Site-specific crop management (SSCM) for Australian grains: how to begin

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Site-specific crop management (SSCM)

SSCM aims to better identify and understand the reasons for changes in yield potential within a field, and then improve decision making about the use of inputs such as fertilisers, pesticides, fungicides, lime, gypsum and fuel to better match the changing requirements of the soil and crop. A better match should mean that inputs are used efficiently, profits are maximised and waste is minimised.

At the heart of the matter is the fact that soil properties, pest and disease loads, terrain and past management contribute to the yield potential of a field. The way these attributes, and their relationships to each other, change across each field on each farm is unique. This type of variability is said to be 'site-specific' and is the reason why there is no single SSCM prescription that can be shared between farms. Because of site-specific variation, the best information for determining SSCM options for each farm/field will undoubtedly come from within its own boundaries.

How to begin

It is important to sort out what the best 'average' management options are for fields and crops before considering the need/requirements for variably applying inputs.

- Any large-scale soil pH and sodicity/salinity issues should be identified. Soil samples, taken from across the farm should be analysed to correctly identify any required treatment.
- The effectiveness of weed control strategies should be examined and improved if required.
- Elevation mapping using GNSS allows field boundaries and working directions to be altered to improve water management if necessary.
- Average yield information gathered for each crop should be used to re-examine crop yield goals on the farm and ensure average nutrient application is suitable. Yield monitors can help here, especially if historical records are missing or the concurrent use of off-farm delivery and on-farm storage makes linking tonnages to specific fields difficult.
- Vehicle navigation aids (guidance or autosteer) offer immediate benefits through reducing the overlap during fertiliser, sowing and chemical operations and providing improvements in soil structure. Auto steer systems can be used to sow into the inter-row between last year's stubble to reduce the incidence of root disease.

Once any alterations are put in place to optimise the 'average' or uniform agronomy on a farm, the aim should then be to test whether SSCM can be used to improve management decisions on the farm. This requires that within an area:

- the amount and pattern of variability in yield and soil conditions can be measured;
- reasons for the variability can be determined; and
- the agronomic implications of the variability and its causes present a practical opportunity to vary management.

The easiest way to start this process is to investigate areas of high, average and low yield within fields. A yield monitor makes it easy to identify these areas and provide the locations to then perform:

- a complete soil profile examination and analysis, including the soil texture, structure, organic matter, depth to constraints, water holding capacity, pH and nutrients;
- crop observation for disease or pests; and
- assessment of the position in the landscape (slope, hill, hollow).

The information gathered should be compared across the sites to determine which properties are varying and if any changes show a consistent trend with crop performance. For example, does the crop performance decrease as the amount of sand in the soil profile increases between the test sites.

It is important to make any interpretations in conjunction with local agronomic understanding and advice to determine whether there are genuine causal relationships being identified and that the amount and pattern of variability is large enough to warrant further consideration. If the answer to both issues is yes, then consideration can be given to identifying whether there are any cropping inputs that could be applied at variable-rates to match the identified variability and improve economic/environmental outcomes.

With this understanding that local variability issues will be the driving factor, it is possible to provide a general strategy to drive the incorporation of SCCM on a farm (Figure 1). A more specific tactical action plan is shown in Figure 2.

