PRECISION AGRICULTURE

FACT SHEET

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How to put precision agriculture into practice

Precision agriculture (PA), also known as site-specific farming, is about doing the right thing, in the right place, in the right way, at the right time.

KEY MESSAGES

- Precision agriculture (PA) enables land and crop variability to be identified and managed.
- Do the sums before investing in PA to ensure any investment in new technology will increase returns and/or improve efficiency.
- When first shifting to variable rate inputs, start with those that are not time-critical such as applying lime, gypsum or top-dressed nitrogen or potassium.

At seeding, PA tools such as guidance, autosteer and variable rate allow seed and fertiliser inputs to be changed on-the-go and placed where they are most needed; in many situations this results in improved productivity.

PHOTO: EMMA LEONARD

Examples of how PA can be used to benefit a farming system include:

- Matching the seed rate to soil type to improve germination.
- Changing varieties or crops within a paddock to meet soil conditions.
- Targeting lime or gypsum to soil pH or sodicity.
- Redistributing seeding fertiliser to allocate higher rates to high performing parts of a paddock.
- Creating fertiliser replacement maps based on previous crop yield.
- Using biomass maps to identify in-crop nitrogen deficiency.
- Reducing overlap so that desired input levels are applied.
- Inter-row weed control non-selective herbicides with shielded sprayers.
- Inter-row seeding to reduce the transmission of soil and stubble-born disease.
- Soil compaction can be reduced when accurate guidance and controlled traffic are combined.
- Targeting in-crop nitrogen to potential production can reduce crop lodging and increase yield.
- Identifying least productive areas with yield maps can mean these can be removed from cropping and inputs focused on productive areas.
- Developing uses:
  - Patching out high densities of weeds and applying different herbicides or rates.
  - Monitoring protein at harvest and blending grain to achieve a specific quality grade.

Some of the financial benefits of PA reported by growers are shown in Table 1.

TABLE 1 ANNUAL DOLLAR BENEFIT OF ADOPTING PRECISION TECHNOLOGIES

	*Annual benefit ($/ha)			
	Savings in overlap	Fertiliser management	Increased production using VRT	Other benefits[1]
**Average of up to six WA growers	9	12	(None reported)	6
***Average of up to eight South Australian growers	6	8	7	13

* Assessed in 2006 and 2007. **CSIRO; ***Source: Dr Matthew McCallum. 1. Inter-row sowing, reduced soil compaction, shielded spraying.

WHAT IS PRECISION AGRICULTURE?

Unlike uniform farming, where all areas in a paddock are treated the same, precision agriculture (PA) uses information from grain yield and quality monitoring equipment, global positioning systems (GPS), in-crop sensors, satellite biomass imagery and electromagnetic imaging (EMI) technology to better match agronomy to the production potential of specific areas.

Currently, the information collected is used to produce maps of soil attributes, grain yield, grain quality, profit and likely management zones.

Maps show where further investigation (ground truthing) is needed to check the extent of a crop's variation, the cause of the variation, the cost of remediation efforts and likely returns from responsive crops.

But the importance of a grower's knowledge of each paddock must not be overlooked. When making site-specific management decisions, grower knowledge needs to be combined with PA data and ground truthing.

Examining maps of crop performance, and ground truthing data such as soil and plant test results, will help determine if grain yield differences are in large, isolated and seasonally stable areas.

If grain yield consistently and/or predictably varies across an area, the area can be zoned according to production potential (for example, low, medium and high) and variable rate (VR) inputs applied (see Figure 1).

To start exploring PA and the use of variable rate (VR) technology, consider investing in low-cost technology first and then moving to increasing levels of sophistication as experience grows. For example, many growers start with a yield monitor with GPS guidance that provides ±10cm accuracy, and combine this with some soil sampling to produce blocked management zones; rates are then changed manually. More experienced growers may install or share a base station and use Real Time Kinematic (RTK) guidance that gives ±2cm accuracy, using autosteer and equipment that can vary rates on the go in response to more complex management zones.

As a first step, the lime, gypsum or top-dressed nitrogen and potassium rate may be varied within or between paddocks based on a comprehensive nutrient analysis involving soil and/or plant tests. Starting VR with these activities allow operators to gain experience with equipment set-up and coverage maps at periods when breakdowns or delays will not impact on harvest returns.

