

Getting Value from Information about Variability

Brett Whelan

*Australian Centre for Precision Agriculture, McMillan Building A05,
University of Sydney, NSW 2006 Australia. Email b.whelan@usyd.edu.au*

More than most production processes, the business of growing crops involves dealing with variability all along the line. The sources of the variability can be internal as well as external. Variability in soil type, input quality, weather, seed-banks, machinery and staff are just some of the attributes that ultimately contribute to variation in the output quantity and quality.

The financial value of this variability itself depends on the perspective. Consider the conditions that combine in the landscape to produce a yield and quality that is the 'average' for a farm. Variability in conditions that produce areas that perform above this average would be considered 'valuable' and underperforming areas could be described as the result of 'poor value' variability.

Alternatively an entirely uniform farm consisting of 'poor' conditions would be considered less financial valuable for cropping than one with variability that produced conditions that scoped from 'good' to 'poor'. Of course a flat farm of uniform, deep, fertile, resilient soil with unlimited irrigation and operated by tireless identical siblings with agronomic qualifications may have some things going for it financially.

The point is that 'variability' itself is not necessarily going to be financially valuable in the job of farming in the vast majority of cases. It is information about the variability that is present within the operation that is 'valuable' and what is done about it in the future dictates the extent of the value. Initially financial outlays may rise but in the long-run, value in terms of both economic and environmental improvements should be gained.

Information about variability on a farm

There is a large list of important components of the farming operation for which it might be useful to have data on the extent of variability. For some, such as fertiliser quality, farmers rely on external sources to minimise the variation and so 'remove' the need for substantial 'on-farm' management. Others, such as the weather, are almost impossible to monitor well over a large area, are more than almost impossible to influence, so management is usually directed by measuring the variability in some indirect effect (such as soil moisture).

Crop Yield

The simplest way to gather information on variability that may be valuable is to explore/sample in regions of different crop growth/yield. This can be done by visually assessing crops, but it can be difficult to tell all but the largest differences and it requires traveling over the whole paddock. There are opportunities for this during spraying operations, and obviously at harvest.

Easier to use a yield monitor or some imagery to define the spatial pattern and provide some numbers for assessment. An example of wheat yield map from a 300ha paddock in NSW (Figure1). Soil samples were taken at points of low/medium/high values across the yield map as shown. The analysis provided valuable insight into the causes of the crop yield variability as shown in Table 1.

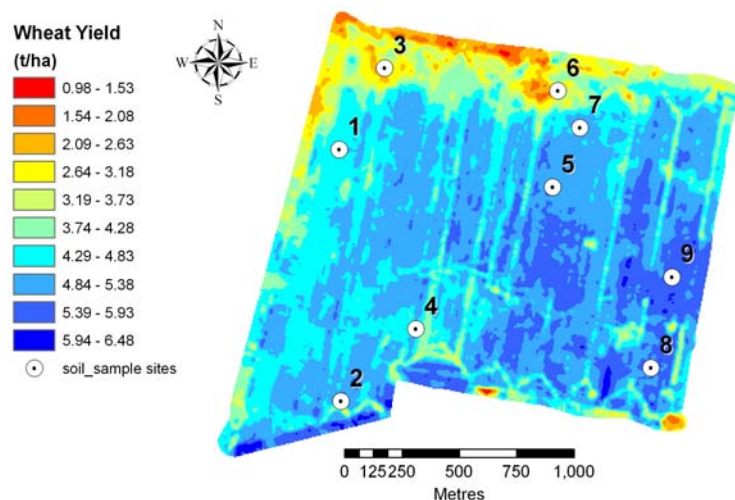


Figure 1. Wheat yield map and soil sample locations.