Incorporating SSCM into Australian farm management

A strategic plan

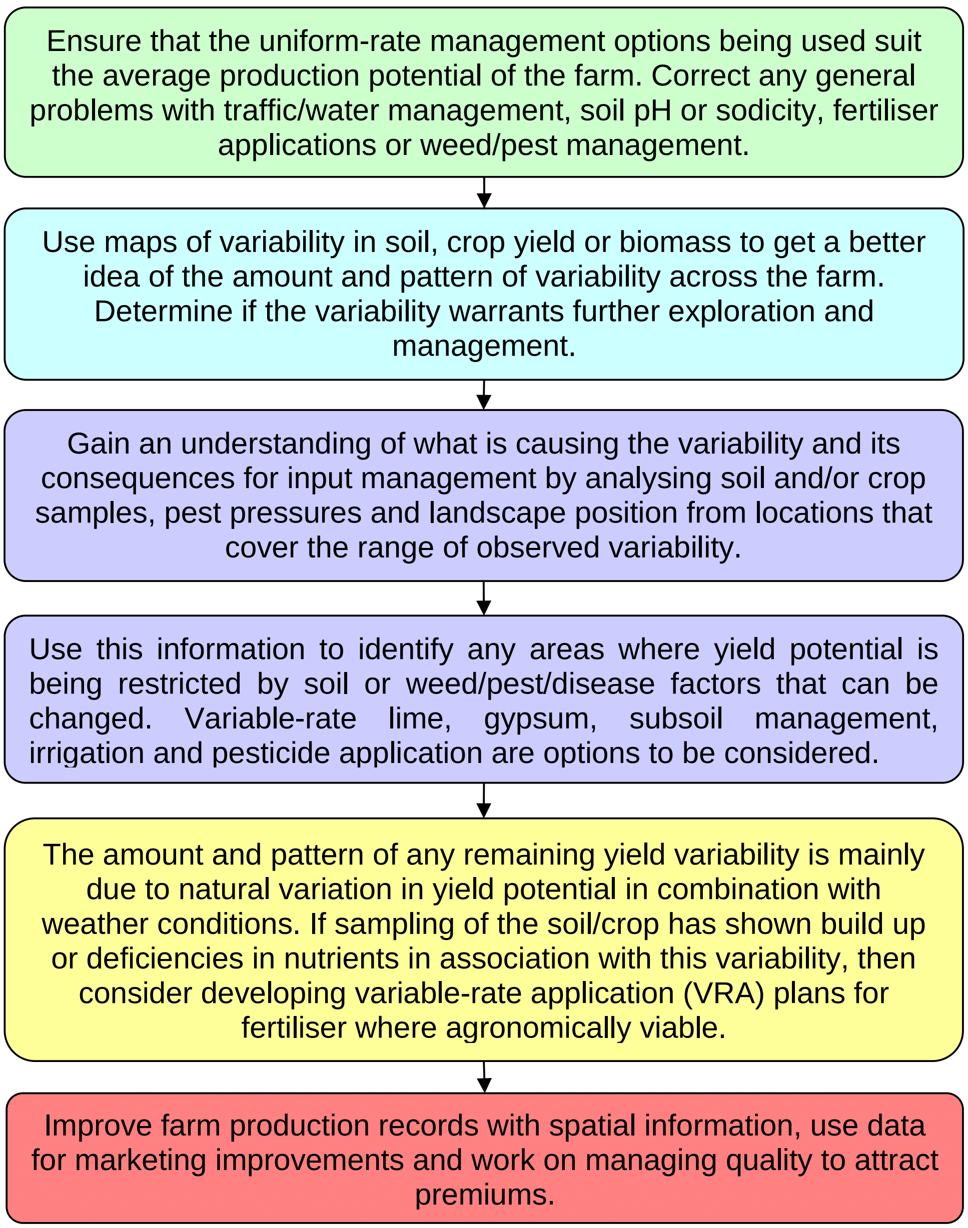
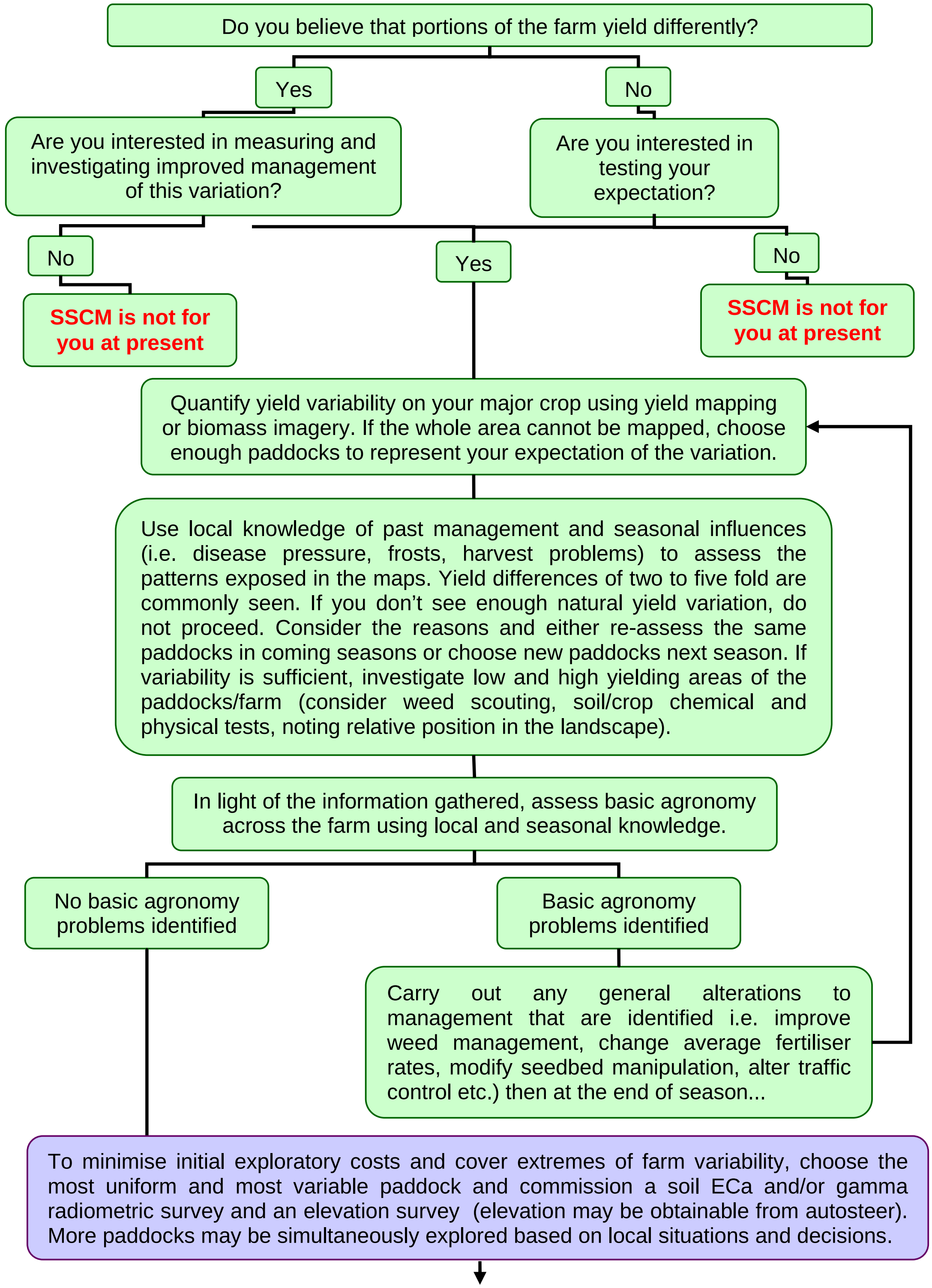


