EMBRACING PRECISION AGRICULTURE

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GROWERS SHARE THEIR EXPERIENCES

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Cover photo: An automated steering system sowing wheat on David Jochinke's farm at Murra Warra, north of Horsham, Vic. – Melissa Powell.

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FOREWORD

Australian farmers are among the most inventive and forward-thinking in the world.

Living and working as we do across a broad continent that covers a huge range of environments, with highly variable weather patterns and an unpredictable changing climate, it's something we tend to take for granted.

Precision agriculture (PA) is one way of harnessing the data that helps us manage, if not tame, this variability.

This book provides a broadly useful compilation of ideas and case studies highlighting innovative approaches and practical strategies for enhancing the PA adoption journey.

It follows a comprehensive review undertaken as part of the Grains Research and Development Corporation (GRDC) investment - Hands-on Precision Agriculture Training for Growers project (GRDC Project Code SPA2001-001).

During that review we were reminded of the many great farmers across Australia who've adopted various forms of PA and generously shared their stories through SPAA's flagship publication, Precision Ag News, fact sheets and other channels.

Rather than trying to 'reinvent the wheel' and recreate this valuable information, SPAA staff and our team of talented writers and project leaders have brought together a collection of these stories in an endeavour to share them more widely and encourage other growers to adopt PA technologies.

We have collected and packaged this material according to four core themes, providing examples of how growers have addressed problems and alleviated the challenges they face.

First, is a glossary of the terms, and their definitions, commonly used in PA, which will be especially valuable for those who are new to it.

There's also sections on the four themes:

- The financial pressures PA can help address
- Soil constraints and sensors to aid identification and amendment
- Yield variability and paddock management
- Weed pressure and spraying.

This collection highlights the many ways PA programs can address different goals on- and off-farm, offering concrete examples of effective programs. It shows what a good PA program looks like, how it is run and how PA can be an important source of triple bottom line gains on-farm.

This book covers and describes all the major factors involved in building successful PA programs and is an important resource for growers, as well as the agronomists and resellers that make up your PA team.

Clearly written, well organised and enormously practical, it deserves a place in the library of every grower and adviser.

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GRDC Grower Relations Manager - South

Controlled traffic. Photo: Evan Collis

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FINANCIAL PRESSURES AND PA

The following article was first published in December 2018

Alternative data mined for yield

Rebecca Thyer

A lack of yield-monitoring tools for non grain crops started a search for alternative data sources to support PA decisions.

North Queensland farmer Ben Poggioli began his PA journey about 10 years ago, with a Trimble RTK (real time kinematic) autosteer, in a bid to cut input costs and move to strip tillage on his then conventionally tilled farm.

Although a keen PA enthusiast, Ben's mission has often been hampered by the lack of yield-monitoring tools for his speciality crops. In a bid to address this problem Ben has begun using satellite imagery to better understand crop yields.

Yield data

Ben grows potatoes, peanuts, corn, tropical pasture seeds and hay, sugar cane and avocados.

Using a Greentronics load cell based yield monitor on his Case IH tractor, Ben can easily gather potato yield data. However, this is not available for his other crops. With potatoes only in the rotation every five years, it is difficult to rely on a yield map created that infrequently.

Ben, who farms 200-300 hectares (depending on share-farm arrangements) with his father Guido and mother Jennifer, says the lack of yield monitoring tools in the crops he grows prompted his decision to access satellite imagery, via Proagrica's Sirrus mapping app. (SST Software is now called Proagrica).

Farm details

Farming Personnel:	Ben Poggioli and his parents Guido and Jennifer
Location:	Tolga, on north Queensland's Atherton Tablelands
Farm size:	200-300 hectares, depending on share farming arrangements
Annual rainfall:	Annual average 1200-1400mm
Soil:	red volcanic soil and clay loam, with some areas of sand and a pH of 5.5-6.5
Enterprises:	potatoes, peanuts, corn, tropical pasture seeds and hay, sugar cane and avocados
Yield:	Average potato yield is 35 tonnes per hectare

PA applications

Technology	Year started using
Trimble RTK autosteer –	2009
John Deere planter fitted with a Precision Planting seed planter –	2012
Greentronics Yield monitor –	2014/15
Viking variable rate spreader, controlledby Trimble GPS –	2014/15
Precision Planting 20/20 SeedSense seed monitor –	2017
PCA satellite imagery (using Proagrica's (formerly SST Software's) Cirrus mapping) –	2018

Top PA tips

- When starting PA, ask lots of questions to establish which systems talk to each other and to discover if data is transferable.
- Be prepared to work out stuff for yourself. That may be in your tractor or at home at night.
- Understand what you want out of PA. For me it is about placing inputs in the right place at the right time. This can make a massive financial difference every year.
- Choose the right technology and tools for the job and look carefully at the post-purchase support on offer.

The app converts Sentinel and Landsat satellite imagery to a Normalised Difference Vegetation Index (NDVI) reading, which provides a surrogate measure of above ground biomass.

The two Sentinel satellites take images every five days, while the Landsat satellite takes an image every 16 days.

The satellite imagery can be downloaded at any time to a mobile or tablet. This information is used in the app to better understand crop variability and to create a variable-rate map or targeted soil sampling plan.

Ben began using the app in September 2018 and is keen to see how the information might assist his decision making.

"Measuring biomass offers a way to address the yield variability on our specialty crops. I will be looking for anything that highlights a difference, either in moisture, nutrient or disease pressure.

"There will be a lot of ground truthing required, but we will compare the satellite imagery to the paddocks over a period of time and see what it shows. Then I plan to do a small harvest plot and see what it all means."

Ben sees his move to using satellite-generated biomass data as the logical next step for his farm.

"This is the best we can do on our speciality crops. While I'm in the tractor out on a job, I can pull up, get out and look around and do the ground-truthing required."

Early PA R&D

Ben's early days in PA, after his RTK autosteer purchase in 2009, were helped along by a Queensland Department of Agriculture and Fisheries' research project into horticultural PA, led by Ian Layden.

It saw Ben start yield monitoring (with a Greentronics yield monitor) and variably rating his inputs (via a Viking variable-rate spreader, controlled by Trimble GPS), on his potato crop.

"It all went well. I always knew it would. I'm really interested in PA and technology and do believe it is the way forward. Once you know how it all works together, it does make life easier."

Ben also uses a set of Trimble GreenSeekers mounted on his John Deere sprayer to gather crop reflectance data. Dense crops reflect light more intensely and help him identify potential outbreaks of fungal disease in his potato and peanut crops earlier.

"I can look at the NDVI map and see where the disease is coming, even though you can't see it on the crop yet."

Ben looks for any colour change (essentially areas with less green), but also areas with lower NDVI as a sign of disease.

After ground truthing his findings, Ben was able to reduce the fungicide application needed, better manage the disease, and save time and money.

"I caught the disease outbreak two to three weeks earlier than I normally would have and saved a huge amount of money on chemicals because I was able to use a fungicide that cost a third of the price of the one I would have normally applied at a later stage of disease development."

Ben says this example highlights what PA is to him: "To me, it is not about the electronics – it is using the data generated to put down the least amount of inputs and work in the right zone to grow a crop."

Furrow information

Ben's next plans include purchasing a Precision Planting SeedFirmer to allow him to collect data on his seed-furrow environment.

The SeedFirmer uses optical sensors to measure soil moisture, temperature, residue and organic matter providing a live feed of information about the environment in the seed furrow. Ben will use it in his peanut and corn crops, where he uses his row crop planter.

"I really want the information it will provide – as a means of answering some questions I have in regards to disease and residue and also in terms of soil moisture."

As a keen PA enthusiast, Ben will continue to look at new tools and technologies, but would like assurance that different tools will talk to each other.

Details: ***Ben Poggioli, 0407 590 335, @PoggioliBen***

Peanuts are one of several crops on Ben's farm for which on-harvester yield monitoring is not available, but spatially in-crop biomass measurements may overcome this issue. Photo: Ben Poggioli

Peter Kuhlmann at home on the farm at Mudamuckla, SA.
Photo: Jarrad Delaney

Farm profile

Farming personnel:	Peter Kuhlmann
Farm location:	Mudamuckla, Eyre Peninsula, SA
Annual rainfall:	291 millimetres
Soil types:	Clay over sandy loam
Topography:	Undulating dune/swale system
Farm area:	14,500 hectares
Enterprises:	Wheat, barley, sheep
Average wheat yield:	1.2 tonnes per hectare
SPAA member:	Yes
Agronomy consultant:	Andy Bates, independent

PA timeline

Guidance –	2000
Yield mapping –	2003
Autosteer –	2004
Variable rate –	2005
Inter-row seeding –	2005
On-farm trials –	2005
Optical spot spray technology –	2012
Water leak detection –	2014

Top PA tips

- Consider potential efficiency gains when choosing to adopt PA tools
- On-farm trials are valuable in determining the most cost-effective seed and fertiliser inputs in a variable-rate system
- Use data to make more informed management decisions

The following article was first published in February 2019

Efficiency gains the aim on PA adoption

Eyre Peninsula farmer Peter Kuhlmann was quick to recognise the improvements in efficiency precision agriculture tools gave him when he first adopted guidance and autosteer almost two decades ago.

Why did you choose to adopt precision farming technology?

From the beginning, the efficiency gains derived from precision farming technology were obvious to me. I started by investing in GPS guidance and could instantly see the value in minimising overlap and minimising operator error. This allowed me to farm more efficiently.

Which technology tools or components have you adopted and (which do you) continue to adopt?

After purchasing an Outback lightbar with an Omnistar signal for guidance in 2000 we moved into yield mapping. I purchased New Holland TR99 harvesters which came with yield monitoring equipment as standard and then a year later we purchased Ag Leader's SMS software to help us download and map yield data.

We continued to invest in PA technology in 2005 when we purchased an autosteer system from gps-Ag and a variable rate system from Ag Leader in the same year.

We have continued with most of the same technology and software up until 2018. Now we have installed Case IH's AFS Pro 700 screen in the tractor for guidance using RTK in the main tractor.

About seven years ago (2012) we invested in a WeedIt optical spot spraying system. This enables us to only spray just the weeds over the summer period as opposed to applying a blanket spray over the whole paddock, which has led to some big savings in herbicides. We have found this system works best after the first blanket spray or where there is only Lincoln weed or melons to control.

On the livestock side, we have installed water leak detectors across the property, which transmits using a SIM card helps us identify where there are water leaks and fix them accordingly. This has enabled us to farm more efficiently as we don't have to drive around trying to find water leaks and also results in significant savings in our water bill.

What are the factors that motivate you to adopt and use each of the different tools or PA components?

It's all about efficiency. PA technology allows us to put product where it is needed most, whether that be seed,

Peter uses yield data to make more informed farming decisions such as where to put more or less fertiliser and seed in order to get the best dollar return.

fertiliser or pesticides. In our environment where soil types are so variable across the farm, technology such as auto-steer and variable rate are no-brainers. There are a number of benefits in re-directing fertiliser or higher rates of seed to where it is most needed in order to maximise yield.

What types of data and information are you collecting to guide your decision-making to adopt or not adopt each PA component?

Yield data is the main one. Collecting yield data enables us to analyse maps from paddocks across the whole farm and prescribe the appropriate seed and fertiliser regime for it.

In the early days of adopting variable rate we set up some on-farm trials in 2005 and 2006. The aim of this was to help determine the most cost-effective levels of seed and fertiliser inputs, which would then be used to set a paddock's nutrient baseline. These trials found that standard rates of seed (60 kilograms per hectare), phosphorous (5.5kg/ha) and nitrogen (6kg/ha) were the most profitable, despite varying seasons. Starting in the 2019 season we are taking part in a Grains Research and Development Corporation-funded soil testing trial which utilises different fertiliser rates on three different paddocks. These results will add to my database and I may need to adjust my fertiliser strategy.

Has the adoption of PA increased profitability on your farm? How?

There are a lot of different components to PA but there is no doubt for me that technologies such as autosteer and auto shut-off can pay for themselves very rapidly. The yield benefit from PA is a bit harder to quantify but I think it is definitely worthwhile.

How are you using the data generated by PA? Is it leading to further practice change? If so, what kind of practice change?

I am using the data – particularly yield data – to make more informed farming decisions such as where to put more or less fertiliser and seed in order to get the best dollar return. There are a number of benefits to the adoption of variable rate, particularly in our environment where soil types are so variable.

We aren't necessarily adopting any further technologies, just expanding the ones we are currently using. Besides the WeedIt and water leak detection system, I have probably plateaued in my adoption of further PA tools in the past 10 years.

Who is influencing or assisting you with the adoption of PA?

I am a member of SPAA and the information the organisation provides has been and continues to be an influence in my adoption of PA technologies. When we were setting up our yield mapping and variable rate systems we had Ed Cay from gps-Ag helping us to analyse the data and prescribe maps, but now that set-up work is done we don't use a consultant in the PA space. The manufacturers of machinery and PA technologies also provide plenty of information regarding different PA tools.

Are you planning to adopt more or less of these various precision farming technology components in the future?

I am hoping to continue utilising the technology I currently have and to further refine it. There are still improvements we can make in our systems, such as creating permanent boundaries and AB lines and identifying obstacles in the paddocks.

We are looking at options to upgrade some of the technology now, such as the seeder controller. As far as any new technology goes, if there is something which I think could benefit the business then I will explore it further and decide whether or not it fits with our operation.

Details: ***Peter Kuhlmann, 0428 258 032, mudabie@bigpond.com***

Stephen Paddick, SA grower.

Farm profile

Farming personnel:	Stephen, Shane and Brian Paddick
Farm location:	Wallaroo, South Australia
Annual rainfall:	375 millimetres
Soil types:	Grey calcareous loams
Topography:	Flat with little undulation
Farm area:	2000 hectares
Enterprises:	Wheat, barley, lentils, canola, export oaten hay
Average wheat yield:	3 tonnes per hectare
SPAA member:	Yes
Agronomy consultant:	Patrick Redden, Rural Directions

PA timeline

Yield mapping –	2000
Guidance –	2001
Autosteer –	2004
Variable rate –	2007
On-farm trials –	2007
Inter-row sowing –	2012

Top PA tips

- Use PA to help identify zones within paddocks and manage them uniquely.
- Satellite NDVI maps add more depth to yield maps.
- Use yield maps to identify high, medium and low-yielding areas and soil test those areas appropriately.

The following article was first published in September 2020

Paddock mapping lifts yield

Over a decade of yield mapping combined with satellite NDVI imagery and soil testing has helped Stephen Paddick to identify problem saline areas on his farm and treat them accordingly.

Why did you choose to adopt precision farming technology?

We first started using yield maps in 2000 to help us identify different zones of the paddock so we could better prescribe seed and fertiliser rates. One of the initial reasons we started exploring precision ag technology was to lessen the overlap when we were seeding, spraying and spreading. We started by purchasing a Zynx unit from KEE Technologies, which was our first guidance system. We have now progressed to the John Deere StarFire system. Guidance and autosteer mean there is less fatigue on the operator when they are working longer hours during peak times such as seeding and harvest.

Which technology tools or components have you adopted and (which do you) continue to adopt?

Maps have become a very important part of our farming business. We now have about 13 years' worth of yield maps on file which has enabled us to build up a significant amount of records and compare back year after year. We also use satellite NDVI maps now to add more depth to those comparisons and can use both the yield maps and satellite maps to help differentiate the zones in our paddocks. We use John Deere Operations Centre to help us manage that data and build prescription maps for seeding and spreading. We also use data from soil tests to help define different zones in our paddocks.

Looking ahead, we will be going down the path of controlled traffic farming. Our grey calcareous soils compact so we definitely see benefits in keeping machinery on the same tram lines to help limit the compaction.

What are the factors that motivate you to adopt and use each of the different tools or PA components?

The mapping we use has helped us to identify low-performing saline areas on our farm. Our farm is quite close to the coast so these areas are always going to be there, but mapping technology has helped us define those zones and manage them better.

Once we have our paddock zones defined, we know where the saline areas are so we can manage and spread straw to help retain moisture. In those saltier areas, the biomass is much lower so we remove biomass from high-yielding areas by baling straw and putting it on those low yielding areas to get cover and increase yield.

When we first started putting straw back on these low yielding areas, we could definitely see a yield increase. Those areas were yielding about 0.5t/ha and now they are up to 2t/ha quite easily. We've had a straw spreader here for

5-6 years now. We will cut the straw, bale it up with a large square baler and then in March we will spread it. The straw tends to break up quite quickly so the seeder doesn't have any trouble getting through it.

What types of data and information are you collecting to guide your decision-making to adopt or not adopt each PA component?

It is mainly yield, NDVI and soil sampling data we are collecting at the moment. We are happy with the information these tools provide us. We have looked at pH mapping, which might be another option for us in the future.

Yield maps help us identify areas for soil sampling. We sample high, medium and low-yielding areas to see what nutrients have been used by the previous crop. Those low-yielding areas typically still have a lot of nutrients in the ground so we use that information to prescribe variable rate maps. Because we are using variable rate rather than blanket applications, we are putting more fertiliser where it is needed.

Has the adoption of PA increased profitability on your farm? How?

I think PA has definitely increased profitability on our farm. We have reduced those saline areas in the paddocks and lifted the yield in those areas. For example, we could have a 100ha paddock and previously, 20ha would be saline, but that area has now been reduced down to 3-5ha. That has happened just by knowing where those low-yielding saline areas are and creating a map to help us manage it with straw.

How are you using the data generated by PA? Is it leading to further practice change? If so, what kind of practice change?

The data generated by PA has definitely led to practice change on our farm. The straw spreading to treat saline areas is a good example of that.

It's not only that but variable rate as well. We use variable rate for both our fertiliser and seed during seeding, but also for in-crop applications of nitrogen. On low-yielding areas, we try to increase our seeding rates to get plant numbers up, but we also decrease our fertiliser in those areas.

We load those same variable rate maps into the spreader tractor to help us better target areas with more or less nitrogen. We do this in conjunction with satellite NDVI maps which are now being offered on a weekly basis, so we apply those maps to our spreading operation as well.

Who is influencing or assisting you with the adoption of PA?

While I'm not as tech-savvy as my children, I do definitely enjoy the technology side of things. For that reason, I am constantly researching any new or emerging technology. The internet is a fantastic resource where I can go and explore any new technology which might apply to my farm. Social media, particularly Twitter, is another great influencer for me. It has enabled me to connect with farmers around the world who share their own ideas, which definitely perks my interest.

Are you planning to adopt more or less of these various precision farming technology components in the future?

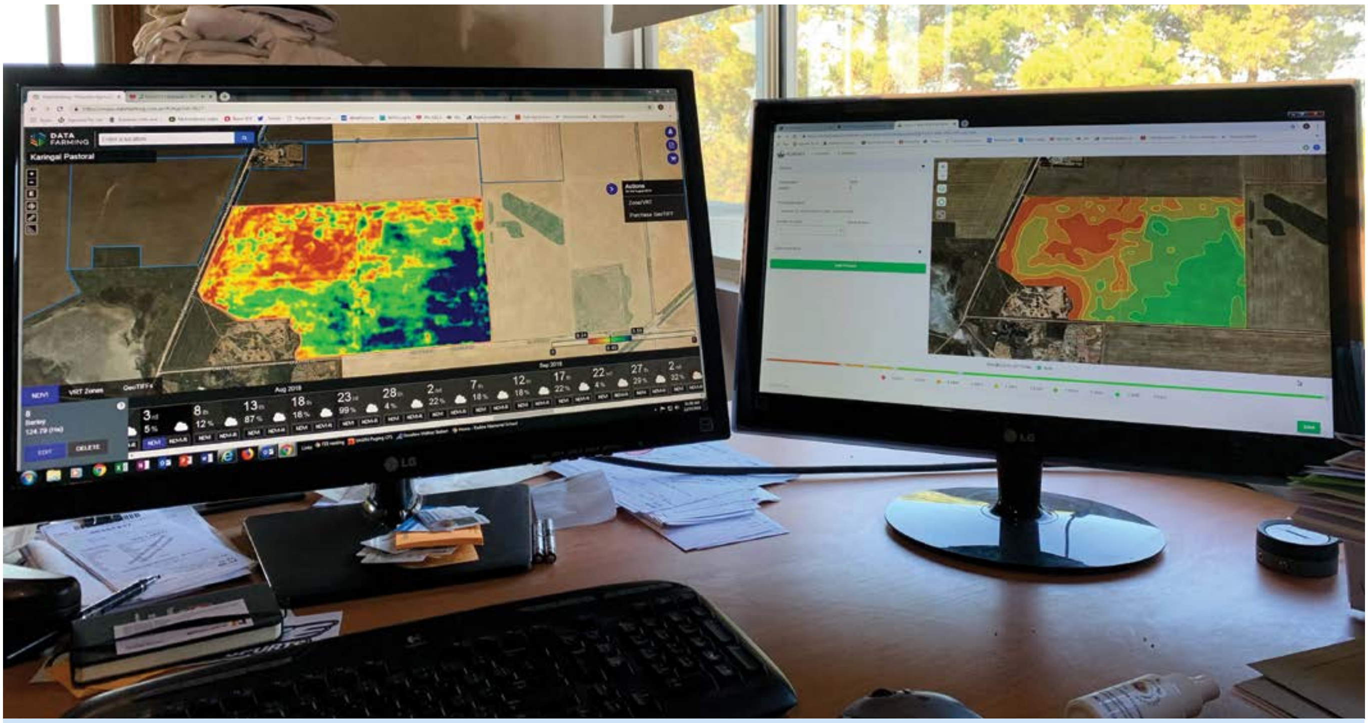
In terms of new technology, we have probably levelled out on what we want to adopt but we will always look for new software which might be able to help us with our operations.

I find real-time technology particularly exciting. For example, as the tractor is pulling the seeder you will be able to see in real-time what is happening as the crop is being planted and make any adjustments on the go.

Robotics is another exciting area. Technology such as SwarmFarm might be commonplace one day. The cost might be prohibitive now, but it's important to remember that it used to cost $50,000 to have guidance on a tractor, whereas nowadays it's a standard feature.

I expect the same thing will happen with robotics.

Details: ***Stephen Paddick, 0438 859 630, stephenpaddick@bigpond.com***



Stephen Paddick combines yield maps with satellite NDVI maps to help identify different zones within paddocks, particularly low-yielding saline zones. Photo: Stephen Paddick

The following article was first published in July 2016

Active paddock management

Emma Leonard

As a self-confessed ‘Techno Addict’, Ashley Wakefield has been an early adopter of many precision agriculture (PA) technologies. He has also spent considerable time helping developers make their technology suitably robust, accurate and ‘friendly’ for Australian farmers.

Ashley has generously shared his PA story many times, including being featured in the SPAA publications PA in Practice I and II. In PA in Practice I, produced in 2008, Ashley estimated that his investment in PA was providing a benefit of $19/ha, basically due to reduced overlap.

In 2008, Ashley was already testing the third prototype on-harvester protein meter but it was not until 2013 that this equipment started to pay its way offering substantial increases to the dollar per hectare value of PA to his farming business (Figure 1 and Table 1).

“In-paddock blending helped ensure 17 out of 18 trucks of wheat were delivered as Australian Premium White (APW protein>10.5%); at $30 a tonne price benefit that represented an increased income of $37.29/ha across this 185ha paddock,” said Ashley.

“If we had not blended, about half of this paddock would have been sold at a lower grade and price.”

Ashley started PA 20 years ago with a Microtrak yield monitor, a Farmscan guidance system and Omnistar GPS correction giving +/-10-30cm accuracy.

He now uses a John Deere yield monitor and has his own base station to provide the correction system for his RTK guidance. All tractor units are fitted with Topcon autosteer and rate controllers, which are used for fertiliser/bait spreading, seeding with a Bourgault disc and on the Miller Nitro self-propelled boomspray which is fitted with Arag Seletron individual nozzle control.

Ashley has worked closely with Topcon on the development of its PA software and hardware including the CropSpec™ sensors which are central to his variable rate program.

Data layers

As an early adopter of PA, Ashley now has multiple data layers for his paddocks and in many cases, multiple yield maps for the same crop in the same paddock.

Farm profile

Farming Personnel:	Ashley Wakefield farms with his wife Louise and son John
Farm location:	Urania, South Australia
Farm area:	1,330 hectares
Annual rainfall:	Annual 400mm, winter dominant
Soil types:	Grey Mallee loams, some sandy loam dune swales
Enterprises:	Continuous cropping – wheat, barley, faba beans, chickpeas and lentils
Yield:	Average wheat yield 4.07t/ha

PA timeline

Guidance and autosteer –	1996
Grain yield monitoring –	1996
Grain protein monitoring –	2002
Auto section control –	2003
On-the go NDVI mapping –	2007
Variable rate fertiliser –	2007
Electromagnetic soil maps –	2000
Gamma-radiometric soil maps –	2007

Top PA tips

- Back-up your data regularly, file carefully and store in two separate locations.
- Test equipment about a month before you want to use it. On the first day of seeding/harvest, etc, you are still likely to have small ‘teething problems’ but you will be much more prepared.
- Work with experts. Use a specialist to process your data as it is very time and cost effective.
- If you have a yield monitor fitted, start gathering data - it might be several years before you use the data but the sooner you start collecting, the sooner it can be put to use.
- Collect and use multiple data layers - they help quantify and qualify your paddock knowledge and in combination help you make better management decisions.

The CropScan is mounted on the clean grain elevator and takes readings approximately every 17m, producing about 15 measurements per hectare. Photo: Emma Leonard

"In the past, we have grown canola but currently we are running a three year rotation of wheat, barley and a legume so we are collecting wheat and barley data from a paddock every three years.

"Combining multiple years of yield, protein, soil and biomass data, as well as our paddock knowledge, is helping to produce more reliable and useful maps."

For example, overlaying protein and yield maps can help determine where additional nitrogen (N) probably will and will not result in a significant yield or protein increase. The remaining areas are probably limited by a soil constraint other than moisture, so the map helps indicate areas for further analysis.

All of the farm has been soil surveyed with EM38 and gamma-radiometrics. The electromagnetic (EM38) soil maps, together with yield maps, have been used to generate replacement fertiliser maps for seeding.

Variable rate

Ashley works on a rule of thumb that four units of phosphorus (P) are removed for one tonne of grain. This means rates of diammonium phosphate at seeding range from 80kg/ha to 120kg/ha. Previously a flat rate of 100kg/ha was applied.

"Following a year with a dry spring, we can produce a disproportionate amount of straw to grain so we add soil data to the rate decision. Any paddocks with a Colwell-P of less than 25ppm will receive an additional base rate of P."

Table 1. N removal maps were generated for 185ha paddock, using the formula 1kg protein removes 0.175kg N. When the rate based on N removal was compared to five blanket rates based on yield, substantial savings in urea were made for all except the lowest yield, where a cost would have been incurred.

	$ urea based on N removal	$ urea based on 2t/ha yield	$ urea based on 2.8t/ha yield	$ urea based on 3t/ha yield	$ urea based on 3.5t/ha yield	$ urea based on 4t/ha yield
	variable	**40kg/ha**	**56kg/ha**	**60kg/ha**	**70kg/ha**	**80kg/ha**
Cost	$10,632	$8,710	$12,194	$13,065	$15,243	$17,420
Saving	$0	-$1,922	$1,562	$2,433	$4,611	$6,789
Saving /ha	$0/ha	-$10.4	$8.40	$13.20	$24.90	$36.70
% saving	0%	-22%	13%	19%	30%	39%

Ashley contracts local PA consultant Peter Treloar and Michael Wells of PCT to produce the maps and to carry out most of the soil surveys and on-farm trial analysis.

Biomass and crop greenness data is recorded during every pass of the boomspray in a cereal crop using the CropSpec™ sensors mounted on the cab roof. This data is used to produce normalised difference vegetation index (NDVI) maps and together with data from the moisture probes and protein meter, is used to establish rates of in-crop nitrogen (N). These NDVI maps have also been used to target weed patches.

“The NDVI maps for N are correlated against N rich strips, which provide a non N limited area of crop, and are now used with the protein maps to help determine N rates.

“The protein meter means we can produce N removal maps. In trials, these maps indicated that in-crop N could be reduced by 30-40 per cent compared to a blanket rate.

“I also use moisture probes to check there is enough subsoil moisture for the proposed fertiliser rate, which I can spread as a granule or apply as liquid to the leaves.”

Protein mapping

Ashley’s interest in protein mapping started when he was still running a piggery and wanted to know the spatial variation in the protein of his feed barley. Moving to continuous cropping in 2003, his interest in protein mapping remained but the objective became focused on the consistent delivery of grain that met higher value protein specifications.

Over the years, Ashley has worked closely with Next Instruments, the Australian company that has developed and now markets the CropScan 3000H.

“There were many times when I nearly threw in the project as it was causing us more problems than benefits, but I love trying to make the technology work and to see a project to its completion.”

Ashley’s commitment and patience have paid off. Over the past four seasons, he has produced meaningful grain protein maps that have supported in-paddock blending (Figure 1) and nitrogen fertiliser decisions (Table 1).

The CropScan is mounted on the clean grain elevator and takes readings approximately every 17m, producing about 15 measurements per hectare as the crop is being harvested. This equates to a reading about every 11 seconds which is at a lower resolution than a yield monitor that samples about every four seconds.

Real-time data for samples is displayed in the cab. For this, Ashley is using an industrialised computer. The individual

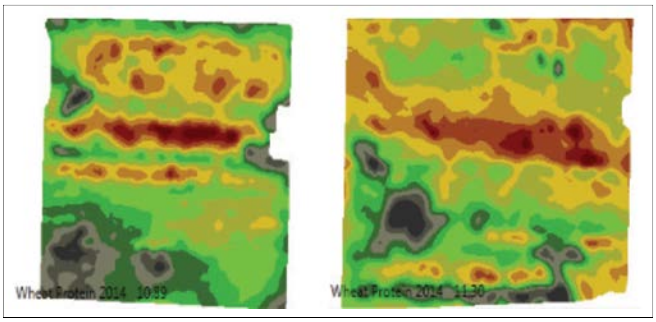


Figure 1: The upper portion of the two paddocks (yellow and red) had protein below 10.5 per cent, while the lower portion (green to black) had protein over 10.5 per cent. Blending resulted in 17 out of 18 trucks going APW rather than ASW, a total increase of $6,900 off the 185 hectares.

Blending resulted in 17 out of 18 trucks going APW rather than ASW, a total increase of $6,900 off the 185 hectares. Photo: Emma Leonard

samples are displayed as a map but for immediate use, the protein is presented as the bin average. This figure can be reset automatically every time the harvester grain box is emptied.

“We use a two bin system with the aim of creating low and high protein silos which are blended as we load the truck.”

Ashley calls this system of blending ‘active paddock management’. He can log on the screen which harvester bin has gone to each silo to produce a running weight and average protein for each silo.

When on-the go data was tested against Viterra’s system at delivery, readings for protein and moisture in wheat and barley were within 0.2%. Ashley encourages users to carefully calibrate the monitor at the start of harvest for each grain type and then stick with that calibration for the season.

By doing this, Ashley can compare protein production and variation within and between paddocks.

“By combining protein, moisture and yield maps, I can look at my gross margin spatially and locate the under-performing or unprofitable parts of the paddock. For example, we found that if we had not cropped the areas producing a gross margin of zero or less in a 185ha paddock, we could have increased the paddock gross margin by $3,835.”

The monitor can measure protein and moisture in wheat, barley, oats and sorghum, as well as chickpeas and lentils. In canola it can measure oil, although Ashley has found that readings were less reliable with very dark canola seed.

The CropScan 3000H can also be mounted on an auger to measure protein in grain coming out of a bin to manage the loading of trucks.

“The protein monitor is probably still creating more questions than it answers. For example, it is still early days for us to understand the relationship between soil and protein, but at least we are now able to collect reliable data.”

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Brendon and Denise Johns.

Farm profile

Farming personnel:	Brendon and Denise Johns
Farm location:	Warnertown, South Australia
Annual rainfall:	340mm
Farm area:	4100 hectares
Soil types:	Sandy loam and clay loam
Topography:	Gently undulating dune/swale sandy loam soils and clay loam flats
Enterprises:	Wheat, barley and lentils
Average wheat yield:	2.7 tonnes per hectare
SPAA member:	Yes
PA consultant:	Sam Trengove, Trengove Consulting
Agronomy consultant:	Sam Trengove, Trengove Consulting

PA timeline

Guidance –	2003
Autosteer –	2003
Yield mapping –	2005
On-farm trials –	2005
Variable rate –	2007
Inter-row seeding –	2013
Optical spot spray technology (Weedseeker) –	2017

Top PA tips

- Use maps and data to manage different zones according to their own unique needs
- Optical spot spraying technology has led to chemical savings of up to 90 per cent
- Read and listen widely and surround yourself with good people to further your knowledge

The following article was first published in September 2020

PA tools 'money in the pocket'

The adoption of precision agriculture technology has enabled Brendon and Denise Johns' business to expand, streamline efficiencies and increase profitability.

Why did you choose to adopt precision farming technology?

Our foray into precision agriculture was originally to enable spraying at night and progress from a foam marker by fitting the spray tractor with autosteer. It was a natural progression but has since become a part of our business' day to day operations.

Which technology tools or components have you adopted and (which do you) continue to adopt?

Autosteer and GPS guidance were the main ones initially. It took us about a decade to get autosteer and inter-row sowing on the seeding tractor and bar completely right, but we have been very satisfied with it since 2013. We were finding we had limited success with inter-row sowing using front-wheel assist tractors combined with a tow-between aircart and Concord bar. We made the decision to move to tracked tractors with a DBS bar and tow-behind aircart which seems to have helped us get better results with inter-row sowing. By using a single-track machine and taking away the pivot points it seems to work better for us.

This has also helped us in our conversion to a two in one controlled-traffic farming system, with most of our machinery now operating on multiples of 12.2 metres. Our seeder is 18.3 metres wide and our sprayer is 36.6 metres wide. That has been an evolution for us over the last five or six years and creates a certain farming skill level which the staff learn to follow.

Another recent adoption has been optical spot spraying technology for summer spraying. We purchased a second-hand Weedseeker in 2017.

We are seeing massive savings with that of up to 90 per cent in chemicals. That machine has the best rate of return for any PA equipment we've purchased and has provided the quickest return on investment.

What are the factors that motivate you to adopt and use each of the different tools or PA components?

I am motivated by the improvements in efficiency we get from PA technology. It makes the job easier for staff, saves money and keeps our business moving forward. If we don't move forward then we get left behind.

What types of data and information are you collecting to guide your decision-making to adopt or not adopt each PA component?

Yield maps are our main source of data. They ground truth what we're doing. We also use NDVI maps to help us check and measure responses to different input applications we have done. Both yield maps and NDVI maps are great validation tools which help us determine if we are doing the right thing and getting a return from the adoption of different tools and methods.

For example, on our dune/swale country, the data from the maps is indicating we need to manage our sandhills better, so we have gone down the path of deep ripping with inclusion plates and applying chicken manure in those parts of the farm. The data helps us to manage different parts of paddocks the way they need to be managed in order to maximise yield. It costs us $200 per hectare to freight and apply chicken manure and the purchase of the deep ripper is a significant investment as well, so we need to make sure we are getting a return on those investments.

Has the adoption of PA increased profitability on your farm? How?

I think PA has increased our profitability. Our business has continually expanded since we started adopting PA technology. It makes machinery easier to use and allows us to work around the clock during busy periods to an improved standard, which we couldn't do without it. Technology such as the Weedseeker just puts dollars in our pocket – the savings we are getting from it is massive.

How are you using the data generated by PA? Is it leading to further practice change? If so, what kind of practice change?

The data from the NDVI maps and yield maps has led us down the path of deep ripping and chicken manure spreading. We have also started pH mapping this year with a Veris machine which will help us in adopting variable rate lime or gypsum to target acidic patches in paddocks.

The data helps us manage paddocks in zones. We have a number of blocks spread up to 40 kilometres apart and no two blocks or paddocks are the same and therefore nothing is treated the same. Different zones get treatments unique to them to maximise yield and return.

Who is influencing or assisting you with the adoption of PA?

Our consultant Sam Trengove helps us with the implementation of different PA tools. But personally, I am continually trying to build my own knowledge by reading, listening and surrounding myself with good, positive people.

Are you planning to adopt more or less of these various precision farming technology components in the future?

We probably do less variable rate in-crop now than what we did in the years when we first adopted it. We have found that crops were less responsive where phosphorous levels were high, so by limiting those inputs on areas with high levels we were limiting our crop yield.

The pH mapping will help us to identify problem areas of soil acidity and see what is required. We will do 400ha this year and see where that takes us.

We were going to purchase protein meters last year but due to the poor season we didn't, so that is something we will look at again this year. I see that as a valuable tool in helping us manage our on-farm storage and what grain goes where. I look at that in a similar way to the Weedseeker. Where a lot of PA tools are profit by default, protein meters and the Weedseeker are money in the hand straight away.

Looking into the future, one area that excites me is the potential for in-crop optical spot spraying, where the machine is able to identify weeds in-crop and spray them out, just like a Weedseeker does in our fallow phase at the moment. That would be a game-changer.

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Andrew Sargent. Photo: Emma Leonard

The following article was first published in July 2020

Open for better data use

Emma Leonard

As early adopters of PA, the Sargents continue to seek better ways to make technology work for them. Using open source software is an approach they are testing.

For Andrew Sargent it is hard to remember farming without PA. His father, Malcolm was an early adopter of the technology starting with an AgLeader yield monitor and GPS in 1999. This was followed by guidance in the sprayer in 2002 and a hefty investment into RTK guidance for most operations in 2004.

Today it is Andrew driving the adoption of new technology through his interest in using open source software solutions.

"Our PA objective was to increase our efficient use of inputs, seed, fertiliser and chemicals, as well as labour and machinery, without reducing yield," Andrew says.

Autosteer and guidance allowed them to adopt practises such as variable rate gypsum and lime, replacement rate phosphorus, inter-row seeding and to carry out their own on-farm trials.

Much of the farm is on undulating land and terrain determines paddock shape, which is often irregular. Adopting autosteer and guidance provided an immediate 3% reduction in overlap. This transferred to reduction in inputs as well as making working longer hours easier and safer.

Similarly, section control on the seeder and boomspray have also resulted in savings in inputs and improved crop performance.

The Sargents have often experienced issues with software and hardware compatibility as well as with putting data to use. To different degrees, these challenges still exist.

In the past 15 years the Sargents have not invested in any new PA tools, instead just upgrading the sensors and controllers as machinery has been replaced. They have focused on how to use the precision and data provided by PA tools to improve their farming practices. When required, this is supported by specialists and contractors, such as for soil mapping using gamma radiometrics and on-the-go pH sampling.

"I think we reached a point of tech fatigue where we felt we had spent enough time and money on PA products that failed to deliver in terms of reliability, usability, compatibility and support," he recalls.

"Our experience has made us assess PA technologies and uses on a case by case basis; if we are going to change, it has to bring a benefit proportional to the time, effort and capital involved."

Andrew points out that compatibility issues are better but still occur, even from technology supplied by the same manufacturer.

Farm details

Farming Personnel:	Andrew, Malcolm and Jane Sargent
Location:	Crystal Brook, South Australia
Farm size:	2,000 hectares
Annual rainfall:	400mm – winter dominant, 300mm GSR.
Soil:	sandy to clay loams
Enterprises:	wheat, barley, canola, lentils, oat hay
Yield:	average wheat yield 3t/ha

Top PA tips

- Check that software/hardware is well supported. Things will invariably go wrong.
- Systems that provide the grower with direct access to their database in a usable format makes data migration to other software easier.
- For paddock recording apps, ease of data entry is paramount, if it's too hard it won't happen.
- Consider open source solutions, the extra initial investment of time could be worth the flexibility later on.

Yield maps

Like many, a yield monitor was the first piece of PA equipment purchased. Yield maps continue to be an important layer for the Sargents providing a starting point for planning the season's agronomy and an end point for measuring the outcome.

The yield maps guide the location of scouting and soil testing because the Sargents know that ground truthing data is a vital process.

"Without ground truthing it is easy to make assumptions regarding the cause of a problem or to presume a high yielding area is performing to its optimum."

Their crop rotation can result in the same crop not returning to a paddock for over three years. In that time varieties may have changed, and seasonal conditions can have gone from average to drought. This makes good record keeping even more important.

The ideal record keeping system for Andrew allows the yield data to be stored both as a map and as a dataset that can be combined with other datasets to make better decisions.

Due to the annual cropping cycle it can be six months or more between software use. Andrew emphasises that this makes the importance of good user interfaces and intuitive design "really, really important". Andrew is still looking for a software that has these credentials and that also integrates paddock output and input data.

Currently he uses New Holland PLM™ software and ProductionWise® for paddock records.

Although ProductionWise® software is helpful, he does find it frustrating. "It is slow and has a long lag time when entering data and errors cannot be quickly corrected."

Variable rate fertiliser

As an early adopter of yield mapping the Sargent's business was a popular location for research trials. The opportunity to be involved in the variable rate phosphorus (P) and nitrogen (N) work with Brett Whelan from the University of Sydney in the mid 2000s fitted with their objective to implement variable rate fertiliser.

"At that stage we all thought variable rate nitrogen and phosphorus was the big next step but without spatial soil maps of soil-available nutrients, we needed data that could infer variation in N and P".

The idea was that yield could be used as a surrogate for nutrient availability, especially for P. This was because P is known to be quickly locked up by soils and slowly mineralised.

Phosphorus response rate trials were established with differences in grain yield being the measure of response. The yield maps identified that in the southern part of the farm, high soil P levels resulted in low-crop response to added P, while high yielding areas only had a moderate response to P fertiliser. In the low yielding areas, high levels of soil P resulted in a low response to P fertiliser, as a result of years of blanket applications

These results combined with their yield maps and electromagnetic (EM) and gamma-radiometrics maps of soils in the northern part of the farm were used to create their variable rate P zones. They found that EM was a better indicator of soil type in the northern part of the farm on the sand dune swale soils. Gamma was a better representation on the southern part, a heavier loam soil.

The relationship between P, soil type and yield was not clear cut and varied seasonally. This inconsistency, together with major issues of incompatibility between the Flexicoil airseeder and the PLM™ software caused them to stop using variable rate P.

"We are always revisiting potential PA approaches as the technology and data collection systems improve.

"However, I am constantly frustrated by wanting to use multiple data sets and the fact that they are stored in different software and formats."

Open source software

This frustration lead Andrew to look at open source software for agriculture on his Nuffield Farming Scholarship.

"The majority of software and data platforms developed for agriculture lack flexibility and the option to add to or modify the software to meet a need or correct a problem; that could be as simple as wanting to add another crop such as faba beans to the US-based crop list" explains Andrew.

"Open source software allows programmers to access the source code that makes the software work, so they can make add-ons and help develop the program.

"The data held within that software can be as available or tightly held as the farmer chooses."

Andrew discovered that often people confuse open source software with open data. He says, open data generally relates to public datasets, but ironically, is closer to what we have with proprietary software.

That is because the data agreement often requires the user to give very broad access rights to the software owner.

The beauty of open source software is that it allows programmers access to the source code, but the farm business retains ownership and administration of their data. With programs and add-ons using

open source software, your data is stored on your computer or private cloud storage. If you want to share your data with another software product your historic data canbe transferred.

"Open source gives the potential for a farmer to store their raw data in a format that is independent of the software being used to analyse that data," Andrew says.

"Often proprietary software locks you in by making it hard to integrate or transfer your historic data to other products. Open source software is a way to overcome this problem."

Open source software needs to be aligned with a set of best practice standards to make data in open source software interoperable and exchangeable. This set of standards should not be confused with the Australian Farm Data Code, developed by the National Farmers Federation. This data code relates to how farmers data is used, shared and managed.

Andrew admits that much of this was new to him and he is still learning about the opportunities, and pitfalls of open source software.

Experience has made Andrew assess the PA technologies he uses on a case by case basis. "If we are going to change, it has to bring a benefit proportional to the time, effort and capital involved." Photo: Emma Leonard

What options are there?

Andrew has been looking at an open source software option for their farm. For management records he is considering changing to FarmOS, which as well as usual input/output data, can accommodate soil and weather data from on-farm sensors.

He is currently retrofitting a tractor with AgOpenGPS to provide autosteer and control for up to sixteen sections on an implement. This software can also control remote hydraulics and end of row turns.

There is open source software for irrigation management (Vinduino) and robotics (ROS agriculture). Another that Andrew explored as part of his Nuffield Farming Scholarship was FieldKit for collecting and sharing field-based environmental research data.

"Unlike much agtech that seems to be developed and then seeks a purpose, these open source projects were started to solve a problem for farmers and are quietly serving a purpose, not looking for a purpose."

Andrew uses The Things Network, an open source connectivity solution for the Internet of Things (IoT), to connect on-farm sensors. He has soil moisture probes, weather stations, water meter monitors and a temperature inversion sensor, some of which he has made from cost effective components sourced on-line.

"I am currently looking at FIWARE as an open source platform. It has developed a standard way to integrate data sources and allows me to display results as a dashboard."

Such a platform, combined with the other open source tools would help Andrew integrate management, yield, biomass and sensor data in one place. The next step is to build in analytical tools to help make sense of the data. Artificial intelligence is much better at looking for patterns in data than humans.

"Starting with databases that can work together, even using Microsoft Excel to bring together data in a .CSV format (comma separated values) is a starting point.

Andrew believes there is a role for proprietary systems, but those systems must not try to reinvent the wheel. Instead they should leverage farm data in an open source platform to build better products.

He encourages all farmers to consider the data layers they want or might want to use to improve decisions and workflows and to start collecting it, preferably in a format that can be integrated.

"I don't think open source will be the solution to all of the challenges, but it will go a long way to solving some of the basic hurdles we currently face."

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Photo: Mark Branson

The following article was first published in April 2015

PA pays its way

Emma Leonard

After 10 years of PA and CTF Stockport farmer Mark Branson crunched the numbers to calculate the financial influence these systems have on his bottom-line.

Early adoption of new technology is nothing new to the Branson family. When Mark's forefathers established the farm near Stockport in 1898, they became some of the first to adopt the research issued from local Roseworthy Agricultural Institute on superphosphate.

2014 not only marked 116 years of productive farming by the Bransons, it also was 10 years since Mark had converted to RTK guidance, controlled traffic farming, full no-till and really kicked started his use of yield data, which had been collected since 1997.

So, Mark decided it was time to crunch the numbers to see what impact PA technologies were having on his bottom line and what changes were providing the greatest financial gains.

"Most people look to yield as the benchmark for justifying system changes but yield is too influenced by seasonal factors. Input savings can represent greater benefits, as I found out," said Mark.

But Mark did need to include yield gain in his calculations but based this information on gains in water use efficiency (WUE) from data he had collected since 1988. WUE is used because it takes into consideration the largest outside influence on yield, the amount of growing season rainfall (GSR). Mark used the change in five year rolling averages of WUE over time to indicate the improvement in yield with the adoption of new technology. The calculation of WUE uses actual yield divided by potential yield.

Potential yield, based on the French Schultz model, is growing season rainfall minus 110mm for evaporation losses multiplied by 20 for wheat.

So, for 350mm GSR the potential yield is 4800kg/ha but if only 4000kg/ha is achieved then 83% of potential has been achieved.