As experience and confidence grows, inputs can be varied at seeding when every second counts.

HOW DO I IDENTIFY IN-PADDOCK VARIATION?

To adopt precision agriculture (PA), the starting point is identifying in-paddock variation and deciding whether this warrants variable management.

In-paddock variation can be measured and mapped at harvest and during the growing season while crops are growing. Soil variation is best measured between seasons. This data can be combined to produce management zones.

Mature crop variation

Some harvesters are fitted with on-board monitors that measure grain yield and/or protein information and save it on data cards similar to those used in digital cameras.

The data cards are downloaded to computers and mapping software is used to convert the information into maps.

Harvester manufacturers and third-party software suppliers provide mapping software.

Growing crop variation

Differences in growing crops can be detected using hand-held active sensors or retro-fitting these sensors to tractors and boomsprays.

Another way to see differences in crop growth is with satellite images.

Both technologies use a Normalised Difference Vegetation Index (NDVI), which is related to the crop's density and nitrogen status.

Biomass images can be purchased from image providers in the form of analysed satellite or aircraft imagery.

Maps of estimated biomass derived from Landsat satellite imagery give historic data on variation across a paddock, potentially from 1986 until the present day and in certain circumstances can be an acceptable substitute for a series of yield maps.

Also, biomass maps are useful in conjunction with yield maps to determine whether or not biomass was converted to yield. If not, further investigation is warranted.

The same technology is being tested to detect and spray weed patches on

PHOTO: EMMA LEONARD

Is this paddock variable? Variation is not always obvious. Soil data, satellite imagery and yield maps can help identify variation.

CASE STUDY

PA SAVES $25/HA IN INPUTS EVERY YEAR

Kym I'Anson saves $25 a hectare every year by using precision agriculture (PA) technologies such as autosteering, inter-row sowing and variable rate (VR) management of inputs.

Mr I'Anson, who farms 1250ha in South Australia, started investigating PA in 1999 when he bought a grain yield monitor for $6000.

But the Marrabel grower was unable to map yield variation across paddocks until 2002 when he bought a John Deere global positioning system (GPS) receiver, processor and software.

Two years later (2004), Mr I'Anson bought a ±10 centimetre hydraulic autosteer kit for $6000, which could be linked to the GPS receiver and processor. For guidance, he uses the StarFire2 correction signal, which he says is reliable and repeatable.

During 2005, he upgraded to a newer display and mobile processor to autosteer two tractors and the harvester. Mr I'Anson says adding autosteer reduces overlap by eight per cent and enables successful inter-row sowing.

Another useful piece of PA equipment is a hand-held iPAQ and/or Toughbook computer coupled with a GPS receiver and software, which allows soil zones to be mapped across the farm for VR gypsum and lime application.

Acidity and sodicity have been key constraints to crop production on the I'Anson farm, which are characterised by three soil types.

To manage acidity and sodicity, Mr I'Anson has manually mapped the soil types in each paddock using precision farming software.

The software draws a grid across the paddock and pinpoints where each hectare needs to be soil sampled. Using these locations and soil colour, Mr I'Anson takes about 30 individual samples for soil testing.

He then uses soil test results to create VR zones for lime and gypsum.

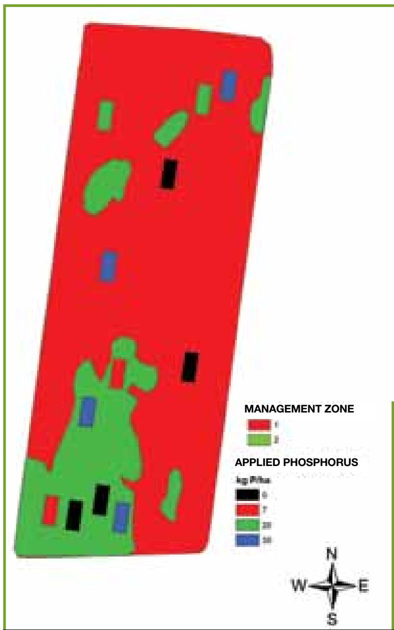
Seventy per cent of Mr I'Anson's property comprises heavy red clay soils, which are sodic and acid (pH 4.0 to 5.5 in calcium chloride). Harvest monitoring reveals crops grown on these soils yield 30 per cent less than others.