Figure 1: General strategy to drive the incorporation of SCCM on a farm.

A tactical decision tree



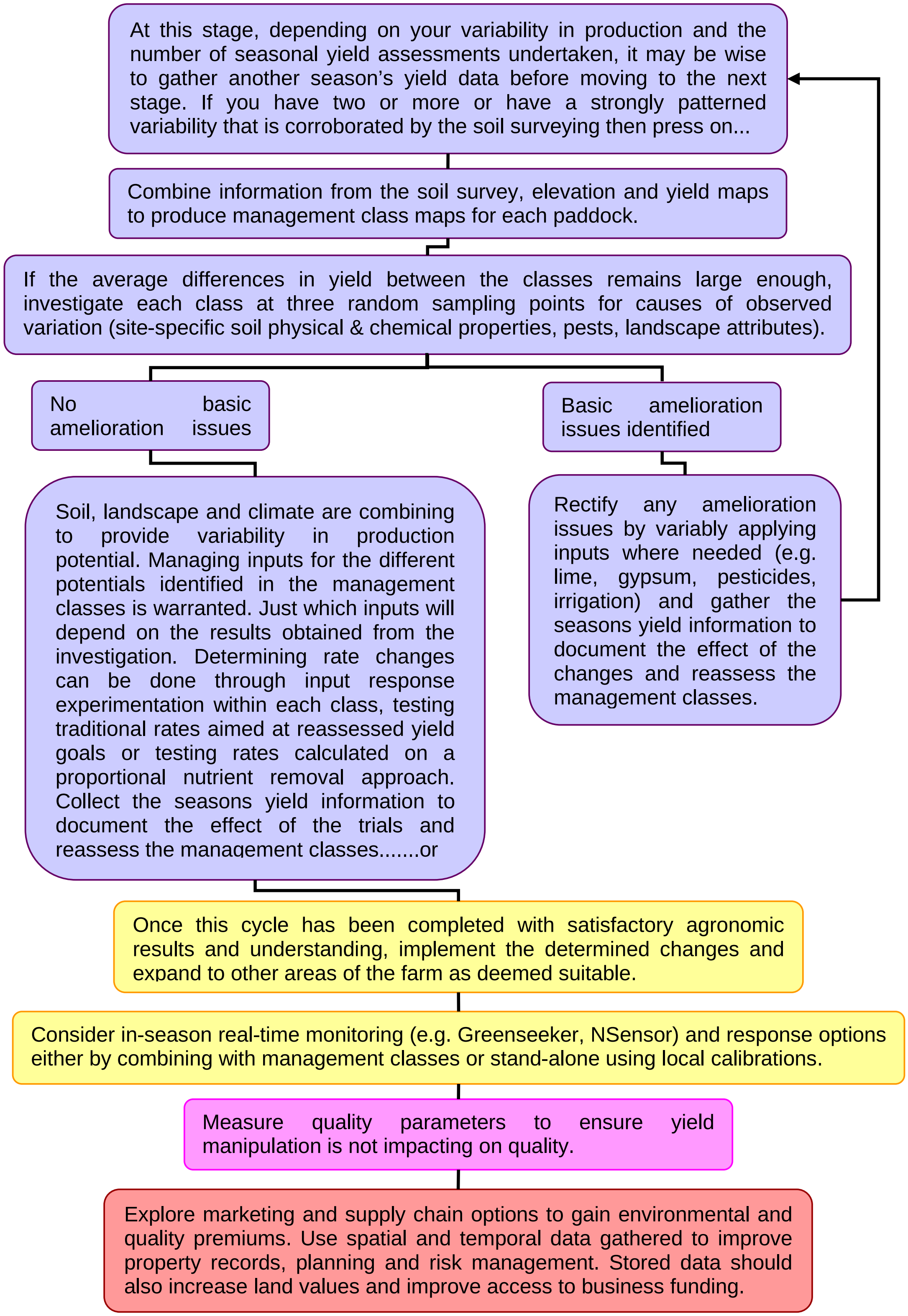


Figure 2: A tactical decision tree for incorporating SSCM in Australia.

Variable-rate application (VRA) of inputs

The basic idea is that instead of applying a single rate of input throughout an entire field, the rate should be adjusted to match changing local requirements. VRA can be aimed at any rate-based operations that influence crop yield and can be done with the help of variable-rate technology (VRT) or by using manual switching or multi-pass applications. Using VRT just makes the job less stressful and allows more sophisticated positioning and rate adjustments. The main target operations for VRA in grain cropping are:

- fertiliser ;
- soil ameliorants (lime, gypsum);
- pesticides (herbicide, insecticide, fungicide);
- sowing;
- tillage; and
- irrigation.

Ideally, the use of VRA should optimise both the economic and environmental outcome of a field. In Australia the economic considerations dominate as there is little regulatory auditing on the levels of approved chemicals in the agricultural environment. However, most crop producers are well aware that maintaining a healthy environment is important for sustainability and economic success.