Farm details

Farming Personnel:	Mark and Nola Branson and son Sam (apprentice part time), parents Deane and Jennifer Branson and full time workman Ryan
Location:	Stockport, SA
Farm size:	1200ha two blocks 12km apart (80% cropped)
Annual rainfall:	425mm to 525mm
Soil:	Red brown earth and self-mulching dark brown cracking clay, pH ranging from acid to alkaline, undulating land, creeks.
Enterprises:	durum and bread wheat, malting barley, canola, faba beans, field peas, self-replacing merino flock and prime lambs
Yield:	Average wheat 4.2t/ha

PA applications

Technology	Year started using
Lightbar Guidance –	2003
Grain yield monitoring –	2003
Grid Soil Sampling –	2005
Electromagnetic soil maps –	2005
On-farm research –	2005
VR seed tested –	2005-2014
plan to start –	2015
Vehicle steering –	2008
RTK –	2010
Spray application mapping –	2010
Variable rate phosphorus and nitrogen –	2013

Top PA tips

- Changing to PA, CTF and no-till has helped increase returns by $57/ha.
- Input savings have a substantial impact on gross margin and where achieved without a yield penalty.
- Mark finds nitrogen models under-estimate mineralisation and assessing crop need is a more reliable indicator.

Table 1. Farming systems changes that significantly influence yield and profit on Mark Branson's dryland winter cropping system.

1988 to 2001

- Introduction of grain legumes and oilseed crops.
- Introduced new wheat varieties.
- Nitrogen based fertilisers introduced.
- Stubble retention enforced.
- No-till introduced.

2002 to 2014

- No-till enforced.
- Precision agriculture using variable rate technology introduced in 2006.
- Controlled Traffic introduced in 2004.
- Introduction of animal manures as an additional carbon source.
- Growing as many high carbon crops as possible.
- Inter-row sowing introduced.

"Between 1988 and 2014 we have moved from achieving 63% to nearly 100% of potential yield, which suggests changing systems is having a positive impact on production."

In Table 1 the key changes to Mark's cropping systems by period can be seen. These include adopting full no-till in 2002.

As Mark really wanted to see the impact of the adoption of PA technology and CTF systems he dissected the figures into WUE gain pre 2002 and post 2002. Based on this he established pre 2002 the annual average gain was 1.1%, while post 2002 to 2014 it was 2.2% for wheat.

Based on this Mark attributed the additional annual 1.1% gain to no-till, PA technology and CTF systems. Parallel calculations were done for other crops. Smaller yield gains were recorded for barley and faba beans but no yield gains were recorded for canola nor field peas.

Mark calculated that yield gains in the past 10 years across his 900ha cropping program represent a total of increase in income of $7.87/ha, based on:

Wheat	(380ha)	$16.2
Barley	(260ha)	$ 3.79
Faba Beans	(88ha)	$ 1.21
Total (900ha)		**$7.87/ha**

Mark's CTF system has evolved and now is based on a 1 to 4 system with the seeder 9.8m wide and the boomspray and fertiliser spreader 39.2m. All vehicles are on 3m axles and all implements fit the system except the harvester.

The combination of RTK guidance and CTF has helped Mark reduce overlap by up to 4% and consequently inputs of seed, fertiliser and sprays. Savings in the latter have also been boosted by the addition of auto-section control on the boomspray and auto-width and auto cut-off on the fertiliser spreader. Mark has not included any saving for time or fuel due to reduced area driven and increased work rate as these are tricky to calculate.

So purely on reduced inputs due to less overlap Mark estimates a saving of $7.24/ha with fertiliser representing the biggest saving.

Seed	$1.69
Sowing Fertiliser	$3.64
Chemical	$1.33
Post Fertiliser	$0.58
Total (900ha)	**$7.24/ha**

Savings in fertiliser, lime and gypsum and herbicides have also been achieved from targeting inputs to need. Mark has the ability to vary input rates on the seeder, sprayer and fertiliser spreader.

Varying herbicides has been used on a trial basis and is currently too hard to calculate its economic benefits. However, the use of replacement phosphorus and nitrogen based on budgeting and crop scanning have generated substantial savings without any yield penalties. Inputs of gypsum and lime are varied based on soil colour and yield data. Locations are ground truthed to confirm the rate and type of amendment.

VR nutrients

Phosphorus (P), if adequate, is applied in the soil during the seeding pass at replacement rates derived from the previous year's yield maps. The lower the yield the less P removed, so less is applied. Rates are calculated from the P lost in grain from the previous crop plus a buffer P rate for P lost to the soil etc. Mark makes his own rate maps using the SMS Advanced software. Adequacy is assessed by a program of checking soil samples over time to see if P is changing, but this is difficult as P changes slowly over time.

As a producer of durum and bread wheat, and malting barley, achieving the correct protein percentage is a high priority for Mark. He has experimented with a harvester mounted protein meter but has not yet purchased one, so nitrogen (N) management remains his main method of managing protein content.

Mark uses many different methods to calculate the rate of N to be applied to the crop. The main method is using N-Rich strips which are assed using a handheld GreenSeeker®.This technique uses the crop as the indicator of its N needs. He also measures deep soil nitrogen to assess available N and uses this with a forecast yield at the time of application to see if top up N is required.

"In some crops no nitrogen has been applied until flag leaf emergence; with the nitrogen rich strips giving me the confidence not to apply rather than adding an insurance dose."

Nitrogen rich strips are located on various soil types in a paddock and these provide a reference that is unlimited by nitrogen. The scanned readings from the crop and N-rich strips are compared and identify if additional nitrogen is required and maximum and minimum application rates are determined.

Tractor mounted CropSpec sensors are used to vary the N rate on-the-go according to the site specific canopy requirements.

"I have not been able to make nitrogen models work for my farm for years. We are finding more mineral nitrogen is available than they predict; sensors enable me to confidently respond to the crops' needs.

"Deciding not to apply nitrogen is often a harder decision than deciding to apply; this is where the sensors really give me confidence."

Mark uses a handheld biomass sensor to compare crop reflectance of the N-Rich strip against the adjacent crop to establish the range of N requirement. Photo: Emma Leonard

N-Rich strips are put in all crops including barley and canola, but Mark has the most confidence using them in wheat crops where the most research has been done. More research needs to be done on barley and canola nutrition to improve the agronomy in those crops.

His ability to save on fertiliser and soil amendments, while maintaining a yield gain has provided the greatest savings, representing $54.14/ha.

"Savings in fertiliser inputs due to the adoption of PA technologies – yield mapping, targeted soil sampling and crop sensing represent nearly 80% of the financial benefits I have recorded from systems changes in the past 10 years."

- Phosphorus $16.0/ha
- Nitrogen $33.78/ha
- Gypsum/Lime $4.36/ha

Total/ha **$54.14/ha**

So, Mark's total savings and gains from his systems changes in the past 10 years are $69.25/ha. Of course these are not without some additional costs. Mark has used current prices for machinery and software and averaged these over his 900 hectare cropping program for 10 years, which equals $11.11/ha.

Machinery Expenses

- RTK GPS/console unlocks $44,000
- Tramline renovator $18,000
- Modifications to airseeder $15,000
- Software $ 3,000
- Biomass sensors $20,000

Total **$100,000**

In addition Mark estimates a cost of $1/ha for time managing data and $0.67/ha for RTK GPS signal which he now receives from a dealer owned network. This brings total cost per hectare to $12.28/ha.

Across Mark's 900 hectare cropping program he calculates that changes to his system in the past 10 years have increased his profit by $56.97/ha each year which is $51,273 across the whole cropping program (Table 2).

Table 2. A summary of the increased income, savings and costs attributed to adopting PA technology, CTF and no-till in the past 10 years on Mark's 900 hectare cropping program.

	$/ha
Yield gains/ha	$7.87
Input overlap savings	$7.24
Nutrient savings/ha	$54.14
Subtotal of savings	$69.25
Total expenses	-$12.28
Annual profit	**$56.97**

"Yield gains have yet to plateau and it could take another 10 years to fully realise the benefit of all these changes as the soil is still improving and more nutrients are cycling each year."

Details: *Mark Branson, 0417 832 776, mark@bransonfarms.com.au*

Ben Cripps Photo: Emma Leonard

Farm details

Farming Personnel: Ben farms with wife Ange and parents Terry and Ros

Location: Ogilvie, 40km NE Northampton, WA

Farm size: 4215ha

Annual rainfall: Annual average 300mm

Soil: 60% sand plain, some non-wetting, 40% sandy loam and gravely loam. pH5.5 to 4.8 at depth

Enterprises: wheat, lupins, canola, barley and oats

Yield: Average wheat yield 2.2t/ha

PA applications

Technology	Year started using
Guidance –	2004, RTK 2011
Vehicle steering –	2008
Grain yield monitoring –	2011
Variable rate inputs –	2012
Electromagnetic soil maps –	2012
NDVI mapping tested –	2014
Spray application mapping –	2013
CTF –	2015

What Ben suggests to new PA adopters

- Buy the best computer you can - fastest, heaps of RAM, big screen, portable.
- Establish a background system on your computer that works for you.
- One step at a time – is it nitrogen, potash, CTF or something else that will give you the biggest bang for your bucks?
- Every time you can record what you did in a paddock, do it. You never know when it will come in useful.
- The benefits of one machinery operating system make life much easier when under pressure.
- Spend the time learning your computer software inside out, then VRT and PA become easy.
- Collate information in one system. It means less for you to remember.
- Backup!!

The following article was first published in November 2015

Variable rate in action

Emma Leonard

Ben Cripps brings some of the skills and discipline he learnt in the army to help the profitability of his family farm.

As an ex-soldier it is not surprising that Ben Cripps applies military precision to his farming but destroying the harvester with fire during his first harvest seems a bit of an extreme way of converting to PA.

In Ben's case the harvester fire helped accelerate an upgrade to one fitted with a yield monitor and the Ag Leader software SMS™ Basic, which he now uses for all record keeping. This change helped underpin the adoption of a comprehensive variable rate approach to inputs.

While the harvester might have been the tipping point, the soil is very much the starting point for Ben's approach to PA. While some of his soils have high clay content, others are sand plain. Ben and his father initiated a program of electromagnetic (EM) and gamma radiometric soil mapping to really understand soil properties.

About 50% of the farm has been mapped and the remainder has been zoned based on similar soil properties and performance.

"My objective was to gain a clear understanding of soil water holding capacity; for us these soil measurements have provided the basis for robust zones and we have only made minor modifications based on yield data," said Ben.

"Costing about $30/ha, soil mapping is one of the best investments I have made. We now have variable rate inputs based on these zones and that is generating substantial savings."

GRDC

Ground truthing

While the soil surveys provided the overview, going out into the paddock and checking is vital for Ben. Soil samples were taken across the farm to ground truth the soil maps and zones. This ground truthing is an on-going process for Ben.

As he is not keen on a shovel, during the summer when soils are dry he uses a mini digger to dig into the soil profile. While this cannot stay on his tracks, Ben believes the information it helps him discover is greater than the compaction the mini digger might cause.

"When I notice something different in the growing crop or in the yield map, I will go and look for the cause and that can include looking into the root zone for compaction, residual soil moisture or chemical issues."

Ben uses a motorbike to scout his crops as he does not want any vehicle going off his controlled traffic tracks.

"I won't let a ute on our paddocks; all scouting is done by bike and I am able to cover large areas and see more detail without dismounting."

Scouting can include gathering soil and plant samples and sweeping for insects.

Ben has trialled a UAV for crop scouting but it was attacked by a wedge-tailed eagle, which normally he never sees on his property.

Varaible rate

Ben regularly scouts paddocks for weeds, pest and disease and to check on the effectiveness of a treatment. He uses an app called GIS Kit Pro on his iPad where he can drop pins onto the map. As he scouts a paddock, he adds a red pin to a zone that requires pesticide, for example. This map is then created in SMS™ Basic and can then be exported to the controller in the CASE Patriot sprayer. Basically, he has two zones/rates - sprayed/full rate or not sprayed/zero.

"We only use variable rate herbicides where it is clearly obvious it will not compromise weed control."

Figure 1 illustrates Ben's variable rate (VR) strategy on a 293ha paddock. If he had applied a pre-seeding knockdown herbicide of Sakura® it would have cost $14,796.50.

After scouting Ben established that only 163ha required spraying with Sakura® generating a saving of $6565.

Of the remaining 130ha, no pre-seeding herbicide was applied to 70ha; the remaining 60ha were treated with Treflan™ in a second pass at a cost of $1096.20. So the saving on pre-seeding spray was $5468.80, including application costs, by creating spray zones.

A similar approach to his post emergent spray in this paddock resulted in a further saving of $3170.26.

"For us, VR is both money saving and money making as it is helping us manage to the soil's capability and to a zone's specific characteristics."

Ben's attitude is to kill weeds when they are small, as even resistant weeds can be susceptible at early growth stages and then to worry about the next generation of weeds when they appear.

"Do not delay weed control because the next rain will germinate more, because that rain may not come when forecast; kill those that are already there early and use lower rates to achieve a better kill."

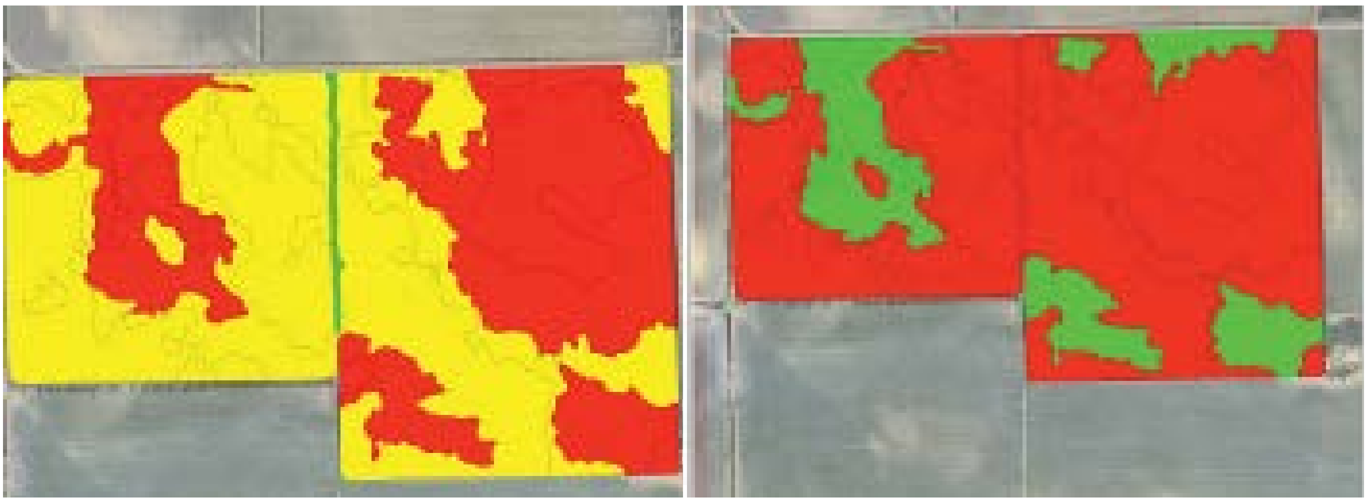
In addition to VR pesticides, the Cripps are applying fertiliser and lime variably. Indeed Ben's father Terry had been applying either 1.5 or 2.5t/ha of lime based on his knowledge of the paddock and some soil testing before Ben returned home.

Seed and fertiliser rates are closely tied to soil water holding capacity. Basically, three zones – high, average and low - are used. So for seed, a high performing area would receive less seed (providing the high performance area is weed free) and more fertiliser and the low performing the opposite. The higher seed rate is to try and achieve target establishment.

"The average area is treated as if we were using the blanket rate, then the low and high will be plus or minus about 20kg for wheat seed, for example."

VRT potash (K) was the main reason the Cripps wanted to start VRT as there are big variations across their soil types. Since adopting VR for K in 2012, they have saved $40,000 with no noticeable impact on yield or quality.

Figure 1: VRT herbicide maps illustrating Ben's simple two zone system.



yellow 163ha - full rate Sakura®

red 130ha – zero rate Sakura®

green 60ha – received Treflan™,

red 70ha + 163ha (already sprayed with Sakura) no Treflan™

All GPS equipment is Case IH and compatible with the SMS™ operating and recording software. A single platform simplifies synching machinery and data and makes life easier during the busy periods when you need it to work. Photo: Emma Leonard

In 2014, nitrogen in the form of Flex N was applied variably. Rates were modified by water holding capacity in relation to Yield Prophet® recommendations. Two post N treatments are normal but staying flexible and responding to the season is important.

Ben has three soil characterisation sites that represent average production on different soil types across the farm. Nitrogen decisions are modified up or down from

Yield Prophet® forecast depending on the zone. His Yield Prophet® subscription so far has paid for itself every year. He finds the biggest limitation with Yield Prophet® is in soils where there is a hard pan and it does not compensate well for heat events.

Record keeping

Generating new VRT zones for every application makes the importance of record keeping paramount. All of Ben's input and output data is logged in SMS™ Basic, including prices, and prescription maps are generated with this software.

From his army days on night patrols Ben understands the importance of good organisation; knowing exactly where everything was in your pack could be the difference between life and death. He applies the same degree of rigour to his record keeping and knows that the background filing system is really important so data can be easily and correctly entered and retrieved.

All GPS equipment is Case IH and compatible with the SMS™ operating and recording software.

"A single platform simplifies synching machinery and data and makes life easier during the busy periods when you need it to work."

Details: ***Ben Cripps, 0427 772 755, @bencrippsC97, bangewpowie@bigpond.com***

Photo: Emma Leonard

The following article was first published in November 2015

Big picture detail

Emma Leonard

Without good records and data analysis, the full benefits of PA farming tools might not be realised.

Reducing within paddock variation and improving profitability through the use of good agronomy and record keeping are at the heart of Warwick and Di Holding's cropping operation in southern New South Wales.

For the past 10 years, they have run a continuous cropping system on tramlines, using a tined no-till system. They have no livestock.

The controlled traffic farming (CTF) system is based on 3m wheel centres and implements in multiples of 12m. For example, they have a 12m seeding bar and harvester comb and a 36m spray boom.

Machines are driven on permanent, uncultivated bare wheel tracks leaving the crops to grow in uncompacted soil. In areas where water lies, and that can be whole paddocks in some years, the hard tracks are helping them drive on the paddock much sooner after heavy rainfall and ensure operations are as timely as possible.

"Our yield maps are showing removing random traffic and soil compaction is reducing yield variation; the other great benefit of CTF is it makes running on-farm trials much easier," said Warwick.

Warwick is dogmatic about not running on the tracks but wanted to burn narrow windrows as part of his integrated weed control. Normally this requires lighting across the rows but Warwick has been inventive and built a 36m, three jet burner pulled by a tractor. The harvester dumps the chaff and grass seeds in the centre of wheel tracks. The tractor runs on every third set of tracks burning the row immediately behind and each row in the set of wheel tracks to left and right.

Warwick admits they had a few near misses when setting the system up due to solenoids sticking. Di reminds those considering this system to think carefully where you will start and finish to make sure you have not boxed yourself into a burning paddock.

From his experience, if you cannot see any evidence of wheel tracks in a paddock, then the whole paddock is compacted. If you can, CTF will still help improve the soil for crops and machine trafficability.

Farm details

Farming Personnel:	Warwick and Di Holding and full-time employee Ryan
Location:	Yerong Creek, NSW
Farm size:	2000ha
Annual rainfall:	Annual 510mm winter dominant
Soil:	sandy loam, loam, clay loam and sodic red clay with pH from 4.5 to 5.8 ($CaCl_2$)
Enterprises:	Continuous grain crops – wheat, lupins, canola, field peas, and occasionally faba beans
Yield:	Target wheat yield 4t/ha

PA applications

Technology	Year started using
Guidance –	2004
Grain yield monitoring –	2004
Electromagnetic soil maps –	2005
Vehicle steering –	2006
Controlled traffic farming –	2006
Spray application mapping –	2008
pH mapping and variable rate lime and gypsum –	2014

Stubble management

While too much or too little water have been big challenges over the past 10 years, so has growing crops with large stubbles.

"In heavy stubbles, poor establishment can reduce wheat yields by as much as a tonne, which is just not acceptable."

Using 2cm RTK guidance and autosteer has enabled most paddocks to be sown inter-row in most seasons, but where the stubbles lodge, stubble burning can be the only option.

"I prefer to retain the stubble but if we cannot seed through it, we burn immediately before the seeder but after a knockdown. The burn is like a double knock. We can then take the opportunity to use pre-emergents on the weeds as the herbicide is more effective with less stubble."

Other techniques being explored to manage wheat stubble are growth regulators, harvest cut height and post-harvest stubble mulching.

Where growth regulators were trialled last year, no difference was measured. Warwick and Di are continuing to investigate timing and rates of growth regulators to shorten and strengthen wheat stubble.

If the rotation includes wheat, pulse, wheat, they will sow the second wheat on the stubble row of the pulse to try and minimise disease from the first wheat stubble and to capitalise on any nitrogen fixed by a pulse.

Paddock records

Paddock records are an important part of Warwick and Di's business, helping them fully understand the costs and returns driving profitability. Each year Di compiles all production and financial records in a book. The figures are used to analyse productivity and profitability and to compare crops, varieties and farms (soil types) based on cost per tonne and per hectare.

They also use return on dollars spent as a key indicator to compare crops, farms and seasons. Fifteen years of records have allowed them to look at the big picture in detail. This has helped identify profitable rotations and also quantify the differences in profitability and sustainability between properties. They use this to underpin the profitability of leased properties and to be confident in determining realistic lease rates.

"There is no point being pin-point precise in your paddocks if you are sloppy with your records and business analysis."

Measuring and recording operations, inputs and outputs allow Warwick and Di to revisit the numbers and learn how their decisions around rotations, nutrition, operations and the smaller details affect the big picture - profitability.

Variable rate

Like many farmers, Warwick and Di have tried a range of PA tools and applications including electromagnetic soil surveying, yield mapping, satellite imagery and variable rate inputs. While they have seen some value, they are not putting all of them to use year on year.

For example, at this stage the initial set-up cost of going to variable rate phosphorous (P) and the medium term savings anticipated from trials and their detailed paddock records have made them decide not to adopt variable rate P at the moment. However, they have been pleased with the use of pH mapping and variable rate lime and gypsum.

About 10 per cent of the farm has been treated with variable rate lime or gypsum. The same amount of lime was used over a total area but higher or lower rates were applied based on pH and soil type. This means there was no cost saving but the Holdings are hoping to see yield benefits and reduced in paddock variation. They hope to expand this program across the farm.

On farm trials

The combination of Di's agronomy background, Warwick's continual search for improvement and CTF makes running trials an integral part of the Holding's business.

They are co-operators in the National Frost Initiative and they have seen correlations between frost damage and yield from the elevation maps generated from the RTK system. Management options are also part of the potential solutions package for frost management, but it is early days for the research.

Foliar fungicide use at flowering to target Sclerotinia in canola is another trial. However, the one Warwick is especially keen to see the yield maps for this year is a canola seed size trial.

For a number of reasons, Warwick has been grading and then passing the canola seed over a gravity table to ideally only save seed greater than 2mm; in some years they have reduced this to 1.8mm. This year the seed has been sown in the same paddock of commercially bought seed of the same variety and a hybrid. In September dry matter differences indicate the precision graded seed should yield the best, but time will tell.

"We start with about 10 tonne of seed and by the time put over the gravity cleaning table and down to 2mm, we have about 600kg; the rest is sold."

Like many farmers, Warwick is enjoying flying his UAV and gathering aerial images of the farm and the trial plots. These are giving him records of real time crop inspections and he can compare change over time and identify areas that require further inspection.

Details: ***Warwick Holding, 0428 306 500, @PontaraGrain, pontaragrain@bigpond.com***

Home-designed and built narrow windrow burner to suit the 12m controlled traffic system. Photo: Emma Leonard

Neale Postlethwaite. Photo: Emma Leonard

Farm details

Farming personnel:	Allen, Trevor and Neale Postlethwaite
Location:	Gooroc between St Arnaud and Donald, Victoria
Annual rainfall:	400mm, 275mm GSR winter dominant but often soaking summer rain
Soil:	Self-mulching grey clay to red loam, mostly pH8
Enterprises:	Continuous cropping, winter cereals and legumes
Yield:	Average wheat yield 3t/ha, variation 1-7t/ha

PA applications

Technology

Guidance

Vehicle steering

Grain yield monitoring

Variable rate seed, phosphorus and nitrogen in 2014

Electromagnetic soil maps

NDVI mapping

Boomspray section control

Variable spray rate control and application mapping

The following article was first published in October 2014

Early adopter

Emma Leonard

The Postlethwaites have never been scared of being the first in the district to try a new system. Some might think their early adoption is just because they love new technology or modifying their own machinery. However, the underlying driver is their desire to measure and then manage their system efficiently and sustainably.

Varying rates manually was initiated after a triple bin variable rate air-seeder was purchased. However, this practice totally relied on the operator's memory and knowledge of the field.

In addition to running the farming enterprise, the three families run two other businesses. TPOS Fabrications manufactures specialised farming equipment and repairs damaged header fronts and Wimmera Crop Watch, which sells and supports Farmscan AG GPS equipment and until recently provided a contract soil sampling and testing service.

These separate but parallel businesses have helped them source and build the tools required to implement a full stubble retention, no-till seeding system, which they converted to in 1982, run with controlled traffic farming (CTF). For example, they have designed and built a chaff spreader capable of evenly distributing chaff across the full 11m cut.

"Returning chaff evenly across the cut width is really important, especially in a controlled traffic system. We want to feed the soil biology across the whole surface and don't want to introduce variation due to poor spread patterns," explained Neale.

The whole farm has been electromagnetically mapped using an EM38. While about a third of the farm showed variation due to soil characteristics, the remainder was pretty much one colour.

However, this lack of variation is not reflected in yield maps where a 6t/ha yield range can be recorded. This yield variation is more related to topography and soil water holding capacity. Low lying areas suffer water logging in wet years, or frost.

"Knowing the location and causes of variation in yield and quality is essential if we are to apply the correct management practices to reduce or capitalise on this variation."

Controlled traffic farming

When converting to CTF in 2000, the Postlethwaites chose a swath width of 11m. The harvester and seeder are on 11m implement widths and the self-propelled sprayer is now 33m.

All equipment is on 3m wheel centres and has RTK guidance, with correction provided by their own base station, and autosteer.

A key reason for selecting this swath width, other than availability of equipment, was that it fitted neatly into their paddocks.

"In our district most of the paddocks are laid out on a mile or half mile grid. A swath width of 11m results in a 75cm gap between the fence and one headland on a half mile paddock and 1.30m gap on a mile grid."

A special three quarter shielded spray unit mounted on an extendable arm is used to apply herbicide to these areas, while the tractor remains on the first wheel track, about 4m from the fence.

Neale is now considering increasing the swath width as wider machinery is available. Whether he should go metric or imperial was one of the questions he put out on Wimmera Crop Watch twitter feed.

"It was great to receive answers and thoughts on changing CTF set-ups from other experienced farmers."

From Neale's perspective CTF has been integral to improving crop production, especially on the heavier soils. By confining all weight bearing wheels to the same tracks he has seen the structure of the un-trafficked soil improve, resulting in increased water infiltration and biological activity.

"CTF means rain events don't delay paddock operations due to sticky un-trafficable soil; stubble breakdown has accelerated and nitrogen mineralisation seems to be increasing."

In the past 15 years, stubble breakdown has changed from taking several seasons to only standing stubble remaining at seeding. Four tonne wheat crops are being harvested from applications of 120kg urea, this quantity used to produce only 3t/ha.

Crop choice

Each year the Postlethwaites aim to sow half the farm to cereals – wheat or barley – and half to legumes – chickpeas, lentils or faba beans. They do this to provide diversity, spread workloads and to reduce risk.

"Yield maps, which have been gathered since 1995, have shown us that our choice of legume can have a big impact on the following cereal crop. In this region faba beans tend to finish in December, while chickpeas can keep drawing water well into January."

This reduction in stored moisture can impact on grain fill in the following cereal, especially in a year with a dry spring. So, Neale is more likely to sow an early finishing barley after chickpeas rather than canola. However, ultimately the crop type will be determined by weed control needs.

Three rows of cereals and two paired rows of legume are sown per metre. These different spacings have been established to maximise yield and weed competition, while fitting within the same wheel tracks. They also allow for different weed control equipment to be used.

Pesticide application

A shielded sprayer has been built for use in the legume crops. With RTK guidance on the tractor but not on the implement and the wide row spacing, accurate placement of the herbicide between the pairs of crop rows is achieved.

The boomspray is set up with two spray lines and sets of nozzles, one set over the crop row, the other between the rows. Controlled traffic ensures the exact placement of the nozzles between the row for herbicide application or above the row for fungicide, insecticide or spray topping.

In the pulse crops this means the Postlethwaites have managed to halve the fungicide cost by applying the same rate of fungicide but only to the crop rows. The positioning of the nozzles means that each plant receives an application from each direction as the machine moves up and down the rows, ensuring excellent coverage.

The Farmscan AG software runs on a Windows tablet PC, so a single screen can be used for applications, crop scouting and checking the weather or grain prices on-line. Photo: Emma Leonard

Applying PA tools to patch or variably manage weeds is probably the next area of investment for the Postlethwaites. They have already used maps and manual triggering of direct injection herbicide mixes on areas of wild oats.

Neale has also successfully identified areas of ryegrass in wheat from NDVI satellite imagery taken in October.

Nutrition

As of this year seedbed phosphorus (P) will be applied variably, while late in-crop nitrogen (N) has been applied variably for a couple of seasons.

Yield maps are being used to calculate a base rate for replacement P. This is then modified depending on the crop being sown and a blanket buffer rate is added to create the final application.

The yield maps are produced in the CASE AFS software, and converted to application maps in FarmWorks software. The rate is controlled by a Raven rate controller.

Section control is not run on the seeder but the system is programmed to turn off automatically on the headlands, minimising overlap.

Wheat protein can vary between 9.5 and 12 per cent across a paddock. To try and reduce this range and increase the overall protein content, Neale has started to use in crop biomass sensing.

Nitrogen is applied as a blanket rate of granular to cereals after emergence. A late application of liquid urea (UAN) is applied variably through the boomspray, which has six sections controlled by the Farmscan AG controller.

The N rate is determined by scanning the crop with a single biomass sensor mounted on the centre of the boomspray. This data is collected during the application of a later herbicide or fungicide. Neale reviews the data before the rate for each zone is determined.

At least three sensors would be required to biomass sense and apply nitrogen on the go.

Instead, Neale uses a handheld GreenSeeker® and the mobile software to check rates required in parts of the paddock where he feels the boom mounted sensor may have misrepresented the nitrogen requirement. He likes the ability to edit the nitrogen rate maps before application.

Neale has only been using this system for the past two seasons so, it is still early days. However, he feels he is starting to control the range of protein levels in many paddocks.

Wish list

What will be the next PA tool in the Postlethwaites' technology tool box?

Neale has a few items on his wish list but nothing definite. However, if an unmanned aerial vehicle fitted with appropriate software and tools for remote sensing came on the market, his arm might be twisted.

Details: ***Neale Postlethwaite, 0407 547 848, nealepos@gmail.com***

GRDC


James Hill (left) and Matthew Watson are using a similar PA approach to manage broadacre crops, almonds and grapes. Photo: Point Farms

The following article was first published in June 2019

Data analytics drives efficiency

Emma Leonard

Four years since the adoption of PA technologies, the team at Point Farms is seeing improvements in management, production and the bottom line.

The team at Point Farms is always willing to embrace new technology and practices if they offer improvements in management, production or profitability. Even better if they offer all three and precision agriculture (PA) technologies are ticking all of these boxes.

Cotton is the most financially important crop produced. It is grown in strict rotation with barley and popcorn to help minimise soil borne disease. Almonds and grapes are also grown. In 2013, the team felt confident it had the skills to implement precision management across the production systems.

This recent adoption and team approach has helped the business implement some of the latest PA technologies including machinery data analytics and weather based irrigation scheduling.

Farm details

Farming Personnel:	Mathew Stott (owner), James Hill (manager), Matthew Watson (agronomist, PA specialist).
Location:	Darlington Point, New South Wales
Farm size:	2,084 hectares
Annual rainfall:	Annual: 400mm but whole farm under irrigation
Soil:	Grey clay loam, sandy red loam and sandy clay loam
Enterprises:	Cotton, popcorn, barley, almonds and grapes

PA applications

Technology	**Year started using**
Guidance and autosteer –	2013
Yield mapping –	2013
Auto section control –	
on-the go NDVI mapping –	2013
Variable rate inputs –	2013
Electromagnetic soil maps –	2013
Machinery data analytics –	2015

Variable rate

Precision tools have been used since 2013 when electromagnetic (EM38) soil surveys were updated for the entire landholding. In the same year, yield data started to be collected for cotton, barley and popcorn. This data has been used to produce variable input maps for water and nutrients.

The variable rate (VR) approach is used with all crops and follows the same basic principles irrespective of crop type. The approach is based on the knowledge that soils with high or low water holding capacities require greater attention in regards to irrigation scheduling and nutrient timing to avoid water logging and nutrient leaching or moisture stress. The lighter soils have a tendency to leach nutrients faster.

"We understand that all soils have yield limitations and that by focusing on our better soils instead of attempting to condition poorly textured soil types, we have lifted our paddock averages."

Yield data, along with EM surveys, multispectral imagery from satellite data and elevation data are all used to construct a VR cotton planting prescription. The lighter soils that will dry down faster and result in a higher seedling mortality rate will receive a higher sowing rate.

Average sowing rates in all blocks are calculated from soil tilth; a finer tilth with good seed/soil contact will obtain a sowing rate of between 12-14 seeds/m^2. The lighter soil types in the paddock will receive 13-15 seeds/m^2 and the heavier soils 10-12 seeds/m^2.

Variable rate fertiliser is based on the same principles of farming to soil type as nutrient holding capacity varies by soil type. The lighter soil generally receives more nitrogen compared to the heavy clay that tends to have a greater nutrient holding capacity.

Anhydrous ammonium VR maps are uploaded to the in cabin rate controllers and rates are changed on the go. In crop nutrients, which are usually side dressed on the cotton mid-season, are also applied via a VR map. This map is derived from a mid-season normalised difference vegetation index (NDVI) based on satellite data.

For Point Farms, VR means a redistribution of inputs to where they are most required, and about trying to farm to the soil type's potential.

Remote water scheduling

All crops are grown with irrigation, so optimising water use is central to profitable production.

From the EM38 soil maps, the appropriate location for 1.5m soil exploration cores was identified. Analysis of these soil cores has provided baseline data on soil water holding capacity of the different soil types, which in general range from clay to sandy loams.

In a similar way, the EM38 maps were used to locate suitable Goanna Telemetry moisture probes. These probes help identify moisture stress points in cotton and almond crops. Constant soil and plant sampling throughout the season takes place to track moisture levels.

The results from this sampling help to ground truth information provided by the satellite based crop moisture sensing system Irrisat (see Precision Ag News 13.1).

Irrisat is an irrigation scheduling tool that combines weather data with crop water requirement to provide a daily water use that can also be used in forecasting. Irrisat uses real time local weather data with Landsat-8 and Sentinel-2 satellite images to calculate crop water use coefficient (Kc) across the crop on a 30m grid i.e. each pixel is 30m^2.

"The spatial representation of Kc allows us to make inferences about vegetative state that may be reflective of poor soils, water logging, inefficient irrigations or other cultural practices," explained Matthew Watson.

"Using this information, we can tailor our irrigation scheduling to meet specific needs of blocks rather than relying on probe data. Within our syphon irrigation layout, this allows us to micromanage certain areas to maximise our water-use efficiency, save time and maximise crop potential."

Remote water scheduling using Irrisat helps underpin all PA management including variable rate inputs.
Photo: Matthew Watson

Photo: Emma Leonard

Point Farms routinely gathers multispectral and thermal imagery and uses a number of vegetation indices ((NDVI), normalised difference red edge (NDRE), optimised soil adjusted vegetation index (OSAVI), chlorophyll-index) to highlight specific aspects of vegetative growth.

"We are currently working with the Centre for Regional and Rural Futures (Deakin University) using UAVs to capture high resolution images to improve crop management."

Data analytics

While VR has played a part in lifting farming efficiencies, it has been the collection and analysis of machine operating data that have proved to be particularly useful in improving performance.

All tractors on the property are John Deere. Each tractor is connected to the John Deere system JDLink™ so all operations and tractor performance are tracked online.

All crops, whether it be row crop or permanent plantings, are harvested by the Point Farms team rather than contractors.

Yield data is sent wirelessly from the monitor to the John Deere's cloud storage at the end of each harvest day. From the JD cloud, it is transferred to and interpreted through Apex, John Deere's software.

Working closely with Wagga based John Deere consultant Andrew Watt, the JDLink™ software is being tested fully on the cotton pickers. There are four cotton pickers on-farm. Total harvested area is calculated to gauge harvest progression and a mid-season machine performance analysis is done to assess efficiency. Using the data collected on JDLink™, picking hours, transport hours, fuel usage, and idling hours are all recorded and can be tracked by the operator.

"If one of the picker drivers has been identified to be driving the picker at a higher fuel usage, then he/she can be trained to drive the machine in a lower gear to reduce fuel consumption, but maintain harvestable area each day."

Simple tasks such as transport can account for over 15% of total fuel used, while idling hours when cleaning down or starting in the morning is a big fuel user. By turning the machines off during this time, Matt has recorded a saving of over two hours/day/machine of fuel consumption.

These might seem like simple measures, but until they were graphed through the use of JDLink™, it had been hard to quantify the wastage.

"Making these changes is money in the bank for us that we never thought we could access."

Adopting PA

Matthew Watson and the team have been pleased with the benefits that PA technology has already brought to their diverse farming system. As they learn more about the software, they feel even more opportunities will be captured.

From his experience, Matt's tips for the PA novice are:

- Yield data and elevation maps are two forms of data that are collected in the tractor without having to spend big money.
- Use this data to then build information layers of each paddock.
- Start small, do not try to be too ambitious.
- Pick out the weakest spots and identify why the better performing areas behaved the way they did.

Details: ***Matthew Watson, 0499 091 114, mwatson@onpointag.com***

Brad Jones.

The following article was first published in June 2019

PA harnesses 4D approach

Sue Knights

Applying a four dimensional philosophy to farming while using economic aids to choose PA tools is paying dividends.

As a pilot, Brad Jones from Tammin in Western Australia has a unique perspective on his farming enterprise.

"Years of flying have taught me to take a four dimensional view of the world around us and honed my spatial, time management and data analysis skills. Looking down on my land gives me a different lens to assess production variability."

Brad sold his Queensland-based aviation business several years after he married and moved to his wife Kate's family farm in WA in the early 2000s. He still maintains four aircraft for contract and personal use, but now also uses his aviation skills in applying a four dimensional strategy to analyse and improve the performance of their 11,000-hectare cropping enterprise in the mid-rainfall zone. The farm, located 180km east of Perth, is three times the local average.

"Our most important asset is our soil as it supports production, so this is the fundamental part of the sub-terrannean dimension. This supports the terrestrial dimension, the crops we produce. The next, and often limiting, asset comes from the atmospheric dimension; rainfall. The fourth one I use is temporal. This is the ability to look backwards and forwards over time to learn how to improve our operations."

Key to Brad's success, since 2008, has been the calculated adoption of PA tools within his farm workflow (Figure 1) using economic decision aids.

"You need to have a clear focus on what you want to do," he says. "It may be growing more or saving costs and this will determine which tool is the most appropriate. Having a clear handle on your workflow provides an excellent framework to evaluate new tools."

Farm details

Farming Personnel:	Brad, business manager, and Kate Jones, 5 fulltime staff including a farm manager
Location:	'Bungulla' Tammin, Kwinana East, Western Australia
Farm size:	11,000 hectares
Annual rainfall:	GSR 240mm, annual 300mm
Soil:	sand, sand over clay, sand over gravel, loamy valley floor - pH 4.5 to 6.2
Enterprises:	wheat - 45%, barley - 30%, oaten hay - 10%, canola - 15%, field pea - 10%
Yield:	2.2 tonnes per hectare wheat, 2.5t/ha barley, 0.9t/ha both canola and field peas

PA applications

Technology	**Year started using**
Spatial soil mapping tools –	2007
GPS,variable rate on seeders –	2008
GPS, yield data on harvesters –	2000
StarFire™ John Deere –	2000
Weedseeker® –	2009
Predictive yield models –	2017
Greenseeker® –	2009
Data integration- My John Deere, AgWorld, VA Gateway™ –	2010 onwards

Top PA tips

- Figure out what you want to achieve with PA tools. For example do you want to grow more or save money? Then determine what tools are most appropriate
- Talk to people about the technology. It is rapidly changing and continuous learning is required
- Trust your data and commit to decisions informed by that data
- Mistakes will be made, but this is an important part of learning

Data is gathered at strategic points along the annual 'Bungulla Farm' workflow, which provides insights to improving business operations.

Economic decision aids

Within the complex skill set required of a pilot is the ability to process multiple sources of data and make decisions quickly, says Brad, and he applies this experience to farming.

Using customised spreadsheets he assesses the economic merit of adopting new business options. These may range from PA tools to new haulage systems.

He makes assumptions on costs and savings of adopting a new business approach to determine its payback value. If the new approach passes the hurdle of 15% return on investment (ROI), he then drills deeper to find out more about the approach.

"The value proposition has to be flagged through this process to then justify doing due diligence on adopting the new tool or approach."

Subterranean dimension

Core to Brad's faming philosophy is how he manages the soil.

Bungulla is an undulating property consisting of a range of soil types; sand, sand over clay, sand over gravel and loamy valley floors.

"As we have added scale to the farming business by purchasing more land we have been very aware of the increasing risk of farming a bigger area. To lower the risk we have focussed on managing the soil types and overlaying economic reasoning. We have learnt over time that crops on the poorer soils stress earlier and these are the key weak points in the business to manage."

The property was electromagnetically mapped in 2007 to identify constraints and their locations. This determined changes in soil salinity together with texture and soil moisture. Gamma-radioactive spectrometry was also used to provide an indication of the soil's parent material.

Now over 570 soil sampling sites are spread across Bungulla and reviewed and re-sampled every three years under the guidance of a soil scientist. Acidic soils and associated problem weeds like radish and ryegrass were identified as limiting production and have been managed with lime and herbicide rates matched to the severity of the problem. From the soil sampling information, fertiliser prescription maps are generated that can be used by ground or air operated machines.

Terrestrial dimension

In 2008, Brad started using variable rate technology and began reducing fertiliser nitrogen (N) application rates. Some years later Brad switched to liquid fertiliser application, which is also varied to crop potential. Brad estimates that this has given the business a 17% efficiency gain for labour use and machinery.

"In our environment, grain protein is the most limiting factor and we have learnt that this is highly seasonally dependent."

To lower his risk Brad targets the lower protein markets, aiming for maximum yield rather than having to put more N down to increase grain protein levels.

It is for this reason that Brad uses noodle and soft wheat varieties together with oaten hay and barley and targets feed markets. Canola, field peas and chemical fallow are used as rotation aids.

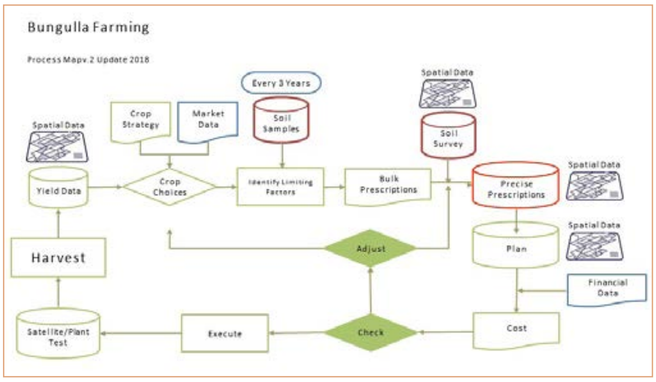


Figure 1. Major decision points within 'Bungulla' workflow showing feedback loops and adjustments together with key points where spatial and other key data is collected.

Satellite generated Normalized Difference Vegetation Index (NDVI) maps are used together with in-crop sap nitrate testing and a handheld GreenSeeker® to assess the N status of crops. N-rich strips are used as a reference tool to monitor and assess more precise N application.

"We focus on enough N to maintain crop strength to support as many tillers as possible. Layering the NDVI image over soil maps gives us an N master application plan. And then in-crop, we can add further data from the atmospheric dimension."

Atmospheric dimension

The key atmospheric dimension is rainfall. It is 25km between the perimeter fences of Bungulla, so there can be significant differences in atmospheric conditions, which influence management.

Brad uses a network of 15 automated rainfall gauges and soil moisture monitors to generate spatial rainfall and moisture maps by kriging, with assistance from Origo Pty Ltd. (Figure 2). Using these he can pin point where to inspect paddocks to identify production issues during the season which reduces the laborious aspect of driving around paddocks. For example he can address N deficiency issues in areas of higher rainfall that are identified using this approach.

Temporal dimension

Data from the various dimensions of the farm business is accumulated over time to show variability, trends and probabilities. This provides insights into soil changes, yield trends or financial opportunities.

Table 1. Value estimates of new technology trialled and adopted on 'Bungalla'.