But Mr I'Anson says adding 2.5t/ha of lime every four years and 3t/ha of gypsum every five years, while retaining stubble, is improving yield potential and reducing ryegrass through increased crop competition.

He spreads lime and gypsum using a belt spreader and varies rates manually, using the GPS receiver, drums and pegs to identify the three different soil zones in each paddock.

Twenty per cent of the farm (mostly on hill tops) comprises shallow grey shale soils which have tested acid (pH 5.2 in calcium chloride) but not sodic.

Yield and soil data were combined to create two management zones. Four rates of phosphorus were tested in strips in each zone. Zone 2 was more responsive to P than Zone 1. Instead of applying a blanket rateof 11kg P/ha at seeding, the rate was reduced the rate to 7kg P/ha on Zone 1 and increased to 20kg P/ha on Zone 2. Overall paddock production was increased.



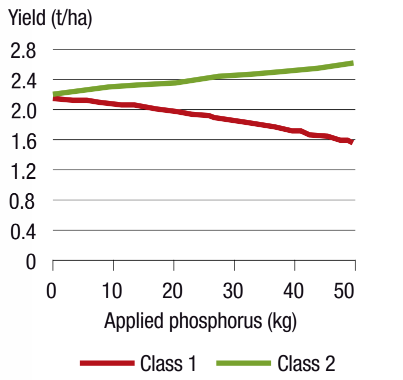


FIGURE 1 IDENTIFYING AND MANAGING VARIATION

the go, as dense weed patches have a higher sensor biomass reading than areas of weed-free crop.

Soil and land differences

Aerial photographs that can be geographically referenced can indicate changes in soil type (colour) if taken during the fallow, and provide a ready indication of where management zone boundaries might occur.

Electromagnetic imaging (EMI) technology measures and maps the electrical conductivity of soil, which is influenced by soil moisture, salt and clay content.

EMI has been used to map soil types and detect zones of contrasting subsoil constraints and hence crop yield potential.

Elevation data can be collected with an EMI survey. Elevation maps indicate variation in topography and where this may be associated with changes in soil type or water logging and run-off.

Gamma radiometric surveys indicate the variation in surface soil texture – sands through to clays.

Physical soil tests targeted to different yield potential zones indicate variation in pH, sodicity, soil water holding capacity and where nutrients have built up or been depleted – through past uniform fertiliser rates mismatched to crop removal.

Variation in soil nutrient supply together with yield potential maps can indicate where variable rate could be applied.

PreDicta B® tests can indicate spatial variation of soil-borne diseases.

These areas are limed at 2.5t/ha. The remaining 10 per cent is deep black soil (pH 6.0 to 7.0) which does not require lime or gypsum.

Mr I'Anson estimates VR saves $8000 in lime and $20,000 in gypsum over the application cycle of four to five years.

For grain production, di-ammonium phosphate (DAP) is applied variably using the previous year's yield map to replace the phosphorous removed. Also, to maximise grain and hay yields, 30 to 70 kilograms per hectare of urea is applied according to soil type.

Deep (0 to 60cm) nitrogen soil tests in different zones showed scope for VR due to nitrogen reserves varying from 80kg/ha to 250kg/ha within the same paddock.

An in-crop sensor identifies where additional nitrogen will be needed during the growing season. The sensor measures crop greenness during July and August, which is then used to produce a biomass image, from which a fertiliser nitrogen map is made to target urea to crop demand.

Blanket nitrogen application at sowing has shown to decrease hay and wheat crop productivity in some areas due to lodging and increased water use. Mr I'Anson says VR nitrogen application has eliminated lodging and enabled him to produce a higher hay and grain yield from those areas while reducing nitrogen inputs by 70 per cent.

For Kym I'Anson, Marrabel, South Australia, PA has resulted in cost savings and improved crop production. He started PA using autosteer to reduce overlap. Using a hand-held GPS unit he delineated soil zones and manually varied rates of gypsum and lime. He now uses yield maps to create phosphorus replacement maps and in-crop biomass sensing to regulate nitrogen inputs.

PHOTO: EMMA LEONARD

ARE VARIABLE RATE (VR) INPUTS JUSTIFIED?

If yield variation is sufficient to justify targeting inputs to certain areas, management zones can be created. A management zone is an area of the paddock that will be managed in a particular way for a specified input.