Sample	Average Profile Moisture Content	CEC 0-30cm	ESP 0_30cm (%)	Bulk Density (0_30)	Gypsum Requirement (t/ha)
1	25.6	44.54	7.95	1.27	4.3
2	26.8	37.43	6.21	1.22	1.4
3	19.3	23.94	10.97	1.44	5.3
4	27.3	37.95	2.70	1.27	0
5	27.0	38.30	3.73	1.26	0
6	19.1	34.34	10.56	1.38	6.8
7	24.8	33.78	4.51	1.28	0
8	26.0	43.39	3.46	1.29	0
9	25.8	45.13	2.47	1.27	0

Table 1. Soil sample analysis across the yield pattern in Figure 1.

Firstly, the most obvious factor was the high soil ESP values at the lower yielding sites (1,3,6). The low yielding area at site 4 was not restricted by high ESP but was found in a depression which was evidenced by the highest observed average profile moisture content, leading to the theory that some waterlogging had occurred.

If the soil sampling had been used to produce a single composite sample then the average figures would have produced a requirement for 1.27 t/ha gypsum application over the entire area (\$6,358.00 @ \$20.00 ton gypsum). Just by sampling using the yield map pattern, it is obvious that much of the paddock is not restricted by high ESP and that the 1.27t/ha would not be sufficient to ameliorate the poor areas.

The simplest way of dealing with this is to compartmentalize the poor area and apply gypsum at the average required from the enclosed sample points. This would result in the lowest yielding 92 hectares (~ 3.5 t/ha wheat yield) being treated at a gypsum rate of 5.8 t/ha (\$10,724.00) and 208 hectares (~ 5.0 t/ha wheat yield) being untreated along the design shown in Figure 2.

Here the financial cost of the gypsum is actually higher, but it is likely to actually benefit the crop yield into the future, whereas the whole field application would provide little value and greater application costs. Just improving the wheat yield by a total of 1.0 t/ha (0.33 t/ha per year) over 3 years would return over \$40,000 at 2008 crop prices.

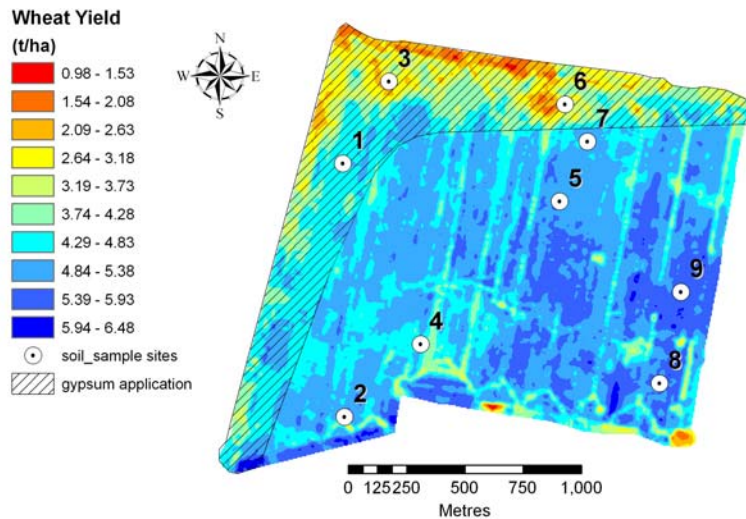


Figure 2. Possible gypsum application map based on the yield map sampling scheme.

Potential Management Classes

A more objective approach that has been employed to explore the variability in crop growth is the use of 'potential management classes' (PMC). Here paddocks are partitioned into areas of land identified as possessing relatively similar production attributes. The classes are separable by a difference in the average level of those production attributes. The PMC are typically built by combining crop yield maps, soil ECa or gammaradiometric maps and elevation maps using a statistical procedure to draw the boundaries.

In this example (Figure 3), the 75 ha paddock has been broken into 3 PMC. The sampling within the classes highlighted a build up in soil N levels in the low yielding class relative to the higher yielding classes.