Innovation	Year trialled	Year fully adopted	Benefit description	Value estimate
Extensive soil test sites	2008	2018	Currently about 570 sites provide extensive data to monitor soil conditions	Payback 1 year on lower inputs
Variable rate technology	2008	2010, ongoing	Cost reductions in fertiliser, lime and chemical applications	1 year payback
Weedseeker	2009	2009	Greatly reduced chemical application	2 year payback
9,000-tonne silo complex	2012	2014	Operational, logistical and sales efficiencies, able to meet contract, specifications direct marketing	20% return on investment (ROI)
Backhaul/continuous trucking for direct marketing	2012	2014	Operational, logistical and sales efficiencies, able to meet contract specifications	20% ROI
Design and build of seed singulator precision planting technology for canola	2015	On-going	Using precision planting technology for seed reduction of hybrid canola	Estimated 20% ROI
Satellite NDVI imagery	2016	2016	Using satellite imagery for prescription map building	Immediate

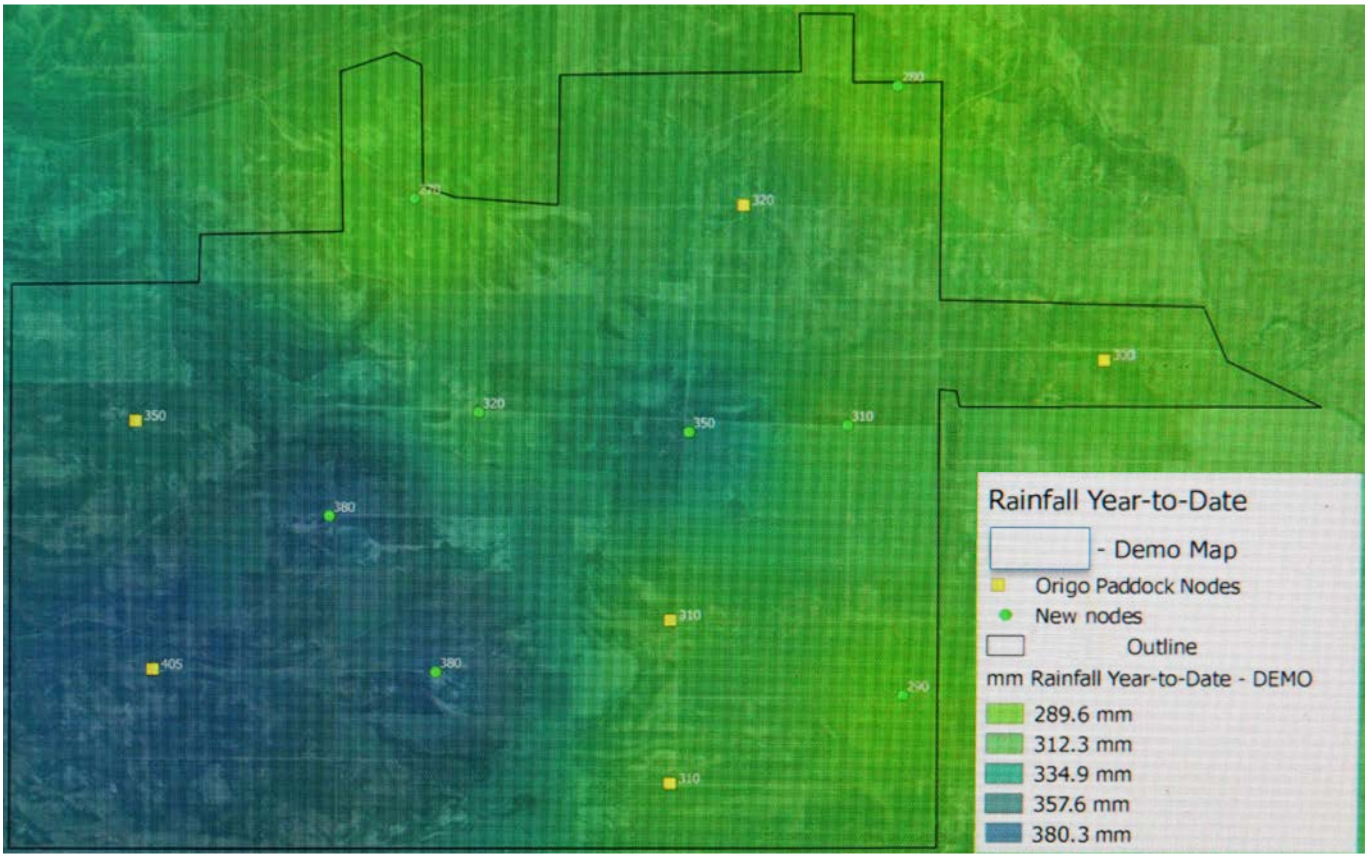


Figure 2. Example rainfall map showing year to date variability.

"We can look backwards over this data to plan going forwards."

In fact, Brad has 100 years of rainfall data for the farm. This enables him to look for similar patterns and calculate percentiles and, most importantly, the probability of spring drought, which can really inform decision making.

Temperature maps are also being used to identify areas exposed to frost that may require different management at harvest.

"These maps can be overlaid with yield maps to provide actual profit of a crop per millimetre of rainfall, or the cost of a frost event. In turn this could change variety choice or planting dates of subsequent crops."

Additionally temporal data is gathered on in crop weeds via a Weedseeker®, which triggers herbicide application on an inter-row shielded sprayer. At harvest, pins can be dropped on the screen to mark weed hot spots. From this data weed maps are generated which are looked back on before planting the next year to plan single or double herbicide knocks.

Key to Brad's business time management has been the investment in on-farm storage and his own haulage system.

"This adds significantly to operational efficiency and marketing decisions. We can harvest at higher moisture and dry down, or store grain on farm to target improved markets. It's all about how to best manage our time".

Having his own haulage system means he can avoid choke points in conventional bulk handling systems and back fill with fertiliser and other soil ameliorants, again saving time and money.

Integrating data

The data collected from the various dimensions of the farm are integrated using a selection of software platforms. Brad started using VA Gateway™ to build prescription maps from the data captured and logs all farm operations, like yearly paddock plans, rainfall data, seeding dates and costings in AgWorld. The software platforms talk to each other through My John Deere and all staff has access to them, which provides for excellent communication and timely operations. It also acts as a double checking system so that all machine operators can be sure of the task they are to begin once a paddock is entered.

The workflow is a way of keeping all these data sets aligned to the business model as it shows the point at which they can be used. Without a plan much of the data would be captured, but can become redundant through lack of process.

It can be updated at anytime should a new piece of technology be adopted.

The next dimension

As Brad and his team build an extensive bank of data from each dimension of the business over time, the logical next dimensional step change will be the use of artificial intelligence, which includes machine learning.

"We are already on the road to autonomous machinery and have virtual assistants such as Siri. If we take another step and have smart machines which are programmed to act intelligently, using years of insightful data, we will replace manually overseen activities in our workflow."

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The following article was first published in April 2020

Show me the money

Emma Leonard

Before jumping into any new practice, it is important to understand the impact on profit. A new GRDC publication provides a comprehensive and practical guide to assist economic decisions about PA.

Management of variation is a key component of PA. Yet, the fact that every farming business is different can make it hard to assess if adopting a PA practice is a profitable option for your farm.

One approach is to use Net Benefit. This assesses the potential difference in profit generated between current practices and targeted management using PA tools. Appropriate to all industry sectors, the Net Benefit approach can assess differences in yield potential, savings in inputs, and payback from the investment in capital items.

Applying this approach, the GRDC has recently launched a comprehensive step-wise guide titled 'Profit from Precision Agriculture'. It aims to help grain growers calculate the potential profitability of adopting PA practices on farm. This practical document is supported by five case studies for grain production practices in the high, medium and low rainfall regions of southern Australia.

Project leader Patrick Redden, from Rural Directions, says the degree of spatial variability determines the case for spatial management, but the size of the financial gain comes from the profit change against the capital investment and recurring costs to implement the PA.

"To establish if PA will be profitable it is critical farmers crunch their own figures".

A step by step approach

Each step asks a question and provides supporting information and directions to help farmers generate an answer for their business.

What profit gain opportunities exist for the farm business?

The answer to this will focus on the potential to manage variability by targeting inputs more effectively (and that could include labour), improving yield, improving quality and consequently price, or combinations of these improvements.

Honesty is essential otherwise the foundation of the whole project will be flawed.

Does PA have a role in addressing these opportunities?

The greater the variability, the greater the opportunity to gain a return from targeted management, rather than applying a blanket approach.

Issues such as summer weed control, surface pH and even deep ripping a hard pan can be targeted. However, the return from investing in targeted management will vary between regions, farming systems, current practice and scale of operation.

The case studies help identify these influences by assessing and comparing the economic impact for the same practice in different regions and different farms.

For example, the case study on optical spraying identifies that the seasonal conditions will influence weed germination and number of control passes required. Factors increasing the likelihood of a positive return from using optical spot spraying include a combination of:

- Weed population of less than 30% of total area.
- Minimum of two passes replacing blanket coverage.
- Chemical cost/ha above $10/ha.
- Annual operating costs below $10/ha.

Does the business have the capacity to usefully implement PA?

It is one thing that the dollar figures stack up to offer an economic benefit but are there other more pressing investments or changes required?

Also, capitalising on any potential economic benefits requires the people in or supporting the business to have the time, skills and willingness to implement adopting the PA practice.

The 'PA profit ready check list' is a quick and simple list of questions to help determine business capacity. Answers help establish if adopting the PA practice should occur and if it should occur now.

There is also a useful section on farmers' experiences; on things that went wrong or had not been anticipated. In addition, each case study has a section on the barriers to practice adoption. While these barriers will vary between farming businesses it is important to be able to recognise and overcome them.

Do the economics stack up and what else needs consideration?

This is where the real number crunching comes. Decision trees help work through the questions that need to be addressed and quantified. The starting point is to understand where the financial gain will be achieved, and if there is no financial gain are there intangible or indirect benefits.

Such intangible benefits could relate to health and safety, timeliness where in direct benefits might be time saving or less wear and tear on equipment. Except

when health and safety or legal compliance is concerned, the intangible benefits alone are usually not enough to justify implementation without additional economic benefits.

The Net Benefit (Figure 1) is calculated as likely financial gain less the operating and capital costs and can be expressed in a number of ways.

This publication used net benefit per hectare, per year and the payback period as the two main metrics. A marginal benefit:cost ratio is also used to test the relative cost to attain a benefit.

This section provides detailed examples of how to do the calculation required to make a robust financial assessment. Each business will need to use their own figures to calculate their specific outcome.

However, the ability to quantify existing variation is a key component of these figures. Most farmers will have experience of the range of variability but spatial data layers such as maps of soil properties, biomass and yield can help quantify the size of the problem. A table of options for assessing variation is provided together with the following tips on minimising costs and properly accounting for the time and analysis required:

- Have a plan.
- Use existing or low-cost data to gain an initial indication of spatial variability before embarking on higher cost data collection.
- Source a quote from providers before commencement.
- Consider the appropriate resolution needed to make a decision and gain benefit. More costly higher resolution data is not always required.
- Consider data integration - are my map layers useful and in the best format for my machinery and software?
- Assign a realistic value to the time spent ground truthing and developing plans.
- Account for the total cost of sampling, testing, and surveying.
- Bring the cost of data and mapping back to a dollar per hectare cost where possible. This will make it easier to account for when determining final results.

How do we make it happen?

The practical, on farm application can be where reaping PA's profit potential can fail. Having an implementation plan that includes all team members and an evaluation phase is essential.

The publication provides a check list of different players' roles, including growers, agronomists, PA consultants, contractors and mechanics. This details the value they can add as well as how to extract value from each player.

The second important check list in this section covers the steps in the implementation process: Plan, select team, gather data, effective execution, and evaluation.

Creating an implementation planning tool is complex, due to the diverse requirements of individual businesses. This check list certainly raises many questions that need to be answered to support successful implementation but finding or generating the answers to many will take time, research and input from various members of the team. All considerations that need to be built into the time bound plan.

Copies of 'Profit from Precision Agriculture' and the supporting case studies can be found at www.grdc.com.au/profit-for-precision-agriculture

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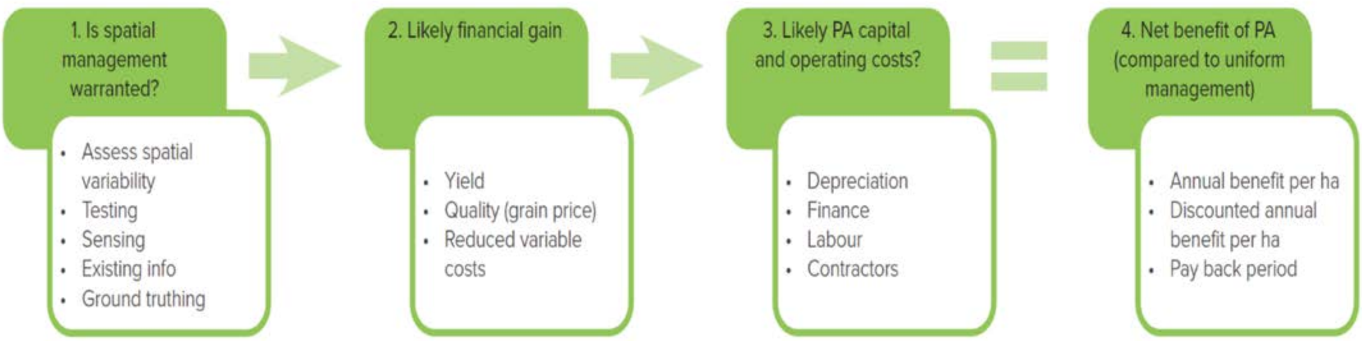

Figure 1. The bottom line, the steps in identifying the net annual benefit and if a PA approach increases.

Photo: Emma Leonard

The following article was first published in July 2016

Managing your ag data

Leanne Wiseman

Farmers need to read and understand the small print associated with the data contracts before signing.

Who controls the access to the agricultural data (ag data) that is being collected from your farming operations? In Australia and around the globe, this issue is attracting more and more attention.

While the potential for increases in productivity from the use of digital farming technologies are undeniable, the issue of who controls access to and use of the data that has been collected, aggregated and stored is one that is often overlooked and ignored.

One notable exception is the Australian Farm Institute (AFI) that has recently released a research report "The Implications of Digital Agriculture and Big Data for Australian Agriculture" (discussed in this article).

Those farmers aware of the lack of clarity around data ownership and control are concerned about the security and privacy of their farm data, as well as the terms that regulate the collection storage and use of their farm data by third parties.

With the myriad of new digital technologies and apps in the agricultural marketplace, it is hard to keep abreast of the agreements entered into when using precision or digital agriculture. As a result, many farmers do not know where and how the data that is being collected by these technologies is being used.

Software versus hardware

Twenty years ago, when a farmer purchased farming equipment, it was a straightforward transaction of purchasing the physical machine. Today farmers who buy digital farming machinery may own the machine and associated controllers, sensors and monitors, but they do not own the technology that operates the machine.

Basically, when purchasing digital equipment, be it a machine, computer or phone, farmers enter into an agreement with the technology owner that grants them permission to use the sophisticated software that operates the digital machinery. This permission is in the form of a software licence or a data contract.

It is these licences and contracts that regulate the ownership of the input data and the resultant aggregated data, the storage and management of that data, the security and privacy provisions of the data, and the restrictions on the use or modification of the data.

Typically, the entry into the software licences or data contracts occurs at the point of sale of the physical equipment. It is at this time, that a farmer agrees to terms that regulate ownership and use of their farm data. The software licence terms need be fully transparent to all parties.

If you are concerned about who controls and can access your farm data, now and into the future, it is worth doing some homework. Prior to, or at the time of purchase of the digital machinery, examine the terms of the data contracts thoroughly, and discuss the terms with your digital technology suppliers. It is important that farmers read the agreements before accepting the terms offered. This is important whether the technology is in the form of an app and/or a cloud-based recording system.

While this issue is often put into the too hard basket, the US has taken an interesting approach to ensure their farmers are more aware of, and confident about the terms of the software agreements they are entering into when adopting new digital technologies. It is useful to here examine what they have done.

Approaches to data contracts in the US

Raising awareness of the contractual terms in data contracts with farmers has gained momentum in the United States. In 2014, the American Farm Bureau Federation (AFBF) responded to concerns raised by American farmers about the ownership and use of their farm data. After much lobbying and negotiations, the AFBF reached agreement with a number of significant technology providers on some Principles of Data Management.

These data principles, which address data transparency, were agreed to by the AFBF and 37 agricultural technology companies including Monsanto, John Deere and DuPont Pioneer. The aim of the data principles is that they encourage technology providers to contract with farmers on a basis that is consistent with the data principles.

More details about these principles can be found at http://www.fb.org/tmp/uploads/PrivacyAndSecurityPrinciplesForFarmData.pdf

While many of the technology providers' contracts addressed these matters, it was still not necessarily easy for farmers to identify those companies whose contracts complied with the data principles and those that did not. To address this, the AFBF also created a "Read before you sign" guide to inform

The data principles highlight the importance of a range of factors including:

- farmers' education;
- simple, plainly drafted contracts that are easy to understand;
- principles around ownership of data and the use and sharing of data;
- the idea that access and control of data only be with the explicit consent of the farmers who must be notified that their data is being collected; and
- how the farm data will be disclosed to others and used.

farmers/farmers about what questions they should raise with their technology providers. Examples of the questions include: what information was being collected; what controls farmers had over the data collected and if a company will advise them of any policy changes.

The "Read before you sign" guide can be downloaded fromhttp://www.fb.org/issues/bigdata/questionagtechprovider/

More recently, an Ag Data Transparency Evaluator (http://www.fb.org/agdatatransparent/) has been developed. US farmers can use this to assess agricultural technology providers' contracts and policies about ownership and sharing of data. This is a process by which US ag technology providers voluntarily submit their ag data contracts to a simple, 10 question evaluation. Answers are reviewed by an independent third party administrator, and the results are posted on http://www.aglaw.us/ for farmers and other ag professionals to consult and review. Only companies receiving approval are allowed to use the 'Ag Data Transparent' seal. The seal appears to be similar to certification Trade Marks that can be registered in Australia by organisations who strictly control the use of their trade mark.

One word of caution when looking at the US approach, contracts from the US can differ to those offered to farmers outside the US due to differences in legislation that operate in each legal jurisdiction.

Another approach to ag data control and management can be seen in New Zealand. Here, the Farm Data Code of Practice is an example of an alternative approach. For further details see - http://www.farmdatastandards.org.nz/about-2/

Conclusion

I am not suggesting that the approach taken by the AFBF in the US is necessarily the right approach for Australian farmers.

What I am suggesting is that a greater awareness and understanding of the terms of the data contracts and licences associated with current agricultural machinery would certainly empower farmers to have a more meaningful dialogue with their equipment suppliers. This would assist in encouraging transparency around the terms of the data licences which in turn would develop more trust in the parties' contractual relationships.

This suggestion is consistent with the recent recommendations made by the AFI in their 'Digital Agriculture and Big Data' report.

In relation to the management and access to farm data, the AFI have recommended that Australian agricultural industries and agricultural technology providers 'should commit to open access data protocols, modelled on the standards adopted by the Open Agriculture Data Alliance established in the US' (Recommendation 3) and that there should also be 'the appointment of a Farm Data Ombudsman to oversee data privacy standards, to establish data use categories, and to audit compliance by providers with industry standards for data privacy' (Recommendation 4).

Securing farmer confidence in the use and control of their data is important. Opening meaningful debate and dialogue about the control of and access to and use of farm data in Australia is an important step toward building this trust and confidence.

Editor's note: Dr Wiseman is currently conducting research into legal implications of agricultural data and the types of licences that are governing digital agricultural machinery in Australia. She would be interested to hear from farmers who are also interested in the control and management of their farm data.

Biog. Dr Leanne Wiseman is an Associate Professor of Law and Associate Director of the Australian Centre for Intellectual Property in Agriculture (ACIPA), based at the Griffith Law School at Griffith University, Nathan, Queensland.

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An example of the type of agreement received with and app which the majority of us accept without reading.

SOILS AND SENSORS

Ben Pratt.

The following article was first published in April 2019

Slopes and soil drive yield

Rebecca Thyer

With an honours degree in GIS under his belt, this young SA farmer is re-zoning the family farm using elevation data.

With any change of structure on long-held family farms comes new ways of thinking. This was the case for Ben Pratt who returned to work full time on his 6th generation family-run grains farm in Blyth, South Australia in late 2017. With his family on board, he began dynamic zone management.

His skills in PA have been honed through his first class honours degree in GIS (geographic information systems) at the University of Adelaide. For his thesis, he concentrated on using satellite imagery for dynamic zone management in dryland cropping.

Ben, who crops grains, pulses and hay with his dad Kevin and one full-time employee (Adam Rowley), says the zones help target soil testing. They also provide the opportunity to variably rate seed, urea and gypsum – and have already improved water use efficiency.

Dynamic zone

Ben's studies in GIS – a framework for gathering, managing, and analysing spatial data into visuals such as maps – have definitely helped to zone the 2000ha grains farm, he says.

Farm details

Farming Personnel:	Ben and Kevin Pratt, with full-time employee Adam Rowley and up to four extra staff at harvest. Financial advisor and agronomist Sam Trengove
Location:	Blyth, South Australia, with blocks stretching 50km from Andrews to Snowtown
Farm size:	2,000 hectares
Annual rainfall:	Annual 375mm to 450mm
Soil:	Soils range from loams, sandy rises, shallow limestone rises and gilgai clays, to sodic Condowie clay, red-hard setting clays and acid sand over clay. pH- 4.5 to 9
Enterprises:	Wheat, barley, lentils, multi-species hay
Yield:	Average wheat yield 3.4t/ha

PA applications

Technology	Year started using
Guidance – steering (Greenstar)	2001
Guidance – handsfree (Greenstar)	2004
Boom spray – section control (Greenstar)	2007
Yield monitor (Case New Holland on header)	2007
Satellite imagery (NDVI imagery sourced through Esri's Sentinel Explorer accessing Landsat Public Datasets running on the Amazon Web Services Cloud (www.arcgis.com) and processed through a subscription to PA Source (www.pasource.com); Decipher app for paddock scouting (www.decipher.com.au))	2013
Veris mapping for soil EC and pH	2017
Protrakker guidance system – for interrow sowing	2017

Top PA tips

- When thinking about zoning, make sure you start with a reliable base layer of cleaned data. I use the free software Yield Editor to do both tasks.
- Cleaning data is an important step. If you don't find enough variation in your data, then you should ask yourself – should I be implementing PA? You don't need to vary management options in a uniform paddock.
- Have a good understanding of your own soil – keep a shovel handy to explore your soils when out in the paddock.
- Any new tools must have a financial justification. And if you're not confident about a new process, technique or machinery purchase, ask for help or outsource expert help.

CTF has paved the way for inter-row sowing, which sees crops sown precisely between the previous year's crop rows.

In the past he used Sentinel satellite imagery of crop growth from Esri and yield maps to create managment zones. These layers are now used to track variation and the results of zone management. Managment zones are now created based on soil and elevation data.

This decision is proving to be important given the family's owned and leased properties vary from crabholes and stony or sandy rises on the home block, to very steep slopes that feel like they could tip the header. "Even on our very flat land at Snowtown we still find very slight changes in elevation and that drives soil type. Our most reliable soils are the sandy loams, with clays flip flopping depending on the season."

Ben says any variable on-farm data collected can be used to create zones, but his reading on the subject has shown that digital elevation models (DEMs) are gaining traction. (PA stalwart, CSIRO's Dr Rob Bramley, says DEMs can be a useful layer in understanding field-scale variation in crop performance. See story p10)

"Landscapes drive plant available water so elevation data is an important layer," Ben says. "Its first derivative is slope, which drives water movement and capture. Slope will influences soil properties and those properties will impact on yield."

Slope helps to explain variation in soil electro conductivity (EC) and pH. Detailed soil maps produced from data collected with a Veris® on-the-go soil sampling machine are used to augment the landscape data.

In addition to using yield maps to track variation, they are also used to to support replacement phosphorus fertiliser decisions.

Zoning steps

To start the zoning process, Ben collected topography data from his RTK guidance system from a seeding or harvester pass as this is three times the resolution of the sprayer (see Controlled traffic farming). Soil was measured for its electrical conductivity (EC) and pH levels using Veris® mapping.

The Pratt's agronomist Sam Trengove collected dual soil EC data at 0-30cm and 0-90cm to better under soil at all levels. Smaller soil particles like clay conduct more electric current than larger silt and sand particles, effectively 'mapping' soil texture. Sam also mapped the farm for its pH level.

Using these three variables Ben started to establish his management zones.

Ben undertook the statistical process of Principle Components Analysis (PCA) and used an algorithm to group the data into soil zones. Both processes were performed using Esri's ArcGIS, a mapping and analytics software platform.

ArcGIS reduced the data size, so that only the top principle component layers that explain 75% of the variation were kept.

"Some maps become too detailed. You get tied up trying to be perfect, but the best returns are often found in the first 10% of effort."

His zones now give him the option to target soil testing. Pre-sowing and in season nitrogen and seed rates are increased on the higher performing sandy loams and decreased on the clay soils and stoney country. Gypsum is targeted to soils with higher clay content, especially if sodic. Pig manure is spread across the farm with higher rates on sands.

The most impressive result of zoning so far has been an increase in water use efficiency. "WUE has increased the last two years by two kilograms per hectare per millimetre (in wheat) in both 2016-17 and 2017-18."

Before embarking on any zone creation, Ben says it is important to have a good understanding of soil types. "Keep a shovel on the ute to dig when checking crops to better understand plant/soil biophysical interactions. And if you're not confident in your own zone creations, outsource expert help."

Likewise, before asking staff to make variable rate applications, make sure you also have a good understanding of the hardware.

"It might be useful to write up notes so that everyone can remember steps and possible issues."

Controlled traffic farming

The farm has also recently moved to using controlled traffic farming (CTF) and inter-row sowing practices.

"When I returned home fulltime in late 2017, the farm had been divided between my dad and my uncle. So, we needed to find extra returns and savings. CTF should help us with that."

Ben says they chose the CTF route after more than a decade of no-till farming and because available scientific literature shows that not only does it pay for itself in a decade, it works across soil types.

The aims are to reduce compaction through the profile; increase early vigour and germination; increase plant available water at flowering/grain fill; decrease haying off; increase water infiltration; decrease fuel use; reduce horsepower needs; increase soil health and keep standing stubble for interrow sowing.

The CTF system now works on a 12 metre, 3:1 system. That is a 12m seeder matches a 12m harvester, a 36m boomspray and a 36m spreader which is on three point linkage.

To keep costs low, the Pratts converted their original Conserva Pak seeder from 16m to 12m; swapped their John Deere 9530 for John Deere 8335RT (a smaller tractor on 3m centres for better economy); bought second hand tyres for the airseeder; and bought custom-made axle extensions for the Brochard spreader. Total costs came in at $12,000.

Early results show a 20% decrease in sprayer fuel use on sandy paddocks, while overall fuel use has been cut by 15%. "It is early days, but so far, the soil types where it really responds, such as loams, are doing well and even the sands are too."

Issues to address in the future include weed competition on bare tramlines. "We maybe underestimated this. Pre-emergent herbicides failed to kill the ryegrass so we are looking into a shielded sprayer that will give us the flexibility to use other herbicides, like paraquat and glyphosate."

CTF also paved the way for inter-row sowing which began in 2018. The practice sees crops sown precisely (-/+2 centimetres) between the previous year's crop rows.

It has taken three years to establish inter-row sowing but Ben is optimistic that the practice is helping to retain more residue, protect plants in early growth stages, provide trellis for lentils, reducing root disease and improving early vigor.

Using the Protrakker guidance system, bought in 2017, has made a huge difference, he says. "We would not have been able to keep the implement on track in heavy stubbles without it. We estimate it also saved us about one working day per 1,000 hectares. It didn't get stuck once and we had a very heavy wheat stubble burden."

Costs and benefits

Ben says that while his university degree fundamentally taught him about GIS, it also gave him crucial skills in analysis, which he uses to financially judge new tools, technologies or techniques.

"They have to have a positive economic justification. It is vital to syphon out the 'snake oil' when looking to introduce new tools, technologies and practices on farm. My degree has given me the ability to critically analyse issues. I'm not pessimistic about technology, but realistic and realise that many things cannot happen overnight. There are no quick fixes and I believe in the 'law of diminishing returns' – 90% of the benefit often comes from the first 10% of effort," he says.

This analysis includes researching all options, estimating how long it would take to receive a return on investment, and talking it over with their financial advisor and agronomist. "With this informal mini-board – Dad, me and our independent advisors – we can work out what is best at that point in time."

The on-farm father and son team is also working well. For Ben's dad Kevin, his son's understanding about the data generated and how it can be used has been hugely beneficial.

"His ability to understand what the maps indicate about varying soils has been eye opening. He's been great at explaining how all the data comes together and how it then translates to input decisions. He's taken to it like a duck to water."

Kevin says moving to the practice of variable-rate inputs has been a great example of what data can explain about soil differences.

"We often used to think you should put more nitrogen down on areas that weren't performing well to 'bring them up'. But, putting more on the performing soils is working so much better. Now we are not wasting inputs and are improving our returns. This is the future – growing more grain from less land and less water."

Details: *Ben Pratt, 0427 323 232, @benpratt9, bdellagri@gmail.com*

After more than a decade on no-till farming, the Pratts have recently moved to using CTF and inter-row sowing practices. The system works on a 12 metre, 3:1 system -- a 12m seeder matches a 12m header, which is covered by a 36m boomspray and 36m linkage spreader.

The following article was first published in April 2019

pH maps pay their way

Emma Leonard

On-the-go pH mapping is showing clear value for money, but machine calibration is proving vital to achieving the best results.

Between 2015 and 2018 more than 125,000 hectares of South Australia's farmland was mapped for its soil pH properties.

One of the collectors of this information has been Primary Industries and Regions SA (PIRSA). As well as working out how best to operate, and calibrate, the machinery that collects the data, PIRSA has also shown the value of targeted lime applications to combat soil acidity.

Acid soils

Soil acidity is a major constraint to crop and pasture production in many parts of Australia. In SA more than 2.1 million hectares are susceptible to soil acidification with many surface and sub-surface soils having a pH less than 5.5 (equal to calcium chloride, $CaCl_2$).

With the onset of tools to map the spatial variability of soil pH across paddocks, zones can be created so that targeted lime applications – to combat soil acidity – can be applied.

Since 2015, soil pH mapping has been offered on a commercial basis in SA with three businesses operating Veris® pH on-the-go machines and other businesses using soil sampling equipment attached to Quad bikes or all terrain vehicles (ATVs) and sampling on a grid basis.

PIRSA has also been involved in pH mapping, purchasing and importing a Veris® MSP-3 (Mobile Sensory Platform) from the US in June 2015. This machine has sensors to measure soil pH and soil electrical conductivity (EC). It also has a built-in GPS for georeferencing the sampling locations.

Andrew Harding, senior soil and land management consultant with Rural Solutions SA (part of PIRSA), manages the machine. He says that as well as providing commercial on-the-go pH testing, mapping and variable rate lime prescriptions, the PIRSA machine is being used for trial work.

"This has helped us to learn more about how the machine operates and the value of variable liming."

Variable liming

Using a pH map and the target of achieving a soil pH equal to or greater than 5.5, Andrew has seen a significant change in liming application and rates. Lime prescription maps (based on the soil pH maps) show that variable rates of lime are required in paddocks (Figures 1 and 2). In some parts of the paddock no lime may be required because the soil pH is well above 5.5 ($CaCl_2$) but in other areas one to five tonnes of lime may be required to raise the pH to the correct level.

Table 1. Savings in lime between a uniform and targeted lime application based on the soil maps and prescriptions detailed in Figures 1 and 2.

	Uniform rate of lime (2.5 t/ha)	Variable rate of lime only applied to area less than pH 5.5 ($CaCl_2$)
Area requiring lime (ha)	51.3	33.9
Total lime required (t) (based on 50% NV)	256	131
Cost lime (Exc GST) ($)	2,793	1,429
Freight ($0.18 x km x t) ($)	2,903	1,486
Spreading ($12/ha) ($)	616	407
Cost of mapping ($15/ha) ($)	-	770
Total cost ($)	**6,316**	**4,092**
SAVINGS	**$2,224 (35%)**	

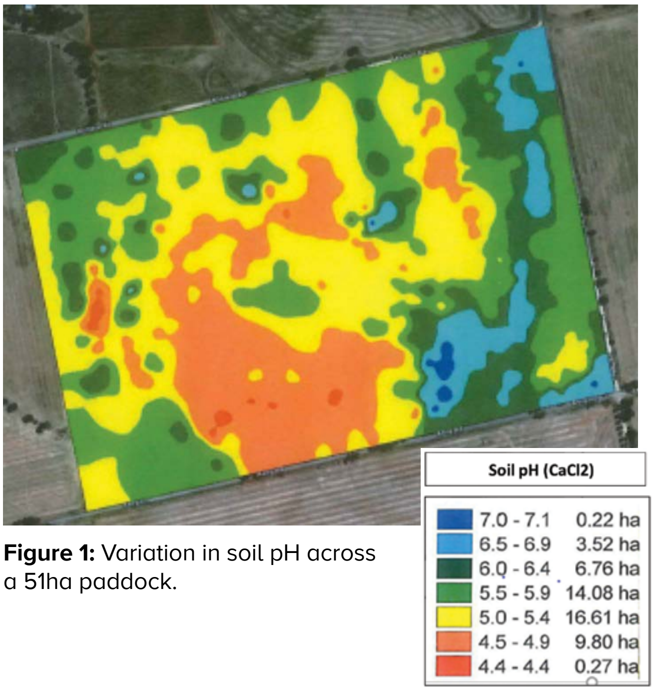


Figure 1: Variation in soil pH across a 51ha paddock.

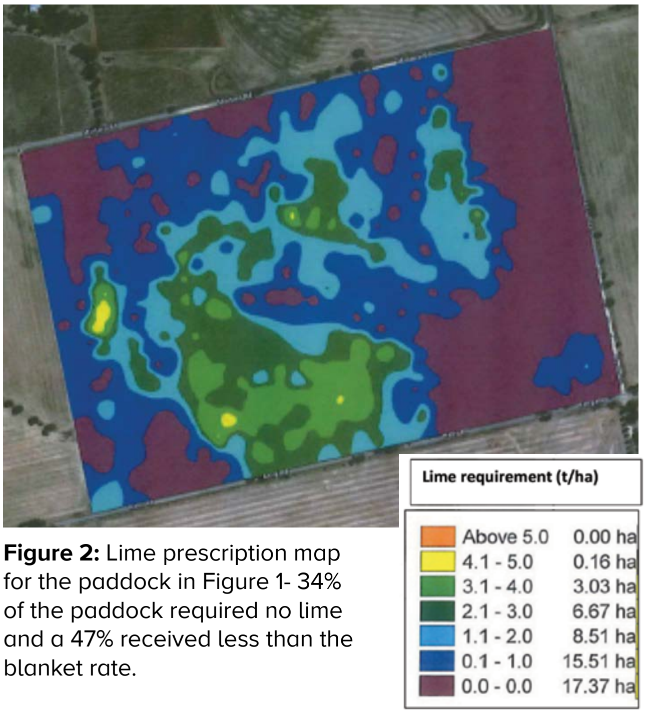


Figure 2: Lime prescription map for the paddock in Figure 1- 34% of the paddock required no lime and a 47% received less than the blanket rate.

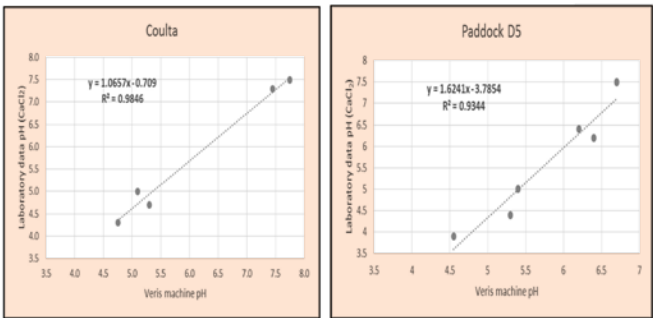
The cost-savings of applying targeted lime (rather than a 'blanket' or 'uniform' application) can be in the order of 25-30% or more (Table 1).

"We are also identifying low pH in areas that were not regarded as 'traditional' acid areas and we are currently exploring the impact of low pH on grain legumes particularly lentils where production losses can be significant."

The machine

The machine is towed by a 4WD utility. Travelling at about 11 kilometres an hour and at a swath width of 36 metres, the machine takes 8 to 10 samples per hectare and can cover 20 hectares per hour. This swath width works well with the turning circle and Andrew finds following crop rows is enough to keep the sampling line straight.

The machine can be operated in moist or dry soils and takes a sample of eight to 10 centimetres deep. However, if samples



Figures 3a and b: Show examples of calibration between machine pH and laboratory pH data (1:5 $CaCl_2$). The difference between the two calibration lines emphasises the need for a calibration curve to be produced for every paddock.

are too dry and hard it may indicate a problem in getting to the right depth. Pasture paddocks can also be challenging due to surface soil compaction, while heavy clay soils and stones can be challenging and block up the machine.

Machine calibration

Correct calibration of the pH sensor on the Veris testing machine is important. Experience has shown that each paddock needs to be calibrated separately to take into account different soil properties and in particular soil texture and moisture content.

To produce lime recommendations for Australian farms, the machine readings are converted to pH in 1:5 calcium chloride ($CaCl_2$) solution, the system used for pH reporting and testing in Australia.

"When using the Veris® machine we take about one sample per 10 hectares of paddock in order to accommodate a range of pH values. For example, in a 60ha paddock we will take about six calibration samples. The soil samples are taken directly from the sampling 'shoe' of the Veris® machine and are then sent to the laboratory for analysis."

A simple linear regression is used to assess the relationship between the machine readings and the laboratory readings (examples are shown in Figure 3a and b). "In most cases the r^2 is greater than 0.90 thereby giving us a very high correlation. The closer the correlation is to 1.0, the higher the reliability of the result."

All the machine readings for the paddock are converted to pH ($CaCl_2$) using the regression formula established from the calibration line. The pH map is then prepared based on the pH ($CaCl_2$) readings. The lime prescription maps are based on a formula taking into account the pH reading ($CaCl_2$), soil texture and the target soil pH.

"Although we produce our soil pH and lime prescription maps using Farmworks software, most farm mapping software will be able to generate the maps."

The pH and lime prescription maps are generally available within a fortnight. Mapping early in the season allows the maps to be prepared before lime is spread before seeding.

The PIRSA work is showing that the use of on-the-go soil pH mapping is not only providing a reliable measurement of soil pH but also a greater understanding about the spatial variability of this important soil property.

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David McGavin. Photo: Lauren McGavin

The following article was first published in September 2018

Precision planting

Rebecca Thyer

Real-time data varies variety and seeding decisions.

This summer NSW grain grower David McGavin plans to use real-time data to make decisions on variably planting his sorghum crop. This is the second year he has sown two sorghum varieties by soil type but this year he is using additional on-the-go sensors to refine planting rates.

David, who farms 400 hectares on NSW's Liverpool Plains, plans to use the US-designed Precision Planting's SmartFirmer and V-Set Select Multi-Hybrid Planter to make hybrid and seed rate choices based on soil moisture and organic matter (OM) levels.

He says research and practice in the US has shown yield benefits from sowing different maize varieties and varying seed rates across a paddock based on soil types. "So I am experimenting with this approach with my summer sown sorghum crops."

SmartFirmer was released in the US last year by Precision Planting and David is so convinced by this technology that he has become an Australian distributer for the company's equipment.

In the 2016 season David used the V-Set Select Multi-Hybrid Planter for the first time. It has twin mini-hoppers that feed two separate, side-by-side meters. These meters switch back and forth as the unit travels over different soil types, planting the variety best suited to that soil.

Soil variability

David's journey to variable-rate planting began 12 years ago when he first forayed into yield mapping and culminated two years ago in variable sorghum planting. (That decision and its result led to his 2017 Brownhill Cup Award win for farm innovation.)

Farm details

Farming Personnel:	David works with his parents Helen and Tony McGavin, and his wife Lauren
Location:	NSW Liverpool Plains, between Premer and Bundella
Farm size:	400 hectares
Annual rainfall:	675mm
Soil:	heavy black self-mulching clay able to hold 150mm to 250mm of water
Enterprises:	sorghum, chickpea and durum wheat
Yield:	Sorghum average is 6.5-7.5t/ha, chickpea average is 3t/ha, and durum wheat is 5-6t/ha

Top PA tips

- Precision planting creates an opportunity to improve yields and dramatically improve the overall average.
- In summer cropping systems, varying the variety and seeding rate to match soil conditions can lend itself to yield improvement.
- High-tech equipment is available to allow you to be informed on every seed planted. After all, you cannot manage what you cannot measure.
- Witnessing a yield increase from varied inputs shows you that just small changes in inputs can make a greater return.

"When I came back to the farm about 12 years ago, Dad (Tony) and I used to talk about our good black soils not having much variability. But at the same time we'd always noticed that some parts of the farm did better than others."

It led to yield mapping and the installation of a Precision Planting YieldSense yield monitor. Although it narrowed down underperforming and outstanding areas, David felt they needed to look further than yield data.

"We wanted to create a map of change in soil and then overlay the yield data to make a better educated decision on how to start changing our outcomes. We bought a Veris U series - which gives continuous soil texture (EC) and soil OM readings, pH readings and elevation data - to make sure we were in charge of our data collection and responsible for our decision making."

For David however, there was the underlying feeling that planting equipment was also letting them down and led to his precision planting journey.

In-furrow sensing

Using optical sensors, the SmartFirmer measures soil moisture, temperature, residue and OM providing a live feed of information about the environment in the seed furrow.

The sensors, designed to be used on twin disc machines, are attached to individual row units and are dragged in the seed trench. They track between the two opening discs so they are protected from obstacles in the soil, such as rocks. The sensors, which could be adapted to fit other machines, read the seed trench where the seed is being placed.

"They become my eyes in the furrow. Any number can be attached to the planter but a minimum of three are required for automatic control."

David, who uses a Challenger Tracked tractor, has so far fitted three sensors to his 19-row summer disc planter. The custom planter has a central fill and is fitted with Precision Planting parts, including full individual row control ofall inputs.

Using the SmartFirmer sensors means, that in real time, different productivity zones can be mapped and planting decisions made based on pre-defined parameters.

For David, decisions about sorghum hybrid choice and planting rate will be based on soil moisture and OM levels.

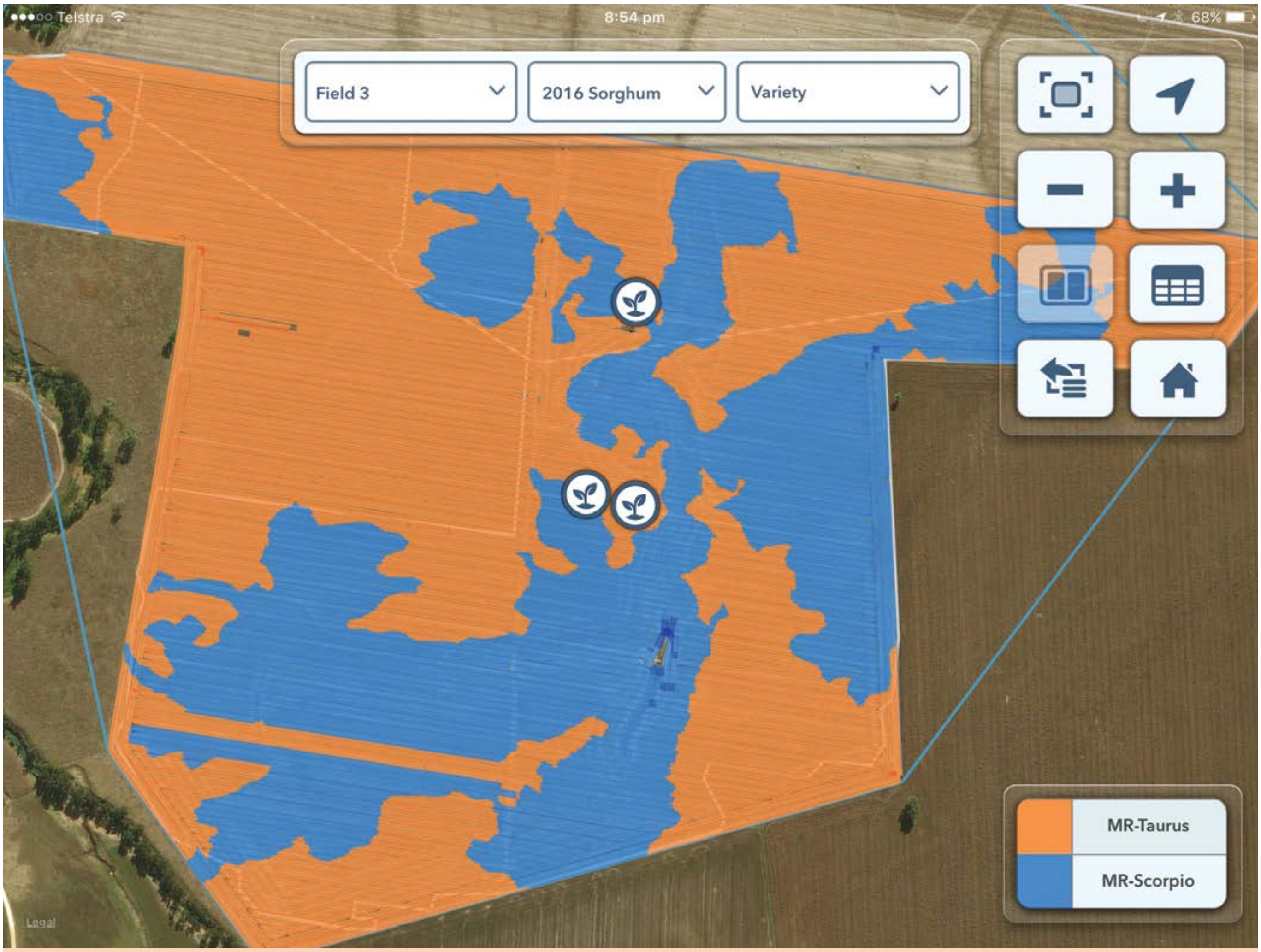
As an example, David explains that if OM levels were 3.5% (a high rate) a decision may be made to plant a high-yielding variety at a high population rate. Likewise, if OM levels were lower, a more stress-tolerant variety may be chosen and planted at a lower density.

David says national trial data helps him make decisions on hybrids and population rate and his local seed dealers and agronomist help give that information a local angle.

Density decisions

With soil moisture lacking this season, he is modifying plans and intends to plant a sorghum all-rounder on the majority of his farm, changing population density depending on OM levels. A tougher hybrid will be planted on his worst soil, however, he is still deciding on what hybrids to use.

In the past he has planted at a rate of 60,000 seeds/ha. "But I think our better areas could be 70,000 seeds/ha and our light areas down to 50,000."



This map shows how David McGavin planted his sorghum hybrids – MR Taurus (in orange) and MR Scorpio (in blue) in 2016. This view is what David sees on his SeedSense monitor. Photo: David McGavin

This image shows the V-Set Select, which allows David to plant two varieties side by side. Photo: David McGavin

He sees the ability to vary population density as a natural next step in precision planting.

In 2016 he planted 44% MR Scorpio and 56% MR Taurus on 50-centimetre rows all at the same rate.

"From the maps we had generated, by Adrian Roles from JMAJ (in a standard map format) we worked out the seeding rate and how much seed we needed. I plugged that information into the 20/20 SeedSense monitor according to soil type and the V-Set Select did the rest."

For David, the decision to plant two hybrids side-by-side was made to make the most of both the varieties and his soils.

Like most farmers, David says he aims for high yields, and MR Scorpio - a medium-long maturity grain sorghum hybrid - is ideal for high yielding situations and best suits deep soils.

"In 2016 we decided we would need a full profile and a good season for MR Scorpio to shine.

"But we also needed to protect ourselves from failure on our toughest soils, which is where MR Taurus, was needed." It offers stress tolerance to protect yield under tougher conditions and this need led to the decision to plant both.

David says with a variable-rate map, the V-Set Select is very simple to use. "Maps are loaded onto the monitor in tractor's cab (via a USB stick or via the 'cloud') and are used to make decisions on what varieties to plant and where."

The decision to plant two hybrids side-by-side saw yields even out across the farm to 6.7t/ha, a tonnage he found was worth it for the extra costs involved.

David says the economic incentive of using the V-Set Select Multi-Hybrid Planter compared to a conventional planter was worked out by costing the planter against improved tonnages.

"It is a one-off cost of an extra $1000 a row to use the V-Set Select. We worked out we would need an extra 80 tonnes of sorghum to make up for this cost. We thought this would be very achievable by lifting the yield in our poor areas by planting a safer variety while still letting our best soil shine."

The plan worked: Yields were 7.1t/ha for MR Scorpio and 6.3t/ha for MR Taurus.