Management zones are currently the most practical way to apply the correct or desired amount of input where and when it is likely to be needed.

Simple management zones can be created based on knowledge of soil type and productivity. But more detailed and accurate zones are produced using statistical software packages that combine different layers of spatial data (such as yield and EMI maps, see Figure 2).

Zones need regular review as target management, such as the addition of lime to correct acidity in parts of a paddock, may result in a more even yield across a paddock. Inputs may be applied within a zone as a flat rate or varied on-the-go. A management zone for fertiliser may differ from one for seed, for example, so a prescription map may be required for each input.

Data layers are combined to make detailed management zones. The three layers show elevation and are 1) soil electroconductivty (EM38), 2) two years of combined yield data, 3) management zones, for a paddock at Carwarp, Victorian Mallee. Subsequent soil testing within these zones highlighted a significant difference in phosphorus fertility between the zones.

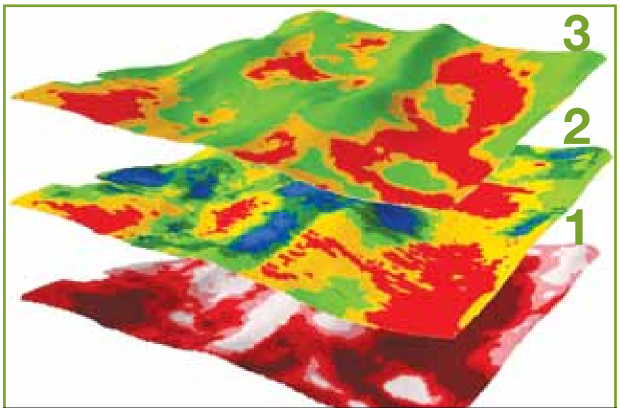


FIGURE 2 ZONE MAP FOR A PADDOCK IN THE VICTORIAN MALLEE

Active sensors that measure the reflectance of a growing crop can identify and target variability at a finer scale than broad management zones, as they adjust inputs continuously according to crop growth as equipment moves across a paddock.

IMPLEMENTING VR FERTILISER AT SEEDING

The following example illustrates how VR fertiliser rates are developed for seeding. A similar process would be applied for varying gypsum, lime and seed rates.

1 Set-up zones

A base layer of spatial data, usually yield or satellite biomass maps, is needed to produce a VR prescription map.

However, because grain yield and biomass patterns change from season to season according to growing conditions, the preference is to collect several years' maps to improve the →

PHOTO: MALLEE SUSTAINABLE FARMING

PHOTO: EMMA LEONARD

(Above) An EMI survey is carried out to map soil types and detect crop yield potential. (Right) Grain yield mapping is the basis of a precision agriculture system as it allows variations to be measured.

base data before making a VR map. PA specialists can use satellite images to provide a source of pseudo-yield data.

Use credible and independent soil tests including deep soil tests, where applicable, to assess nutrient supply relative to plant demand. This will highlight any possible nutrient deficiencies or toxicities down the soil profile.

Rather than mixing soil samples from the entire paddock, target the sampling through the soil and nutrient characteristics of the main soil types; results will help to highlight if variation exists.

Check (ground truth) why low production areas have not achieved their water-limited yield potential by working with an agronomist to consider the impact of weeds, disease, compaction, acidity, nutrient deficiency, pests, frost, poor crop establishment, water-logging, moisture stress or previous treatments and methods.

Create zones, depending on what is known about soil type differences (including soil moisture holding and soil fertility differences), yield variability in the paddock and any other known causes of variability (such as weed density or disease severity).

Commonly, three zones are established; low, medium and high inputs. However, some growers prefer up to 10 zones so equipment responds to more but less extreme rate changes.

Modify zones, if required, based on knowledge of the paddock and further ground truthing.

This often means accounting for human influences on the crop's performance such as where fence lines have been removed between paddocks.

Decide if yield variability can be practically overcome (such as by ripping, correcting a nutrient deficiency or adding lime) or if management needs to change (to include a different crop variety or reducing fertiliser inputs on non-responsive areas and increasing them where there is likely to be an economic yield response).

Determine whether addressing yield variability using PA is economically sensible and the priority this will take in the budget. Discussing these issues with an agronomist may be beneficial.