The potential benefits of VRA are generally higher when:

- the amount of spatial variation is larger;
- the pattern of spatial variability tends more towards coherent patches. This usually means fewer rate changes are required;
- the pattern of variability is driven by spatial rather than temporal factors, so it is likely to be relatively stable from season to season and easier to formulate VRA plans; and/or
- the unit cost of input is high relative to the price paid for the crop.

VRA operating scale

Given that the variation in crop yield can be measured at fine-scales in a field, it would be good to be able to change management responses using VRA at the same scale if needed. At present, the ability to achieve this goal depends on the input that is to be varied. In particular, whether the information on variability needed to make the rate-change decisions can be accurately gathered at fine-scale and whether the available application equipment can make the changes required.

Gathering information

There is a variety of technologies and techniques to gather information on variability for PA. The number of measurements each system can make in a field differs. This has led to the assessment of variability on two different scales for VRA decisions:

Whole field

Variability in the attribute of interest can be measured accurately at a fine scale across a field to produce a detailed map such as the examples in Figure 3.

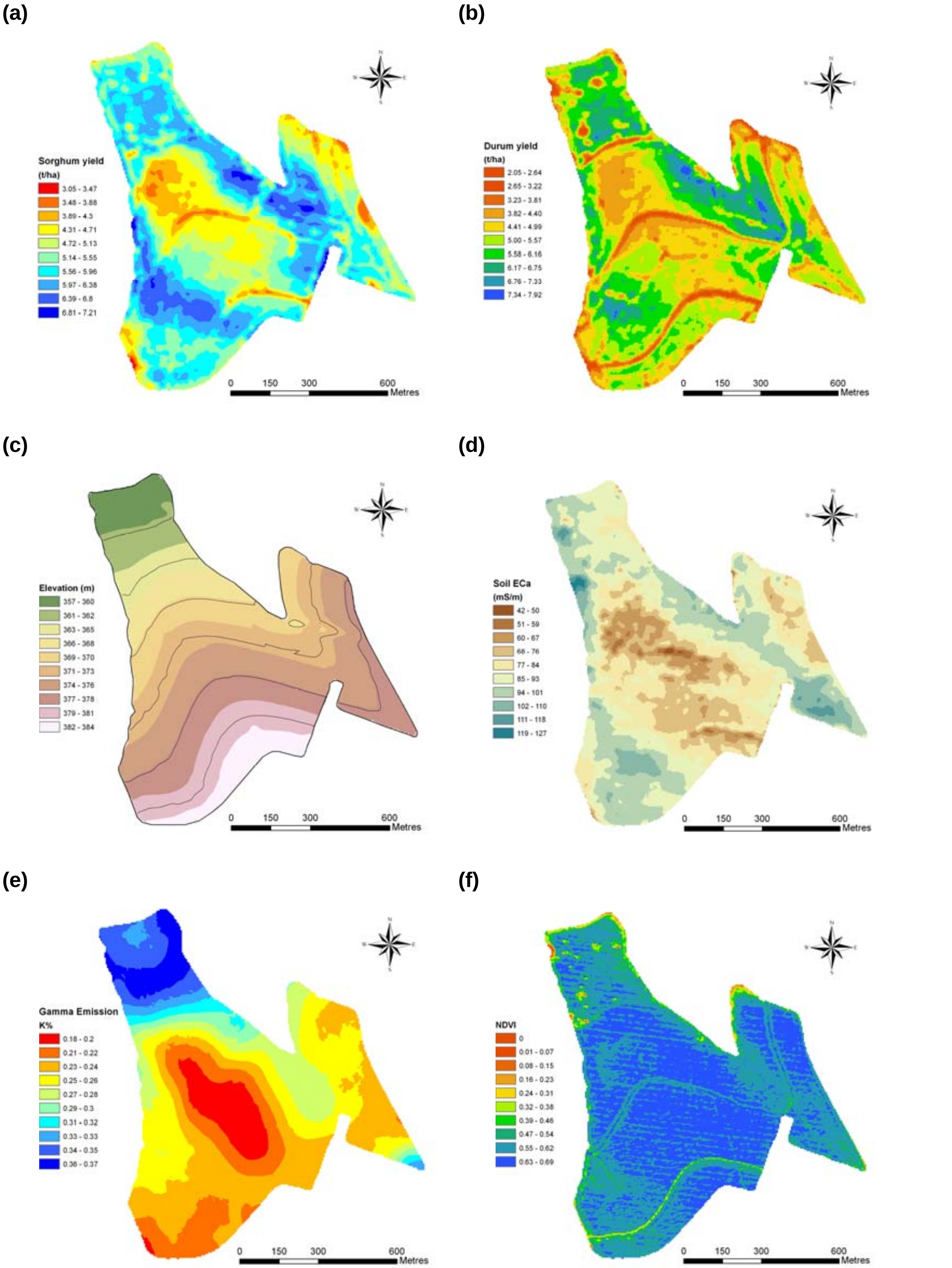


Figure 3: Whole field variability in crop yield (a and b), elevation (c), soil ECa (d), gamma emission (e), crop reflectance (f).

Potential management classes (PMC)