That season he kept seeding rates and inputs the same to better compare how dual planting worked. This season, in a year where moisture is scarce, he will vary population density using the SmartFirmer.

In his fallow paddock trial in June, David used three sensors but is planning to fit one per row at sorghum planting time.

US-based Precision Planting says that having high-resolution zones already mapped out after planting adds to existing data and could help to make more informed decisions on fertiliser or other in-season inputs.

For David, the sensors' real benefit is a better knowledge of in-furrow moisture at planting time: "It is another step in automation. If it works as well here as it does in the US, it will be amazing."

Details: ***David McGavin, 0447 442 136, @PSS_David, david@precisionseedingsolutions.com.au***

GRDC

Leigh Bryan. Photo: Leigh Bryan

Farm profile

Farming Personnel:	Leigh and Susie Bryan, Leigh's parents Dale and Sue
Farm location:	Swan Hill, Victoria
Farm size:	2,400 hectares
Annual rainfall:	Annual 348mm, GSR 230mm – winter dominant
Soil types:	Sand over clay (pH 6) to heavy self-mulching clay (pH 10 -11, boron)
Enterprises:	Wheat, barley, canola, lentils, field peas, brown manure
Yield:	Average wheat yield 2.43t/ha

PA timeline

Guidance	
(submeter) –	2002
cors network –	2010
RTK dealer base station –	2016
Controlled traffic	
– ex harvester –	
(50ft 2:1) –	2002
(13.7m 2:1) –	2015
Autosteer –	2005
Yield mapping –	2006
Variable rate inputs –	2007
Shielded sprayer –	2009
Moisture probes and rain gauge –	2016
UAV –	2014

Top PA tips

- Learn from others' mistakes, ask questions of farmers actually using the technologies, do not just take the word of the salesman.
- Keep it as simple as possible - multiple interfaces can be a source of frustration, particularly when troubleshooting.
- If you are not tech savvy, go with the product that has the best local backup service. You will inevitably have issues at some stage, regardless of brand.
- Do not be put off by my previous three tips. 98% of the time the technology works great and contributes significantly to your bottom line.

The following article was first published in April 2018

A layered approach

Emma Leonard

Using a small suite of PA tools and integrating multiple data layers, Leigh Bryan is targeting seeding and inputs to highly variable soils.

Averages can conceal considerable variation and this is certainly the case for soils on Leigh and Susie Bryan's farm near Swan Hill, Victoria. Located on the edge of the Victorian Mallee, the farm's soils range from white sands to heavy clay soils, but what lies beneath can vary and unlike in the dune swale feature in the Mallee, elevation does not help define soil types on the Bryan's property.

"Soils that seem similar at the surface can differ down the profile changing the way moisture can be accessed by roots or is stored or lost from the profile," explains Leigh.

"Our yields can vary between 0.3t/ha and 3t/ha in the same season, just because of changes in soil."

The Bryans can have very different soil types within one hectare. To optimise production, Leigh has tried to understand the soil profile and how this influences plant available water (PAW) across his paddocks.

Managing production to soil type by varying inputs is central to Leigh's approach to farming. Having worked as a PA adviser with a strong interest in data analysis, Leigh applies a very analytical approach to understanding his soil's strengths and weaknesses and how these might be managed profitably.

For Leigh, the data helps him decide what to do where and the equipment enables him to put his decisions to work.

Soil data layers

As would be expected, soil data is a central component to the construction of Leigh's input zones, but he is not content with an electromagnetic soil survey (EM38) or a few strategic soil coring points. Indeed, up to six different soil layers are combined to create his soil zones.

The first data layer is his and his father's knowledge of their paddocks, which they used before purchasing their first GPS in 2002, to manually map out sands where inputs would be varied.

A few paddocks were surveyed using an EM38, as this had proved useful in the region, but on the soil types on Leigh's farm, these failed to match up with the yield maps collected.

An EM38 map provides a picture of the change in soil electrical conductivity (EC) across and down the soil profile, usually being presented in a 0-75cm and 0-150cm profile. Coarse textured soils, such as sand, have lower conductivity than clay, but EC is also increased by salt and moisture content.

"Now we have established many of the reasons for seeing a high EC with low yield, one of which is often a high boron layer that can block the roots of some varieties growing through to the clay containing PAW."

Disappointed by the results from the EM38 survey, Leigh went back to first principles to identify surface variation and then target further deep investigation. Using high quality aerial photos taken of bare soil images after trash had been incorporated, Leigh marked out changes in soil colour onto Google Earth. This gave him images, areas and geographic locations for different soils. For many years, Leigh used these zones to help target a regular soil coring program, including full physical and chemical characterisation to depth.

However, it was libraries of historic soils data that Leigh started to explore other soil properties. He used Landsat (30m resolution) and more recently Sentinel (10m resolution). From the satellite data, he has worked with multiple layers of information - thermal taken in late spring, Normalised Difference Vegetation Index (NDVI) and pure red. The gammaradiometrics data was collated from aerial mining surveys.

"I grouped the multiple layers for all the dry seasons since 2000, as these really distinguish between the high and low PAW soils.

"Variation in the potassium (K) layer in the gammaradiometrics is very reliable here for identifying constrained clay soils, while the red layer from spring quickly indicates crop yellowing on the sands."

Leigh also used 15 years of NDVI data produced from satellite imagery and a decade worth of yield maps. This he divided into two sets, one for wet years, the other for dry years.

With all these data layers, Leigh established his soil zones in each paddock. If he chooses, he can continue to refine these datasets with data from more years, but basically this picture is now complete. What will change each year is how much yield varies in each zone due to differences in rainfall and other seasonal issues such as frost.

Outputs to inputs to outputs

Varying input rates to match availability and potential need is a cyclical decision. For each paddock, Leigh creates three input maps, one for each box on the air-seeder. Each map consists of 11 zones to help smooth the transitions between zones. This reduces pressure on mechanics, but also reflects the fact that zones will never be perfect.

"In many soils, we have had really high levels of available soil nitrate, as much as 250kg nitrogen (N)/ha, so I have hardly applied N fertiliser in these areas. Elsewhere and for other nutrients, the aim is to maintain levels, which are periodically tracked by a soil test in a high, medium and low production soil zone in a paddock."

To calculate phosphorus (P) and zinc (Zn) rates, Leigh uses an audit approach, balancing removal with replacement plus an adjustment for the nutritional requirement of the following crop (Figure1).

To create the 11 zones, Leigh takes the rate required for the highest yield and that for the lowest yield and then divides by 10. For example, if the highest rate was 80kg/ha and the lowest 50kg/ha, the difference would be 30/10=3kg increments.

Leigh generates the rate maps (Figure 2) using the software Manifold, which he has used for many years and has learnt to write the code and program. Yield data is gathered using Trimble Farmworks on which the rate maps could also be produced. All equipment is guided and steered and rates

Kilograms of nutrient/ha = (yield x nutrient removed/t) – nutrient applied + average nutrient required for the following crop

For example:

1.8t/ha wheat crop that received enough P for 2.5t/ha

The following crop will be lentils, average long-term P requirement for lentils 4.32kgP/ha

kgP/ha = (1.8 x 2.5) – 6.25 +4.32 = 2.57kgP/ha

Figure 1. Nutrient replacement for a lentil crop following a wheat crop.

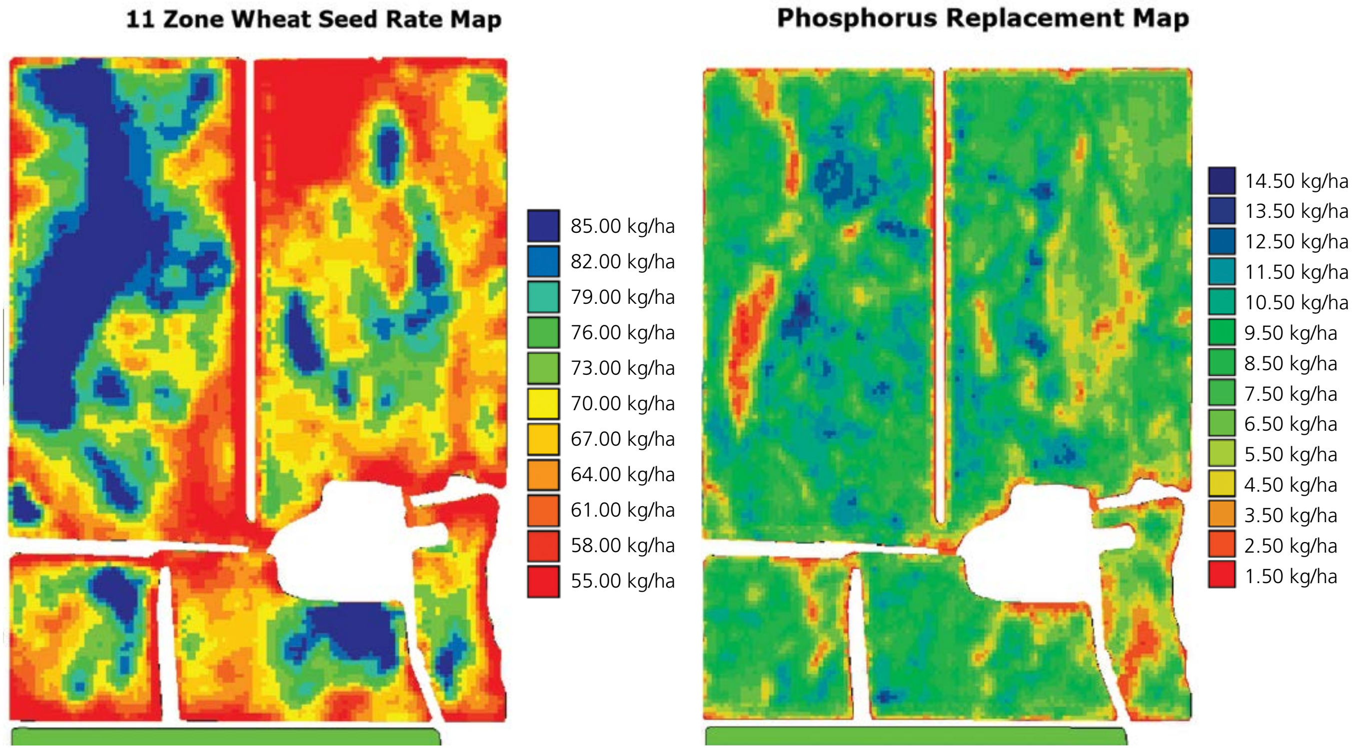


Figure 2. Variable rate maps for the same paddock for wheat seed and phosphorus generated using Leigh's replacement calculation for nutrients.

controlled using Trimble equipment (seeder rate control is via a Topcon X20), even though all tractors are John Deere and the harvester is a Case 7120. From Leigh's current perspective, equipment compatibility is not as big an issue as it once was, but could still be improved.

The Horwood Bagshaw 9000l air-seeder has three boxes – bin 1 seed, bin 2 fertiliser N sulphur blend, bin 3 mono ammonium phosphate with Zn blend. Any additional N is top dressed during the growing season based on satellite biomass imagery, and supported by soil moisture data from moisture probes.

Leigh has found that on his sandy soils, variable rate has helped improve yield and profit, while on other soil, he has simply seen a saving in money. What the system also enables him to do is generate gross margin maps so he can really see what area and how much is making money.

Crops and water

PAW is a key driver of all production systems. With a group of other farmers in his region, Leigh has now invested in five moisture probes and three rain gauges to help with decisions as wide ranging as in-crop N and the timing of desiccation of brown manure crops.

Each rain gauge is located on a fence line at a point between two paddocks where each soil moisture probe can be located in different crops. The probes and gauges are hardwired to a logger, which in turn transmits data via the 3/4G mobile network back to the central server then displayed via a web interface in the office or on a mobile device.

"To date, I have located all probes into our loamy soils and from these I can infer water storage in other soil types. As I invest in more probes, I will consider locating them in soils with more extreme moisture retention patterns."

Leigh uses the soil moisture probes to indicate the total volume of water available and if this is enough to support additional in-crop N. He also looks for decrease trends and when PAW starts declining below the 0-50cm layer, he will desiccate any brown manure crops.

"Having the probes makes these decisions easier and helps reinforce my gut feelings."

Twice a year, a quick whole farm aerial photo is gathered with his UAV. This has been used to quantify issues including patchy germination or mice damage and the consequent production of re-sowing or baiting maps. One year in lentils the very low biomass areas identified from the aerial image were mapped and not sprayed with fungicide as canopy closure was not achieved, resulting in input savings.

The future

When asked, Leigh says little has changed on the farm in the past 10 years, but many of the above approaches have been tweaked, improved or supported with additional low cost technology such as the UAV, moisture probes and rain gauges.

While he would like a weed selective sprayer, pulse width modulation on all spray nozzles or a weed spraying robot, he does not expect to be buying any of these in the near future as he cannot justify the cost of the robots as they are still in development.

Details: ***Leigh Bryan, 0427 321969, @leighjbryan, leighjbryan@gmail.com***

Leigh Fuller. Photo: Emma Leonard

Farm details

Farming personnel: Three full time family labour units – Fuller family – Leigh, his father and uncle

Location: Koolunga, South Australia

Farm size: 3,800 hectares

Annual rainfall: Annual 400mm, growing season 284mm

Soil: Black cracking clays through to sand

Enterprises: Wheat, durum, barley, canola, faba beans, lentils and vetch. Trade sheep

Yield: Wheat yield 3.8t/ha average for the past seven years

Top PA tips

- Do the figures and assess what you are doing and why.
- Pick suppliers with good local knowledge and backup.
- Work with people who know what you do not - professional services can save considerable time.

The following article was first published in July 2018

Varying inputs

Emma Leonard

Working with his PA agronomist, Leigh Fuller has converted to varying inputs of lime and some nutrients.

The Fullers had generally considered their soils to be neutral pH with alkaline limestone ridges and rock. So they were a little surprised to discover some of their soils were strongly acid (pH 4-4.5).

"At these levels of acidity, plant availability of nutrients changes and generally they become less available, so we knew we had to do something," said Leigh Fuller.

"We immediately noticed higher levels of ryegrass in the acidic areas. These were where the crop was less competitive."

The pH readings were taken by their agronomist Sam Trengove using a Veris on-the-go pH sampler. This machine takes 10-12 samples per hectare. On completing the sampling, the raw data was cleaned using the Farm Works software and exported as an ISOXML file for use in the TOPCONX30 rate controller in the Bredal spreader.

"We selected the Bredal as the belts and spinners are hydraulically driven so rates can be changed on-the-go. It is also relatively cheap to run, low maintenance and gives us good road speeds, which is important as the farms are 35km apart."

The spreader is versatile, able to spread mouse bait (1kg/ha), snail bait (5kg/ha), urea, lime/gypsum and biosolids (10t/ha). It holds about 13.5t lime, which is spread to 12m at a rate of 50-60t/hour as rates are varied. The spreader holds 6.5t urea, which is spread to 36m, at a rate of 100 to 130ha/hour.

The lime used has an equivalent neutralising value of 55-65% and is considered moderate quality. It costs $16-18/t plus transport and spreading. The Fullers work on 3t/ha to raise pH by one unit.

"Spreading lime is an expensive operation - spreading about 4.5t/ha costs more than $100/ha."

The aim is to raise the soil to pH6. The sands are generally more acidic, but more responsive to lime and receive 2t/ha of lime, while loams receive 3t/ha and clays 4-6t/ha.

Leigh has found redistributing lime to areas of need still results in less lime for a paddock compared to a blanket rate of 4.5t/ha. For example, in a 45ha paddock, only 36ha required any lime and across these the rate averaged 3.65t/ha, a saving of 71t of lime.

They realise that cropping will continue to acidify their soils so anticipate returning to a paddock to reapply lime after about 10 years.

"We aim to map and spread 500ha per year and we have an eight to 10 year plan."

Other precision approaches used by Leigh include applying phosphorus (P) at a replacement rate. He has done this for the four years, since purchasing the Flexicoil air-seeder that has electric over hydraulic drives on the air-cart. Rates are based on 4kg P per tonne per hectare of cereal or 5kg/t/ha of legume or oilseed. So, if last year's yield was 3t/ha of wheat, 12kg/ha of P is applied.

Yield data from the John Deere 2630 harvester is imported to Farm Works, cleaned and mapped as three to five yield zones. The P prescription is assigned and zones are exported as an ISOXML file to the Case New Holland Pro 700 rate controller.

Leigh's wish list for future PA tools includes a ProTrakker to improve inter-row sowing accuracy, section control on the air-seeder and a CropSpec to do on-the-go variable rate in-crop nitrogen.

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Michael Pfitzner is using safflower as a biocultivator to punch through the soil hard pan. Photo: Emma Leonard

The following article was first published in July 2014

Better systems harvest more moisture

Emma Leonard

Capturing as much rainfall as possible is essential in a very variable rainfall area and controlling traffic is playing a central role.

Michael and Larissa Pfitzner's farming philosophy revolves around maintaining ground cover and farming soil moisture. Applying a precision approach across his operations is helping to improve productivity by better achieving ground cover and use of soil moisture.

"In 2013, we received only 187mm of growing season rainfall, about 60% of average, but still achieved excellent water use efficiency, 26kg/mm for wheat and 33kg/mm for barley; to me that shows the system is working," said Michael.

This district shows the distinct rainfall pattern of the millennium drought. Figure 1 shows the cumulative effect of average rainfall to gain an understanding of building or declining rainfall cycles. This gives an indication of building or declining moisture reserves.

While Michael has been using PA tools since 1997, it was in 2006 that his approach really started to change. In that year, the livestock were sold and guidance was upgraded to +/- 2cm accuracy. In 2009, fences and random in paddock trees were pulled out and paddocks realigned to create larger square paddocks. The direction of operations was changed from an east to west, to north to south in line with the natural fall of the land.

Converting to CTF

Like most farmers Michael was aware of some of the in paddock variation across his farm, especially on the poorer performing sandier rises. However, it was not until he looked at some high resolution satellite imagery for the whole farm that he realised some of the variation was of his own creation.

Farm details

Farming personnel:	Michael Pfitzner and family and casual labour
Location:	Griffith, New South Wales
Farm size:	2830 hectares
Annual rainfall:	annual 430mm but last 5 years average 323mm, despite 799mm in 2010, GSR last 5 years 176mm (Figure 1)
Soil:	Red sandy loam, pH5.8(CaCl)
Enterprises:	wheat, peas, canola, safflower and vetch for brown manure
Yield:	average wheat yield 3t/ha

PA applications

Technology	**Year started using**
Guidance –	1997, RTK 2006
Controlled traffic 12m units –	2006
Autosteer –	2005
Grain yield monitoring –	1999
Variable rate seed and nutrients –	2007
Inter-row seeding –	2006
On-farm trials	
Spray application mapping	

The NDVI satellite imagery clearly showed the old wheel tracks as well as the new wheel tracks running at 90 degrees. With a bit of detective work he was able to identify which machines caused the wheel tracks. He also calculated that even using a one pass seeding system but with the sprayer and tractor on different tracks 48% of the farm was driven over by at least one operation. That did not include random operations such as chaser bin movement.

"Based on what I had seen I was convinced to head down the path of controlled traffic farming (CTF) but it was surprising how many farmers and machinery dealers were experts in why this would not work on these red sandy soils."

In order to quantify the potential of CTF Michael decided to look at areas of the paddock that were least likely to have suffered from random traffic. He selected his A-B line, as this is a constant. Just before harvesting a barley crop in 2009, Michael weighed the heads from 50cm of each row across the width of the seeder and converted this to tonnes per hectare per row (Figure 2).

Despite 2009 being well below average, water was still recorded laying in the wheel tracks after a 3mm rain event. In the wheel track the yield averaged 1.77t/ha and returned a gross margin of $47/ha. However, this was a 30% reduction in yield compared to the average from rows 1-24 (excluding the wheeled rows) and a drop in gross margin of $87/ha (Table 1). Rows 27-41, which are affected by random traffic only averaged 1.35t/ha and a negative gross margin of $20/ha, compared to rows 1-24, this equates to a loss of profit of $152/ha.

"While the paddock averaged 1.35t/ha these test figures suggested that the lost potential was in the order of $20,000 for this 130ha paddock. If that was replicated across the farm we could assume a loss of profit of $425,000."

After this experiment Michael required no further justification and purchased a 12m disc seeder, built a 36m boomspray and runs a 12.2m (40ft) harvester front. All are on 3m wheel spacing. Fertiliser is spread on 24m using a urea boom towed behind the air-cart. This CTF system results in 12% of the paddock being trafficked, a reduction of 36%.

Michael's choice of equipment is designed to optimise the efficiency and productivity of his system.

"We find the slight overlap with the harvester front helps collect all the rows into the front even if plants are falling out of the row."

Typical work rates of 18ha/hr are achieved with the disc seeder and 80ha/hr with the boomspray, which is fitted with a 7000L tank."

Everyone talks about matching widths as the starting point for machinery modifications for CTF. However, Michael suggests that if he were starting again he would invest in a really good spreader for straw and chaff the year before converting to CTF. Achieving an even spread of material out of the back of the harvester is vital.

"Now we have fitted a MAV Redekop chopper/spreader to the harvester. It is not perfect but it spreads chaff and straw together and achieves a relatively even distribution across the 12m width."

Michael suggests that all farmers, not just those doing CTF, should be lobbying machinery manufacturers to improve the ability to both evenly spread and place chaff and straw in narrow rows.

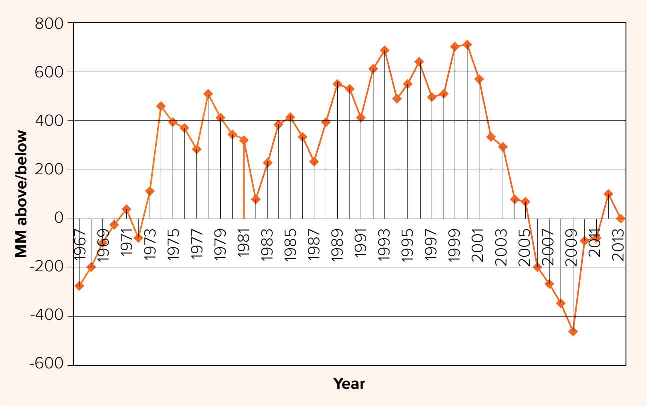


Figure 1. Rolling average rainfall 1967 to 2013.

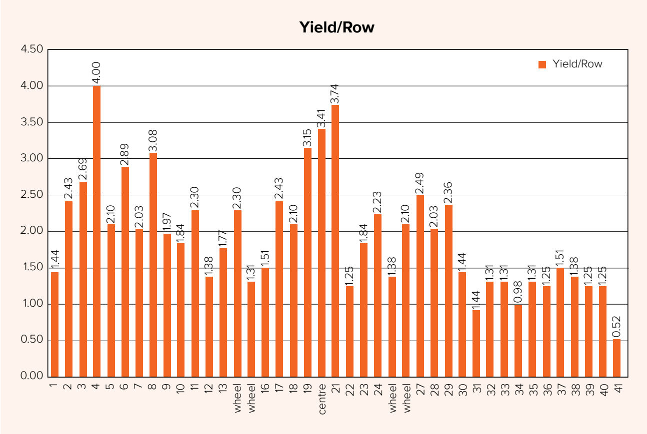


Figure 2. Yield variation across the implement, a Morris Contour drill, highlighting the impact of wheel traffic and random traffic (rows 30 plus). Row 1 is adjacent to the fence.

Matching machinery

Using a disc seeder allows narrower row spacing without problems of dealing with stubble. Research in this region with row width, seeding rate and wheat variety clearly showed that 250mm rows (10inch) to be superior with both 20kg/ha and 40kg/ha seeding rates.

Michael has opted for a row spacing of 272mm across the 12m bar as this allows for the two disc units behind the tractor wheels to be removed, leaving 42 units. Early crops are sown at 20kg/ha while later sowings are at 40kg/ha.

Having matching widths also means that spacing of the seed row and spray nozzles can be easily matched. Spray nozzles are spaced at 272mm rather than the standard 500mm and located between the crop rows. To achieve a one nozzle overlap this spacing equals 133 nozzles on the 36m boom. This spacing provides much better coverage both in crop (drift guard 80 degree nozzles) and during the fallow (air induction 110 degree nozzles).

Table 1. The cost of compaction – variation in barley yield measure along half metre row across the width of the machine – row 1 is closest to the fence.

Rows	Averaged yield	Gross margin	% Reduction from 1-24
1-24 (ex wheel tracks)	2.3t/ha	$132/ha	-
Wheel tracks	1.77t/ha	$47/ha	35%
27-41 (random trafficked areas)	1.35t/ha	-$20/ha	115%

Achieving good flotation has been an issue with the sprayer, despite the tracks becoming fairly hard. Initially, the sprayer was fitted with 380mm tyres but these are like 'pizza cutters' on wet soil and do considerable damage to the tramlines. So, in wet conditions these are changed for another set of wheels fitted with 650mm tyres.

Running the sprayer on hard tramlines has significantly reduced dust, which has improved the efficacy of summer sprays. Fleabane is a major summer weed and Michael has used free Pastures from Space imagery to identify key weed areas. A double knock of 1.75L Roundup CT, plus 1.75L Surpass 475 applied with a coarse droplet; followed 10 days later with 1.5L Gramoxone in rain water, is producing the best results. This is not a cheap mix so making it as effective as possible is essential.

The double knock achieves 100 per cent control and results in about a 0.5t/ha increase in yield compared to incomplete control.

Running the sprayer on the tramlines also results in a fuel saving of about 5L/hr, which adds up as the sprayer averages 300hrs per year.

Fixing up

While converting to CTF prevents compaction occurring, it does not rectify compacted soil. While this will occur over time, these red sandy loams show very little shrink and swell as typified by the self-mulching soils, so some assistance was felt to be necessary.

Safflower, with its penetrating roots has been sown in order to punch holes through the compaction layer found at about 12cm. Deep ripping plus deep placement of lime has also been tried but with mixed results. A brown manure crop of vetch also proves beneficial for soil structure and nutrient accumulation.

While permanent tracks are helping the soil and crops, in turn they can require renovation. Michael has found the narrow spray tyres and the first running water and last trickle from heavy rainfall do the most damage.

The addition of a roller set at about 45 degrees to the track and a hydraulically adjustable scraper to a commercial track renovator which is used judicially to reinstate smooth, hard tracks. Photo: M Pfitzner

"Looking after the tracks is really important. I have tried a few types of track renovator and adding a scraper blade and roller has helped create a smoother renovated track."

On-farm trials

Michael is continuously recording and analysing the performance of his system. Precision tools have helped him run many on-farm trials and he was involved in the SPAA-Precision Agriculture Australia and Central West Farming Systems trial in 2011. This looked at variable chicken manure and lime. Other trials have related to varying inputs of seed and fertiliser but all of those deserve another article.

However, details of the project trial can be found at - www.spaa.com.au/projects.php Select past projects and then 'Training and demonstration of PA in Practice'.

Details: ***Michael Pfitzner, 02 6963 4859, fitz001@bigpond.com***

Using the air-cart and fertiliser boom allows up to three products to be applied at variable rates. The boom heads are the same as the airseeder and distribution is spaced between the crop rows. Photo: Emma Leonard

Neil Ennis.

The following article was first published in July 2020

Sound investment in soil

Rebecca Thyer

When soil is everything, it pays to invest.

For Nick Ennis, any investment in PA is an investment in soils. Nick manages Lawson Grains' Borambil aggregation in southern NSW.

Borambil's 8,400 hectares are spread across nine farms, from Rand in the north to Howlong in the south, and encompass differing soil types, paddock histories and rainfall amounts.

Using PA, Nick and his team have worked to variably apply soil ameliorants, fertilisers and seeds to match the aggregation's conditions - all the while keeping in mind the need to ground truth any findings. For Nick, that means a shovel is always on hand.

PA Journey

Prior to the aggregation's creation in 2013, Lawson Grains undertook due diligence via extensive soil testing.

Farm profile

Farming personnel:	Manager Nick Ennis, plus three full time professional farmers, casual seeding and harvest staff and agronomist
Farm location:	Rand, NSW
Farm size:	8,400 hectares
Annual rainfall:	Annually is 450mm across the north and 525mm further south
Soil types:	ranges from sand to black cracking clays, pH 5+
Enterprises:	wheat, barley, canola, vetch
Yield:	Average wheat yield 2.43t/ha

PA timeline

Technology	Year started using
EM38 maps –	2013
VR MAP starter fertilser –	2014
VR lime and gypsum –	2014
VR seeding –	2016

Top PA tips

- Soil is everything and it is important to understand it. Carry a shovel and ground truth and test what the PA map shows.
- Variable rate inputs are not about saving money, but using inputs where needed to optimise crop yield at all locations
- Conduct input-rich and lean test strips each year to ensure fertilisers are not being under, or over applied.
- Make sure all equipment is calibrated correctly, for example, seeders, spreaders and harvester yield monitors.

"We wanted to understand our soils and have a better idea of what extra capital would be required to bring all soil types to a minimum pH of 5," Nick says.

The idea also included investigating under-performing zones to improve them; identifying high production zones and push them; and importantly applying the right amount of inputs to match the productivity of each zone.

"Our goal has always been to apply the right amount of inputs to a specific location, with no waste.

It is not about saving money, it's about putting money exactly where it is needed."

The first step was electromagnetic (EM38) mapping, undertaken with local business Rand Ag and Fertiliser.

By measuring electromagnetic conductivity (EC), EM38 mapping helps identify soil types. For example, sands have low conductivity, clays high conductivity, with saline soils the most conductive. With ground truthing these EC measurements can then be correlated to soil texture and moisture; important factors in crop yields.

The EM38 maps 'clicked' with what Nick knew about the farms and their paddock histories. "Some of the farms had been mixed agriculture and where lucerne had been planted it showed up noticeably on the maps, because the deep roots had mined soil moisture from deep in the soil profile.

"But there were still some surprises. When we ground truthed the soils we anticipated to be sandy loams, they were not as sandy as we thought, they had more clay content."

The EM38 mapping provided an initial indication of different soil types across the aggregation, helping to establish management zones. Further soil tests using a coring machine were then undertaken to evaluate pH levels and test for trace elements.

"Pits were dug over many different soil types to understand what constraints there might be in the soils. We continue to dig pits today and feel this is a very important tool to understand our soils better."

Nick also ground truthed the initial soil results when they came in. "I went around on a gator digging holes to check what the EM38 survey and soil testing had found. I kept it simple, but it is important to understand your soils."

Variable amelioration

With soil results in, variable soil amelioration to correct pH began in 2014. Some of the soils did not need any

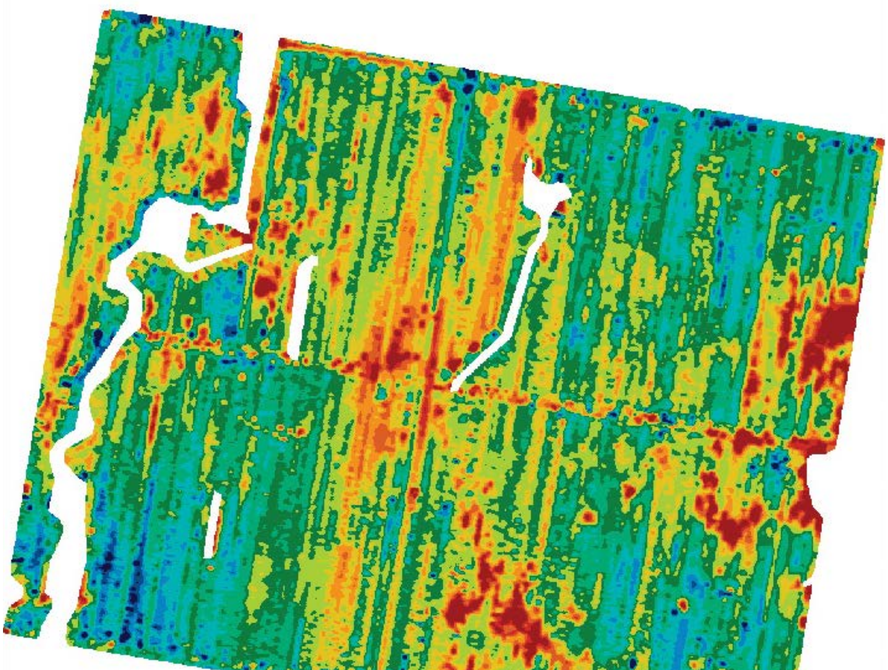
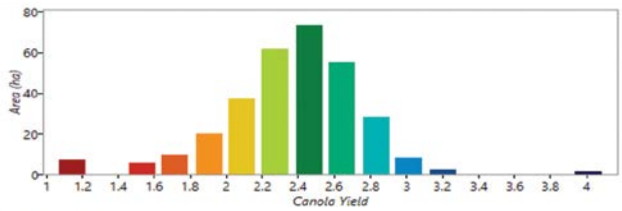


Figure 1a.

This map, for a 311-hectare paddock, highlights the variation in 2017 canola yields.

Darker green to darker blue colours indicate higher yields of between 2.4-3.2t/ha.

Dark red yields are lowest at 1.2t/ha.The map indicates that about two-thirds of the paddock is performing well, but one third could be improved. Lawson Grains is tackling this variability using yield data, plus scheduled soil testing, to calculate P removal.



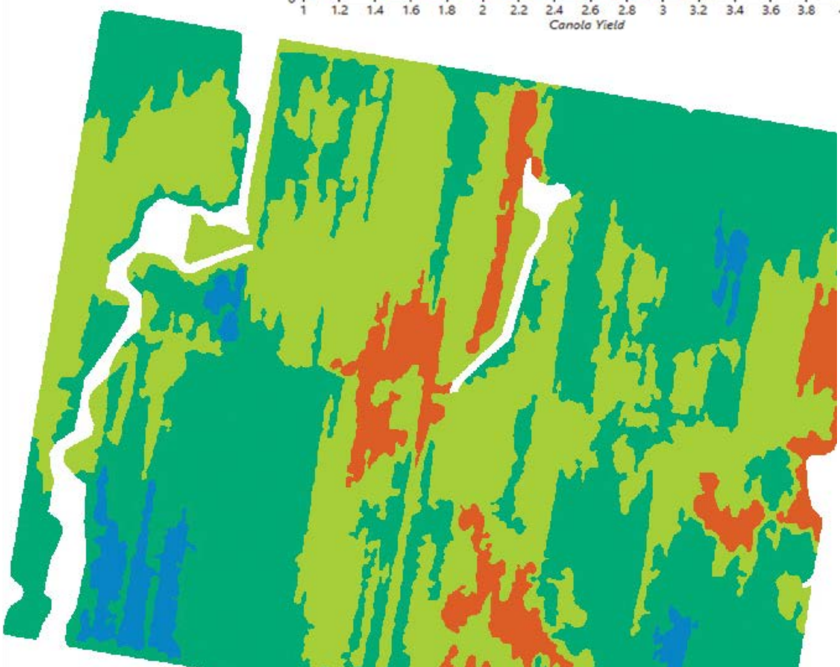


Figure 1b.

This shows the 2018 prescription for MAP fertiliser. The prescription is based on yield information, plus soil data.

After initially creating zones based on soil types, MAP is now variably applied based on the previous crop's P removal and requirement of the following crop.

amelioration while others required substantial inputs, with the biggest gains in deep sandy soils.

Deep sandy soils had traditionally been quite acidic at pH levels of 3.4-3.5. Investigations found that the first 0-10 cm of soil was acidic (~pH4), whereas the next 10-40cm was very acidic (<pH3). There was also a huge amount of aluminium in this layer. Below 40cm, the sand was alkaline. Meanwhile, the heavy soils varied from a pH of 4.9 - 7.5.

"We were targeting a pH level of 5.2 - 5.4, so we began a variable amelioration program based on maps produced from the EM38, and in zone sampling."

This included variable lime, gypsum, spading and ripping the deep sands to 70cm, before applying 3.5-4 tonnes of lime/ha. The soils were then spaded to inverse the layers.

"It is now a consistent pH of 5.2, which we maintain by checking with targeted soil testing. We've not seen a decrease in pH yet, but we will undertake a capital application, that is invest over and above our usual maintenance program, if we need to."

Nick says the deep ripping, spading, depreciation, fuel and labour cost about $220/ha. The lime applied was an additional cost.

The process has been worth the time and money. "We used to receive very little income from that sandy soil. "However, even in a decile one rainfall like last year we achieved a yield of 2t/ha for canola in those soils. It was a payback of about a year and half."

Other variables

As pH levels were being addressed, Lawson Grains was also deciding on taking a variable approach to other inputs, including fertiliser and seed.

Lawson Grains began variably rating Mono-Ammonium Phosphate (MAP) starter fertiliser in 2014 . This was based on the up to five zones created via the initial EM38 mapping. Nick says the VR application is now based on yield maps and is formulated based on P removal.

He explains that he and agronomist James Challis from Nutrien at Echuca pour over yield maps, generated via John Deere software and cleaned by PCT at Narrabri.

"We spend days and days analysing yield maps to make sure it is right. It is an important part of what we do. We are looking at what the prior crop has removed and ensuring that it is being replaced, including a capital application if a nutrient is deficient."

This means MAP applications vary from 45kg/ha to 130kg/ha. Nick also tests this against high and low P rates by conducting strip trials, planned in soil zones. In addition, every field and soil zone is tested for pH, trace elements and P every three years prior to the canola phase of the rotation.

"We do not want to under apply and miss out on yield benefits. We have seen an increase in returns per hectare because we are putting inputs where they are needed. That means pushing high production areas but bearing in mind the season and those soils' water-holding capacities."

This also includes limiting inputs in poorer zones and has included a variable approach to seeding.

Initially, VR seeding on sandy soils began as a means to an end – the only way to seed after they had been deep ripped – but it continues today.

"Trafficability was horrible. Being so soft after the sand was deep ripped and spaded, it was easy to bury seed deep, so we increased the seeding rate using VR maps in those areas to compensate."

Prescription maps for seed, fertiliser, lime and gypsum are made using PCT Ag Cloud software and applied using John Deere rate controllers.

"We make the prescription maps using PCT Ag Cloud in the back office, then send the files remotely to the tractors using My John Deere. It is easy to use, and staff benefit from that. You just need to click on the file once it has been received and get the VR map for the job."

Nick would contemplate using precision seeding techniques on other areas in the future. "We have some heavy chocolate to black cracking clay. It is a challenge because it is soft and friable. This soil is similar to sand – if it is dry, we need to use more seed. We want to place the seed in the right spot, so I will be using VR seeding in those soils in the future."

Other tools

Other management tools include NDVI satellite maps, used once the crop is established. Nick looks for crop health, pests and disease issues and overlays other maps, including elevation, soil zones, EM38 and prior yield maps, to make sense of what he is seeing.

"This helps me to understand why a crop might be growing better in one area compared to another. If you know your soils well, the imagery can show where there may be a problem and we can get to that area quickly – for stripe rust or millipede incursions, for example."

When Nick talks about PA and new on-farm approaches, from more established technologies to blue-sky ones, he is firm in the belief that associated costs and efforts are not just for Borambil's most economically viable crop.

"Wheat is probably our 'bread and butter' crop. However, everything we grow has to be financially viable unless it has a long-term benefit on other crops. For example, vetch was profitable last year but with a glut of hay this year, it may not be as profitable. Yet, the benefits of growing it are seen in the following seasons' wheat, canola and barley crops."

For him, PA investments are investments in soil to benefit all crops and a sustainable future.

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The influence of row placement in non-wetting soils. Photo: Paul Hicks

The following article was first published in November 2013

Systems approach to climate and soil challenges

Emma Leonard

Combining new technologies has enabled Pingrup farmer Paul Hicks manage challenges created by frost, dry seasons and non-wetting soils.

Early sown cereals and spring frost are not a productive combination as frost sterilises the plant and prevents seed-set. Germination is also a challenge for crops sown early in non-wetting soils.

However, late sowing and short, dry seasons are equally a poor combination, as crops have insufficient time to reach production potential before maturity.

Located in the Western Australian Mallee, about 320km south east of Perth, Paul Hicks has applied technology to help him overcome this cropping dilemma.

"CSIRO is projecting that over my farming, lifetime average temperatures will increase by up to 2°C, and rainfall will decrease by 10 to 20 per cent in the next 80 years," said Paul.

"So the chance of frost might decrease but the likelihood of receiving the 200mm of growing season rainfall I need to finish a cereal crop will become more risky."

Paul is also finding that more rainfall is being received in the out of crop, summer period.

In order to improve water use efficiency and increase early biomass production, Paul has now opted to sow all crops as early as possible. For canola that can mean dry sowing and for cereals he aims to sow just in front of an opening rain.

However, early sowing increases exposure to frost on about 10% of the farm and to very poor germination on the 20 per cent that is extremely non-wetting.

Farm details

Farming personnel:	Paul Hicks, plus two full-time staff
Location:	Pingrup, Western Australia
Farm size:	3700 hectares
Annual rainfall:	Annual 320mm
Soil:	Mallee soils - sand over gravel or clay, non-wetting topsoil, pH 4-8 but the majority slightly acid
Enterprises:	Continuous cropping – wheat, barley, canola, export hay and field peas
Yield:	Average wheat yield 1.8t/ha

PA applications

Technology

Guidance

Vehicle and implement steering

Grain yield and protein monitoring

Hay yield monitoring

Variable rate phosphorus

Soil and frost mapping

Paul is using a combination of detailed mapping, in-paddock temperature sensors and hay production to manage the frost. For the non-wetting sands, he has developed a new tillage system.

Frost mapping

Between 2008 and 2009, Paul engaged Precision Agronomics and Precision Cropping Technologies to produce gamma-radiometric and electromagnetic (EM38) maps of the whole farm. The EM38 provides a useful picture of soil conductivity and changes in sand, clay and salinity.

The gamma map is useful for identifying underlying gravel, with the thorium layer being especially useful for differentiating between sand and gravel.

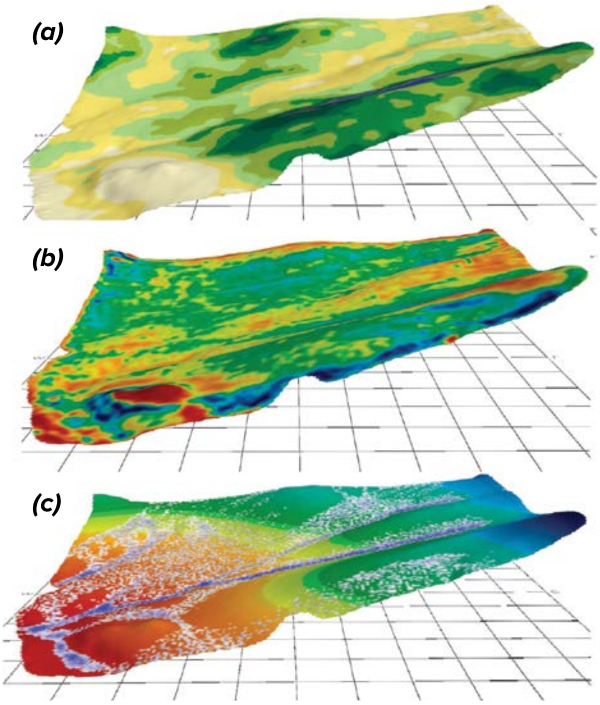

Figure 1. The paddock looks pretty flat but looks can be deceiving as the maps show. Gamma radiometric thorium (a), surface biomass (b), slope (c) including an indication of air movement. The frost damaged areas strongly aligned with lowest slope – flatter areas where cold air does not drain away as readily. Photo: Paul Hicks

"We discovered there were more gravel subsoils than we had thought, which helped to identify why some of our soils had poor water holding capacity."

More recently Paul has had digital elevation model (DEM) processed from the farm elevation maps and last year Specterra flew a sample area of the farm at 4500m to collect biomass data.

The elevation data was used to produce slope maps. Unlike elevation maps, which focus on peaks and troughs, slope maps indicate where water would move through the landscape. Cold air and water move through the landscape in a similar way, so slope maps highlight where cold air will move and sit (Figure 1).

From the slope maps, the area of land at risk to frost could be calculated. The frost prone areas could be accurately located in the paddock using the geo-referenced maps and the boundaries mapped. The most appropriate locations for frost buttons could also be identified from these maps.

Frost buttons (i-buttons) are small, cheap data loggers that can record changes in temperature at determined time intervals to measure the duration and chill factor of a frost. A reader stores the information that can then be downloaded onto a computer.

The buttons can be placed at a range of heights in the crop canopy as well as through the frost catchment to determine the height, (i.e. was the ear frosted), size and degree of frost damage.

"Last year, I put the buttons out on a cold night at about 11pm. The reading immediately dropped to -3°C and went as low as -6°C but the next day the temperature peaked at about 30°C.

"With such temperature extremes, the crop dries down very quickly and we started to see awns turning white after about four days."

Paul now has a good handle on what and how much crop has been frosted. He has also calculated that his breakeven cereal yield is about 1.3t/ha.

On the lighter textured soils, especially over gravel, he has found that achieving his breakeven yield is difficult, especially in years with an early finish. Paul has found that the frost, soil and biomass maps are closely related.

From the EM38 and gamma soil maps he can locate the light textured areas. So, after some ground truthing the crop for that season, the hay cutting program will be extended to frosted and low production parts of his paddocks that have been sown to wheat and barley.

"Maps of the frosted and low production patches are loaded onto a guidance system on the self-propelled mower and we can quickly and accurately locate where we need to cut."

Hay yield monitoring

Working with Precision Agronomics Australia, Paul has also developed a hay yield monitor. They have experimented with using load cells (weight) and also measuring how quickly the bale came out of the baler chamber but found these methods to be relatively inaccurate. This was because the data collected was delayed and had to be post processed to assign yield to the correct area of the paddock.

Instead they have developed a system that records changes in the hydraulic pressure driving the hydramotor at the cutter head and converting that into hay yield.

The system is fitted to a John Deere self-propelled mower, which is hydraulically driven. As with all yield monitoring, calibration is important. For this system it is especially important as the pressure will vary between cutting at night and during the day due to changes in humidity and the level of dew present.

Intelligent tillage

By harnessing a suite of technology Paul has developed a new seeding system iTiLL® to improve crop establishment, especially in non-wetting soil.

Like many innovations it was triggered from a mistake. In 2011, Paul purchased an 18.5m John Deere air-seeder, which was set up with 25.4cm (10 inch) row spacing and controlled by +/-10cm guidance using StarFire™ 2 GPS.

In the first year the swath width was not set up exactly resulting in some overlap. This was resolved in year two resulting in each run being shifted by about 20cm. Seeding is carried out up and back, without race tracking/skipping rows.

When the crop emerged, there was poor germination in every other pass. On closer inspection the rows that were emerging were sown into last year's stubble row. Those that were failing were sown in last year's inter-row (see PAN Vol 9 Issue 3).

"Inspecting the top soil we found that under the stubble it was moist where the rainfall on the non-wetting surface had been wicked down the stubble into the root zone."

Paul's challenge was to ensure his seeder accurately followed the band of moisture under the stubble without blocking. He took a systems approach to producing a solution.