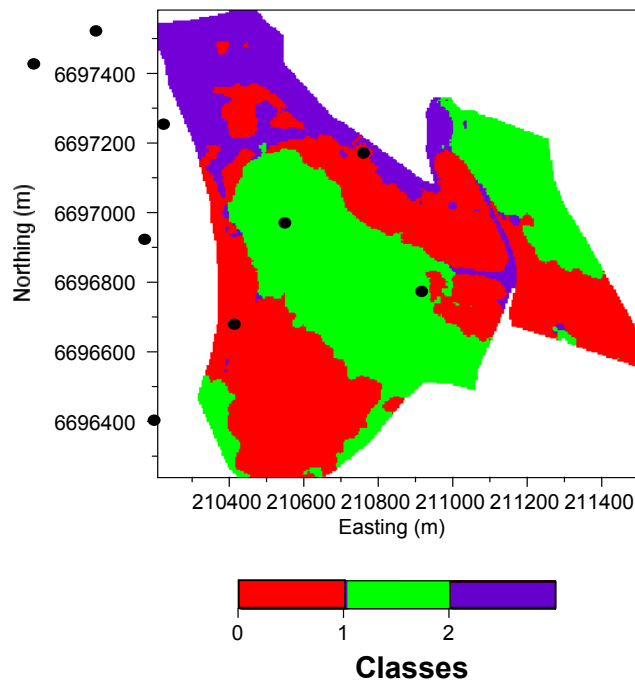


Figure 3. Three PMC with soil sampling locations in a 75ha paddock.

Performing some traditional agronomic techniques for calculating nutrition requirements on the data highlights the value of this information on variability within a paddock. Equation 1 is often used to calculate N requirements for wheat crops.

$$\text{N req. (kg/ha)} = \text{yield goal} \times \text{protein goal} \times 1.75 \times 2 \quad \text{Equation 1}$$

For a 4.5 t/ha yield goal at 13% protein, 205kg/ha N is required. So if the yield goal remains constant across the paddock, then the data in Table 2 shows that very different amounts of fertiliser could be applied within each PMC. The average treatment would over fertilise Class 2 and under fertilise the other two classes. The wasted fertiliser equated to an \$11/ha inefficiency across the whole paddock at 2004 prices. Today it is a cost of \$22/ha. On top of that, the underfertilisation would potentially result in yield and protein losses.

	Class 1 (33 ha)	Class 2 (29 ha)	Class 3 (13 ha)	Paddock Avg. (75 ha)
Median N (kg N/ha)	105	259	158	165
Uniform N application (kg N/ha)	40	40	40	40
N Required (kg N/ha)	100	0	47	
Consequence of uniform N application	60% underfertilised	2.5 t urea waste	15% underfertilised	

Table 2. Soil N contents and calculated requirements for 3 PMC in Figure 3. Comparison between uniform treatment based on and average soil N content and variable-rate treatment.

Modifying Yield Goals Between Classes

Just sampling and then modifying fertiliser rates to reach an even 'mass balance' across a paddock does not acknowledge that in many cases the yield potential is different within the management classes. Here site-specific data on variability is used to remove the uniform yield goal for a paddock and allocating new yield goals to potential management classes. This can be achieved by assessing the relative yield potentials shown in the previous crop yield maps. Local knowledge of factors impacting on the yield data is imperative but the process also lets local experience set the maximum yield goal for the highest performing class and the other class/es follow on a percentage basis.

Figure 4 shows the yield data and potential management class map for a 40ha paddock. The management classes were built using yield, soil ECa and elevation data.