2 Determine input rates

One approach for determining fertiliser rates for zones looks at fertiliser optimums based on predicted response curves and economics, while the other chooses to replace, at least, the nutrients removed by the previous crop.

The response curve approach works well in responsive situations and where soil test calibrations exist.

The nutrient replacement approach is useful in fertile environments where the crop is relatively non-responsive to fertiliser and cash flow is not an immediate priority.

The response curve approach is easily evaluated for its immediate return on investment. But, the replacement approach is a longer-term decision based on how much a grower is willing to invest now to preserve production into the future.

Response curve approach

The response curve approach requires information on the yield potential and nutrient availability (from soil tests) in each zone.

Any deficit between the nutrient available from the soil and that required to obtain yield potential can be overcome through applying fertiliser in a cost-effective manner.

In many areas, growing season rainfall has the biggest influence on yield potential. With highly variable seasonal rainfall and imprecise climate forecasts, predicting yield early in the season is problematic.

While this makes it difficult to calculate accurate fertiliser rates for zones at sowing, the response curve approach does allow consideration of the risks of over and under fertilising in the different zones for various types of seasons (and different yield potentials).

A solution, especially for nitrogen and to a lesser extent for potassium and sulphur, is to delay fertiliser application until as late as possible and until additional information is obtained with plant tests – to gain as much knowledge about the season and its yield potential without compromising crop yield.

Nutrient replacement approach

Nutrient replacement is based on the grain yield removed from the paddock and the average nutrient concentration of that grain.

Data exist for the range of nutrient concentrations found in grain, and these could be used as a guide for each zone's fertiliser requirement.

Soil tests or in-season plant tissue analysis may help validate these conclusions.

Other methods to determine fertiliser rates for management zones include:

- using yield goals based on different water-holding capacities of soil;
- using simulation programs such as Yield Prophet to predict yield goals in different zones; and
- using a fixed fertiliser budget and distributing fertiliser based on the percentage difference between zones in yield potential.

3 Produce prescription maps

Using mapping software, prescribe each input rate to the zones to produce a VR prescription map and data files for loading into the tractor's task controller, so rates can be varied when sowing.

If unfamiliar with the software or the file types that the task controller needs, seek advice from a PA specialist or equipment supplier.

4 Do a test strip

Run a test strip (with a zero or control treatment of the paddock average) to compare different treatments, or use paddock-scale trials to fine-tune the input rate for each zone in future years.

5 Test the prescription maps

Well before sowing, test the prescription map with the seeder and do a 'dry run' across a paddock.

Check the rates change on all bins when driving over different zones.

Check the GPS receiver is working correctly on the controller, especially if configured differently to communicate with the yield monitor.

Make any last minute changes to prescription maps.

6 Check the results

Use in-crop plant tests, especially for different test strips, to measure plant nutrient uptake to assess the success or otherwise of variable rates.

Sampling whole tops from a known length of crop row or quadrant area can be used for assessing crop growth and nitrogen uptake.

Sampling the youngest emerged blade (YEBs or YMLs) is useful for comparing the concentration of a wide range of nutrients such as phosphorus, potassium, sulphur, magnesium and calcium and the micronutrients zinc, manganese, copper and iron.

An agronomist can advise which are the most appropriate tests to assess the treatments.

Record the growth stage at the time of sampling to allow valid comparisons with known standards for assessing nutrient deficiencies and toxicities.

Collect yield data and compare with the control strip.

Useful resources:

Southern Precision Agriculture Association (SPAA)	**www.spaa.com.au**
The Australian Centre for Precision Agriculture (ACPA)	**www.usyd.edu.au/su/agric/acpa**
David Lamb, University of New England	**0428 886 088 Email dlamb@une.edu.au**
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Michael Robertson, CSIRO	**(08) 9333 6461 Email michael.robertson@csiro.au**
Sam Trengove, Southern Precision Agriculture Association	**(08) 8842 3230 Email samtrengove@spaa.com.au**
Brett Whelan, Australian Centre for Precision Agriculture	**(02) 9351 2947 Email b.whelan@usyd.edu.au**
GRDC Precision Agriculture Manual	**www.grdc.com.au/pamanual/**
***PA in Practice* – Grain growers' experience of using variable rate and other PA technologies**	**Ground Cover Direct, 1800 11 00 44**

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