Paul's systematic approach to improving crop establishment in non-wetting soils. Photo: Paul Hicks

With AgMaster he helped to develop a knife point with a side wing. The point was designed to run about 25mm away from last year's stubble row; behind this is placed a continuous band of liquid nitrogen and a broad-spectrum fungicide (Flutriafol - Impact®).

The wing is designed to lift the soil under the stubble row, the seed is deposited from the wing and the soil drops back. If a soil wetter is being used, this is dispensed as a continuous stream with the seed at a rate of 1L/ha in 50L/ha of water.

"I was concerned about root disease and CSIRO is currently running a trial looking at the biology in these non-wetting soils. Initial results show there is more bacteria under the row, which is helping to break down the non-wetting properties and root disease has not been an issue."

Paul now uses RTK GPS on his seeding rig, which consists of the 18.5m seederbar plus about a12t triple bin and a liquid cart with two 7000L liquid tanks, which is pulled by a JD9520T tracked tractor.

To keep the seeding implement in place he uses a combination of physical and GPS guidance systems. Between the 10 inch rows runs an 8 inch paddle (7 inch in barley), which senses last year's stubble row. As this occurs, a signal is relayed to a hydraulic hitch and the bar is re-aligned with the stubble.

The system allows adjustment for use in different crops, for example the amount of stubble after canola is very different to a cereal. The software in iTiLL® allows for this and steers the bar accordingly.

The physical guidance can be run in tandem with JD iSteer™. This GPS guided implement steering system can be used when there is no stubble, for example when following a legume crop or where windrow rows have been burnt.

The system can switch between the two forms of guidance on the run.

"With dry starts, we have seen cereal yield improvements of 20 per cent using the iTiLL® system.

"I emphasise it is a system as it relies on good set-up of the seeding rows in the year before introducing the paddle. This means all equipment must only use one A-B line to ensure no errors can be introduced."

Other technologies

Paul is experimenting with an unmanned aerial vehicle (UAV) as a platform to carry a near infra-red/red camera to produce his own biomass images.

He is also looking forward to the new sensor head in the CropScan protein monitor on his harvester, as this should make protein readings more consistent with yield readings.

Paul produces his own prescription maps using the John Deere APEX software but all the grain yield and protein data and hay yield data are post processed by Precision Agronomics Australia.

Currently putting variable rate into practice is a fairly time consuming process. Data has to be exported from PCT's Gateway to APEX, where the prescription maps are created for phosphorus, which is based on replacement, and finally these are loaded into the seeding tractor.

"I am looking forward to implementing a wireless telemetry based system."

Based on the innovations to date and his aims for the future, it looks like more than just the climate will be changing at Pingrup in Paul Hicks' farming lifetime.

Details: *Paul Hicks, p_hicks1@bigpond.com*

YIELD VARIABILITY AND PADDOCK MANAGEMENT

Left - Chris Holland (manager) and son Broden Holland - Right.

The following article was first published in September 2019

Monitor helps simplify decisions

Sue Knights

From seat-of-their-pants fertiliser application to variable rate, the Holland family are ironing out a patchwork of yield variability.

Like many farming families, the Hollands have expanded their property and paddock size over generations. For them, the result on their farm at Thuddungra, north-west of Young in NSW, is a patchwork of variability across 4,500 hectares.

Two decades of yield maps were showing variation in wheat and canola across paddocks – up to 40% in wheat and 30% in canola, mainly due to inherent variation as paddocks were expanded.

Broden Holland, who farms with his parents and grandparents, says that although they were interested in

Farm profile

Farming personnel:	Broden Holland, his parents Chris (manager) and Kelly and grandparents Nevin and Marie Holland, 2 full time employees
Farm location:	Thuddungra, 30km north west of Young, NSW
Farm size:	4,500 hectares
Annual rainfall:	Annual 600 mm GSR 350 mm – winter dominant
Soil types:	sandy, clay, loam pH 4.6- 6.0
Enterprises:	70% cropping, 30% self replacing merinos
Yield:	Average wheat yield 3.5/ha, average canola yield 1.7t/ha

PA timeline

Technology	**Year started using**
Yield monitoring (sporadically) –	2002
Guidance Trimble Ez-guide –	2006
Trimble RTK –	2010
Yield data (using of maps and consistent data collection –	2015
Modified Marshall Multispreader and Wallaby spreader (VR lime and manure) –	2016
CropScan 3000H On Combine Analyser –	2016

Top PA tips

- PA tools are the last ten percenters. Timing, and general farming practices are still the most important.
- Adopting PA technologies and practices will most likely create more questions than answers.
- Identify your biggest constraint and see if it can be overcome by applying PA.
- Adopting PA takes time, make sure it is not to the detriment of other farming practices.
- Be prepared to make incremental improvements with PA.
- Purchase a protein monitor for your harvester and make sure you actively use the data.

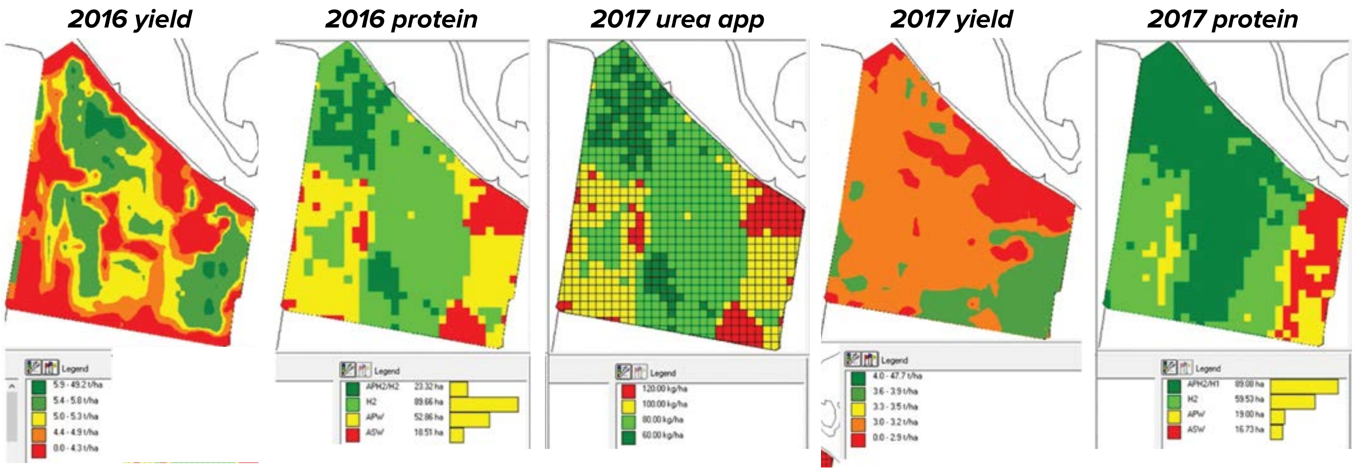

Figure 1. 2016 harvest protein map for wheat, matched variable rate urea map and resulting protein map for 2017 wheat.

Figure 2. 2017 yield maps showed a 40% reduction in variability compared to 2016 – on a paddock with a wheat on wheat rotation using the 2017 VR urea application map.

what the maps where showing them, they also left them somewhat confused.

"We suspected there was something to be gained from this information, but we were a little perplexed as to how to use the yield map data. There appeared to be a lot of 'noise' in them, which could be attributed to factors other than nitrogen."

This changed when Broden returned from Charles Sturt University in 2016 with a degree in Agricultural Business Management and an additional full-time employee was recruited. The family decided to invest more time researching and adopting new PA tools to improve efficiency and extract greater returns from the enterprise.

Starting point

Around the same time and at a SPAA event, the family came across grid soil sampling. It determines a baseline of pH and phosphorus variability.

The family decided to use service provider Precision Agriculture to map its variability for these nutrients. This was done on two-hectare samples across every paddock. From that information, variable rate (VR) application maps were processed.

Broden says the type of mapping chosen was based on cost and effectiveness. "Essentially, the maximum amount of information we could obtain with minimum investment," he says.

The results showed that pH ranged from 4.2 to 6.0 in calcium chloride. The aim was to lift this level to 5.5 across the property. Although the family did not expect to see a yield response from this goal, they knew it was going to be a significant risk to plant production if pH levels dropped any further.

Lime was applied using a Marshall Multispread with rates controlled via the Marshall app and rate controller retrofitted to a 810T machine. This approach was selected for ease of use and low cost. Using the application map, lime was spread at VRs, from 500 kilograms a hectare to 3,500kg/ha.

The grid soil samples showed phosphorus varied from a Colwell P of 20 to 80 and a target of 55 was established. To achieve this, rates of 1,000kg/ha to 7,000kg/ha of chicken manure at 25 kilometres per hour were applied using a Marshall Multispread hydraulic rate control kit retrofitted to a Wallaby Manure Spreader.

Manure was chosen based on numbers: The family was able to obtain manure economically, initially from their own on-farm poultry operation and then from a nearby business.

The farm has now been progressively treated during the past three years for both pH and phosphorus. In 2021 some paddocks will be re-tested to determine the effect of the VR applications and then maintenance levels of manure applied every three to five years.

Broden says that at $17/ha, the soil grid mapping exercise was not cheap, but the family will consider re-mapping some paddocks every five years to monitor changes.

Nitrogen challenge

The nutrient still to be addressed however was nitrogen (N). It was proving to be more of a challenge as it can be cost prohibitive to map any variation. This is partly because N mapping needs to be done more frequently than pH and phosphorus, while the Hollands felt it was difficult to attribute variation solely to N levels.

However, following advice from their local dealer and agronomist and installing a 3000H protein meter on their Case 7240 harvester three years ago, they had a significant break-through. It led to blending benefits and eventually N-prescription maps.

Table 1.Formula used for variable rate of urea applied according to previous crops' protein level.

Protein %	Rate of urea applied (kg/ha)
>13.5	30
>12.5	60
>11.5	90
>10.5	120
>9.5	150
<8.5	180

The 3000H protein meter is a near infrared (NIR) analyser designed to measure protein, oil and moisture content in grains and oilseeds as the crops are harvested. This data is presented in real-time paddock maps, trend plots or bin by bin. Maps can be sent to a website for viewing on a tablet, computer or mobile phone.

"We are able to collect protein, oil and moisture data every 5-10 seconds or at approximately 15-20 metre intervals across every cropped paddock. Initially this gave us insights into how to blend our crops for protein and moisture during harvest using mother bins and achieve greater returns," Broden says.

The Hollands estimate that using the data from the 3000H to blend grain to a higher specification returns a minimum of $15,000 a year. Additional gains can be achieved when the protein data is used to establish N prescriptions.

VR urea application

The Holland's N strategy aims to maintain a protein level of 11.5-12% in wheat, with VR maps changed depending on the season to reduce protein variability across paddocks. The same method is applied to canola in the following year. The method needs to be further tested but is showing very convincing data trends across both crop types.

Figure 1 shows the 2016 harvest protein map, the matched variable rate urea map and resulting protein map in 2017 for wheat. Broden used a simple calculation shown in Table 1 to determine the VRs for urea.

"Initially, we chose to keep our VR approach simple by separating protein from yield to avoid the noise that we saw in the yield maps," he says.

With a complete paddock protein map, it takes around 10 minutes to make a VR urea map regardless of size of paddock.

"This is much more time efficient than using yield maps or tissue testing and so far, we have been pleased with the results," Broden says.

Variable rates of urea were applied using an Amazone Profis Spreader and Amatron-3 with VR controlled by serial rate control through Trimble FMX. Figure 3 shows the reduction in yield variability for a wheat crop.

Further investigation

Calculating N rates based on protein is a simple and less time-consuming way of applying N. However, yield may still be variable so further investigation is needed.

Figure 3 shows a correlation map of yield and protein dividing the paddock into four performance areas. This enables strategic placement of soil tests or provides defined areas for ground truthing and further investigation of the crop's performance.

Strategic ground truthing over the past three years has been carried out using deep N soil sampling on high and low performing paddock areas guided by maps such as the one shown in Figure 3. So far the deep N data has correlated well with the protein monitor and tests will continue each year until adequate information has been gathered and the method is fully tested.

Generations of insights

All generations of the Holland family have learnt from their venture into PA.

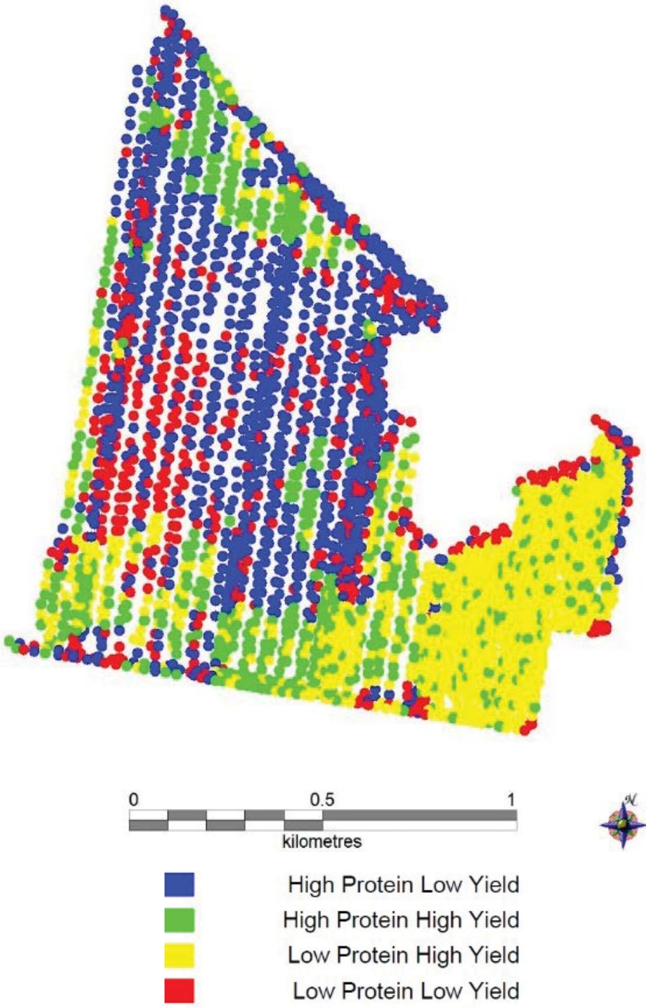

Figure 3. Correlation map combining 2017 yield and 2017 protein data.

"Although a bit unorthodox, our initial foray into PA, driven primarily by time and cost savings, is proving beneficial, we can measure that it's working," Broden says.

Broden's grandfather Nevin Holland has seen many on-farm developments in his life - from the introduction of no till to the use of chemicals – but now believes technology or PA is farming's biggest advance.

"We started with 'seat-of-our-pants' agriculture, didn't know how many or where to put our bags of super (fertiliser) per acre. Now we have variable rate applications for just about everything and our management is more precise within the paddock as the paddocks become larger," he says.

"Increasingly Australian agriculture needs to be more sustainable and competitive. This means more precise application of inputs and growing more from less, and only technology and precision agriculture can aid in that."

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Luke Bradley.

The following article was first published in April 2020

Contracting leads to variability plan

Rebecca Thyer

Treating areas differently can decrease environmental and financial risks.

Although he grew up around grain farms in central Queensland, it was while contract farming and harvesting that Luke Bradley started thinking more about variability.

In an area that stretches about 2,500 kilometres from Queensland's Richmond to Uralla in NSW, Luke was contracting up to 20,000 hectares. It gave him the chance to mull over the variability he was seeing – and on-farm responses.

"It was easy to see there were enormous variations in fields. Yet, they were all being treated the same way, in regard to seeding rates and nutrition. It was a 'we've always done it this way approach'."

Luke says this was happening despite most farming equipment being able to observe and store data, and in many instances, vary rates. It led Luke to look more closely at his home farm.

"I started to think, we need to be flexible to deal with our seasons to decrease risks both environmentally and financially. We have the ability to treat areas differently – and the equipment and technology to do that – we just need to make sure it is worthwhile."

Farm profile

Farming personnel:	Luke Bradley and wife Sophie and Luke's parents Peter and Kerrie
Farm location:	Springsure, central Queensland
Farm size:	5,300 hectares
Annual rainfall:	Annual 603mm
Soil types:	Alkaline self-cracking clay with a pH of 8 to 9
Enterprises:	Sorghum, corn, chickpea, wheat and barley cropping, plus a beef cattle operation
Yield:	3t/ha sorghum

Top PA tips

- Using readily available, public and on-farm data you can make financial and environmental justifications for varying inputs, such as nutrients.
- Historic NDVI biomass data can be found on-line if you have not collected it previously.
- Water and nitrogen use efficiency go hand in hand but dryland farmers have no control over water. Biomass maps can help show where water is available.
- Be prepared to learn and tweak your thinking. I thought I knew everything about WUE; now I realise there is plenty still to learn.

This thinking eventually led Luke to pursue a Nuffield Australia Farming Scholarship, but in reality, contracting was Luke's first scholarship.

Home and away

The lessons learned contracting he took home to Springsure where he farms 5,300ha with his wife Sophie and parents Peter and Kerrie.

Together they crop 4,000ha of sorghum, barley and wheat and run a 300-head beef cattle herd.

Luke had collected crop yield data for seven years and had begun to benchmark their water use efficiency (WUE) with farm consultancy Agripath.

The farm's annual average rainfall is meant to be 603mm. But Luke says the past four years have seen them record their worst 12, 24, 36 and 48 months in a 132-year record keeping history. Although they still "turned over some grain". Water and its use is paramount for their dryland operation.

"Water is the main variable we need to manage, yet the one we have least control over. WUE and nitrogen or nutrient use efficiency (NUE) go hand in hand, and we need to maximise both. If you don't have an agronomic system in place that maximises WUE, like stubble retention, then any NUE efforts won't work."

The benchmarking with Agripath helped show the Bradleys their WUE rates based on the season and production. "It was all good, but it was still an overall average.

I wanted that information to be more defined."

So, Luke, an industrial electrician by trade and happy to spend time exploring and interpreting data, started his own calculations. He wanted to work out whether creating and implementing variable rate nutrition prescriptions would be worthwhile.

Using readily available WUE data sets from the GRDC for sorghum and a software program called Agrian® he began the work. Luke explains that he exported his harvest yield files to the program and shifted the parameter bars to include nine nutrition zones, building a spread sheet for sorghum yields, based on varied inputs.

That work began to justify the costs involved with creating a variable nutrition program. "It showed a 7% return on investment if we developed prescription maps for our urea.

"This is the data I wanted to justify spending money on changing our nutrient management. I was not re-writing the book but just taking that readily-available information and adding it into our business risk profile to create prescription maps."

With step one – the justification – done, Luke began the process of building the maps. For that, he involved Echelon®, a PA solutions company.

Step two

Echelon® offered the Bradleys variable rate (VR) services that are quite common in the US, Luke says. "And we decided it was worth doing VR for our sorghum on our 4,000ha through one of their programs."

Although Luke had run some calculations himself, he says Echelon® was able to offer a more detailed program, using extra data that included historic NDVI biomass data from satellites.

The colours on the NDVI map (Figure 1) show the average rate of biomass across the field. The red zones show where the biomass is less vigorous and are in Luke's lower plant available water (PAW) zones. In contrast, the darker green zones are where more water is available.

The maps help with Luke's aim to match WUE and NUE. "The areas that we will get more production from, those with a higher PAW content, will receive more nutrition. And vice versa."

Now Luke runs a continuous variable rate nutrient program. "It's scary when you see the controller changing all the time, but it is working well."

Urea used to be blanket rated at 120kg/ha for sorghum. Based on financial risk, Luke decided his urea outlay was still to average 120kg/haacross the paddock, but it would be applied at varying rates, with Echelon®'s help.

"Based on the prescription maps for sorghum, we now spread 60kg/ha in low yielding areas and up to 240kg/ha in the high production areas."

These prescriptions maps are very similar to Luke's initial maps that gave him the confidence to go to VR.

Luke runs all John Deere software and the maps developed by Echelon® were compatible with this and worked well. "John Deere software means we can use third party providers for other jobs and put that information or decision modelling back into our farm machines."

Machinery-wise, the Bradleys added ISOBus-approved equipment on spreaders and sprayers, so all rate controllers are aligned with John Deere software and systems. "

Most people have the hardware that can be equipped cheaply with rate controllers. We have not changed the method of application, just the rates."

The plan is working well, and Luke has seen more than the 7% return on investment that he had originally calculated as part of his justification. "We have probably surpassed that

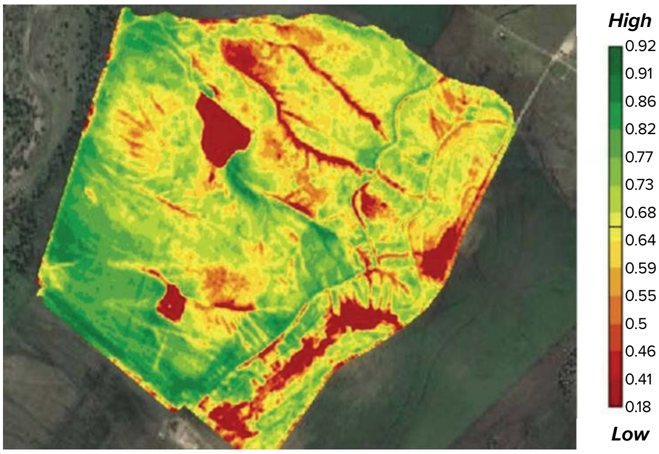

Figure 1. The colours on this NDVI map show the change in biomass across the field. The red zones show where the biomass is less vigorous and are in Luke Bradley's lower plant available water (PAW) zones. In contrast, the darker green zones is where more water is available. Luke aims to match PAW to nutrition. "The areas that we will get more production from, those with a higher PAW content, will receive more nutrition. And vice versa."

He says the image is a good example of the variation across his farm.

GRDC

As a Nuffield Farming Australia scholar, Luke (right) met Dr Bob Stewart from West Texas A&M University (left). Being a dryland grower, Luke thought he knew everything about water and WUE until he met Bob, who taught him to think about how water is turned into grain.

calculation and spent less too. Inputs are focused on the 60% of the paddock that makes the money."

As well as the financial gains, he says that the change is also important to the environment. The family farm falls in the Great Barrier Reef watershed, where cane farms are already being regulated on crop nutrition. "We've seen it happen to cane farmers and I think the reef regulations will become stricter. Our job is to use best practice and innovation to the best of our ability.

"Our spreaders and spray rig are all VR capable so we are organised and ready for any regulatory changes that may happen."

Future

Luke says he is only at the very beginning of where PA tools and technology will take him and the farm.

"For example, we have levels of sodicity at about 5% exchangeable sodium on 1400ha. I know we could address it, but it is cost prohibitive to fix with a blanket rate of gypsum across this area, especially as it is also costly logistically to transport that amount here."

However, undertaking some EM38 work – to provide a measure of soil electrical conductivity and converting this to soil type and sodicity mapping – is helping to identify the areas that will benefit most from treatment.

"I still need to justify what will be the benefit if we do spread gypsum and the income we will get from that decision."

Another plan is to look at the evapotranspiration (ET) in the fields. "I've talked to a few companies about this, to learn how well our total ET in crop and in season compares against WUE.

"Doing so will allow me to assess how well we are set up for making the most out of a season. By that I mean – how well is our stubble management working, our rotations, our move to narrower rows, if we should plant more cover crops or not plant in certain areas. We have the ability to treat areas differently – and the equipment and technology to do that – we just need to make sure it is worthwhile."

Scholarship

It has been a busy few years for Luke. Not only does he (and his family) run the grain and cattle enterprise, but he has undertaken a Nuffield Australia Farming Scholarship.

Supported and often joined by his immediate family, Luke travelled to the US, Argentina, Brazil and New Zealand to see PA and intensive farming in action.

Luke says he wanted to look at similar climates and situations to his.

Building on what he learnt in Australia, one of Luke's memorable moments was meeting Dr Bob Stewart from West Texas A&M University, who he leads the university's Dryland Agricultural Institute.

"I thought I knew everything about water and WUE until I went to Texas and met Bob," Luke recalls.

He says Bob taught him to think about how water is turned into grain. "It is all very well looking at the research data, but how do you manipulate it to your farming system? It's not just about the rain that falls, but also about the water lost through transpiration and evaporation."

Luke is starting to build a system that correlates to these learnings, improving water use.

"We used to have wider rows and have moved to narrower rows (within our CTF system). That should see us grow more biomass in the plants and more organic matter in the soil. Future steps also include considering different harvest options."

Details: ***Luke Bradley, 0400 324 441, @woolaroo5, woolaroo5@bigpond.com***
Luke's Nuffield presentation is available at https://www.nuffield.com.au/luke-bradley-2017

A coin sized temperature sensor suspended 50cm above the ground in a faba bean crop at the mid-north site near Mintaro, SA. Photo: CSIRO

The following article was first published in September 2018

Measurement hones frost management

Sue Knights

Without measuring frost, it remains difficult to manage. Working with farmers, a group of CSIRO scientists in SA are 'wiring up' frosty farming regions to better understand this limitation and improve its management.

Uday Nidumolu from CSIRO discusses his research on frost monitoring with Precision Ag News contributor Sue Knights.

Frost management in grain crops has proven a hard nut to crack. Why work with farmers on frost?

The impact of frost in any production system is erratic as it can differ each season and from region to region. Farmers deal with frost in very different ways according to their risk appetite and can often adopt conservative management practices to cope. Most risks involve a trade-off and being overly conservative on frost risk. For example, delaying sowing can lead to increased risk of heat and water stress and indirect financial loss.

For these reasons collaborative work with farmers on frost management is important. While scientists can help define frost risk and potential impact, it is farmers who deal with that risk, and in the end define the sorts of information that will make a difference to running their farm enterprises.

Our work is part of the multidisciplinary Grains Research and Development Corporation's National Frost Initiative. Collaboration with a diverse team of scientists within this initiative brings new ideas and approaches to the constraint, which we can then directly test with farmers.

How many sites do you have wired for frost?

In the first couple of years (2016-2017) we had two sites on farmers' properties at Mintaro, near Clare in South Australia, and in Hopetoun in the Victorian Mallee. The aim from these sites was to collect preliminary data to establish a statistical model to map cold days for each site.

Eighty loggers were installed over the June-to-October period at both sites covering a four-by-four kilometre area at Mintaro and a three-by-five km area at Hopetoun.

Coin-sized loggers were used because they are reasonably robust, can cover the required temperature range, are able to log at 30-minute intervals, and have a suitable memory. Each logger costs about $50 and can be left up to 80 days in the

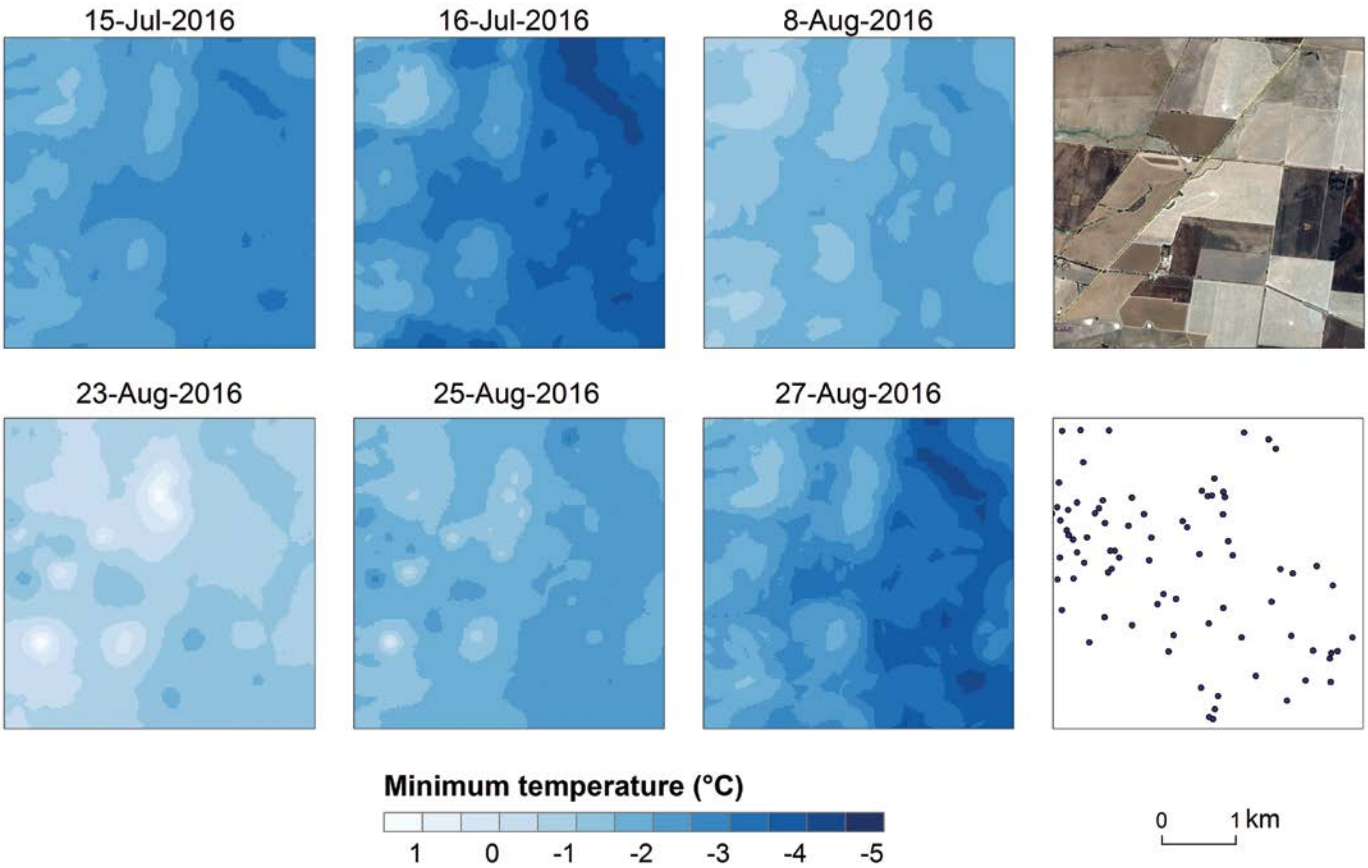

Figure 1. Frost maps generated from the Mintaro, SA site in 2016. The Figure depicts co-krigged (spatial interpolation) maps of 'minimum temperature' for the Mintaro site. The area is 4km X 4km. The temperature loggers have been deployed using a statistical sampling scheme that captures the terrain variability. The time each image was taken varies as the minimum temperature time might vary by day. Logger location (bottom right) directly overlays the terrain photo (top right). The terrain is higher on the left and lower on the right, with two streams flowing from left to right.

field before download, although we downloaded at shorter intervals. All loggers were installed at a 500-millimetre height in the crop and their positions were recorded with a RTK Geographic Positioning System (GPS). Each site had a mini weather station installed to record temperature, rainfall, relative humidity and wind direction.

In 2017-18 we have included six additional sites for model validation in the Southern Grains region. The focus of the work at these sites is to gather data to validate the statistical model, and capture data from a large and varied geographical area. We also want to engage with as many farmers in frost prone regions as we can.

What have you and the farmers learnt so far?

Together with static maps, which are detailed to 30m spatial resolution (Figure 1), we created videos of the temperature changes at the pilot sites at one-minute intervals. Seeing things dynamically like this has showed us that the flow of cold air across a landscape is much more complex than is normally understood. While we see patterns occurring in the maps where certain areas are consistently affected by frost the videos have shown us more surprising results. It turns out that cold air does not simply flow like a stream to low points in the landscape, but has more complex flow dynamics.

Our maps generated from the logger temperature data have been overlayed with maps prepared by farmers marking areas they know are commonly frosted in their landscapes.

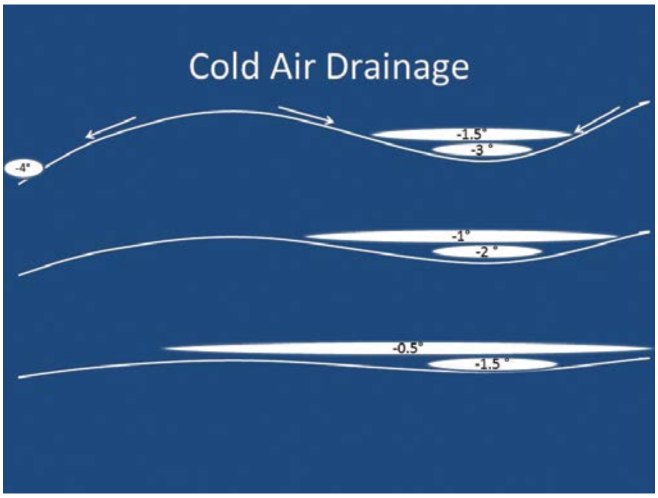

Figure 2. Videos have shown surprising results: It turns out that cold air does not simply flow like a stream to low points in the landscape, but has more complex flow dynamics. Photo: Mick Faulkner

The logger-generated maps have highlighted new frost areas, and although yield maps could perhaps be used as surrogates, they are often too blunt as an instrument. That is because yield is the consequence of many things that occur during crop maturation, in addition to frost.

Uday Nidumolu installing a mini weather station at the Jabuk trial site, SA Mallee. Photo: CSIRO

Being able to confirm that some areas are consistently frosted means that farmers can plan to use these for other purposes at the start of a cropping season.

For example, the area could be used for livestock or to produce a crop that is less susceptible to frost.

(A tool available to aid this decision making is at https://www.nvtonline.com.au/frost/).

Additionally, after a frost event, the maps may help direct farmers to potential frost damage in a crop.

Farmers are looking ahead on how to use the data collected, suggesting that in the longer term the maps might provide the basis for selective grazing using virtual fences – that is, using electronic collars on animals torestrict access to non-frosted areas.

What is the next step for this demonstration work?

Over the next year we will be investigating methods of linking up the loggers via telemetry to enable real time data capture. This will make the system much easier to use. A real time data stream could enable both researchers and farmers to get into the field immediately after frost events to assess damage. In the longer term we will keep a watching brief on new technology to determine what instruments may compliment the use of frost maps to improve frost management practices for farmers. For example, hand held spectrometers that rapidly detect frost damage in crops could enable farmers to make more informed decisions on salvage methods for frosted crops.

Brief Biography

Dr Uday Nidumolu is Principal Research Scientist with the Climate Smart Agriculture/Agriculture Systems Modelling group at CSIRO based in South Australia. His work focuses on linking climate science (short-term weather, seasonal and multi-decadal climate change scales) with food systems analysis to support decision-making processes from farmer to policy levels so as to achieve sustainable development outcomes.

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Phil Longmire. Photo: Emma Leonard

The following article was first published in September 2018

Tools to meet a need

Emma Leonard

With odd shaped paddocks or in paddock obstacles including ponds, Phil Longmire is using PA tools to optimise input placement and logistics.

Profitable farming is the number one objective for Phil Longmire and investments in time and money into precision tools and data farming have to pay a return. Ideally, he is looking for payback in three to four years, but as technology is rapidly moving, it can be easy to 'back the wrong horse', so Phil spends considerable time researching before a purchase and analysing the results.

"Where possible I use open source software and try to make as much use of the technology that comes with a machine," said Phil.

While he considers timeliness of operation as is his primary goal for profitability, putting inputs where they are required is a close second. This is especially true for Phil's farm because he has many irregular shaped paddocks or obstacles within the paddock.

By resizing some paddocks and planning internal roads to minimise the distance to storage, Phil has increased efficiency. For example, he has improved harvest capacity with lower machinery hours. Controlled traffic, with matched implement widths has also helped improve efficiency but in paddock obstacles continue to present challenges.

"Our controlled traffic farming (CTF) system is increasingly being interrupted due to waterlogging in low lying areas. This is caused by high summer rainfall remaining at autumn seeding."

In addition to trafficability, weed management and salinity problems, these semi-permanent ponds create a need for multiple headlands within the paddock.

Farm profile

Farming personnel:	Phil and Bindi Longmire. All casual labour. Three seeding, five harvest extended either side of both periods
Farm location:	100km east of Esperance, WA
Farm size:	5,700 hectares
Annual rainfall:	Average annual 450mm to 475mm
Soil types:	Shallow sand over clay and red to grey sodic clay loam. A small area is non-wetting, pH 5.5 – 7.0
Enterprises:	Continuous cropping – five year rotation – PWCWB - 16% field peas, 33% hard and APW wheat, 16% canola, 33% malting barley. First year of lentils
Yield:	Wheat 2.5 to 6.5t/ha

Top PA tips

- Analyse your system and prioritise your best dollar spend in digital technology for the quickest payback. Do not try to jump too many hurdles at once.
- Good planning and constant reviewing of an integrated system from the ground up - allow a lower long term investment in tools that have longevity.
- Technology must be operator friendly for training casual staff. Use common screens with cheat sheets to assist navigating software to help keep everything running.
- Surround yourself with a support network that can help you turn technology into profit.
- Don't collect data for data's sake – use it to make better decisions and improve your business.

Boundary management

For nearly 10 years, Phil has used a multiple rate system creating one or two boundary zones for fertiliser and seed depending on the proximity to the edge of the paddock. For example, the outside boundary run might deliver 85kg/haof fertiliser (14.5N:14.5P:0K:9S) and 53kg/ha of seed (barley), while the second run with the majority of overlap will distribute 75kg/ha of the same fertiliser and 42.5kg seed. This compares to a paddock rate of 90-100kg/ha of fertiliser and 53kg seed. This management system will become partially superseded by section control technology.

"Our objective is to minimise haying off where overlap occurs while maximising germination and ground cover."

Processing data, including creating variable rate (VR) maps for contract VR spreaders and sprayers is now outsourced.

Initially Phil processed his own data but as services became available, he felt his time was better spent interpreting and using the data.

Phil has been researching section control systems for his 18m Ausplow DBS seeding bar and Simplicity aircart, pulled by a Case Rowtrac 500 with a trailing liquid cart. He plans to upgrade both the air and liquid cart with section control systems by next seeding. In the meantime manual observation is key in minimising overlap in his obstacle laden and odd shaped paddocks.

Phil has identified that driver ability to judge when to pull out around these in paddock obstacles and final runs is the biggest determinant of overlap in his current system. Even with +/-2cm accuracy RTX guidance (the Trimble system that uses satellite correction rather than terrestrial base stations) and autosteer, in 2017 they averaged 14% overlap across the farm at seeding.

"Last year, our smallest overlap was 8% across a 406ha paddock and the highest was 20% in a 166ha paddock."

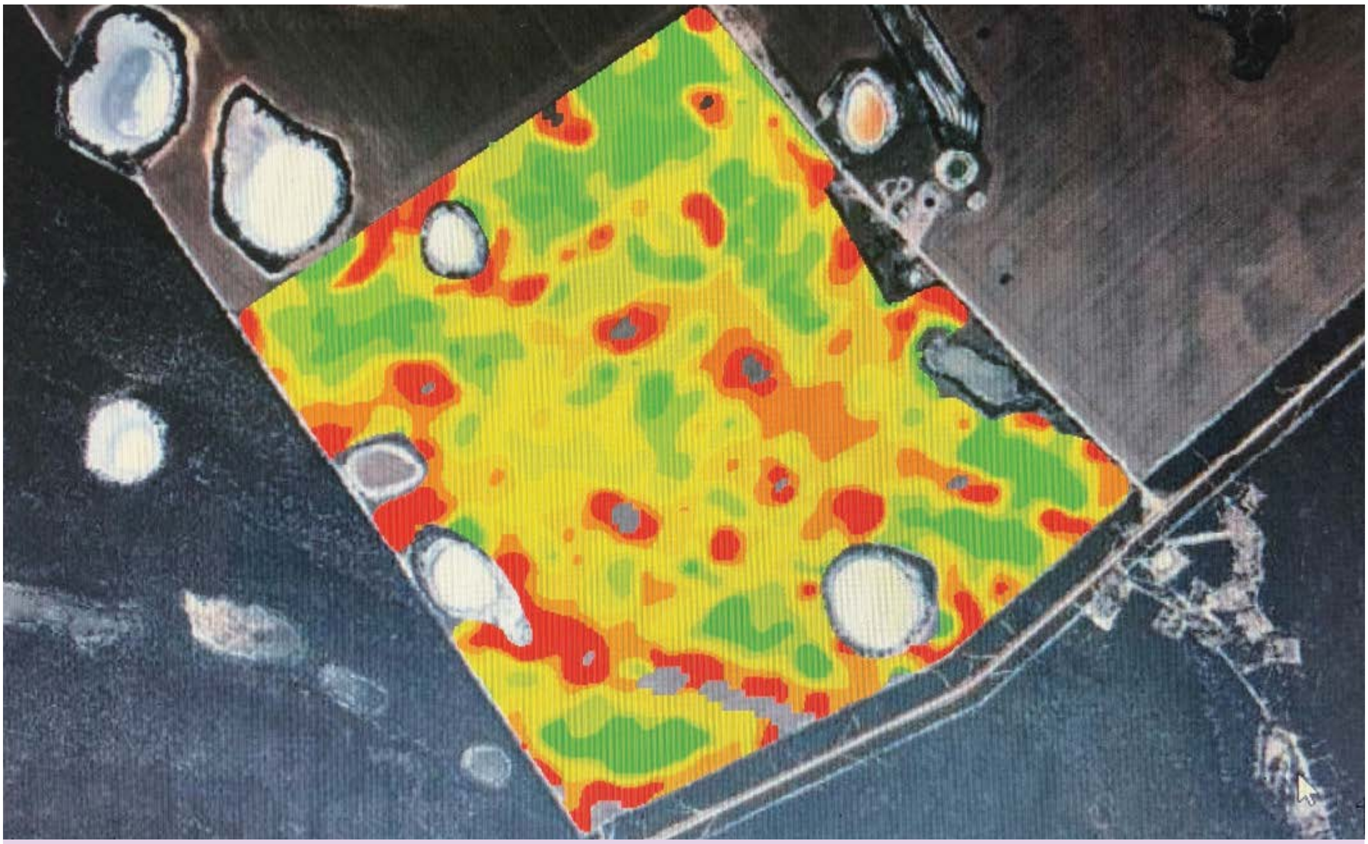
Across the whole cropping program, that represented an extra 27,800 litres of liquid nitrogen (Flexi N) and 28 tonnes of extra starter fertiliser was used due to overlapping implement widths.

"Finding permanent labour is an on-going problem in our area, so we strive for a system using casual labour on modern machinery with low maintenance costs.

"Boundary steering with automatic end turning is now helping to reduce the upskilling required to minimise damage and overlap at the paddock ends."

Phil anticipates going to section control on the seeding bar should reduce overlap to about 8%. This is based on the

Precision tools are helping manage areas prone to waterlogging by allowing summer crops to be sown precisely in these patches, while the surrounding area is in winter cereal. Photo: P Longmire



Boundary steering with automatic end turning will soon be augmented with section control to minimise overlap in Phil's obstacle laden, odd shaped paddocks. Photo: P Longmire

improvement he has seen since upgrading from a boomspray with seven sections to 36m Case IH Patriot® sprayer with 72 individually controlled nozzles. Not only has chemical use reduced by a further 4.5% with the change to individual nozzle control, Phil has seen reduced damage from clethodim when overlap occurred on canola.

Phil is also looking closely at the feasibility of implementing autonomous systems for spraying and simple tasks such as rolling and tramline renovating.

Soaking up excess water

Precision tools are not only helping manage crops at the perimeter of the waterlogged areas, but also within these zones. Phil has been experimenting with growing summer crops in some of the wet areas, such as millet and tillage radish, to use the excess soil water. Soil moisture content was measured before seeding and after harvest/crop desiccation using a Topsoil Mapper. This new electromagnetic sensor is able to measure at four separate depths to provide subsoil maps that will indicate differences in soil moisture and salinity. It is early days with this tool but Phil is keen to keep experimenting with the Topsoil Mapper. The aim is to establish a residual soil water map, while taking into account issues of salinity.

A series of deep drainage channels to connect low lying areas have been implemented over the past six years, with a plan to incorporate both systems.

Grain moisture and protein

While other farmers are putting a protein analyser into their harvesters, Phil has pulled his out and put it onto the 40t triaxle Oztec tramliner chaser bin. This is also fitted with scales. Esperance's coastal environment often results in rapid changes in grain moisture content and a short harvest window. In addition to measuring grain protein, the analyser also provides reliable measurement of grain moisture. Having a moisture measurement for each chaser bin load enables improved storage management.

"With the use of grain bags at harvest, this allows the tonnes and moisture to be recorded, with an approximate location in the bag."

Connected to an in cab WiFi network, the data from the analyser will be automatically transferred to the home office in the 2018 harvest.

Evolving systems

Phil is always looking at new opportunities and ways to improve his farming business. Collecting data for data's sake is not an option for Phil. He wants to use as much information as possible, providing it helps him make more profitable decisions that help him sustain his business. So, while he started to gather protein data spatially on the harvester, it is not a data layer on which he currently places emphasis or uses for his variable rate nitrogen because of the lack of stability in maps between seasons.

Currently, variable rate prescriptions for fertiliser are based on a mix of electromagnetic soil data and yield maps. His goal is to provide a rate that is 5% more than the five year average of nutrient removal.

Phil is unsure where the drainage program and soil water mapping will lead but if successful, a new in paddock, dual cropping farming system might develop. Watch this space.

Details: ***Phil Longmire, 0429 787 055, PBLong@bigpond.com***

The following article was first published in June 2017

Variation management

Emma Leonard

Using yield maps to quantify and locate variation has helped Scott Oehm better target inputs to reduce this variation.

Can you see a yield difference of 1t/ha in your wheat crop? Probably not. Neither could Scott Oehm, although he knew he had variation across his paddocks. However, it was not until he started recording yield that he was able to locate and quantify the extent of the problem, which in most paddocks would be at least a range of +/-1t/ha for a cereal crop.

With yield maps, he was also able to start answering questions about what was causing the variation and how could it be managed.

"Typically pH, soil water holding capacity and nutrient availability influence our yield variation, but to different extents in different parts of each paddock and across the farm.

"Then, as now, I am not actually concerned about the accuracy of the yield, but I want to measure the relative variation so I can decide where to ground truth to identify the causes," said Scott at one of the five IT in Ag Road Shows held in Central West New South Wales in March.

With two part-time employees and a contract harvester, Scott and Sally Oehm crop 3,328 hectares centred on two blocks at Tooraweenah and Collie, in central NSW. They work with private agronomist Glenn Shepherd, IMAG consulting Dubbo, who cleans up the data and produces management zones and prescription maps.

The farm is run on a 9m controlled traffic system on 3m wheel tracks. The heavy soils take time to dry out after rain and CTF has improved timeliness of operation, as well as reduced soil compaction. CTF with RTK guidance has enabled inter-row sowing.

Unlike many, Scott started the conversion to CTF with the harvester opting for a 9m front. As implements were purchased or updated, they had to fit a 9m system. The harvester is unloaded into a chaser bin on the adjacent tramline so there is no jumping off tracks. Autosteer and matching speeds, by talking over the radio, help take the guesswork out of unloading.