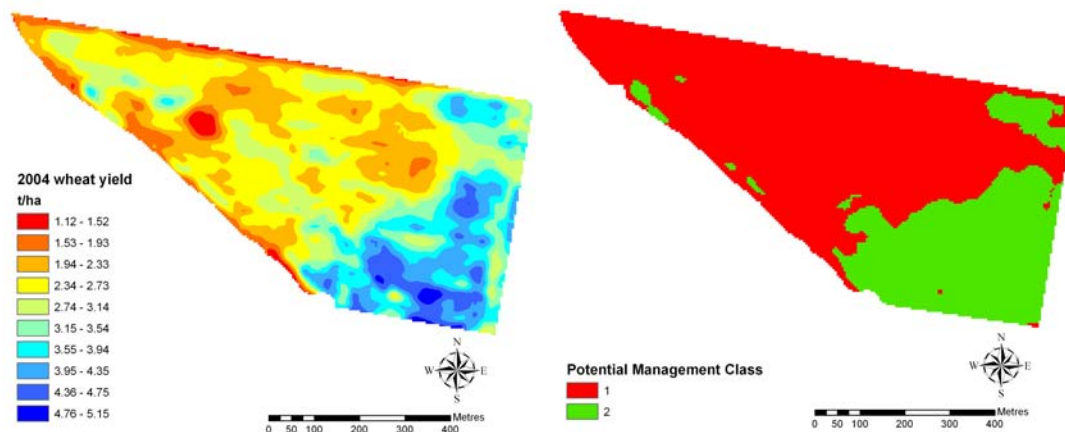


Figure 4. Crop yield map and 2 class PMC map for a 40 ha paddock.

Class	Average Yield (t/ha)
1	2.41
2	3.81
Whole Paddock	2.84

Table 4. Yield differences between classes in Figure 4.

From the average yield differences between the classes shown in Table 4, Class 1 is yielding at 63% that of Class 2. Once the managers are convinced that there are no amelioration questions remaining and that the yield differences are repeating over seasons, they could give consideration to reducing the yield goal in Class 1 to 63% of that in Class 2 and reduce the input rates accordingly. This procedure can be adapted to more 3 or more classes and modified for different crops.

Rate Response Experiments Within Classes

To more accurately define the variability in responses to inputs between classes, field scale experiments can be established to estimate the response in each identified potential management class to a single input. A zero rate treatment should be included in all trials while the alternative treatments could be multiples of the farmer's uniform application rate. The design of the experiments should consider application equipment capability and size, spatial constraints due to management class pattern and a desire to minimize the area/financial impact of the experiment.

Figure 5 shows the potential management classes and the actual fertiliser application map for a N response trial in a 79 ha paddock. The average rate for the paddock was 60kg N applied as BigN. Figure 6 shows the observed yield response from the trial.

The optimums were 100kg N and 39 kg N for class 1 and 2 respectively. Two simple scenarios using this information on variability can be considered. Scenario 1 maintains the total amount of fertiliser applied to the paddock but moves the over-application on class 2 to class 1, and with yield gains in class 1, would improve gross margin by \$11.50/ha across the paddock. Scenario 2 would aim to apply the correct amount to each class, requiring an additional 1.4 t of N, but increased yield would mean that the gross margin for the paddock would be improved by \$25/ha.

