:

- A database of farmers willing to have on farm trials with data about the crop types, soils, and connectivity situation.
- The local shire would need to provide an assessment of facilities that can be of use to an Ag Tech company e.g. video conferencing, fabrication facilities.
- Government incentives for the experience of students. Incentive enough to offset the risk of IP sharing and flying over the company's own team. It may even be wise to send the student over there for training before the action starts here.
- As for the first point of call the 'Ag Tech tourism agent' it would be great to see this as not for profit/ government organisation to stop playing favourites and give farmers and shires confidence in the system. Private information especially needs protection within this current environment. Eventually agencies can switch to being privately owned.
- By having this Ag Tech company come to rural areas it will help produce a better understanding of getting the supply chain for the product in place. This remains one of the main reasons for a slower adoption of driverless technologies by farmers.

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Plain English Compendium Summary

Project Title:	Name of project: Getting Comfortable with No Seat No Cab
Nuffield Australia Project No.:	1814
Scholar:	Boyd Carter
Organisation:	KL Carter & Co 14336 Rabbit Proof Fence Road Wubin 6612
Phone:	042943020
Email:	Boydfarming@live.com.au
Objectives	• Explain to broadacre farmers the technology that is available and how it relates to driverless machines. • Develop a guide for broadacre farmers of steps that can be taken now to be ready for the implementation of driverless machines. • Inform those in the driverless machine supply line of the needs of broadacre farmers so they can help facilitate change. • Step off the farm and investigate how the adoption of driverless machines might affect the life of farming communities.
Background	Broadacre farmers are looking for new ways of meeting the challenges of unpredictable weather, rising costs, a gap in understanding between consumers and growers, and the need to work in an environmentally friendly way - Could Driverless Machines help meet these challenges and if so, how can farmers more easily make the transition?
Research	Research suggests it is inevitable that robotics will transform agriculture and yet most broadacre farmers are unprepared. International trials are only just starting and not yet showing results. What is important now are the issues surrounding the effectiveness of the new technologies and their adoption and their impact on farmers and their communities.
Outcomes	A guide for farmers to enable them to prepare more confidently for trials which includes advice on paddock mapping, regulations around movement of driverless vehicles, costs of operation, assessment of suitability of different machines, use of labour, potential for investment in the supply chain and costs and potential gains for farmers and their communities.
Implications	The adoption of robotics will be a process. There will be opportunities, hard decisions, frustrations, gains and losses. Broadacre farmers and their communities, along with governments and industry need to be prepared for their participation in trials in ways that maintain Australia's reputation for technical efficiency.
Publications	Nuffield Australia National Conference Presentation, Brisbane, Sept 2019.