Farm profile

Farming personnel:	Two part-time employees. Plus contractor at harvest
Farm location:	Tooraweenah and Collie, NSW
Farm size:	3,328 hectares
Annual rainfall:	Annual 556mm, GSR 296mm
Soil types:	Red loam creek flats to sand to black plasticine clays. pH 4.8-6.2
Enterprises:	winter cropping - wheat, barley, triticale, canola, lupin, faba beans, chickpeas
Yield:	Average wheat yield, 3.2t/ha

PA timeline

Technology	Year started using
Autosteer –	2006
Yield monitoring –	2006
Controlled traffic –	2007
RTK guidance –	2011
Variable rate – liquid and granular fertiliser, lime –	2013
Remotely piloted aircraft –	2016

The 27m boomspray is used to apply nitrogen as well as pesticides. The JD disc seeder is an 1890 with a 9000L Gyral airseeder cart. In addition to autosteer, Scott runs iTec™ Pro that coordinates vehicle and implement functions with end turns.

"This system allows the operator to concentrate on the moving parts of the seeder without having to worry about lifting up discs or lining up the next run.

"Boot block sensors are another tool I use to help take the stress out of seeding and prevent the frustration of seeing blocked runs for the next six months."

Each year between 10% and 20% of the farm is under long fallow, primarily as an opportunity to control ryegrass and black oats with different herbicide chemistry.

Scott has found a massive benefit from changing to RTK, not least that year on year data really matches up and inter-row sowing is possible. Photo: Scott Oehm

The remainder is sown to wheat, barley, oats, triticale, canola, lupins, field peas and chickpeas. Pulses are sown on the inter-row of cereals for support and protection and cereals on the row of pulses for nitrogen or canola for biofumigation.

Yield monitoring

The ability to actually measure his crop variation was the reason Scott Oehm started to use PA.

Scott uses all John Deere equipment fitted with JD 2630 screens and RTK guidance. He also uses Apex™ software. Having one system helps keep it simple.

RTK guidance was not added until 2011, six years after he started yield monitoring. Scott has found a massive benefit from RTK, not least that year on year data really matches up.

While Scott has been gathering yield data for the past 12 years, his diverse range of crops, plus the use of long fallow, mean in some paddocks he may only have two or three yield maps for the same crop.

"Generally I try to work on a cereal, canola, cereal, pulse, cereal, canola rotation that sometimes has to be flexible with seasonal conditions, for example, if it is too wet or dry for planting a particular crop type."

From his experience, most yield data has been really interesting and helped him target points for further investigation. Scott encourages other growers to start collecting their yield data as soon as possible, because no one can sell you retrospective records and they are a great starting point for understanding where changes occur.

Scott works on the philosophy of calibrating the yield monitor once each year and leaving it because he does not need his maps to be exact to the last kilogram.

"I am trying to identify patterns of variation, with the number of crops I grow plus seasonal influences — it is relative changes, not exact yields that I need."

His yield maps correlate well with soil, with the lighter sandy ridges producing less. However, lupins generally defy this pattern as they perform poorly on the heavy soils (Figure 1).

"Sometimes a yield map can be crop specific, so it is important to only combine maps from crops that respond in the same way to the paddock soils; seasonal effects such as frost, water logging or drought also need to be taken into account.

"I am continually relooking at old maps and assessing patterns of variation in relation to crop type and season because I need to use truly consistent data to start using management zones."

Scott is using multiple years of cleaned, combined yield data to produce in-crop nitrogen prescription maps. Four zones, high, medium, low and zero nitrogen, are created based on average production figures. These zones are ground truthed to determine nitrogen levels and from this, rates are assigned to Apex™ (Figure 2).

Nitrogen is either applied by the spreader, which can spread up to 36m (every fourth tramline) or a liquid urea through streamer nozzles on the boomspray.

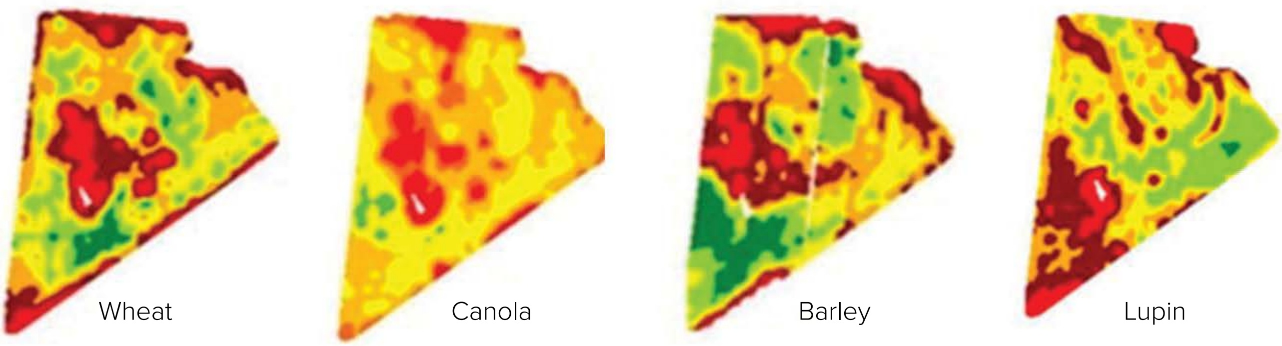
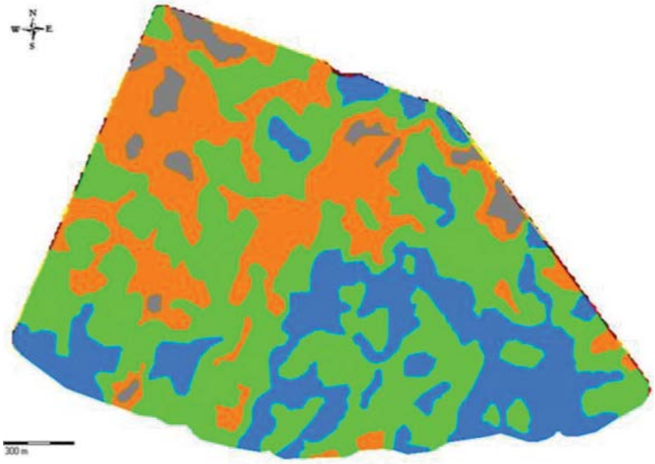


Figure 1. Patterns of variation under different crops in the same paddock. Red is low yield and green high yield. It can be seen that the pattern changes under lupins which do not like the heavier soils. Care needs to be taken when combining historic yield data to create management zones.



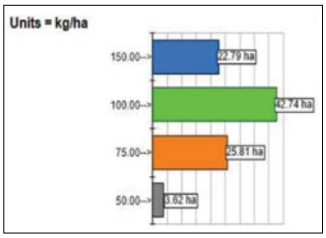


Figure 2. An example of a variable rate nitrogen map based on five years of yield data to create input rate zones.

The software presents the data as a map and a bar chart of yield zones by area (Figure 2), which helps identify if there is a sufficient area to justify a change in management and to calculate input requirements.

Variable rate lime

Soil pH has been identified as a major yield limiting factor across parts of Scott's paddocks. Lime is generally applied in the long fallow to take advantage of out of season rates and availability. For the past three years, Scott has been using variable rate lime, which has introduced significant changes, but not necessarily savings.

A contractor carries out on-the-go pH and cation exchange sampling using a Veris machine. Between 10 and 25 samples are taken per hectare. These are ground truthed and cleaned, and provided to Scott as a pH zone map. In consultation with his agronomists, lime rates are calculated to ensure pH and cation exchange are balanced.

Lime is spread using a 17000L Bredal spreader which is run up every tramline (9m) to ensure a consistent and even spread pattern.

Figure 3a & 3b show a typical pH map and the lime prescription map for the same 105ha paddock. There are four rates – 5t/ha, 4.3t/ha, 3.4t/ha and 0t/ha. These zones provide sufficient, but not too great a rate change for the spreader.

In the example in Figure 3, a blanket rate of lime would have been spread at 2.5t/ha, a total of 263t of lime at a cost of $16,275 or $155/ha if lime is $62/t. Using variable rate increased the total lime required to 313t and increased the cost to $185/ha, an additional paddock cost of $3,000.

Scott uses his historic, current and will use his future yield maps to help assess how variable rate liming is changing the variability in his paddocks. In one year, he has already seen positive reduction in the range of variation.

"I will be carefully monitoring yield and change patterns of yield variation over the next eight years to make sure variable rate lime is cost effective."

In another paddock (100ha), the same process resulted in a saving on lime of $7,000.

Scott prefers more rather than less zones to better match rate to need. They also make it easier for the tractor because if rate transitions are too extreme, the change in speed can cause too great a demand for oil and cause engine problems.

"From my experience, spread speed is dependent on rates - higher rates require slower speeds. Check the revolutions per minute of the spinners as you change rates from 1t/ha to 4t/ha at the same ground speed – then you will know why I say this."

Scott also suggests mounting a cheap reversing camera on the back of the spreader to see how the lime dumps off the belt onto the spinners at higher ground speeds.

What's next?

Ideally, Scott would like to be able to map pH across the farm at every seeding by pulling a pH sampler through the soil as part of the seeding bar. From discussions with suppliers, he is hopeful such a sensor will be available in the next few years.

Scott has evaluated the use of an on-the-go protein meter at harvest, but could not establish how he would increase profit by its use in his system.

He has already purchased a remotely piloted aircraft (RPA – drone) and is excited by the software Drone Deploy in which two and three dimensional images are created, as well as combined images for crop biomass and plant health. He is currently using the Drone Deploy system to process images, which include an interpretation of crop biomass. He also uses Pix4D software for stitching images.

Scott feels RPAs could be a 'big game changer' for his system as they are cheap, easy to use and can take images under cloud, although minimising shadow and light variation across the image is still important.

From Scott Oehm's perspective, the sky is the limit when it comes to PA in cropping.

Details: ***Scott Oehm, 0409 247 326, @oehm_scott, scottoehm@icloud.com***

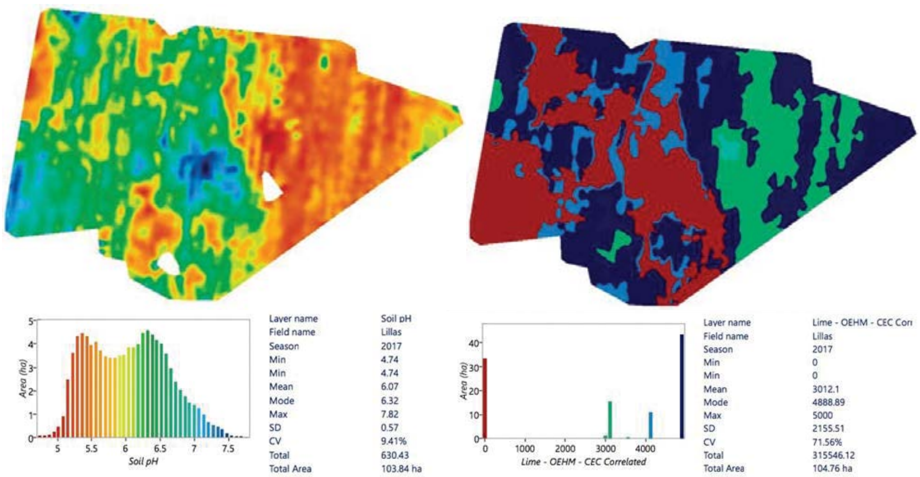


Figure 3a. pH map and **Figure 3b.** lime prescription map for the same 105ha paddock.

GRDC

Left: John Gladigau and right: Robin Schaefer.
Photo: Emma Leonard

Farm profile

Farming personnel: Managers Robin Schaefer, John Gladigau, Andrew Biele plus three permanent staff and up to two casuals at harvest

Farm location: Loxton, South Australia

Farm size: 13,000 hectares - 4400 ha continuously cropped, 8600 crop pasture rotation.

Annual rainfall: Annual 275mm to 290mm, GSR 180 to 200mm

Soil types: Mallee sandy dunes rooting depth up to 2m, and sandy loam swales, some constrained by rooting depth. pH7.5 to 8

Enterprises: wheat, barley, canola, lentils, lupins, pasture

Yield: Average wheat yield 1.4t/ha

PA timeline

Technology –

Guidance

Vehicle steering

Grain yield monitoring

Variable rate seed, phosphorus and nitrogen

Electromagnetic soil maps

NDVI mapping

Spray application mapping

The following article was first published in November 2013

Keep it simple

Emma Leonard

Manually adjusting fertiliser to provide higher rates on sandy rises was the start of Robin Schaefer's journey into PA; that was in 2002. Eleven years later much has changed, not least that the farm area of crop he manages has increased from 2000 to over 8000 hectares and all machinery has been rationalised.

Varying rates manually was initiated after a triple bin variable rate air-seeder was purchased. However, this practice totally relied on the operator's memory and knowledge of the field.

"Today, this seems inconceivable as we have fully automated variable rate systems on seeders and sprayers, together with auto-steer on all machines and RTK guidance for the seeding tractors giving +/-2cm accuracy," said Robin.

In 2004, the harvester was upgraded, which included the ability to yield map using John Deere mapping software but auto steer and guidance were not added until the following year. At the same time a Farmscan GPS unit giving +/-10m accuracy and rate controller were fitted to the seeding tractor.

The seeder upgrade was in conjunction with a project run by Mallee Sustainable Farming Inc. This project was looking at strategic use of inputs through varying rates of seed and fertiliser to soil type.

"We now know that we can hold the most water in the mid-slope so this is where we place our highest fertiliser rates. Medium rates are applied on the dune and low rates are applied to the constrained areas of the swale as both of these areas can suffer in prolonged dry periods during the growing season.

Research found a strong correlation between the variation in yield and soil electromagnetic properties across the Mallee landscape. This gave Robin the confidence to create nitrogen input zones based on EM and yield.

On farm trials showed that adjusting phosphorus fertiliser inputs to match removal rates was appropriate. So within four years Robin had moved from a manual variable rate nitrogen system to a fully automated variable nitrogen, phosphorus and seed based on management zones.

The run of dry seasons curtailed investment in EM mapping but Robin found that the run of dry springs together with personal knowledge of his paddocks enabled him to develop pretty good zone maps just from yield data.

Collaborative farming

Things might have continued in this manner if Robin had not been approached by near neighbour John Gladigau.

"John proposed a collaborative farming venture where our two family farms totalling 4000ha would be transformed into a business cropping at least 8000ha."

Five steps were implemented to enable a collaborative farming approach to be adopted by the two family businesses.

The first step was to create a new company 'Bulla Burra'. The second was for Bulla Burra to lease the land from each family as well as from other farmers in the region. Some land is also under share farming agreements.

John and Robin's initial target was to farm 8000ha in two 4000ha cells. These cell sizes are based on what they believe is the most efficient match of land, machinery, labour and infrastructure for the area. It is also influenced by t he crop mix, farm set-up, length of runs and distances between paddocks.

"There is no set area that will make a collaborative farming venture work. It will depend on a range of factors and the importance of these factors will vary between regions, partly but not solely due to differences in yield potential."

The next step was to determine the machinery required to run this enterprise based on two cells of 4000ha each. All machinery owned by the families was sold, either to Bulla Burra, if it was the perfect fit for the system or on the open market. The remainder was purchased outside of their existing farming operations.

The other steps are people, especially having the right people in the right jobs and having a board of directors with an independent chair person.

Just enough machinery

For Bulla Burra, the objective is to have enough machinery but to keep it working as much as possible. For example, in just under 12 months the sprayer clocked up 1400 hours.

Having said that, the aim is to complete harvest in about six weeks and seeding in five. This is achieved by working around the clock to be as timely as possible. They start sowing by the calendar and block crop the wheat, barley, canola, lentil and lupin crops. This provides efficiencies when spraying and avoids wasting time cleaning down at seeding and harvest.

"We have been using a wheeled and a tracked tractor but in 2014 will run two JD 8335RT track tractors to pull the two 12m JD air-seeders. One of these also pulls the chaser bin. We have two harvesters with 12m fronts and one self-propelled JD 4940 36m sprayer," explained Robin.

All equipment is fitted with GPS guidance. On the tractors pulling the seeding rigs, the signal is provided by John Deere StarFire™ 2, which gives +/-2cm RTK accuracy. Everything else is on StarFire™ 1 giving +/-10cm accuracy. This signal feeds to the JD GreenStar™ 2630 screens that provide rate control and Autotrack™ autosteer.

In 2014, all equipment will be on 3m wheel spacing and implement widths matched on 12m units, enabling controlled traffic to be implemented. This allows the team to focus on seeding and harvesting operations.

Bulla Burra does not own any trucks as all carting of grain and fertiliser is done by a local carrier.

"We have developed a strong relationship with a local carrier that ensures we have secure carting capacity and provides the carrier with guaranteed work," said Robin.

A single PA platform

When the two businesses joined, Robin was already experiencing considerable difficulty using yield maps generated on John Deere 'Apex' software to produce application maps for the Farmscan software running the rate controllers.

On merging the businesses, these problems increased as different PA platforms were being run in each harvester and in each seeder. This meant multiple prescription files had to be produced so that variable rate could be achieved by both seeders working in the same paddock.

"These problems were frustrating but manageable when I was the owner operator but at Bulla Burra, with up to seven staff at peak times, placing rigid time constraints on key operations, there is no place for managing compatibility problems."

Over the past four years, Bulla Burra has upgraded machinery and moved to all John Deere equipment and not just because the colours match its logo.

"The 24 hour Stella Support has proved to be extremely valuable to us. Breakdowns are part of farming but this system has helped keep PA breakdowns as short and manageable as possible."

Having the same screen in every machine keeps learning time to a minimum and means it is easy to talk through problems remotely.

The telemetric system is still in its infancy but Robin is finding the ability to compare machinery performance useful: another benefit of having everything the same brand. He particularly likes the ability to monitor fuel usage between operators and tasks.

Precision weather forecasting

Robin has mounted an 'on the go' weather station on the sprayer, which continuously logs wind, temperature and humidity while spraying. He had some teething issues with software and also with where to place the weather station to ensure the data was collected reliably.

Robin has been exploring tools that offer other ways to improve his precision management. He has recently completed a Nuffield Farming Scholarship on Weather Forecasting and Business Management Systems.

While his international experience has helped him understand more about the processes and future of weather forecasting, it is tools from Australia that he primarily uses to plan on a daily and long-term basis.

"I love the cliMate app, but it would be even better if I could record rainfall at various locations on the property. It would be improved further if linked into the Bureau of Meteorology's POAMA2 model."

Robin also uses the Weatherzone+ app and the Syngenta Agricast website for hourly forecasts out to seven days.

"On my travels, I also discovered an app called "Windmeter" which turns your iPhone® into a mobile wind recording device, which is handy if the kestrel pocket weather station fails."

His report, which will soon be available from www.nuffield.com.au/ will make interesting reading for all farmers.

Details: ***Robin Schaefer, Bulla Burra, 0417 877 578, rsc10092@bigpond.net.au***

The location for the 'on the go' weather station that Robin has found to ensure the data is collected reliably. Photo: Robin Schaefer

Farm profile

Farming personnel:	Jonathan Dyer and father Alwyn and one full-time employee
Farm location:	Kaniva, Victoria
Farm size:	2800 hectares
Annual rainfall:	Annual 450mm GSR 350mm (past 20 years average 300mm)
Soil types:	Heavy Wimmera clay, some surface setting red soils – pH6-7
Enterprises:	Wheat, canola, legumes, livestock over summer
Yield:	Average wheat yield wet year 4.5t/ha, dry year 1-1.5t/ha

PA timeline

Technology	Year started using
Guidance and autosteer –	late 1990s
Grain yield monitoring –	2000
Spray application mapping –	2012
Variable rate - seeding and in crop inputs	2014
Protein mapping –	2016

Top PA tips

- What gets measured gets improved.' What is it about your farm that you wish to improve? Start collecting data about it.
- Record what you are already doing. Almost all farm machinery has the capability to collect information, so switch it on! Once you are recording what you are doing, you can start your own trials.
- Create soil zone maps for your paddocks using your preferred combination of yield maps and/or personal knowledge. Load those maps as background maps onto your tractor screens so you can observe how the different zones react in season.
- All this information is great for staff learning.

The following article was first published in November 2017

Data drives decisions

Emma Leonard

Collecting, combining and analysis of multiple years and types of data are supporting improved management decisions.

Like most farmers, Jonathan Dyer is keen to maximise his grain price. On-farm storage and blending to contract requirements are a key part of meeting this target. However, fluctuations in yield provide significant management challenges before he even gets to harvest.

"In the past four years we have seen our average wheat yields fluctuate from 1-1.5t/ha in the dry years of 2014 and 2015, to 4-5t/ha in the wet years of 2013 and 2016."

Jonathan reports yield fluctuations across his rotation of Roundup Ready® and conventional canola and legume crops – most commonly lentils and chickpeas. The variation is driven by rainfall and soil type. Soils prone to waterlogging could be high yielding in a wet year if sown to canola, but in the same conditions low yielding if sown to lentils.

This inconsistency creates an additional challenge to managing within paddock variability.

"Dad and his brother had been collecting yield data since 2000, so when I returned to the farm I had about 10 years of yield data to evaluate to see if we could identify the drivers for yield variation."

Jonathan has been combining multiple years of yield data from a paddock, irrespective of crop type, to try and establish stable yield zones.

Figure 1 illustrates a map combining five years of yield data: 2012 (wet), Roundup Ready® canola; 2013 (wet), wheat; 2014 (dry), faba beans; 2015 (dry), wheat, and 2016 (wet), RR canola. The average yield for an area is compared to average mean yield for the paddock and then expressed as a positive or negative percentage change.

The map clearly illustrates that there are three main zones in the paddock – two areas that are reliably high yielding and one that is reliably low yielding – irrespective of season.

By analysing the data collected annually and then combining data layers by paddock, by paddock and season, and eventually by paddock season and crop type, Jonathan and his father are trying to determine and manage the drivers of yield variation in order to improve profit.

"By looking, measuring and then analysing multiple data layers, which takes time and processing power, we hope to better understand what is driving the variation in our system."

Variable rate seed

For the past two years, the seeding equipment has been able to vary both seed and fertiliser. Jonathan uses seed weight to determine seed rates with the aim of achieving

150 plants/m^2 for durum and 180 plants/m^2 bread wheat. If the season is good, this seeding rate should result in the main ear plus three tillers per plant, a total of 600 heads/m^2 for durum.

This generally equates to a seeding rate of 70-80kg of seed per hectare. In 2016, a paddock had been allocated for seed production, but the amount of seed available only enabled a seeding rate of 55kg/ha. Jonathan decided to sow the whole area at a low seeding rate, rather than leave a bare patch that would encourage weeds. His decision paid off as this paddock produced his highest wheat yield that year of 6.18t/ha. This result has encouraged him to do some paddock scale strips comparing seed rates at 60, 80 and 100kg/ha and monitoring plants per metre squared and total yield.

Soil and mapping

The consecutive dry years of 2014 and 2015 provide Jonathan with really strong dry season yield patterns. He used these patterns to make soil sampling zone maps, taking four to five soil samples within the zone and combining them before testing.

"We still basically work on a philosophy that high yielding areas require more inputs to replace what has been removed, but in reality the more variables we quantify, the more challenges we have to manage."

One of the variables Jonathan has been looking at is surface soil pH. On average this is considered to be neutral to mildly alkaline (pH7-8), but targeted soil sampling has shown that continuous cropping has increased acidity with pH falling below pH5 on some soils.

Traditionally, gypsum had been applied at a single rate to improve the soil structure, a problem mainly with the surface crusting red soils. About three years ago, Jonathan started using a variable rate spreader and decided to target the gypsum by soil type and add some lime to raise the pH.

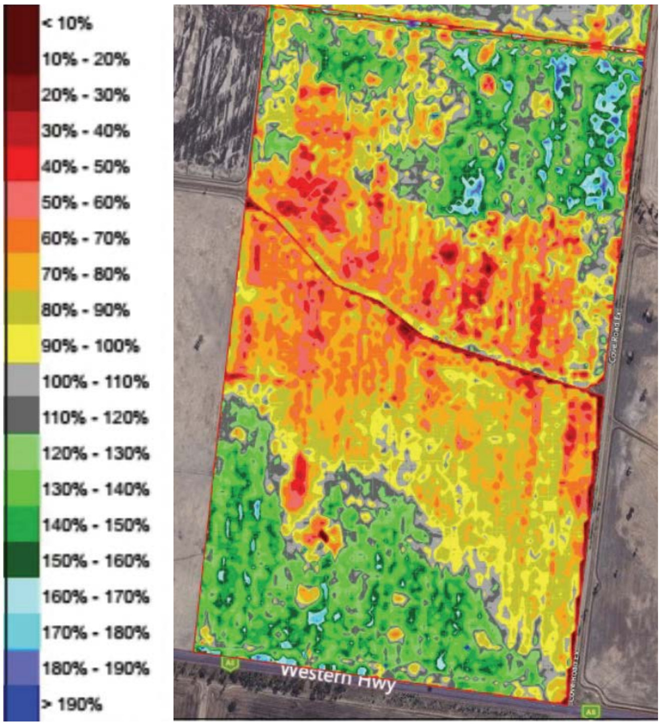


Figure 1. Yield stability or fluctuation map based on combining five years of yield data and comparing the difference from the mean as a percentage.

Gypsum is targeted to the red soils, except if canola is going to be sown where it goes to all soils, but at a higher rate on the red soils. Generally, gypsum rates are 0, 1 or 3t/ha.

The lime zones were primarily determined by areas where ryegrass was a problem. These generally have red soils, but include sandier loamy soil where nutrients are more readily leached.

"I targeted my soil sampling in areas where ryegrass was a problem and found these to be more acidic; applications of 2-2.5t/ha of lime increased the pH from 5 to 6 and ryegrass appears to be reducing."

Research by the Australian Herbicide Resistance Initiative suggests that in a less acid, more neutral soil pH environment, crop competition improves, weed germination may decrease, and herbicides may work more effectively.

"It is another complex set of interactions and ideally I would like to do some on-the-go pH maps, but so far this has been too expensive to justify."

Grain protein mapping

From Jonathan's experience, the biggest bang for their buck in terms of investment in PA tools has been GPS and autosteer and now protein mapping.

They had been using a portable protein monitor for a few years which had helped in doing some on-farm grain segregation and blending. The decision to upgrade to a 'CropScan 3000H On Combine Analyser' was definitely a good one as it paid for itself in one season.

The CropScan is mounted on the clean grain elevator and takes readings approximately every 17m, producing about 15 measurements per hectare as the crop is being harvested. This equates to a reading collected every 7-12 seconds which is displayed on the touch screen PC in the cab. This also shows bin averages, field averages and real-time protein

Table 1. Blending the 800t from a 174ha paddock to reduce quality extremes produced a 7% increase in income.

If sold as harvested					Blended		
Grade	ASW	APW	H2	H1	ASW	APW	H2
Tonnes	350t	200t	200t	50t	150t	50t	600t
Price	$180	$210	$230	$240	$180	$210	$230
Return	$63,000	$42,000	$46,000	$12,000	$27,000	$10,500	$138,000
Total return	$163,000				$175,500		
% increase	+7%						

maps. The software sends the data to the Cloud where it can be monitored using a PC, tablet or smartphone.

“Trying to manage fluctuations in yield is hard enough, but trying to meet contract quality requirements and maximise cereal grain protein in both high and low production years presents an extra challenge.

“Having the protein monitor on the machine has really helped as I can quickly patch out the high protein areas (defined by low elevation, heavy clay, prone to frost) and harvest these with the harvester fitted with the protein monitor, leaving the second harvester to deal with the low protein areas.”

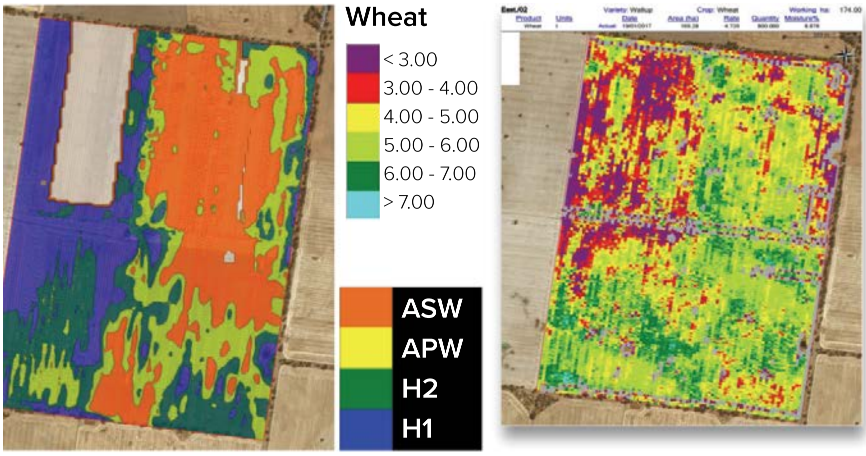


Figure 2. Protein (left) and yield (right) maps harvest 2016.

The Dyers often used the chaser bin as the mechanism for blending, sending it to collect alternate loads from the high or low protein areas. From Jonathan’s point of view, successful in paddock grain blending needs good information and good communication between all parts of the harvest team.

About 50% of the Dyers’ rotation is wheat, 25% bread wheat and 25% durum wheat. For harvest 2016, the price for bread wheat was about $230/t (Hard 2 13-11.5% protein), $210/t for Australian Premium White 1(APW, 11.4-10.5% protein) and $180/t for Australian Standard White Wheat (ASW, no protein parameter).

“Before the ability to accurately monitor protein, we’d go hurrah when we delivered a truckload of high protein wheat and took it on the chin if the majority of the loads went into lower quality segregations.”

The paddock in Figure 2 illustrates the variation in yield and protein that Jonathan was managing in 2016. Protein ranged from 9.5% to 14%. The whole paddock had been fertilised for a target yield of 6t/ha, but frost reduced yield to less than 3t/ha in some areas. The high protein wheat was found in the low yielding areas as would be expected.

The total yield from the 174ha paddock was 800t (4.7t/ha) at 11.2% protein.

Table 1 illustrates how Jonathan used blending to deliver a large portion of grain as higher value Hard 2. This resulted in a 7% increase in income for very little input.

“That is about 25% of our investment returned just from one paddock and we repeated these price improvements across our wheat crops.”

Jonathan appreciates that not every paddock will be this dramatic and returns will depend on the price spread in the market. However, from his experience he feels whether using on-farm or off-farm storage, the potential of quality blending holds significant value.

Replacement nutrients

With a better understanding of cereal grain nutrient removal as yield and protein, Jonathan hopes to be able to better match nitrogen inputs to productivity. Currently his ‘Gatekeeper’ software is struggling to put yield and protein data on the same resolution maps but ‘Next Instruments is helping him to work through this frustration.

For the second year Jonathan has generated variable rate in-crop nitrogen zones based on deep soil nitrogen tests taken by soil zone. Rates fluctuate between 80kg/ha and zero.

Creating true nitrogen removal maps, adjusted for protein and better understanding the relationship between location, yield and protein will help Jonathan progress his plan for better targeting nitrogen to productivity.

“My ultimate dream is to produce accurate gross margin maps so we can really start to understand how to maximise dollar returns from every paddock.”

Jonathan will also invest in tools for remote weather and soil moisture monitoring to help automatically log conditions during spraying and to support in-crop fertiliser decisions.

Details: *Jonathan Dyer, 0423 269 798, @dyerjonathan, jonathan@nerdfarmer.com*

Leigh Bryan.

Farm profile

Farming personnel:	Leigh and Susie Bryan
Farm location:	Swan Hill, Mallee, Victoria
Annual rainfall:	340 millimetres
Soil types:	Sandy clay loams to sandy loams
Topography:	Mallee
Farm area:	2400 hectares
Enterprises:	Wheat, barley, lentils, field peas, chickpeas, canola
Average wheat yield:	2.45 tonnes per hectare
SPAA member:	Yes
PA consultant:	Self
Agronomy consultant:	Matt Whitney, Dodgshun Medlin

PA timeline

Guidance –	2003
Autosteer –	2005
On-farm trials –	2005
Yield mapping –	2006
Direct Injection Spraying –	2006
Variable rate –	2007
Inter-row seeding –	2007

Top PA tips

- Keep your solutions as simple as you can. Aim for one screen and stay with one system.
- Don't try to be perfect. Getting from 90 per cent to 100 per cent accuracy adds a lot of work for little gain.
- Have local support so any issues can be resolved quickly

The following article was first published in June 2020

Tailoring the farm by soil type

Being able to adjust inputs to suit the varying soil types across their property has helped the Bryan family farm more efficiently and increase overall yields.

Why did you choose to adopt precision farming technology?

The main feature of precision farming technologies for me is the guidance technology and the accuracy it offers in functions like variable rate applications and auto steering. We manage inputs to suit our different soil types and their needs. We have a mix of light, sandy soils and heavier loams and precision farming allows us to feed up the sandy areas and back off on the heavier types. It means we do not overfeed the better soil or underfeed the lighter zones. In other words, we are not investing more than we need to in fertilisers and we can be very accurate about how we place that investment.

We also operate a no-till farming system, so guidance and auto-steer helps us to accurately plant in between the previous crop rows or into the previous year's stubble, depending on the crop.

Finally, the guidance reduces mental and physical fatigue. Automated steering means fatigue does not impact on the accuracy of row placements or input applications. It all adds up to less waste, lower costs and better yields.

Which technology tools or components have you adopted and (which do you) continue to adopt?

Along with the guidance-based technologies, we also make use of drone and satellite imagery to map biomass and soil types for our variable rate input programs. For example, we use the maps to adjust the herbicide rate applied on sandy soils, which tend to leech the chemicals more than a heavysoil. We can also reduce the risk of crop damage by mapping sensitive crops and reducing the herbicide application rate in those zones.

Another technology we've adapted is yield mapping on the header, which informs our variable rate fertiliser map. We're able to run a maintenance type program, where the yield data allows us to replace minerals like phosphorus and zinc based on what was removed through harvesting. In paddocks which we know are low in those elements, we can adjust the map to apply a 'maintenance plus' rate that helps us to build those soils up.

We also share maps between machinery. For example, I audit the yield maps and add a layer for soil type. The modified

map is then used on the seeder to vary the seed and urea rates based on the soil type.

What are the factors that motivate you to adopt and use each of the different tools or PA components?

The investment in precision technologies is based on cost savings and efficiency. It is about maximising yield, which is ultimately about the profitability of input costs versus returns.

In the past, we could not justify applying fertiliser at a blanket rate that suited the sandy soils because that would also mean putting three times too much onto the heavy soils, so we had to compromise on both types. Now that we can adjust the inputs by soil type, we are able to feed those sandy soils appropriately. They are now our best soil types, because we can match their nutrition to their plant-available water. We were never able to do that before.

What types of data and information are you collecting to guide your decision-making to adopt or not adopt each PA component?

Generally, social media is the first place I pick up on something new, or someone doing something different. My membership in SPAA and the no-till groups also turns up new ideas.

However, a lot of the research I did years ago has remained valid. I have had the screen for my variable rate seeder for over 14 years now, so the technology does hold up surprisingly well. I have changed my guidance system in that time and there have been various upgrades to the steering screens over the years. Often, those will be raised by the machinery dealer. As the machinery needs to be replaced, an upgraded guidance screen will usually be a part of that renewal.

Has the adoption of PA increased profitability on your farm? How?

Yes, definitely – just through the cost savings and yield increases. With precision technology, there is no need to under and over-do applications as there was in the past. These days, we can apply each input as the crop and soil types need it. It is still not 100 per cent perfect by any means, but it is vastly better than 'blanket' applications.

How are you using the data generated by PA? Is it leading to further practice change? If so, what kind of practice change?

Yes, it is leading to further practice change. For example, I recently normalised my annual yield data from the past 14 years and produced a map showing where we had been getting above and below-average yields. It showed that some areas of the farm were not really worth planting certain crops on. As a result, we have now applied a virtual division into some paddocks and will sow different crops on either side of the line. A paddock that may have had lentils all the way across it has now been sown with lentils on one half and peas as a brown manure crop on the other.

Previously I thought we had grown some reasonable lentil crops in those areas, but the accumulated data clearly showed this was not the case and planting lentils there just wasn't worth the risk. I have created precise seeding maps based on how our soil types lie but they are too irregular. It becomes impractical to manage spraying and harvesting. In the end, simply dividing the paddock has worked out very well. A few good areas ended up on the wrong side of the line, but not enough to worry about.

Who is influencing or assisting you with the adoption of PA?

I do it all myself. When I started experimenting with precision agriculture back in around 2005, I had to figure most of it out myself and fortunately I can do that. Being able to perform tasks like converting drone imagery into application maps means I do not need to out-source a lot of those operational tasks.

Are you planning to adopt more or less of these various precision farming technology components in the future?

Camera sprayers have been an area of interest for several years now and I have been watching them improve. The introduction of green-on-green algorithms will take them to another level. For the moment, however, I am happy to wait until I feel I need one. We don't have a pressing weed problem to justify it yet.

Protein monitoring is also on the horizon. Again, I am waiting for the technology to mature and the prices to be a little more attainable. As that happens, I think it will become a very valuable tool for mapping crop performance and matching that data to the variable inputs we can manage with precision guidance.

Details: ***Leigh Bryan, 0427 321 969, leighjbryan@gmail.com***

Photo: Emma Leonard

The following article was first published in March 2017

VR improves confidence in management

Emma Leonard

Varying seed, fertiliser and post emergent herbicides by zone is complex, but helps Darren Cobley sleep more easily.

There have been many changes since Darren Cobley's father Dick started farming at Walkaway, Western Australia, but walking away is not one of them.

The farm has a diversity of soil types and undulating topography and one of the biggest changes has been a program of farming to soil type, which Darren initiated 20 years ago.

"We can have four different soil types in one run of the seeder and these can range from chocolate clay to white sand; some areas are productive for cropping, others are only suited to livestock. Our objective is to maximise profit from all parts of the farm," said Darren.

Areas not suited to cropping are fenced for livestock. These areas can take 50ha out of a paddock and they do not have to be a regular shape. Initially, these areas were defined by Darren and Dick's knowledge and experience of the paddocks. Now electromagnetic soil surveys (EM38), intensive soil sampling and yield data have been added to this knowledge to refine the production areas and to create variable rate (VR) input zones.

There are key differences in the soils. The sands have very low water holding and consequently low production potential. Clay soils have higher production potential as they hold more water, but can be highly acidic or alkaline. Aluminium toxicity is a problem in all the acidic soils.

A program of VR lime sand, which is incorporated by a soil inversion plate on the deep ripper, has been an important part of meeting Darren's objective of managing to soil type. Lime rates of 2, 3 and 4t/ha are applied based on soil pH. These are applied with an AgriSpread spreader which is capable of adjusting rates by one tonne while on-the-go.

Across the farm, 70 points have been established as annual soil sampling locations. This gives about one sampling point every 50ha.

Farm profile

Farming personnel:	Darren Cobley, his father and two full time workers
Farm location:	Walkaway, 40km SE Geraldton, Western Australia
Farm size:	6,700ha of which 4,700ha is cropped
Annual rainfall:	Annual 325-425mm depending on location
Soil types:	Grey sealing alkaline clay to acid white sand
Enterprises:	Wheat, lupin, canola, sheep and cattler
Yield:	Average yield – wheat 3t/ha

PA timeline

Technology	Year started using
Controlled traffic –	2001 – restarted 2013
Auto section control –	2006
Grain yield mapping –	2009
Electromagnetic soil maps –	2011
Gammaradiometric soil maps –	2011
Guidance and autosteer –	2011
Variable rate inputs –	2011

"These points help us identify any changes in soil properties which our ripping and VR programs might be initiating or need to take into account."

Controlled traffic

Darren first used controlled traffic farming (CTF) 15 years ago, but went away from it as he was seeing no yield benefit. However, CTF was reintroduced since starting a program of deep ripping to remove naturally occurring and traffic induced compaction, as well as to break up the toxic aluminium layer.

All machinery is on 3m wheel centres and implements are in multiples of 6m i.e. 36m boomspray, 18m air-seeder, 12m harvester; tramlines are every 12m. This compromise system works well for efficiency and means the boomspray does one and a half headlands rather than two before moving onto the tracks.

GRDC

Lime rates of 2, 3 and 4t/ha are applied based on soil pH. Crop nutrients and seed are varied based on yield and soil maps and personal knowledge. Photo: Emma Leonard

The ripper is 9m wide and was initially used to delve to 300mm before planting a wheat crop.

Now it is used before any crop and rips to 500mm on sand and a bit less on clay. The ripper works on the tramlines and tramlines are not ripped.

Variable rate

In addition to varying lime inputs by soil type, Darren runs a multilayered VR program at seeding. Rates of the solid products - seed, muriate of potash (K) and mono-ammonium phosphate (MAP) - are varied from a three box Simplicity air-seeder, pulled by a Case IH Quad Track. Input rates are controlled by a Topcon X30. This also controls rates of liquid nitrogen (UAN) and trace elements (zinc and manganese on lupins and copper and zinc on wheat). These have been applied at a single, blanket rate, but that is likely to change this year.

Darren works closely with his agronomist Craig Topham and together they spend two to three days reviewing the yield maps and soil test results before establishing the paddock plan and management zones in each paddock. While high yielding zones are generally consistent and do not move from year to year, low yielding zonescan vary depending on the season.

When planning zones for each input, they are considering last year's yield, this year's potential yield, any stored water and nutrients in the soil profile, as well as the seasonal forecast.

Although Craig produces the initial prescription maps at the beginning of the year, Darren is able to modify these as the season progresses.

Seed rates on high yielding zones will be about 60kg/ha (wheat), while on the worst non-wetting soils they will be increased to 120kg/ha.

Deep banding muriate of potash has allowed Darren to reduce rates from about 50kg/ha when top dressed down to 25kg/ha, but VR has allowed him to achieve a further 20% saving in total K applied. On the high yielding areas, the rate is up to 15kg/ha, if required and on low yielding it might be 40kg/ha. MAP is applied at up to 110kg/ha on high yielding soils and reduced to 40kg/ha where yield is restricted.

While the planning process is more in depth and time consuming than just applying a blanket rate, Darren feels it is worthwhile, especially for his peace of mind.

"Generally we are not seeing a saving in inputs, but are redistributing them to where they are most productive.

"I feel much more confident about my management knowing we are placing inputs where they are required. VR is efficient and I sleep more easily knowing that crops are more likely to perform and not be lost due to too much bulk or too little nutrition.

"The only real way to test if we are gaining is to run blanket rate and VR strips next to each other in the same paddock. I am not doing that, but we are seeing a steady increase in our yield per millimetre of rainfall."

UAN is applied four to six weeks post emergence with rates based on production potential. In a good season, a second application will be applied.

Yield Prophet® is used to determine yield potential for nitrogen input rates. Two main soil types on the farm have been categorised. This data is extrapolated to other soil types on the farm with support of owner knowledge and the results from the 70 annual soil sampling points. With this soil data, Yield Prophet® produces rates for different production zones.

This year, yield zones will be used to target post emergent fungicide. Darren is planning to use a blanket rate for the initial fungicide application to control sclerotinia in canola and follow up with a second spray only on the high yielding zones.

Darren does not currently see an option for VR herbicide in his system, but new opportunities for VR are continuing to evolve. Now Darren is comfortable with managing VR applications, he feels could apply the same principles to any input.

Details: ***Darren Cobley, 0429 108 594, d.vcobley@bigpond.com***

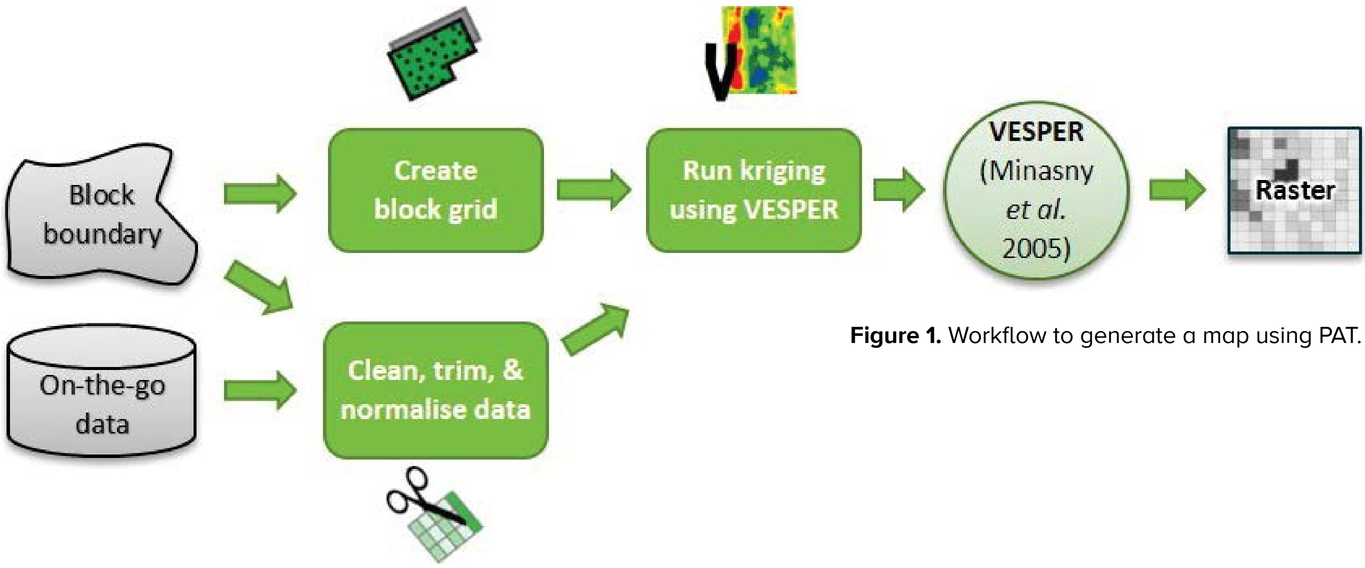


Figure 1. Workflow to generate a map using PAT.

The following article was first published in April 2019

Free GIS 'toolkit' released

Sue Knights

New tools are available to help put farming data to better use.

Christina Ratcliff from CSIRO discusses a toolkit she is developing for growers and advisers to easily process data with Precision Ag News contributor Sue Knights. The tools can be used with free and open source GIS software.

What was the driver for developing the toolkit?

At CSIRO we have been aware that farmers and advisers do not have access to the same, often costly, geographic information system (GIS) software and tools that we are using for research purposes. Additionally, in 2017, we surveyed grain farmers and found that while about 87% of survey respondents have access to yield monitors, only about 50% generate yield maps. One reason could be is the lack of access to user friendly data processing tools.

Who funded the work?

We were contracted by the Federal Department of Agriculture and Water Resources through the Rural R+D for Profit scheme, with additional support from Wine Australia and CSIRO, to provide a suite of PA data analysis tools for growers, consultants and researchers using free and open source GIS software.

The suite of tools has been named Precision Agriculture Tools or 'PAT' and is provided as a 'plugin' for the chosen GIS software. It has been designed to be generic, irrespective of the farming system it is being used for.

What GIS software was chosen for the project?

QGIS (also known as Quantum GIS) was selected as it fitted the criteria of being free and open source and could handle the kinds of analyses we need in PA. It was first released in 2009 as a cross-platform GIS software. It is maintained by a global collaboration of experts and is widely used across industries. Users are supported with on-line training and an active on-line community.

Once downloaded QGIS and PAT can be run on a laptop without internet access. This is essential for agricultural and viticultural applications where businesses may suffer slow internet speeds.