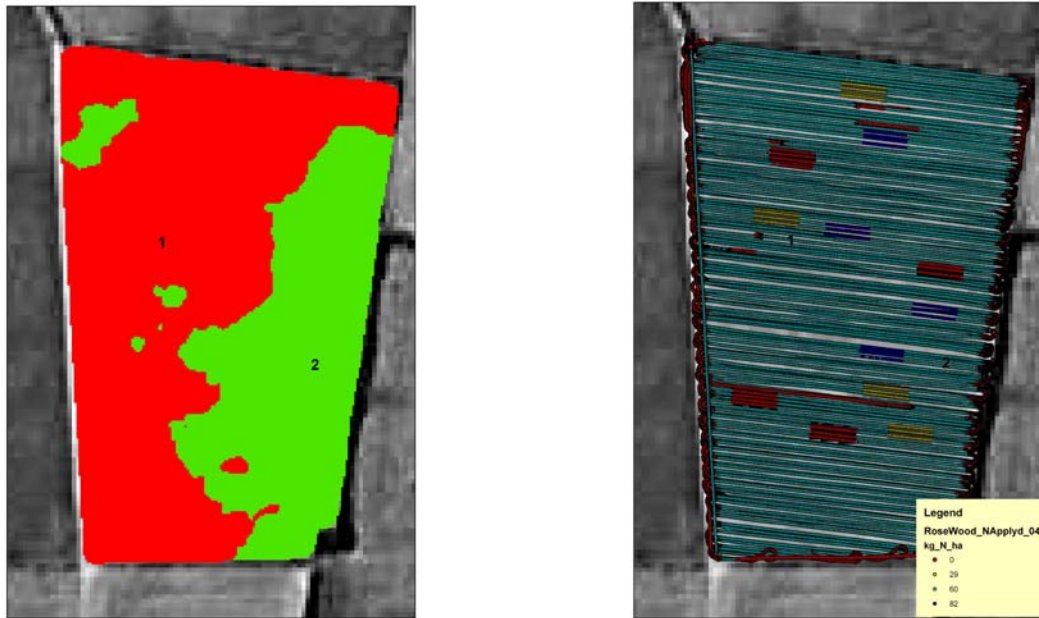


Figure 5. 2 class PMC map and the fertiliser application map for an N response trail in a 79 ha paddock. Paddock average treatment was 60 kg N and the trial rates ranged from 0 to 82 kg N.

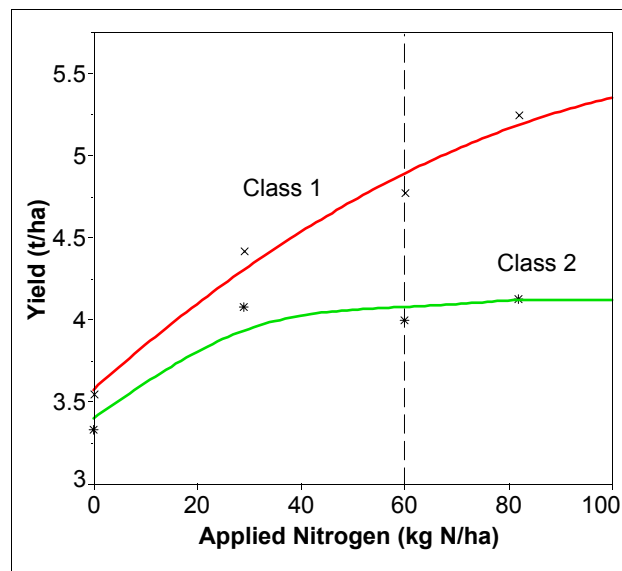


Figure 6. Yield response to applied N fertiliser from the trial in Figure 5. Average paddock application was 60 kg N/ha. Class 1 optimum = 100kg N/ha; Class 2 optimum = 39 kg N/ha.

From 17 such experiments conducted around SA, VIC and NSW, the figures in Table 5 show that the potential gains from variable-rate fertiliser application range by crop and season, but are not necessarily dictated by paddock size. All this work has highlighted just how site-specific the application and value of PA information will be, but also just how useful PA tools are at getting to the specific information for each paddock.

Year	Fertiliser	Crop	Size (ha)	Wastage (A\$/ha)
2003	P	WHEAT	40	54.68
2004	P	FABA BEANS	40	50.31
2005	P	WHEAT	40	*3.31
2004	N	CANOLA	22	*79.31
2003	P	WHEAT	110	35.55
2004	P	FIELD PEA	110	8.22
2005	P	WHEAT	110	65.02
2006	P	BARLEY	110	33.40
2005	N	BARLEY	50	6.95
2006	N	WHEAT	50	50.61
2004	N	WHEAT	49	46.32
2005	N	BARLEY	49	28.32
2003	N	CANOLA	130	23.38
2004	N	WHEAT	130	38.52
2005	N	BARLEY	130	13.50
2004	N	WHEAT	79	25.27
2004	N	WHEAT	80	15.24

Figure 7. Potential gross margin gains from PMC yield response experiments in Australia.

Other Opportunities for Gaining Value from Information on Variability

The examples presented here are just a number of ways that value can be obtained from information on variability on-farm. Some other important areas are:

- Weed and pest location for differential treatment (e.g. weedseeker)
- Crop quality for input management, differential harvesting/delivery/blending, market premiums (e.g. protein in cereals)
- Sowing rates (e.g. higher cereal rates in previously mapped areas of chemically resistant ryegrass)
- Irrigation water (e.g. matching changes in soil texture and crop vigour)
- Crop growth regulators (e.g. aerial PIX application in cotton based on vigour imagery)