How is PAT used?

It currently contains tools for data cleaning and preparation (Table 1)and for analysis (Table 2). PAT operates in QGIS through drop down menus and toolbars.

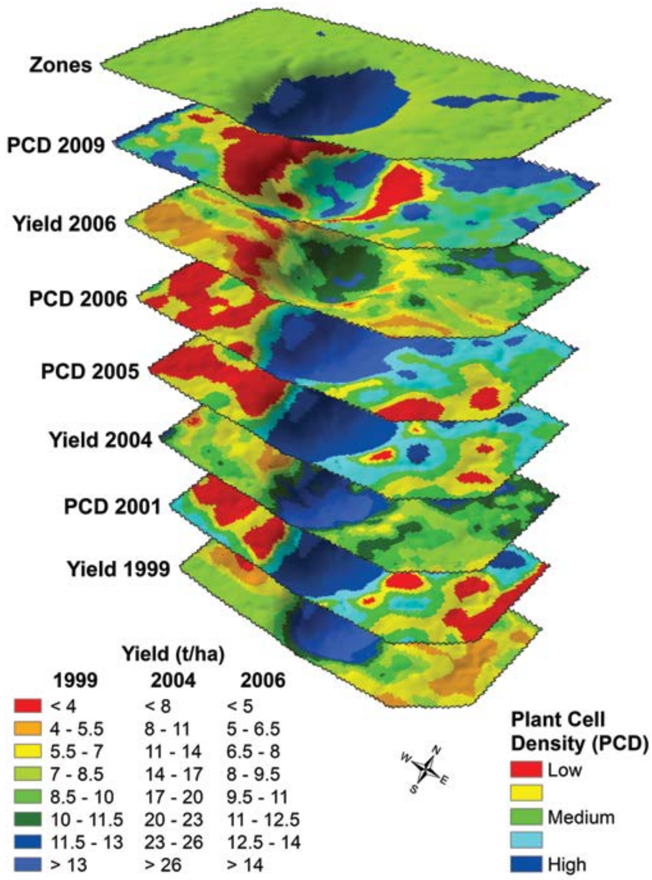


Figure 2. Output of the PAT k-means clustering tool which uses multiple maps to create management zones – in this example, for a Padthaway vineyard. (Figure provided by Rob Bramley)

Table 1. A selection of data cleaning and preparation tasks using PAT.

Tasks	Description
Block grid	Having a common block grid allows comparison of multiple years of data from the same field and different types of data layers. This tool generates a common block grid from polygon boundary features.
Clean, trim and normalise points	Preparing raw data from yield monitors or on-the-go sensors (e.g. from yield monitors) involves clipping, cleaning and using filtering rules.
Prepare for kriging and run VESPER	Prepare and run VESPER which generates interpolated raster maps from prepared raw data.

Table 2. Brief description of a selection of analyses using PAT.

Analyis	Description
Extract pixel statistics for points	Extract pixel statistics from multiple rasters using a square neighbourhood around a set of point locations.
Calculate image indices for blocks	Resample and smooth imagery to a larger pixel size, as well as calculate indices such as PCD and NDVI.
Create zones with k-means clustering	Use k-means clustering to identify zones from multiple years of data, and/or additional layers such as EM38 maps.
Create strip trial points	Create points for a strip trial along a central line and offset at distance. These points can be used for the comparison of performance along and adjacent to a strip trial (such as an N-rich strip) using the Lawes and Bramley (2012) analysis method.
Whole-of-block analysis	Analyse whole-of-block experiments where 2 or 3 treatments are applied across a block or paddock.

Typically the on-the-go paddock data collected has attributes containing the location of the sample point and a mapped value e.g. yield. A boundary around the area of data we want to analyse, often a paddock perimeter, is used to create a common block grid and this allows comparison of multiple years and sources of data from the same field.

When collecting data there will always be some errors and erroneous data points, like crazily high or low yields. These points need to be removed (cleaned) before the data is interpreted. Figure 1 shows the work flow of tasks that PAT supports. A tool from the PAT suite can assist each task in this workflow and is shown by a corresponding icon. Each tool's functionality is further described in Table 1.

Having cleaned the data points, we then want to create a continuous surface of information within the boundary. PAT uses VESPER (Variogram Estimation and Spatial Prediction with Error) - a geostatistical program developed for PC-Windows by Sydney University to produce maps using kriging.

Kriging is a process of looking at the space between the data points and calculating a best value estimate for the unsampled area. VESPER then processes the data to a raster format, a grid of cells (pixels) where each cell contains a value. This raster or map is provided as a georeferenced TIF image file. VESPER is not part of PAT and needs to be downloaded and installed separately.

A set of PAT analysis tools are outlined in Table 2. With these tools, users can combine maps from on-the-go sensors and other acquired data to create more complex maps.

Could you give us an example?

Figure 2 shows the potential management zones created for a vineyard using the PAT k-means clustering tool.

This tool uses yield, imagery and other data layers to derive zones in a paddock that reflect crop performance. In Figure 2, a combination of yield and Plant Cell Density (PCD) maps from multiple years have been used. The resulting zone map could help to make selective harvesting or variable application mulch decisions.

PAT can be used to analyse whole-of-block or 'spatially distributed experiments'. These are trials where treatments are applied 'at scale' over a whole paddock.

Where can I obtain PAT?

https://github.com/CSIRO-Precision-Agriculture/PAT_QGIS_Plugin.

When will PAT be available?

Core data preparation tools are already available, with a second release, planned for June 2019.

For further information contact Christina Ratcliff, David Gobbett or Rob Bramley at PAT@csiro.au

Biog. Christina Ratcliff has expertise in GIS for Agriculture and the Environment and is a PA Principal Research Technician with CSIRO.

Details: ***christina.ratcliff@csiro.au, 08 8303 8400***

The following article was first published in March 2014

Fertiliser optimiser calculator

Roger Lawes

A new streamlined but equally powerful variable rate fertiliser calculator is now on-line for free use.

More targeted allocation of nutrients to parts of the paddock that are responsive can result in economic benefits.

Soil characteristics that determine plant available water are a key determinant of yield variation.

While mapping potential yield variation and identification of causes are the first steps, they are of little use unless followed by sensible management actions.

A tool to assess the economic payoff of variable rate nutrient application to wheat has been developed jointly by CSIRO, Curtin University and the Department of Agriculture and Food WA (DAFWA).

The tool, Fertiliser Optimiser Calculator, was developed in response to farmer demand for applications to help them cheaply and efficiently use precision agriculture technology to help manage crop agronomy.

Simply, the Fertiliser Optimiser Calculator will help consultants and farmers decide which paddocks, sown to wheat, may warrant investment in variable rate technology.

The tool has been developed for WA and provides an indication of the value of varying nitrogen and phosphorus in an individual paddock. Rates for individual situations especially outside WA, should be guided by local agronomic advice.

The Fertiliser Optimiser Calculator can be accessed free of charge online by going to http://optimiser.csiro.au/

Instructions and suggestions for use can be located on the CSIRO website (http://www.csiro.au/Outcomes/Food-and-Agriculture/PrecisionAgriculture/Variable-Rate-Technology.aspx).

The Fertiliser Optimiser Calculator should be used together with other fertiliser decision aids and local agronomic advice to select the precise rate for your soil, as specific recommendations vary with soil type, situation and production objectives.

Details: ***Roger Lawes, 08 9333 6455, roger.lawes@csiro.au***

How to use

Step 1. Set grain price, nitrogen price, phosphorus price.

Step 2. Set the $ limit on fertiliser spend per hectare.*

**A lower limit will result in a lower fertiliser rate*

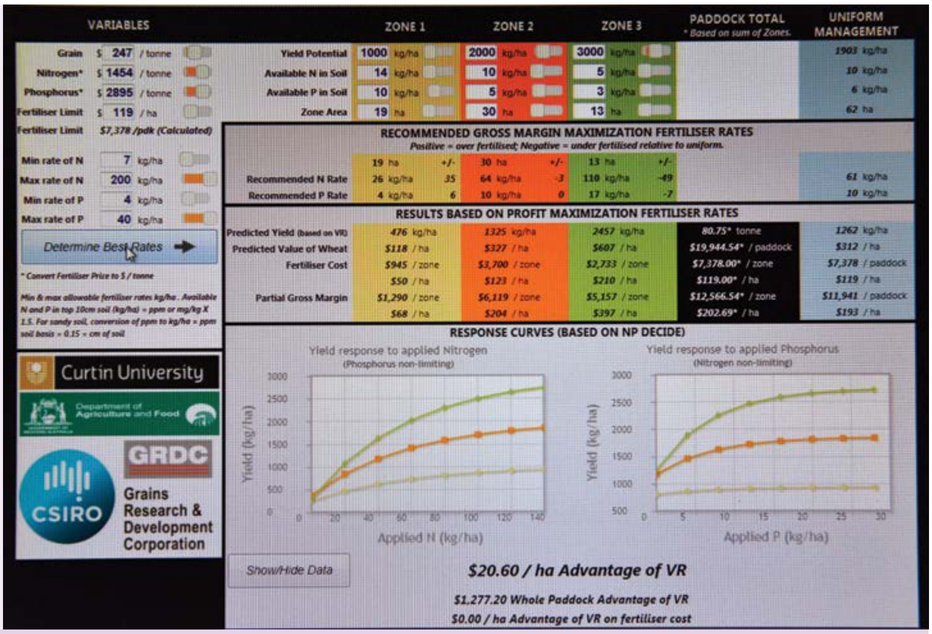
Step 3. Set the chosen minimum and maximum level of N (kg/ha) and P (kg/ha).

Step 4. Set the yield potential in up to three zones.

Step 5. Set the starting levels of N and P (kg/ha) in the soil for each zone

Step 6. Enter the area of each zone in hectares.

Determine the best rates ➜



How it works

The Fertiliser Optimiser generates a N and P rate for up to three zones.

It calculates how much will the zone be over or under fertilised if a uniform rate is applied.

A partial gross margin is calculated for each zone, based on the predicted yield, value of wheat and fertiliser cost.

Two whole paddock gross margins are produced VRT (black) uniform (blue column).

Yield response curves for N and P.

The cost of under and over fertilisation of the high and low yielding zones. This determines the $ advantage of VR.

The following article was first published in January 2020

Accuracy in your hand

Dan Bloomer

A new satellite option for location signal correction is offering sub-meter accuracy depending on the receiver used.

Geo-referenced data is at the core of precision management practices. Without it, on-farm decisions on how to variably manage inputs, for example, cannot be automated.

There are three elements to georeferencing data.

1. Accuracy – the distance between the geographic location reading and your physical location.
2. Repeatability – how much the reading drifts over time, pass to pass, day to day.
3. Reliability – signal stability or frequency of signal drop out.

These factors are determined by the global navigation satellite system (GNSS) such as GPS, GLONASS, Galileo, and BeiDou, the correction signal, the quality of receiving equipment and environmental factors such as trees and tall buildings.

Real time kinematic (RTK) positioning, provides the most accuracy (+/-2cm) but it is expensive, and that level of accuracy is not always required. Researchers are confirming that a new free correction system using satellite-based augmentation (SBAS) is showing the potential to increase the accuracy of the GPS in mobile devices to better than 50cm.

This could enable mobile devices to provide accurate guidance for scouting and ground truthing operations.

RTK vs DGPS and SBAS

RTK providing +/-2cm accuracy is the most accurate, repeatable, reliable and most expensive correction method. It uses a land-based correction signal from a base station.

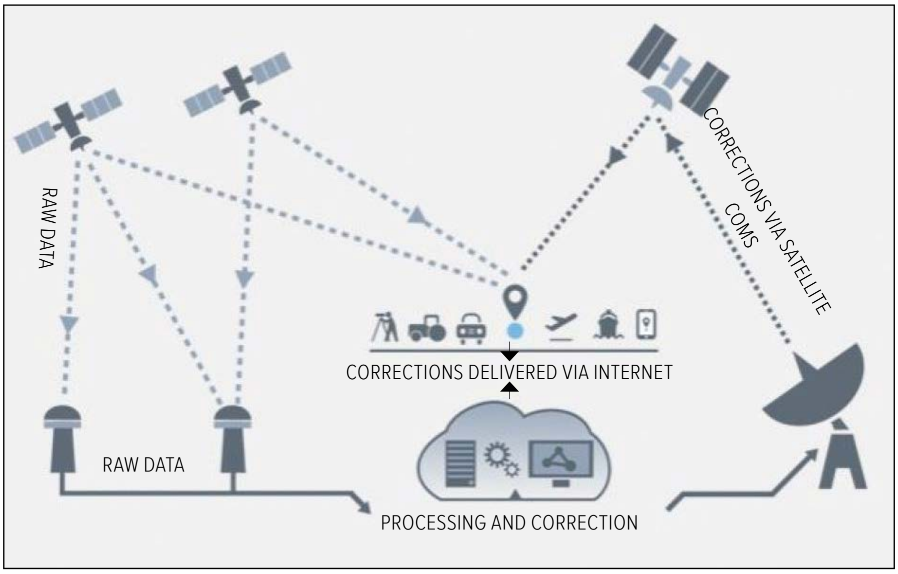


Figure 1. An illustration of a satellite-based augmentation system (SBAS) for location signal correction (from Geoscience Australia).

Location subscription systems offering differential GPS (DGPS) use networks of ground-based reference stations with correction signals sent by ground-based transmitters. DGPS provides accuracy of between +/-1m and 10cm, depending on the subscription.

Satellite based augmentation (SBAS) is similar, with the correction signal broadcast from satellites and is a free service.

Mobile phones have uncorrected signal with a location accuracy of +/-10m accuracy but can be as good as 1.5m and commonly provide 3-4m accuracy. RTK level accuracy is necessary for laying out vineyards, orchards and when sowing or planting. However, for many tasks in the horticultural industry, the cost of this high level of accuracy is hard to warrant.

Projects in Australia and New Zealand have been investigating the accuracy of a non-subscription satellite-based augmentation system (SBAS). This is equivalent to the WAAS correction system in the North America and EGNOS in Europe. These systems use a network of known land-based control points to provide correction via satellite signals to GPS or other GNSS units (Figure 1).

More information on the implementation of SBAS in Australia can be found on the Geoscience Australia website in the section Positioning Australia.

SBAS offers the potential to provide improved positioning accuracy and repeatability, without the need to subscribe to a correction service or to own a base station. As the correction signal is sourced from another satellite, it is more overhead and more vertical than from a base station. This is especially helpful when working in orchards, as the signal is less likely to be blocked by vegetation.

In-field testing

In New Zealand, I tested the SBAS technology on commercially available receivers and compared them to an RTK system. The receivers tested were the internal GNSS on a smart phone (Huawei P10), a Huawei and Samsung phone each fitted with an Eos Arrow 100, and a Bad Elf Surveyor.

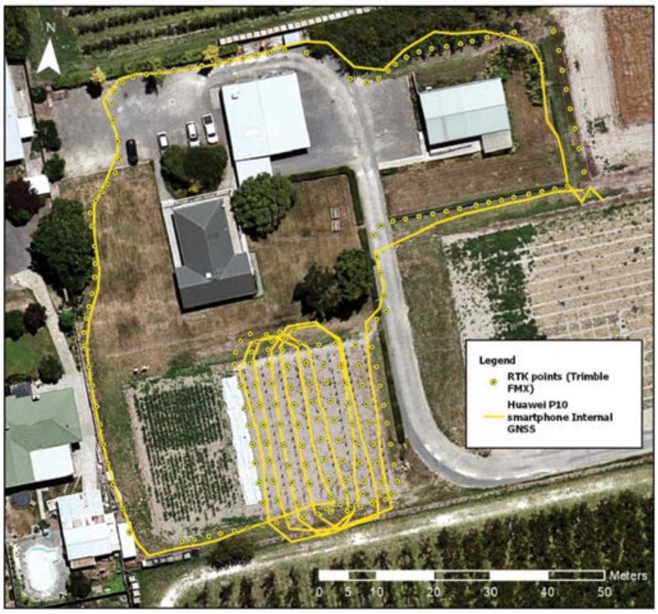


Figure 2. The uncorrected mobile phone trails show inconsistent accuracy when compared to the RTK and inaccuracy of over 1m in places.

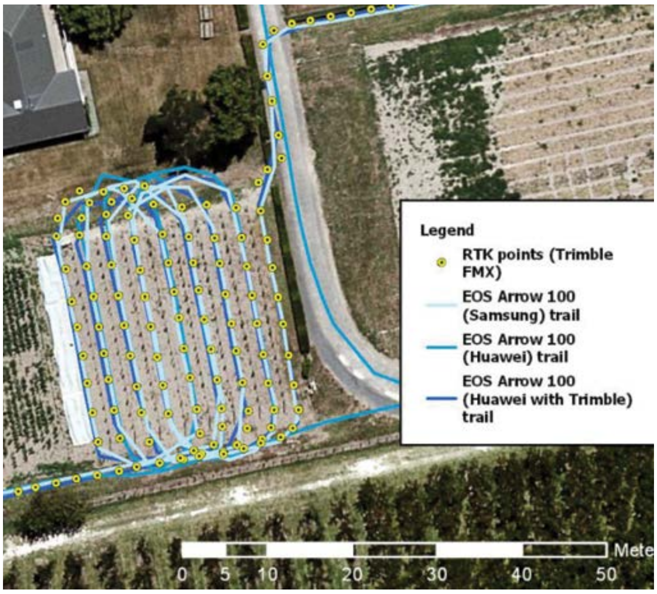


Figure 3. Three successive runs over two days using the Eos Arrow 100 show reliable tracking that compares well with the RTK-GPS plotted points. Deviations are due to the quadbike running different lines rather than GPS errors

Each receiver was tested statically and then mounted on the same quad bike and driven around a circuit that had been laid down with RTK correction.

Figure 2 shows the trails for the comparison of the RTK and uncorrected signal from a mobile phone. It can be seen that while the uncorrected mobile's GNSS is close in some places, it fluctuates and can be off-track by over 1m. It is unreliable for accurate positioning and has lower repeatability.

In the first static test of the SBAS correction with the Eos Arrow 100, an accuracy of between +/-40 to 60cm was achieved (Figure 3). Accuracy was found to improve with software updates. This used the L1 correction band that is broadcast by all satellites. When the static test used 'precise point positioning', which manages the GNSS system errors, accuracy was improved to about +/-20cm, which has also improved with new system and software updates.

Figure 3 shows the SBAS corrected trails using the Eos Arrow 100 and illustrates generally good agreement with the RTK trail marked by the yellow and black dots.

From the trails in Figures 2 and 3 it can be seen that SBAS corrected systems provided greater accuracy and reliability than the uncorrected phone GNSS (yellow line).

The results show the potential of increasing the accuracy of the GPS in mobile devices to better than 50cm using SBAS with tools such as the Eos Arrow 100. Such an improvement in accuracy enables mobile apps to become beneficial tools for scouting activities and lightbar guiding. It is estimated that an RTK system costs about $20,000 plus an annual subscription. This makes SBAS a very cost-effective option for gaining reliable, repeatable, sub-meter accuracy if 2cm accuracy is not required.

Biog. Based in New Zealand, Dan Bloomer is a consultant, advisor, innovation broker, trainer, project manager, technologist, with a special interest in AgTech.

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WEED PRESSURE AND SPRAYING

Mark Branson.

The following article was first published in August 2019

International study highlights PA value

A Nuffield Scholarship equipped Mark Branson with the knowledge required to further explore PA technologies on his farm.

Why did you choose to adopt precision farming technology?

With highly variable soils and undulation we could see the variability in our soil types and topography, so thought there could be money to be made out of having all of that information saved somewhere. We were early adopters of yield mapping in 1997 when we had a yield monitor retro-fitted to a new harvester. That helped us to see the variability between soil types and the yield correlation which came with it, but we didn't see any benefits to that initially. We were trying to find out how to make money from yield mapping by soil testing and ground truthing different areas of paddocks. I was a founding member of SPAA in 2002 and in 2005 I completed a Nuffield Scholarship researching the use of precision and conservation agriculture to improve farm profits and the environment. That experience confirmed a lot of what I was thinking regarding precision agriculture and gave me some ways to further explore different technologies.

Farm profile

Farming personnel:	Mark, Nola and Sam Branson
Farm location:	Stockport, SA
Annual rainfall:	460-500mm
Farm area:	1200 hectares
Soil types:	Red-brown earths, dark brown cracking clays
Topography:	Undulating
Enterprises:	Wheat, barley, field peas, faba beans, lentils, canola, oats
Livestock:	800 Merino ewes
Average wheat yield:	4.5 tonne per hectare
SPAA member:	Yes
PA consultant:	All done in-house
Agronomy consultant:	Peter Wendt, Farmer Johns

PA timeline

Yield mapping –	1997
Guidance –	2002
On-farm trials –	2002
Autosteer –	2004
Controlled-traffic farming –	2005
Variable rate –	2006
Greenseeker –	2006
CropSpec –	2009
Inter-row seeding (ProTrakker) –	2017

Top PA tips

- Identify the problem and whether it is economical to fix before adopting a PA tool
- Use N-rich strips in combination with sensing technology to help determine nitrogen requirements
- Consider the profitability of PA to your business

Which technology tools or components have you adopted and (which do you) continue to adopt?

After yield mapping in 1997 we moved into guidance and autosteer in 2004, which led into controlled-traffic farming in 2005. From 2006 we started to use variable rate for phosphorous, which is something that came out of my Nuffield Scholarship. To do that I take the previous year's yield map and apply a formula accounting for replacement rates for what was lost in yield plus a factor of loss. We then went into variable rate nitrogen and started using N-rich strips. I scan those with a Greenseeker which gives me an indication as to whether crops do or don't need nitrogen. More than anything, that tool has given me the confidence not to apply nitrogen and for that reason we have saved money on input costs. A new take on this is a zero-nitrogen strip, which when compared to a crop that has had some early nitrogen, indicates nitrogen deficiency earlier than the N-rich strip.

Another tool I came across on my Nuffield Scholarship was the Yarra N Sensor which in Australia has become the Topcon CropSpec. The crop canopy sensor measures plant reflectance to determine chlorophyll content of the crop, which correlates to nitrogen concentration in the leaf, and hence potentially the nitrogen status and needs of the crop for optimum yield. When used with the N-rich strips and Greenseeker information, we can determine whether the crop requires nitrogen and by how much. That allows us to apply variable rate nitrogen. I also use visual observations and a DJI Phantom 4 drone to help identify areas of low and high biomass from the air which is used for the variable rate nitrogen algorithms.

We also use the drone to help with weed management. We have some herbicide resistant ryegrass and wild radish in patches, so I identify those areas with extra biomass using the drone and zone them out to cut for hay or to spray them out. If it is an ongoing problem, we will use variable rate to increase the seeding rate in those problems areas and use crop competition to help stop weed seed set with crop competition.

We also use variable rate to apply gypsum on sodic areas we have identified and to apply lime on acidic areas of the paddock which we have identified using a Veris pH mapping machine. We use the pH map to variable rate lime with the lower pH, highly acidic areas receiving a higher rate of lime than the moderately acidic areas, and the neutural to alkaline areas receiving no lime, saving a lot of money on the better targeting of lime.

What are the factors that motivate you to adopt and use each of the different tools or PA components?

Initially it was ad hoc and I didn't know what I was doing. We were collecting a lot of data to identify variability among the different soil types, but we didn't come up with anything to make money out of using that technology. Now it's a completely different approach. My Nuffield Scholarship pointed me in the right direction. Now I have a four-stage approach — identify the problem, determine what the agronomic impact is, identify whether there is there a PA tool to fix the problem and what it is, and then decide whether it is economical to implement. Rather than looking at every tool and working out how we can make money from it, we use the problem to adopt a tool. That's how we make money.

What types of data and information are you collecting to guide your decision-making to adopt or not adopt each PA component?

Yield maps and the associated data is the most important data to collect – it is the end point of the season and tells you where the problems are that require further investigation. We use that data for phosphorous replacement and we can use variable rate to apply phosphorous where it is most needed.

Has the adoption of PA increased profitability on your farm? How?

Yes, it has. I've done an economic study on PA tools on my farm which I have presented on at conferences. In terms of savings across the farm per year, our yield savings over the top of the normal background trend are $7.87 per hectare per year and with RTK guidance there is a further saving of $7.24/ha/year through more accurate placing of inputs. We are saving $16/ha/year on phosphorous, $33.78/ha/year on nitrogen, $15.38/ha/year on gypsum and lime, and $7.17/ha/year on weed control. Added up, that is a saving of $87.42/ha/year. For costs, assuming machinery lasts for 10 years is $12.22/ha/year for machinery and technology across the whole farm, my time is $2/ha/year, RTK is $0.17/ha/year so the total costs are $14.39/ha/year. That gives us a profit of $73.03/ha/year, so it is a significant figure.

How are you using the data generated by PA? Is it leading to further practice change? If so, what kind of practice change?

I think about practice change as going through some simple steps. Firstly, what is the agronomic problem and is it spatial or across the board? If it's spatial then can I permanently fix the problem with deep ripping or in another physical way? Is it economical to deal with it? If I can't fix the problem permanently then what are the tools available to help manage it and is it economical to do so? I then look at all the tools available to fix the problem and do the research, then adopt it if it's spatial and economical to do so. I keep reviewing new tools when they become available to see if they could fix an existing problem. PA is all about solving agronomic problems, not buying trendy tools or services just for the sake of it.

Who is influencing or assisting you with the adoption of PA?

My Nuffield Scholarship has been a big part of it. Research organisations such as CSIRO and the University of Sydney, as well as extension organisations such as SPAA, have also been strong influences for me. Through SPAA I am able to talk to other likeminded farmers adopting PA. Machinery and technology manufacturers are also an influence, but it is important to do your own research before adopting what they are selling.

Are you planning to adopt more or less of these various precision farming technology components in the future?

There is nothing on the horizon I can see at the moment which would be beneficial to us. In terms of adoption, there is the classic case of the drone. When that technology became available and I determined that it was economic to use, it overtook the other tools I was using, such as satellite maps. There is a lot of satellite technology around at the moment, so if I find one of equal accuracy to the drone and it is cheap enough to use then that might overtake the drone.

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The following article was first published in December 2020

A weed fighting revolution

Ann Rawlings

In Western Australia's northern wheatbelt, where yields are relatively low and the seasons highly variable, Mullewa growers Andrew and Rod Messina have been on a long and dedicated journey of weed management.

Their efforts in reducing the weed burden among their cereal crops have involved the adoption of techniques including controlled traffic farming and mouldboard ploughing, in addition to windrow burning, chaff carts, autumn tickles, crop topping and a double knockdown.

Herbicide resistance in wild radish populations has added to the complexity of the task, as is the fact that every drop of water counts in their continuous cropping system. Pre-emergent and in-crop sprays are a significant part of their weed management strategy. "Weeds rule broadacre farming, there are no two ways about that – well, weeds and rainfall," Andrew said.

This year, the family sold their collection of chaff carts and bought three Integrated Harrington Seed Destructors in anticipation of a harvest dominated by cereals and the job of burning chaff dumps across 10,000ha. However, their latest investment in machinery has been allowing for greater levels of precision in herbicide application – an important factor when spending significant amounts of money blanket spraying for small densities of wild radish.

"We have been doing whatever we can to reduce the seed bank for weeds, and we've been doing that for a long time now with mouldboard ploughing and harvest weed seed management," Andrew said.

New tech on farm

For summer and fallow spraying, the Messinas have turned to a machine equipped with camera spot-spraying technology

Andrew Messina, who farms with his brother, Rod, on farm in the Mullewa district of Western Australia.
Photo: Fiona Mann, MDFI co-ordinator

Farm details

Farming personnel:	Andrew and Rod Messina
Location:	Spring Park Farms, Mullewa district, Western Australia
Farm size:	12,500 hectares
Annual rainfall:	250mm to 300mm
Soil:	85 per cent sandplain and remainder sandy loam
Enterprises:	10,000-12,000ha cropped annually (wheat, canola and lupins)

by French firm Bilberry, allowing for real-time and localised herbicide application.

"Being a big family partnership, we've always had to crunch numbers before we make a big decision. You can get a bit excited and spend all the time, but you need to keep things in check," Andrew said.

"But to have a destructing mill on our harvester, that is mechanically driven, and this camera technology ... is the most exciting thing that I have seen in my farming life."

Their 8000-litre Agrifac Condor Endurance II arrived on farm in January, a tad later than expected but there was still time to get to work over 400ha of their sandplain soils.

"We had held off from buying a WeedSeeker-type machine for several years, but were fairly confident that something like this was not too far away," Andrew said.

"When the technology came out, we saw it last year, we were very keen to move that way. Our decision was also pushed by the fact that instead of getting a contractor in for summer spraying, we could recoup some of that cost back into the Agrifac. But given that it was in its developmental stage, and it basically stopped raining once we decided to buy it, we were a bit worried going into this year with such a high-value machine."

The system – called AiCPlus – uses optical cameras and microprocessors to identify weeds ahead of the 48-metre spray boom. Individual nozzles are then triggered as the boom passes overhead to 'spot spray' the weeds. The RGB cameras are fixed at 3m apart, with each linked to the operation of 12 nozzles independently.

Green-on-brown is the only commercially available technology available for this machine at present, but the Messina's have been busy assisting the system's developers trial its green-on-green capabilities.

At the start of July, the machine spent nine days traversing 7000ha at an average speed of 19km/h, with its last run taking place in August. Its target was wild radish within four main wheat varieties, namely Scepter, Devil, Chief and Zen.

"Wild radish is the focus for [green on green] this year but, in turn, we are trialling it on blue and white lupin in wheat," Andrew said.

"We have some of those weeds in the paddocks, so we are still training the algorithm to identify them, which it is doing to a certain degree, but we're certainly not happy with that at the moment. But that is a second-tier part of the program."

With each pass, the cameras captured images that depicted both the crop and weed at different times of day and under various light conditions. These images were used to better inform the algorithm behind the technology. "Our paddocks

Farmers inspect the sprayer in August as part of a Spring Field Walk by the Mullewa Dryland Farmers Initiative (MDFI). Photo: Fiona Mann, MDFI co-ordinator

don't just run one way, no one's do, but it is interesting to see at different times of the day if it's firing or if it's reactive," Andrew said.

The size of the crop and weeds must be taken into account in the learning process, as well as the best nozzle size and water rate.

"When we did the initial spraying we had ultra-coarse droplets, so there was no sideways drift; in some cases, it just caught half a plant. We have changed nozzles to help," Andrew said.

For the trial, they had allowed the radish populations grow to a size that the cameras could easily detect, with the sprayer first being put to work on a paddock with a high weed burden.

"We didn't do what we normally would do as part of a radish strategy; we sort of reversed it to get the Agrifac going in quite weedy conditions, so [the technology] had more of a chance to hit more," Andrew said.

"It's one thing to detect it, it's another thing to kill it, and how long, relative to another sprayer or broadblanket spray."

In paddocks with high weed burdens, their aim is to knock out weeds early in their growth via a blanket spray, in a bid to conserve crop-available moisture. This would usually occur around the three-leaf stage in wheat.

However, Andrew said where efficiencies could be gained, regarding the use of the greenon- green technology, would be in subsequent sprays that targeted the remaining low populations of radish.

"In that situation, we would go through and broad blanket spray in the first place, to take out 90 per cent of them," he said. "Then we would come back with a spot sprayer to take out the next two subsequent germinations, and we would wait for them to get palmsized before spraying them."

Low weed densities

Luckily, the family's weed-fighting efforts have paid off, with their paddocks hosting low densities of radish. In these areas, Andrew said the initial blanket spray would not be necessary.

He added the results of the trial, and the current effectiveness of the technology, would not be fully known until harvest.

"We're confident with what it is doing, because we are following up with harvest weed seed management," Andrew said. "If a few radish get through, it's certainly not going to be an economical cost, just a simple, we don't like weeds getting through. So if we need to deal with them, we will deal with them at harvest.

"But when we go walking through the paddock, most of the weeds have been hit, which is important. Really, that is the key."

The family has used a controlled traffic farming system since 2007, with all machinery being based on multiples of 36.4m. "Everything after seeding is on 36.4m tram, but the Agrifac is 48m, so it doesn't run on the tram that our normal sprayers do; it runs on the header track," Andrew said.

"If we went to 48m, we could spray at 19km/h and get over the country the same as what our 36m sprayers do at 26km/h. We needed to get over the country just as quick with the new machine as the others."

Soil testing is another regular practice across their landholdings, with this work backed up by several soil-moisture probes that monitor plant-available water and nitrogen requirements. On-property weather stations aid their decision-making throughout the year. “Soil testing is an integral part of what we do,” Andrew said. “We do that to keep track of pH and the trace elements going into wheat, mainly.”

Each soil sample site was GPS referenced 10 years ago, to allow for greater consistency in testing. “We don’t do the same sites every year, but they would be done every three years down to 30cm,” Andrew said.

The results, by the way of their agricultural consultant, are used to fine-tune inputs, with Andrew saying that came down to how many “dollars you wanted to spend”.

Yield Prophet, an online yield simulation tool, has also been used in the past to back their infield nutrition decisions. However, Andrew said this year they had steered clear of the tool, due to the lack of summer rain.

“It is a good tool, but last year it just stopped raining, so it didn’t take long to work out that our last application of nitrogen was not going to be used,” he said.

“But the crops have benefitted from that nitrogen this year. That’s quite an arguable point, whether nitrogen is still left in the soil. Well, it hasn’t gone anywhere, because it didn’t rain. We literally had 20mm of rain after the last application of nitrogen to when we started seeding, and we knew that it was there because we do soil testing.”

The family started exploring their land’s soil constraints in 2008, mainly to determine if soil acidity, aluminium toxicity or nutrient deficiencies had been limiting yields.

Testing uncovered pH levels of around 5.3 to 5.5 at the surface and 4.4 to 4.6 at depth (30cm), while non-wetting soils and compaction were also identified as potential limiting factors. “With our mouldboard ploughing program, we put a lot of lime in front of that, so that got turned in,” Andrew said. “But the main thing we have been doing for the past five years has been deep ripping, which has taken our sand to another level.”

Deep ripping to depths of 60cm to 70cm prior to seeding has maximised the ability of crops to access moisture and nutrition in the profile, with the brothers spreading two tonnes a hectare of lime ahead of the ripper. Paddocks are treated with lime usually every three years.

Their soils now feature pH levels in the range of 5.5 to 6.2. “Initially we weren’t doing the headlands, because it made them too soft for our machines to turn on, and the crops on the headlands were half the height of the rest of the paddock. So it was a very physical thing to see, and in yield comparison as well. It didn’t take a lot of number crunching to work it out,” Andrew said.

“Again, this has been one of those small game changers for our soil type that gives us good quality wheat at the end, rather than shrivelled wheat. In our system, if the plants set themselves up really well, generally they will finish well.”

Details: ***Andrew Messina, @AndrewMessina15***

At the start of July, the machine spent nine days traversing 7000ha at an average speed of 19km/h, with its last run taking place in August. Photo: Fiona Mann, Mullewa Dryland Farmers Initiative co-ordinator

The following article was first published in December 2020

A green-on-green journey

Haidee Vandenberghe

For the past decade, green-on-green weed detection has been touted as a game changer for agriculture. With ag-tech companies – big and small – starting to roll out commercialised units, Australian agriculture is close to seeing evidence of accurate in-crop detection and treatment. However, the technology still has its challenges.

The ability to selectively spray weeds in crop – or green-ongreen technology – has been one of the most hyped advances of the past decade.

It has been possible to detect weeds using infrared reflectance from green plant material for more than two decades, but while the ability to detect weeds in fallow, or green on brown, has been commercialised for some time, green on green has remained elusive until recently.

There are now several options either on the market or close to commercialisation for green on green, although currently all are constrained by weed and crop type, growth stage – or both.

Big international players such as John Deere (through its Blue River acquisition) and Bosch (with its investment in Xarvio technology) have thrown significant resources at achieving successful and accurate in-crop detection and treatment, while a host of smaller players are also emerging with technology.

Greeneye, an Israeli startup, has the backing of agrochemical company Syngenta and raised $7 million to progress its retrofitted Selective Spraying System.

Closer to home, Australian-owned startup AutoWeed launched what was the first commercialised green-on-green weed detection and control system in Australia earlier this year.

Stemming from postgraduate research at James Cook University, the AutoWeed system is the brainchild of Alex Olsen and uses standard RGB cameras and deep learning to detect weeds in real time in both crops and pasture. The system is scalable and is designed to be an all-in-one unit that is retrofitted to vehicles. Cameras and processors are mounted 30-40cm from solenoids, with each camera covering up to one metre.

There are now two systems in commercial use in Queensland – one targeting Navua Sedge in pasture and another Harrisia Catcus in pasture. That second system has also been used to target milk thistle in wheat on the same property.

"Our technology has focused on weeds that are a little larger than 10cm that we can achieve 95 per cent accuracy on," Mr Olsen said. "As the technology advances, we expect to see the accuracy on smaller weeds improve over time."

The system uses deep learning, so detection accuracy improves the more it is able to capture images under different circumstances.

"If we want to detect the weed under different conditions, that data set must also have those conditions," Mr Olsen said. "Ideally, you will install one of the detection units onto your system and drive it as you would normally through the paddock.

Bilberry recently completed its first Australian commercial-scale trial of green-on-green detection and selective spray.

"Every time the farmer takes the vehicle out, it is automatically collecting and saving images and sending them to AutoWeed for us to prepare our detection models."

This opens the door to innovative use of the data set and the potential for growers to pull up models that may relate specifically to a particular paddock or season, thereby honing detection accuracy. However, for many developers, simply collecting the sheer number of various weed and crop images to initialise algorithm development can be a challenge.

It is a process that is being kicked along by University of Sydney researchers. In addition to work to crack the algorithm for annual ryegrass detection in cereal crops, they are developing an open-source image data set specifically for grains in broadacre.

According to Mr Olsen, it is an initiative that will help to get greenon- green solutions to market more quickly. "The key factor is collecting more and more images of these weeds," he said.

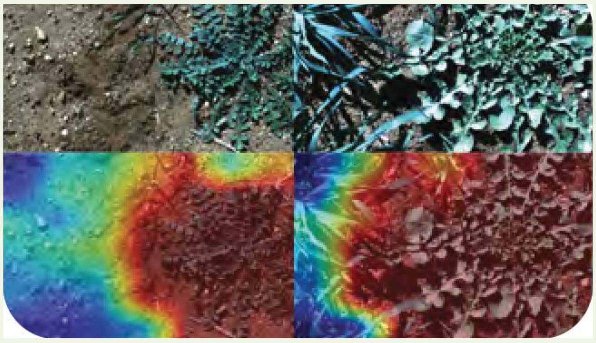
"In order for a model to yield good spraying accuracy, you need about 100,000 images of that weed in that environment.

"AutoWeed is based in Townsville and we don't have direct access to a grains database like that, so for us to be able to go to a grains farmer and already have a model to deploy and see if it works with our equipment, it provides developers with a head start.

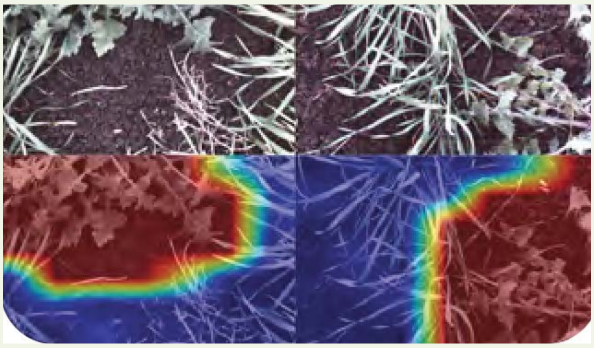
"We can stand on the shoulders of that data set to get a solution to farmers faster."

How AutoWeed 'sees' weeds within crops

Turnip weed in oats



Milk thistle in wheat



Meanwhile, Bilberry recently completed its first Australian commercial-scale trial of green-ongreen detection and selective spray, targeting primarily wild radish in wheat.

The French tech-startup, which has partnered with Agrifac and Ballaratbased Goldacres, has been running a series of on-farm trials in Western Australia's northern wheatbelt in a bid to assess the capabilities of the system.

Located at Andrew and Rod Messina's Mullewa property, about 70km east of Geraldton, the trial has involved spraying several thousand hectares of wheat using an Agrifac Condor Endurance II with the camera spot spraying system AiCPlus.

The machine, purchased earlier this year, has been used by the Messinas to conduct green-onbrown spraying.

However, unlike other systems that focus on NIR, AiCPlus uses RGB cameras, meaning the system can be upgraded to have greenon-green capabilities once the algorithms and software have been developed.

In the trial, the first sprays were conducted when the wheat was at the three to four-leaf stage and then continued throughout the season to assess the system's performance under a range of conditions.

Although Bilberry will not be releasing data from the trial until post-harvest, its co-founder and CEO Guillaume Jourdain said the detection and hit rate has thus far been greater than expected.

However, he said the challenge for developers is more than just solving the algorithm conundrum. Integrating artificial intelligence with spot spraying adds a layer of complexity that should not be underestimated.

"It's easy just to think about the algorithm's ability to recognise, for instance, wild radish in wheat, but you have to make sure that your system behind that – the hardware and the software – is robust," Mr Jourdain said.

"Then you also need to understand the spraying side, so the nozzles, the rates you are using and the pressure, because if you don't have the right coverage, in the end even if you hit them it's not going to do a good job. There's a lot of learning there and I would say it's that global process that makes it complicated."

At least for the foreseeable future, systems will continue to be limited to plant size and type. For that reason, Mr Jourdain tempers hype that this kind of technology will be a catch-all solution for weed management.

"It's important to understand what to expect in terms of what are you going to hit and miss and have a weed strategy that is working according to that," he said.

Mr Jourdain believes extension work will be a crucial step in the success of green-on-green systems.

"It's something that we will have to discuss a lot in the future and make sure farmers, agronomists and all the people involved know when and how to use the cameras," Mr Jourdain said.

"[Weed management] strategies will have to be adapted."

As the technology improves, and more hectares are covered by systems with this kind of artificial intelligence, new questions also arise.

"The collection of all this data is a new problem that hasn't emerged [before]," AutoWeed's Mr Olsen said.

"We're developing our technology to store all this data securely and have it utilisable for farmers over different seasons. These are new and exciting challenges that are being introduced because this technology is new."

Regardless, as the technology begins to hit the market, Australia is expected to be the epicentre of uptake.

It is for that reason that Bilberry established a footprint in Australia, opening an office in Perth more than 12 months ago.

Mr Jourdain said green-on-green uptake is likely to shadow that of green on brown.

"Green on brown has been used extensively in Australia ... that's definitely not the case world-wide," he said. "The average savings of green on brown in Australia are higher than 90 per cent compared to blanket spraying. In Europe, you have a 10 to 50 per cent saving."

Depending on the results from the trial on the Messinas' property, commercialisation for the Bilberry green-on-green technology in some weed and crop types could be as soon as next year, or 2022.

For now, the French startup is laying the foundations to expand its commercial trial program in Australia, looking at a range of weed and crop types, potentially including grass weeds in cereals.

Details: ***Alex Olsen, @Auto_Weed***
Guillaume Jourdain, @BilberryAgri

Jock McNeil.

The following article was first published in March 2014

Targeted attack on weeds

At Loxton, Jock McNeil is running 7800ha

under continuous crops as part of the family's farming business.

On the sandy, sometimes non-wetting soils that only receive an average annual rainfall of 270mm, conserving soil moisture is vital. Consequently, summer weed control is a priority.

Five years of relentless summer weed spraying and preventing weed-seed set are starting to pay off with improved productivity.

Using weed sensing technology has supported this improvement. This has allowed cost effective summer weed control to be achieved with multiple passes and robust rates.

The McNeils have one WeedIT sensor per metre of boom, each controlling five nozzles.

Herbicide inputs have been slashed by about 80%, for example at 10% weed coverage 2L/ha of glyphosate is equivalent to 200mL/ha.

Savings in chemical have been reinvested in other areas such as nutrition and technology.

Tank fills and water usage have been reduced so at 100L/ha a blanket rate required 130 fills compared to less than 10 for the WeedIT.

That also means considerable savings in time and improvements in timeliness.

The system will not detect every weed; the minimum size is about 3cm diameter. Jock estimates that if the target is to spray 10% of the paddock the miss rate will be about 1%. High stubble also interferes with the cameras.

The bottom line is the advantages far out weigh any disadvantage.

The following article was first published in March 2016

Weed mapping

Sam Trengove - @TrengoveSam

The lack of a reliable sensor is limiting the development of on-the-go weed maps for site specific weed management. But what can be achieved and what is in the pipeline?

For the past eight years, agronomist and PA specialist Sam Trengove has spent much of his time researching the potential application of site specific weed management (SSWM). This includes completing a Masters on SSWM in annual ryegrass and on-going trials for SPAA, with support from the SA Grains Industry Trust, into the use of a German designed weed sensor, H-sensor, in Australian field crops.

In this article, Sam shares some of his experience and thoughts on SSWM and its automation.

Site specific weed management (SSWM), like all weed management, aims to achieve cost effective control of weeds to reduce crop competition and reduce the size of the weed seedbank.

Basically, there are four components to SSWM:

- Weed identification – location, weed type and density;
- Treatment decision – selection of the appropriate control treatment;
- Control application – this could be a herbicide, mechanical weeding or the use of increased crop competition; and
- Documentation - weed mapping, spatial records of treatments and weed changes over time.

To a greater or lesser degree, each of these steps could be automated. However, automation relies on the ability of sensors to identify different weed species at different growth stages and to distinguish weeds from crops.

Weed mapping

The starting point, and to some degree the sticking point, for automated SSWM is the generation of a reliable weed map.

Farmers are having some success in implementing SSWM by manually identifying weed patches. With the support of soil type, yield or biomass maps, they are using flagging tools on spray controllers or in PA software to identify areas where different herbicide mixes or higher seeding rates are required. Such systems require dedication and time but can be an excellent starting point for SSWM.

The commercial availability of on-the go weed sensors to identify and map weeds is still limited.

The H-sensor (see breakout), which uses shape to identify grass and broadleaf weeds can only distinguish weeds at early growth stages where there is minimal interaction between the crop canopy and weed. Inter-row weed identification can occur providing the canopy has not closed.

Various research groups across the globe are working on new systems of weed mapping and application control. But each system has to be calibrated to crops, weeds and cropping system. For example, in Europe most paddocks are cultivated so the H-sensor does not have to cope with differentiating weeds from stubble.

Our research to date in Australia has not found stubble to be an impediment to the accuracy of the H-sensor. It is expected that there is a threshold level of stubble above which weed detection is reduced.

Broad weed infestation: millet, chamomile, fat-hen, bindweed (plants/m^{-2})

From my research, I have found that using the normalised difference vegetation index (NDVI) as a surrogate for biomass and weed density provides highly variable results in relation to identifying weed patches. These measurements were made using an N-Sensor, GreenSeeker® or Crop Circle™.

Unless working with wide row spacing where soil will also come into the image, the sensor is responding to both green crop and weed. Therefore NDVI (and other vegetative indices) can be useful in identifying weed patches where the crop is relatively uniform and NDVI varies in response to weed density. However, crop growth is rarely uniform. It is often observed that high density weed patches occur where crop vigour is lower, with an NDVI value similar to or less than the higher vigour weed free crop.

Farmers may opportunistically use NDVI measurements successfully but intensive ground truthing of the data is required.

Both manual and automated systems of weed detection are producing, to some degree, information on the location, type and density of weeds. These are the three components required from a weed map.

Patch stability

The good news is that some weed maps can be of value for multiple seasons. This is primarily true for grass weeds such as annual ryegrass, wild oats and brome grass. These weeds naturally tend to spread only a few metres each year. However, ryegrass weed seeds have been found to be spread up to 20m in the harvest direction from the point of origin. This compares to weeds with seeds in pod like wild radish which can be moved by the harvester 100m from point of origin.

Grass weed seeds which do not go through the harvester's repeats are expelled earlier than podded seeds such as wild radish.

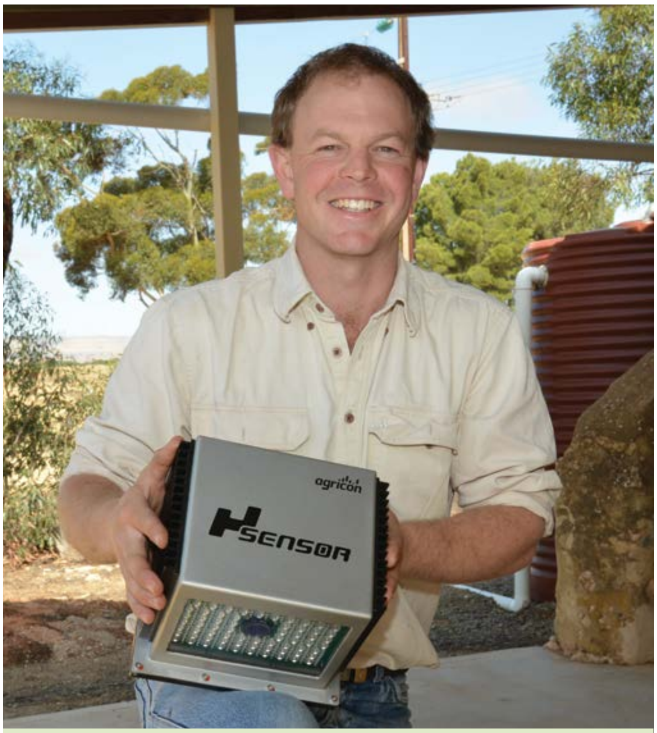
Similarly, the density of grass weed patches has been found to remain relatively stable with high density patches remaining high. However, the density is also determined by rotation (crop competition and herbicide use) and seasonal conditions (germination).

After weed control, I found more annual ryegrass plants survived in high density locations, due to the higher initial populations. Basic mathematics indicates that when the same weed control efficacy is achieved in high and low weed densities, more weeds will survive in the high density location. So, high density weed patches will remain higher, due to higher seed production.

To reduce high density patches to the equivalent of the low density weed population requires a higher efficacy treatment, or it will take longer to eliminate dense patches compared with sparse weed patches.

Due to the patch stability of key grass weeds, farmers have had some success opportunistically generating weed maps in one season that are then stored and used to apply controls to these weed patches the following season.

For example, targeted burning of dense weed patches is used by some farmers, using the map to help locate a fire break around the patch to be burnt. Others may raise seed rates to increase competition or use higher chemical rates or mixes containing more expensive herbicides only on the dense weed patches. A blanket rate of cheaper herbicide is generally still applied across the paddock.



Stuart Sheriff with the H-sensor which is a single sensor with its own light source and can control one or more spray nozzles. Photo: Emma Leonard.

H-sensor trial

This three year project started in mid 2014 to assess the German designed H-sensor in Australian conditions.

Funded by the SA Grains Industry Trust and run in collaboration between SPAA and AgriCon, the trial is building new weed classifiers for Australian crop and weed combinations.

In Europe, the H-sensor which classifies weeds on plant shape, has performed successfully in wheat, canola, sugar beet and maize. In Australia, it has been tested successfully in lentils, faba beans, chickpeas and lupins, as well as wheat and barley. Grass weeds have been identified successfully in broadleaf crop types and broadleaf weeds in grass crops.

The H-sensor achieves the following steps:

1. Gathers red and near infrared (NIR) images;
2. Separates all crop and weed segments from background stubble, soil and rock;
3. Identifies weeds from crop based on leaf and plant shape parameters; and
4. Initiates spray/management decision based on weed type and density.

It contains its own light source so can be used at any time of the day or at night. However, if the sensor cannot see the weed clearly due to leaf overlap identification, accuracy can be reduced.

The more results we analyse in this project, the more we conclude that it will be difficult to identify too many specific weed groups. We may have to lower our ambitions and rather than identify many weed species, make sure we achieve the basics first of differentiating broadleaf from cereals in our cropping systems.

The prospect of separating ryegrass from wild oats is a long way off, if possible at all with the H-sensor.

Maps of windblown weed seeds such as thistles and fleabanes are of little value from year to year. Maps of these weeds need to be made and used in the same season.

Keeping good records of weed location, patch stability and changes in weed density is important in the assessment of the success of SSWM practices.

Economics

Most farmers have low tolerance to weeds and weed control is a major driver of rotation. So controlling only weed patches and leaving other areas untreated is generally not an option. SSWM often relates to the application of additional or different management of problem weeds or weed patches.

For SSWM to be economically viable, the saving from applying the control to only parts of the paddock has to exceed the risk of yield reduction due to weeds left uncontrolled, phytotoxicity of the herbicide and the cost of management to achieve patch weed control.

In some situations, farmers may have been prepared to invest in a high cost treatment for the whole paddock, so SSWM allows them to reduce inputs confidently in low weed areas. Whereas in another situation the farmer may plan to take a more conservative low cost approach on a whole paddock basis but SSWM allows them to confidently invest additional inputs into the high density weed patches.

Consequently, SSWM is most appropriate when expensive chemicals are required to achieve adequate weed control in part of the paddock.

The development of a simple calculator to assess cost savings with different size patches and different cost chemicals could help increase the adoption of SSWM.

Phytotoxicity can cause yield loss, so being better able to target herbicides to less area of crop may also provide yield benefits. Data regarding the tolerance of different crops and varieties to specific herbicides is found on the NVT website (www.NVTonline.com.au).

Tools for SSWM

The WeedSmart app (IOS) provides a simple tool to gauge herbicide resistance and weed seedbank management. Used strategically it could help to establish if SSWM will achieve weed seedbank reduction.

RIM – Ryegrass integrated management tool (http://ahri.uwa.edu.au/). While this is promoted as a paddock scale tool, paddocks can be divided into smaller areas and the economics of different treatments compared.

A guidance and section control profit calculator is available on the Kansas State University website (http://www.agmanager.info/tools/). While not specifically for SSWM, this calculator can show the benefits of section control to reduce overlap and so decrease the potential for herbicide damage.

Biog. Sam Trengove is a private agronomist based in Bute, South Australia. He specialises in the use of PA tools to augment agronomic management and site specific weed management research. He is a long standing committee member of SPAA.

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Sam Trengove (L) and Stuart Sherriff who are demonstrating the potential use of the H-sensor for weed patch management in Australian crop and weed combinations. Photo: Emma Leonard

GLOSSARY – DEFINITIONS OF COMMONLY USED TERMS RELATED TO PRECISION AGRICULTURE

A

A-B line

An imaginary straight line between two points, A and B, chosen by a machine operator and calculated by a guidance system to follow. The A-B line defines a series of wheelings, a fixed distance apart, across the whole field. There are different reference lines that can be set in a field to fit a particular geography or layout.

Accuracy

The precision with which a positioning system can locate a point at which data is recorded or the position of a vehicle. Different systems vary in their accuracy and their suitability for different tasks. There are three levels of accuracy in a GPS system: low (+/– 50-100 cm), medium (+/– 10 cm) and high (+/– 2 cm).

Active light sensor

A light sensor that emits its own light to illuminate the crop and measure the amount of light reflected from it. Active light sensors usually only capture a relatively small number of wavelengths because it is difficult to produce a bright enough light.

Active Sensor

a device that generates a signal, bounces it off an object, and measures the signal reflected from the object.

Aerial Imagery

Photos taken from airplanes, satellites, or UAVs to assist growers to determine variations within an area of interest such as a field

Airborne Scanner

an ultrasound, laser or other scanner mounted on an aircraft, providing continuous data on ground or crop features under a flight path

Application

A practical use of computer software, an electronic system or a concept.

Application map

A plan showing the location and rate at which seed, fertilisers or agrochemicals will be applied across a management zone. An application map is derived manually or automatically from analysis of yield maps, weed maps, etc.

Arc

A line described by an ordered sequence of points associated with vector data models. When a node joins two or more arcs and several arcs are linked together in a loop, they form an area or polygon.

Archive

The storage of historical records and data. When you have collected a year or two of data from your precision farming applications, you have started your own archive.

Area Mapping

the production of a plan which defines an area in a field or a field boundary, or calculates the size of an area, by remote sensing technology

Assisted Steering

An adaptation of the steering system of an existing vehicle to GPS automation, by replacing the standard steering wheel with a powered version or fitting a drive mechanism to it a system that operates boom sections automatically using a positioning system and precise on-off timing to minimise over-application caused by overlapping or missed areas caused by underlapping.

Attribute value

A value or property that is a characteristic of a spatial element. For example, a specific symbol or color may represent 150-160 bushels/acre that is a value assigned to that attribute.

Automatic Machine Control

Computer control of operations carried out by agricultural vehicles, based on a positioning system, and often combined with information collected by remote sensing technology. Automatic control can be used to control, for example, steering, headland management, spray boom height and rate of application of seed, fertilisers or agrochemicals

Automatic Steering or Auto Steering

A system based on GPS signals that steers a vehicle across a field without overlapping or underlapping. Auto steering is used on tractors, combines, and forage harvesters, and on self-propelled sprayers, spreaders and mowers

Automatic Section Control

Turns application equipment OFF in areas that have been previously covered, or ON and OFF at headland turns, point rows, terraces, and/or no-spray zones such as grass waterways. Sections of a boom or planter or individual nozzles/rows may be controlled.

Autopilot

A system using corrected GPS signals to steer and guide a tractor/sprayer/spreader automatically through the field. A typical autopilot system would consist of one or two GPS receivers, a radio to receive corrections, a controller, a computer display, sensors, and electro-hydraulic valves or servo motor. Currently, most automated guidance systems only steer the tractor and the operator is required to control the throttle position, implement height, etc.

B

Base Map

The outline of your field with its proper coordinates is your base map. Data collected within the field by your yield monitor will be defined in location by the base map, which is a binary digital map. This simple map that shows the boundaries of a field or section and information about any unique feature.

Base Station

A stationary GPS/GNSS receiver, setup over a geo-referenced point that provides correction data to a GPS/GNSS rover unit. Correction data can be broadcast via radio frequency or the internet. The premise behind the service is simple: a base station receiver is placed on a stable, immobile mount at a known point; the base station continually collects static position information under local or wide-area field conditions and the positioning errors computed at the base station (the differences between "observed" values and "truth") are assumed to be the same errors occurring at the mobile receiver (rover). The base-station errors are transmitted to the mobile receiver on the tractor, allowing the rover unit to use this information to calculate corrected positions.

Biomass Map

A plan that shows the variation in the crop canopy within a field, based on the data from a biomass sensor. It can indicate differences in soil fertility and therefore crop nutrient requirements, allowing fertiliser to be applied at different rates in different places.

Biomass Sensor

A remote sensor that measures biomass by measuring the light reflected from the crop canopy. The data can be combined with GPS to make maps of canopy size, indicating differences in soil fertility.

Boom Levelling

Automatic adjustment by ultrasound sensors of the height of a spray boom so that the spray pattern is uniform Sensors mounted at the centre and tips of the booms monitor nozzle height above the round or crop and feed the information to a computer that makes small alterations to the boom hundreds of times a second. The boom can also be raised on headlands to avoid obstacles.

Boom Section

A part of a spray boom that can be turned on or off independently from other sections along the boom. Automatic systems control boom sections using a positioning system and precise on-off timing to minimise over-application caused by overlapping or missed areas caused by underlapping.

Boundary

A GPS referenced definition of the exterior of a field. Used to delineate field area (hectares) and provide a basis for map creation. Important in Precision Ag equipment for the defining where controllers should 'shutoff' (not apply product).

C

CANBUS

A digital wiring system that connects different control units in a vehicle such as a tractor or combine, allowing data for machine control and diagnostics to be transferred between them CAN is an abbreviation of 'Controller Area Network'.

Can-bus (in tractors and implements)

Can-Bus is a high-speed, wired data network connection between electronic devices. The hardware/wiring of Can-Bus networks are generally the same, while the protocols for communication can be different and vary depending on the industry where they are used. These networks are used to link multiple sensors to an electronic controller, which can be linked to relays or other devices on a single set of wires. This reduces the amount of wires needed for a system and allows for a cleaner way to connect additional devices as system demands change.

Canopy Sensing

the process of collecting information on crop characteristics such as biomass and chlorophyll content from a distance, by means of satellite, aerial or tractor-mounted remote sensors.

(The) Cloud

"The cloud" refers to servers that are accessed over the Internet, and the software and databases that run on those servers. Cloud servers are located in data centers all over the world. By using cloud computing, users and companies don't have to manage physical servers themselves or run software applications on their own machines. The cloud enables users to access the same files and applications from almost any device, because the computing and storage takes place on servers in a data center, instead of locally on the user device.

Compaction

Compressed soil structure caused by pressure on the soil by vehicles, producing poor growing conditions. Soil compaction has a significant negative effect on crop yields. Factors associated with compaction that reduce growth potential include oxygen supply, volumetric water content and vulnerability to losing nitrogen into the atmosphere; the crop may also root poorly.

Compatibility

The ability of mapping software to work with different makes of machinery control equipment.

Controlled traffic farming (CTF)

A management system that ensures that all the vehicles used in a field keep to the same permanent traffic lanes every year in order to restrict compaction of the soil to the smallest possible area. The benefits are improved soil structure on untrafficked areas, which then require less tillage and have better drainage and less erosion, with resultant yield increases. *Abbr.* **CTF**

Correction Signal

A radio signal that improves the positioning accuracy provided by the basic GPS signal to much less than one metre Inaccuracies in the GPS signal, caused by interference in the ionosphere and other factors, are measured and correction data are broadcast, also via satellite or ground system, to the GPS receiver in the tractor or other vehicle.

Crop Calibration

the adjustment of machinery to the characteristics of a specific crop at a specific time, such as moisture content at harvest, or the different reflectance characteristics of different wheat varieties.

Crop Reflectance

the amount of visible or invisible light reflected by a crop. Infrared reflectance, which cannot be seen by the human eye, broadly measures canopy size/biomass and together with the amount of visible green light reflected from a crop gives an indication of its total green area.

Crop Sensing

The process of collecting information on crop characteristics such as biomass and chlorophyll content from a distance, by means of satellite, aerial or tractor-mounted remote sensors.

Crop Variability

Differences in crop yields within a field caused by factors such as differences in soil type, soil fertility, compaction and previous cropping patterns.

Contour Map

Yield map that combines dots of the same intensity/yield level by interpolating (or kriging).

Contour Line

A line used to represent the same value of an attribute (elevation or yield).

Contouring

Interpolation method used to distinguish between different levels of an attribute (elevation, fertility, yield).

Control Segment T

he network of tracking stations that monitor and control GPS satellites.

CF card (Compact Flash card)

A small, portable card used for storing data in electronic devices. In precision ag equipment it is used in monitors and/or controllers to store and transfer data.

Controller

An electronic device used to change product application rates on-the-go, based on user directions or prescription applications maps.

Coordinate System

Coordinate systems are used in GPS/GNSS navigational systems to reference locations on Earth. There are many coordinate systems, but frequently used ones include: latitude and longitude, Universal Transverse Mercator (UTM), and State Plane coordinate systems.

CORS (network)
(Continuously Operating Reference Station)

Continuously Operating Reference Station. A network managed by the U.S. office of National Ocean Service (NOAA) to provide GNSS data consisting of carrier phase measurements throughout the United States.

Contour

A line connecting a set of points, all of which have the same value. A contour line will show elevations of the same value.

Crop Scouting

Precise assessments of pest pressure and crop performance that can be tied to a specific location for better interpretation.

D

Database

A logical collection of files managed as unit. A GIS database includes data about both the position and the attributes of geographic features.

Database management system (DBMS)

A collection of software for organizing the information in a database that might contain routines for data input, verification, storage, retrieval, and combination.

Data File

An electronic data record collected during a field operation and typically saved in the storage card. Common delimiter-separated formats are comma-separated-value (.csv), .dat, and .txt.

Data Input

The entry of information into a computer through the use of a keyboard, digitizer, scanner, or even entering data from already existing databases.

Data layer (in GIS)

A layer of information on a GIS map. A map can have many layers to present different types of information. For example, the first layer of a map may be a satellite image of an area. The next layer may have only lines that represent roads or highways. The next layer may contain topographic information and so forth.

Data Standardization

The process of achieving agreement on common data definitions, representation, and structures to which all data layers must conform.

Data Collection

In precision farming, the gathering of information on fields and crops in digital form by sensors, in addition to data collected manually or visually.

Data Logging

The automatic recording by a computer of information gathered digitally over time.

Datum

A geodetic datum defines the reference systems that describe the size and shape of the earth. Datum have evolved from those describing a spherical earth to ellipsoidal models derived from years of satellite measurements. Frequently used datum include: World Geodetic System 1984 (WGS 84), North American Datum of 1983 (NAD 83), and North American Datum of 1927 (NAD 27). Referencing geodetic coordinates to the wrong datum can result in large position errors.

DEM (Digital Elevation Model)

A digital representation of the elevation of locations on the land surface. A DEM is often used in reference to a set of elevation values representing the elevations at points in a rectangular grid on the Earth's surface.

Differential Global Positioning System (DGPS

A system for providing a very accurate position, by calculating the difference between the actual location of a fixed-position ground station and the satellite-located position of the station, and providing a correction signal to a mobile user, either directly from a ground station or via a satellite.

This system corrects for errors introduced by interference with the GPS signal and produces a very accurate signal of well below one metre, which agricultural applications require. *Abbr.* **dGPS, DGPS**

Directed Soil Sampling

Traditionally fields have been sampled on a whole-field basis, i.e. one sample from an entire field. With directed soil sampling, a field is divided into grids (typically 2.5 acres each) or zones (typically 10-20 acres each) and a soil sample is collected from each grid or zone. Directed soil sampling allows targeted application of specific nutrients within a field.

Differential Correction

Correction of a GPS signal that is used to improve its accuracy (to less than 100 m/~330 ft) big using a stationary GPS receiver whose location is known. A second receiver computes the error in signal by comparing the true distance from the satellites to the GPS measured distance.

Documentation

A term commonly used to describe the recording of mapping or paddock data to a hardware console or display.

Drift

The change in a GPS position over time, by up to as much as 1.5 metres in an hour. This variation occurs as a result of changes in the orbit of the satellites providing the positioning signal, which rise and set like the sun, as well as interference to the signal by atmospheric conditions.

E

EC mapping

The use of information on the characteristics of a soil revealed by measuring its electrical conductivity to create a soil map. EC measurements can be taken at two depths, referred to as shallow arrayand deep array measurements, and the relationship between the two can also provide useful information.

Electrical Conductivity

A measure of how easily an electrical current flows through a material such as soil. The electrical conductivity of a soil sample indicates the amount of salt, sand, clay, organic matter, and water it contains, so with GPS input it can be used to create a soil map. Measurements can be taken at two depths, referred to as shallow array and deep array measurements, and the relationship between the two can provide useful information. *See also*

EC mapping electromagnetic induction

A method of measuring the electrical conductivity of soil by passing an electromagnetic wave through the ground. *Abbr.* **EMI**

Electromagnetic Radiation

Radiation in the form of electromagnetic waves such as visible and invisible light rays, gamma rays, X-rays and radio waves.

Electromagnetic Spectrum

The full range of electromagnetic radiation from the shortest to the longest waves.

Electronic sensor (optical, spectral, displacement)

A device consisting of electronic circuitry used to measure the physical world. Optical sensors use the physics of light to generate an electronic signal that can be used to measure physical characteristics. Spectral sensors refer to a line of electronic sensors that also use the physics of light to generate electronic signals but generally refer to sensing multi-bandwidths in the visible to infrared part of the electromagnetic spectrum. Displacement sensors refer to a line of sensors that use a reflected signal (sound/sonar, light/laser, radar/radio-waves) to find the distance between the sensor and an object.

End Turn Automation/Auto Turn

Allows tractors, sprayers and combines to make fully automated turns at headlands using alternating, infill and single direction infill patterns. It works by assessing the machinery geometry and available turning space on the headland to calculate the best turn path, so that it is positioned, ready for the next oass.

Extrapolation

A method or technique to extend data or inferences from a known location to another location for which the values are not known.

F

Field

A set of alphanumeric characters comprising a unit of information.

A location in a data record in which a unit of information is stored. For example, in your database, one of your crops may contain columns of data such as location #, crop type, variety, date of planting, etc. (all of which are fields).

A specific location (or paddock) on a person's farm that may be called "Field # 10A".

File Formats

CSV file - A Comma Separated Values (CSV) file is a plain text file that contains a list of data. These files are often used for exchanging data between different applications. These files may sometimes be called Character Separated Values or Comma Delimited files. They mostly use the comma character to separate (or delimit) data, but sometimes use other characters, like semicolons.

GEOTIFF - GeoTIFF is a public domain metadata standard which allows georeferencing information to be embedded within a TIFF file. The potential additional information includes map projection, coordinate systems, ellipsoids, datums, and everything else necessary to establish the exact spatial reference for the file.

KML & KMZ - Keyhole Markup Language is an XML notation for expressing geographic annotation and visualization within two-dimensional maps and three-dimensional Earth browsers.

KML is the file extension for an unzipped file, while **KMZ** is the zipped version of a KML file. 3. **KML** is used to save and store map locations in general, while **KMZ** is used in the same capacity for more specific locations like placemarks. ... As a compressed or zipped file, **KMZ** has a smaller file space and size.

Shape file - A **shapefile** is a simple, nontopological format for storing the geometric location and attribute information of geographic features. Geographic features in a **shapefile** can be represented by points, lines, or polygons (areas). **Shape file** – A GIS software file that can contain many pieces of information about a geographical area. There are 3 'pieces' of a shape file: .shp, .dbf, and .shx.

Flow Sensor

A sensor that measures the amount of flow through an enclosure (tube, pipe or housing) per unit of time.

G

Geographic Information System (GIS)

A computer-based system used to input, store, retrieve, and analyze geographic data sets. The GIS is usually composed of map-like spatial representations called layers which contain information on a number of attributes such as elevation, land ownership and use, crop yield and soil nutrient levels.

Geographic (spatial) data

Data that contains information about the spatial location (position) and the attribute being monitored such as yield, soil properties, plant variables, seed population, etc.

Geo-Stationary Satellite

An orbital path of a satellite that is synchronized with the earth's orbit or space vehicles in an orbit which keep them over the same location on the earth at all times.

Georeferencing

The association of information on yield, pH, soil nitrogen or other factor with a position in a field Map coordinates are assigned to an image derived by remote sensing.

GLONASS (Global Navigation Satellite System)

A satellite-based navigational system based on a constellation of satellites owned by the Russian Federation government.

GPS (Global Positioning System)

The satellite-navigation network maintained by the United States Department of Defense (USDoD). The Global Positioning System consists of a minimum of 24 operational satellites that orbit the earth and provide positional information to GPS receivers. Using the geometric principle of triangulation, a position on earth can be determined when a GPS receiver obtains data from a minimum of three satellites. Receiving data from additional satellites further increases the positional accuracy.

GPS antenna

The device that receives satellite signals from space. On most hand-held GPS devices, the antenna is integrated into the receiver device. For machine GPS systems, the antenna is typically an external device that can be mounted on top of the vehicle, away from the receiver.

GPS-compatible controller

A system that can operate a sprayer, spreader or drill automatically according to an application map, using the Global Positioning System.

Graphic Display Unit

A device that receives digital data and converts it to a visual image.

Ground Penetrating Radar

A non-destructive system that uses pulses of electromagnetic radiation in the UHF and VHF bands to penetrate the ground and create an image of the subsurface from the reflected rays. The depth to which it can penetrate is greater when electrical conductivity is lower.

Ground Truthing

Observing and measuring something such as leaf area index in the field, to compare it with values calculated from an image obtained by remote sensing.

Ground-Based Sensor

A sensor mounted on a vehicle or building.

Grid

A data structure that uses rectangular units or grid cells arranged in rows and columns to represent an area like a field.

Grid Mapping/Sampling

Predetermined locations in a field where soil or plant samples may be obtained for analysis. The test information can be used for assessing fertility needs and determining approximate locations for varying fertilizer and lime applications.

Ground Control Points

Stationary objects/areas on the earth's surface that provide georeferenced points in a remote sensing image/aerial photograph.

Ground Reference Data

The field collection of data that is used in the interpretation of information gathered from other sources such as a yield image or a remotely sensed image. Also known as ground truth but the preferred terminology is ground reference.

Guidance

A system based on a positioning system that shows a driver where to steer to cover a field at the spacing required for the implement being used without overlapping or underlapping Guided steering avoids losses from underlapping or overlapping and allows more accurate working in the dark.

Guided Crop Scouting

Assessment and recording of crop anomaly and conditions on a site-specific basis using a backpack GPS receiver and hand-held computer. The system allows the user to record growth stage/maturity, plant vigor, presence of disease, weed and insect infestation.

H

Headland Management

In precision farming, the use of a guidance system to control the turn made by a tractor at field edges automatically and precisely, controlling the implements and minimising overlap when lifting and replacing implements. The use of such a system increases the speed of turn and the accuracy of placement while reducing operator workload.

I

Image Classification

Processing techniques which apply quantitative methods to the values in a digital yield or remotely sensed scene to group pixels with similar digital number values into feature classes or categories.

Internet of Things (IoT)

The Internet of Things, or IoT, refers to the billions of physical devices around the world that are now connected to the internet, all collecting and sharing data. In agriculture the term is often used to describe sensors in the field or in machines. Devices can be remotely monitored and controlled in real time, and can include anything from pumps, sheds and tractors to weather stations and computers.

In-field Variation

Differences in a factor such as yield, soil fertility or soil type in different parts of a field.

Infrared Reflectance

The reflection of invisible light in the infrared wavelengths of the spectrum from an object or area. Infrared reflectance, especially near infrared reflectance, is used for remote sensing of soil and crop characteristics.

Infrared Sensor

A device that can detect information about a field, soil, or crop from a distance, by measuring the amount of infrared light reflected from it.

ISOBUS

An international standard, ISO 11738, for communication between tractors and implements. ISOBUS potentially allows the operation of different implements with one tractor control terminal.

ISOBUS-compatible

Software and systems complying with the ISOBUS standard.

K

Kriging

An interpolation method for obtaining statistically unbiased estimates for field attributes (yield, nutrients, elevation) from a set of neighboring points.

L

LANDSAT (LAND SATellite)

A series of U.S. satellites used to study the earth's surface using remote sensing techniques.

Layer

A logical separation of mapped information representing common data (e.g., roads, soils, yields, vegetative cover, and soil tests).

Legend

A map section containing explanations of symbols, colors and/or shades that signify various elements and data values on the map. A yield map will contain a listing of yield values and the color denoting a range of yields.

LIDAR

An airborne system that uses height data received from laser beams scanning the ground to provide very accurate maps of the ground surface. It can be used for mapping soils, monitoring erosion, floodplain management, etc. LIDAR stands for 'Light Detection and Ranging'.

Light Sensor

A device that can measure from a distance the visible and invisible light reflected from a field, soil or crop, in order to assess various characteristics and calculate their values. Infrared sensors, which monitor the light reflected from a crop that cannot be seen by the human eye, broadly measure canopy size/biomass. The total green area of a crop is calculated as the ratio of this infrared reflectance measurement to the visible green light reflected from a crop.

Lightbar (in machine guidance)

A device connected to a GPS receiver typically consisting of a row of led lights to provide the tractor operator with a visual guide, day or night. The lightbar does not automatically steer the tractor or machine, rather it aids the operator in driving on the imaginary reference line.

LoRaWAN

The **LoRaWAN**® specification is a Low Power, Wide Area (LPWA) networking protocol designed to wirelessly connect battery operated 'things' to the internet in regional, national or global networks, and targets key Internet of Things (IoT) requirements such as bi-directional communication, end-to-end security, mobility and location services.

M

Management Zones

Management zones are created by subdividing a field into areas with similar characteristics. Yield maps, soil texture maps, elevation data, EC data, sensor data and farmer knowledge can be used to create management zones in GIS software. There are several methods available for creating management zones.

Mapping Software

A computer program that uses GPS data to produce a map such as a yield map, a nutrient map or a treatment map, or that is used for the measurement of cropping areas.

Multispectral Reflectance Spectrometry

The use of remote sensors to collect information about an object or area by building up an image based on tens to hundreds of adjacent wavelength bands. The image for each waveband is displayed in a different colour in a composite image.

N

NIR (Near Infrared Reflectance)

The reflection of invisible light in the near infrared wavebands of the electromagnetic spectrum from an object or area. Near infrared reflectance is used for remote sensing of soil and crop characteristics. A portion of the electromagnetic spectrum representing light waves approaching infrared. Near-infrared light waves are on the far-red end of the spectrum, some of which appear as extremely dark red or maroon and end at wavelengths that can't be seen by the human eye.

Non-Trafficked Soil

Soil that has not been driven over by vehicles and is therefore less compacted.

NDVI (Normalised Difference Vegetative Index)

The relationship between visible light reflectance and near infrared reflectance of a crop canopy, that allows assessment of its size, nutrient status, and health. Healthy vegetation absorbs most of the visible light that it receives and reflects a lot of the near-infrared light, while unhealthy or sparse vegetation reflects more visible light and less near-infrared light.

O

On-board computer display

A computer screen that the operator uses to monitor, and control machine related electronic systems.

P

Passive Sensor

A light sensor that captures data in daytime, by measuring the amount of light reflected from the crop (for visible wavelengths), or absorbed and then re-emitted (for thermal infrared wavelengths) Passive light sensors are affected by the angle of the sun and cloud cover, although some can correct for changes.

Pass-to-Pass Accuracy

A measure of the relative accuracy of a GPS receiver over a 15 minute interval. This is typically thought of as "guess row error" when driving rows, or skip/overlap from one pass to the next when driving swaths.

Patch Map

A plan that shows where patches of agronomically important weeds are located in a field.

Patch Spraying

Treating only the discrete patches of agronomically important weeds in a field with herbicide rather than spraying the whole field. There are considerable cost benefits from reduced herbicide use, while an environmental benefit is increased floral diversity.

Permanent Traffic Lane

Strip of soil that is permanently compacted, created by a single vehicle wheel or track.

Pixel

A term used in remote sensing referring to the fundamental unit of data collection which is an abbreviation for "picture element". A pixel is represented in a remotely sensed image as a rectangular cell in an array of data values and contains a data value that represents a measurement of some real-world feature.

Point sampling

A method of grid sampling in which a sample is taken in a 10-30 foot radius at the centre point of each grid location.

Polygon

An area enclosed by a line describing spatial elements, such as a similar yields range, land use or soil type.

Positioning Signal

Signal broadcast by a satellite to a receiver on the ground which, when a minimum of three signals are coordinated, allows a location to be established.

Positioning System

A system of linked satellites that transmit radio signals to receivers on the ground, allowing a location to be accurately pinpointed. The core satellite systems are free, as are some of the enhanced dGPS systems such as WAAS (US) and EGNOS (EU). Subscription dGPS services offering high accuracy are available from commercial providers. *Also called* **global navigation satellite system**

Precision

Refers to repeatability of multiple position measurements of the same object or condition.

Precision Farming/Ag/Technology

Management of farming practices that uses computers, satellite positioning systems, and remote sensing devices to provide information on which enhanced decisions can be made. Sensors can determine whether crops are growing at maximum efficiency, highly specific local environmental conditions can be identified, and the nature and location of problems pinpointed. Information collected can be used to produce maps showing variation in factors such as crop yield or soil nutrient status, and provides a basis for decisions on, for example, seed rates and application of fertilisers and agrochemicals, as well for the automatic guidance of equipment.

Prescription

Refers to the map created in an AgGIS which assigns product application rates for variable rate applications. Prescription information is exported to a precision ag controller for application. Prescription maps are commonly used for variable rate seeding, fertilizer, lime and irrigation.

Projection

Refers to the map projection used for precision ag data and mapping. A map projection represents the surface of the earth (sphere) as a flat plane for GIS analysis. Different mathematical parameters are used in the calculation of each projection therefore it is important when working with GIS data that the projection of the data is taken into consideration. Using data layers with varying projections can result in erroneous analyses.

Proximal sensing

Using sensors or instruments close to the object being measured, but not necessarily in contact with the object. Proximal sensing refers to the measurement of physical properties with electronic instrumentation, from a distance. The scale is much smaller than traditional remote sensing from satellites or aircraft.

R

Radiometer

A device that measures the amount of electromagnetic radiation, including visible and invisible light waves.

Radiometric data

Information on crop or soil conditions obtained by sensors detecting visible and invisible light reflected from surfaces.

Radiometric map

A plan created based on the amount of visible and invisible light reflected from the area being studied A radiometric map can identify differences such as those in soil fertility and crop disease.

Random traffic farming

The use of tractors and other vehicles on farm land where operations are carried out in different directions without a fixed pattern of wheelings being established. *Abbr.* **RTF**

Raster Format

Format for storing GIS spatial data in which the data is stored in cells which are addressed by rows and columns of the cells.

Raster-to-vector conversion

A process in which one converts an image such as a yield map of grid cells into a data set layer of lines and polygons.

Rate Controller

An electronic device that varies the amount of chemical/plant nutrient applied to a given area.

Real-Time Application

Using sensors to obtain information from a crop and applying materials at the same time. Real-time application commonly goes hand-in-hand with variable-rate systems. As differences in the crop are measured by a group of sensors, the variable-rate controller changes the amount of material/chemical dispensed in a given area. Information is made use of in 'real-time' as opposed to just collecting it and making use of it later.

Real-Time Correction

Correction of a GPS signal by simultaneously transmitting the differential correction information to a mobile receiver.

Real-Time Mapping

The production of a map by processing and updating data as soon as it is received, for example as a sprayer shows where it has sprayed.

Receiver (in GPS hardware)

A computer-radio device that receives satellite (GPS/GLONASS) information by way of radio waves to determine the position of its antenna relative to the earth's surface. The antenna can be integrated into the receiver or connected externally with a cable.

Reflectance Radiometry

The measurement of electromagnetic radiation, including visible and invisible light waves, reflected from an object. Reflectance radiometry is used for remote sensing of soil and crop characteristics.

Reflectance Sensor

A sensor that measures the amount of a type of light such as infrared light reflected from an object.

Reflectance Spectrum

The part of the electromagnetic spectrum that is reflected by various materials, which reflect and absorb different wavelengths differently. Remote sensors can form images by detecting the solar radiation reflected from different objects or parts of objects on the ground.

Registration

A process where one can geometrically align maps or images to allow one to have corresponding cells or features. This allows one to relate information from one image to another, or a map to an image, such as registering a yield image to a soil map to determine if soils are influencing the yield response.

Remote Display Access

Allows someone from a remote location to view an operating display, handy for diagnostic purposes.

Remote Sensing

The act of detection and/or identification of an object, series of objects, or landscape without having the sensor in direct contact with the object. The most common forms include color and color infrared aerial photography, satellite imaging and radar sensing. examples of remote sensing data include satellite imagery, aerial photography and thermal imagery. This data can be used to identify problem areas (such as plant stress and irrigation deficiencies), differentiate bare ground from vegetation and as a tool in the creation of management zones.

Remote Sensor

A device that collects and processes the visible and invisible light reflected from an object or area. There are passive sensors, in which the energy that is radiated comes from an external source such as the sun, and active sensors that produce their own energy source.

Repeater

A device that receives a radio signal and amplifies or re-transmits it. It is used to extend the range of base station signals and to expand coverage.

Repeatability

The ability of a positioning system to return to the same spot later on. Because of drift, a vehicle may find itself 0.5-1.5 metre out in as little as an hour, depending on the static accuracy of the equipment. RTK is a system that does not suffer from drift and so has good repeatability.

Resolution

A way of detecting variation. In remote sensing, one has spatial resolution (the variation caused by distance separating adjacent pixels), spectral resolution (the variation from the range of spectral responses covered by a wavelength band), and temporal resolution (the variation caused by time over the same location).

RTK accuracy

The highest level of positioning offered by a GPS system, +/– 2 cm. This system requires a base station (on a tripod or building), with a dGPS receiver and radio transmitter, to get a very local correction signal, accurate to a few centimetres. The base station can transmit to multiple vehicles up to five or six miles away depending on the terrain.

RTK guidance

The use of a positioning system with an RTK correction signal to increase the accuracy of working to +/– 2 cm.

RTK (Real Time Kinematic)

The most accurate form of GPS/GNSS correction and the only GPS/GNSS correction that provides +/-1 inch (centimeter-level) accuracy and year-to-year repeatability. RTK utilizes two dual-frequency receivers which are necessary for highly accurate operations, such as precision guidance for row crop production. RTK correction can be provided in two ways: personal base stations or Continuously Operating Reference Stations (CORS).

Runline

Another term for AB Line.

S

Satellite

A communications vehicle orbiting the Earth. Satellites typically provide a variety of information from weather data to television programming. Satellites send time-stamped signals to GPS receivers to determine the position on the Earth.

Satellite-Mounted Sensor

A remote sensor on a satellite that can capture large amounts of data over a large area quickly.

Sensor

A device that produces an electrical signal in response to a stimulus such as light or ultrasound.

Serial port

A serial communication interface which transfers information. In precision agriculture, serial ports are often used to transfer data between a personal computer and precision ag equipment such as a monitor, modem or receiver.

Site-specific Management (SSM)

Also referred to as precision farming, SSM targets or varies inputs to meet crop needs. In SSM a field is divided into smaller management areas, rather than using the same management on the entire field. For example, fertilizer can be applied in a field only where it is needed instead of applying a broadcast application across the field. GPS/GNSS technology is often used to implement SSM.

Smart Sensor

A sensor that can monitor its own operation and compensate for changes in operating conditions. For example, a group of smart sensors located throughout a field can be used to measure soil moisture in real time and transmit the results to a control system for irrigation.

Smartphone

Refers to a cellular phone with advanced capabilities, often with PC-like functionality, internet capability, and a complete operating system.

Software

The programs, procedures, algorithms (set of rules), and their associated documentation, for a computer system.

Spatial Application Technology

The use of data collection devices such as remote sensors to establish which areas within fields and crops need a specific treatment and then deliver site-specific treatment to that area.

Soil Mapping

The production of a map of a field showing differences in soil characteristics such as texture or fertility that can be used, for example, to apply fertiliser only where it is needed and in appropriate amounts. The production of a soil map can help to reduce the high cost of fertiliser application while maintaining or even increasing yields. *Also called* **nutrient mapping**

Soil Sampling

Taking small amounts of soil from a site to analyse composition, nutrient content or condition.

Soil Sensing

The measurement of soil characteristics by remote sensing techniques.

Soil Texture Map

A plan of soil type, created from a set of samples taken across an area at different depths or inferred from an EMI scan.

Soil Variability

Differences in soil type and fertility across an area, as a result of previous cropping patterns, fertiliser use, underlying soil texture or compaction.

Spatial Data

Data that contains information about the spatial location (position) and the attribute being monitored such as yield, soil properties, plant variables, seed population, etc. Synonymous with geographic data.

Spatial Distribution

The way in which objects or features are located in an area relative to other objects or features; they may be evenly dispersed, randomly dispersed or aggregated (clumped together). Information on the spatial distribution of crop plants, weeds, diseased areas and soil types, for example, may be turned into maps on which site-specific treatments can be based.

Spatial Information

The association of measurements or observations with position in a field.

Spatial Mapping

The production of a field map by associating data on factors such as soil fertility or crop health with field position.

Spatial Resolution

The spacing between the points at which measurements or observations were taken in a field. The closer the sampling points are to one another, the higher the spatial resolution.

Spatially Selective Treatment

The application of different rates of seed, fertiliser, or agrochemicals to soil or plants in different parts of a field, according to need. Herbicide may be applied only to patches of weeds on the basis of a weed map, or fertiliser to specific parts of a field on the basis of a nutrient map.

Spatial Variability

The range of difference occurring in factors such as soil composition, crop yield or insect population according to position in a field.

Speed Sensors

Sensors that measure the rotational speed of a shaft or the reflection of radio or sound waves off the ground to determine forward speed.

Storage card

A memory device used to store data from an electronic device. The most common storage cards are Compact Flash (CF) cards, Secure Digital (SD) cards, and Flash Drives (Thumb Drive/USB Drive). These devices are commonly used in devices such as in-cab displays, mobiles, digital cameras, PDAs, and GPS receivers to store and transfer data.

Steering Assist

A system using corrected GPS signals, a steering motor, and a light-bar to guide the tractor operator through the field. Steering assist systems provide the operator with a visual guide and assist the driver by steering the tractor using an electric servo motor directly attached to the steering wheel.

Sub-Metre Accuracy

Accurate location by GPS to less than one metre.

Subscription Correction Signal

A fee-based GPS/GNSS correction option available through a subscription service from the providing company. For those precision ag applications that need increased accuracy above WAAS or SF1, a subscription correction service can be purchased. OmniStar® (VBS/HP/XP) and John Deere (SF2) both offer subscription correction services that provide a +/- 6, +/- 4, +/- 6, or +/- 4 inch pass-to-pass accuracy, respectively, for agricultural equipment depending on the level purchased. See also HP/XP and SF2.

T

Telematics

The use of telecommunications technology to deliver and store information about the operation of tractors and combines.

Telemetry

Technology that facilitates remote monitoring and measurement.

Terrain compensation

An add-on feature for auto-guidance systems which correct position error that may occur when equipment travels over rolling terrain. Roll, pitch and yaw are commonly referred to when discussing terrain compensation. Roll refers to the change in elevation between the left and right sides of the vehicle; pitch refers to the change in elevation between the front and rear of the vehicle; and yaw refers to any sliding or turning motion of the vehicle to the left of right.

Textural or texture image analysis

The characterisation of regions in a digital image by their texture, allowing, for example, the different leaf types of cereals and weeds to be distinguished.

Thermal Imagery

A type of remote sensing that depicts the heat emitted or reflected by an object, such as plants growing in the field. It can be used to detect plant stress and determine irrigation needs. See also Remote Sensing.

Tractor-mounted sensor

A remote sensor attached to a tractor that captures data in close proximity to it with good resolution.

Traffic lane

A compacted strip of soil created by a single vehicle wheel or track.

Tramlines/traffic lane/wheel track

Parallel lines on the ground created by the wheels or tracks of a vehicle, usually the tracks made by a sprayer or fertiliser spreader.

Treatment map

A plan that defines where the areas of a field to be treated and the application rate that should be used. A treatment map can be used to control, for example, a seed drill, a fertiliser spreader or a sprayer to deliver site-specific treatment.

U

Uniform Rate Technology

The application of a single rate of seeds, fertilisers, or agrochemicals across a whole field. *Abbr.* **URT**

Unmanned Aerial Vehicles (UAVs)

An unmanned aerial vehicle (UAV), commonly known as a drone and also referred by several other names, is an aircraft without a human pilot aboard. The flight of UAVs may be controlled either autonomously by onboard computers or by the remote control of a pilot on the ground or in another vehicle. In agriculture, UAVs are typically used to survey crops. The available two types of UAVs – fixed-wing and rotary-wing – are both equipped with cameras and are guided by GPS. They can travel along a fixed flight path or be controlled remotely.

USB (Universal Serial Bus) Mass Storage Device

A memory device used to transfer and store data which uses the standard USB interface connection. In is also commonly referred to as a jump drive, flash drive or thumb drive.

V

Variability

The range of difference occurring in a soil, crop or other factor.

Variable rate application

The application of seeds, fertilisers or agrochemicals at different rates as required by the conditions in different parts of a field. *Abbr.* **VRA**

Variable Rate Input

The use of different rates of fertilisers or agrochemicals in different parts of a field. For example, fertiliser application can be increased early in the season exactly in those areas where plant density is low in order to build an optimum leaf canopy.

Variable Rate Technology

The devices enabling the differential application of fertilisers or agrochemicals in different parts of afield, according to an application map or real-time sensor. *Abbr.* **VRT**

Vector Format

A format for storing and displaying GIS spatial data that is stored as points, lines or areas to create a map object. By using a nearly continuous coordinate system, vector data can be more accurately georeferenced than raster data.

Vegetation Index

A scale that indicates relative growth and/or vigour of green vegetation, based on a ratio and/or linear combination of measurements of reflected light in the red and near infrared regions of the spectrum. *Abbr.* **VI**

Virtual Reference Station

In a wide-area differential GPS system, a position for which locational corrections are predicted, based on calculations from a network of base stations and the user's position. *Abbr.* **VRS**

W

Waveband

A remote sensing term used to describe a contiguous range of wavelengths of electromagnetic energy. Visible wavelengths (seen by the human eye) which range from 400 to 700 nanometers. Near infrared (NIR) wavelengths are at 700 to 2600 nanometers.

Wavelength

In Precision Agriculture technology, wavelengths are referenced when talking about radio transmissions for wireless communication or devices that measure/emit light in different parts of the spectrum.

Weed Mapping

The production of a plan showing where agronomically important weeds are located in a field. Many such weeds are distributed in patches, and the production of a weed map potentially allows targeted treatment with herbicides.

Wi-Fi

The term Wi-Fi suggests Wireless Fidelity and is used to describe a narrow range of connectivity technologies including wireless local area network (WLAN). Wi-Fi certified and compliant devices can be installed on personal computers and tractor-mounted displays.

Wireless Communication

Data transfer and voice communications using radio frequencies or infrared light.

Wireless Data Transfer

The transmission of data over the air. In agriculture this is most commonly utilized to move mapping data from machine to a cloud-based server or vice versa to eliminate the need for a device like a USB.

Wireless Sensor

Remote sensor that does not require a cable connection except for power.

Y

Yield Map

A map that represents differences in crop yield within a field on-the-go by a harvester equipped with an instantaneous yield monitor. Data is usually collected by a yield monitor on a harvester over one to three second intervals. Each location/ site (pixel) in a field is assigned a specific crop yield value.

Yield Monitor

Electronic device on a harvester that continuously (or regular intervals) measures and records crop yields and moisture on-the-go against field position.

Yield Monitoring

Yield monitoring allows growers to determine higher and lower yielding areas of the field. When coupled with a GPS, yield monitors can be used to produce yield maps. Yield monitor components include sensors (used to measure yield), DGPS (provides position information) and a display (processes information from sensors, displays information in the cab and writes yield data to a data card). Yield monitors are readily available for combines and cotton pickers. Equipment manufacturers offer the option to order yield monitors as a factory add-on and third-party products are also available.

Yield Variation

Differences in yield across a field in any one year, or from year to year.

Z

Zone Management

The information-based division of large areas into smaller areas for site specific management applications.

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