Fields are divided into areas (classes) that have shown differences in production potential that may require different management treatments. The variability of an attribute of interest is described by the average value in each class. A management class can be assigned to one or more management zones within a field.

Figure 4 shows how this process breaks the variability into a number of relative categories, with more classes increasing the ability to describe the range of variability.

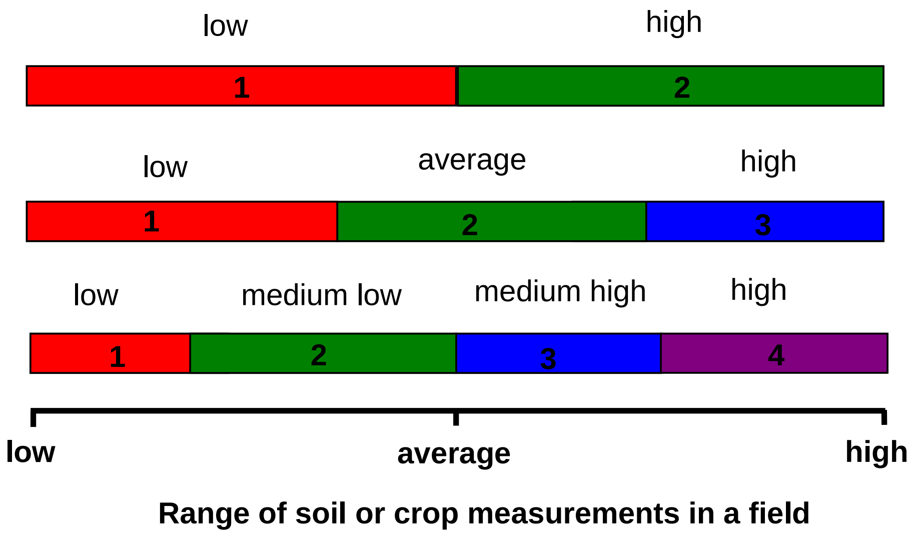


Figure 4: The number of management classes affects the way variability is categorised.

The boundaries of the classes can be drawn using a wide range of methods and initial information. The methods range from growers drawing them by hand using their knowledge of a field, to statistical processes that use one or more whole field maps of variability in yield/soil/terrain/reflectance. Figure 5 shows the result of combining a number of the layers in Figure 3 in a statistical process to form management classes. Using previously gathered maps of variability and statistical processes takes the guesswork out of setting boundaries, but it is important to make sure any maps that are used correctly reflect the variability in the paddock and don't have any problems caused by poor management or collection errors.

As can be seen from the legends in Figures 4 and 5, when the number of management classes is increased the differences between the averages in each class decreases. As these differences decrease, the potential benefits of managing the classes differently are also reduced. So any decision on the number of management classes to use should be made with consideration to both maintaining an agronomically significant difference and ensuring the pattern of variation is not overly broken-up.

(a) (b)

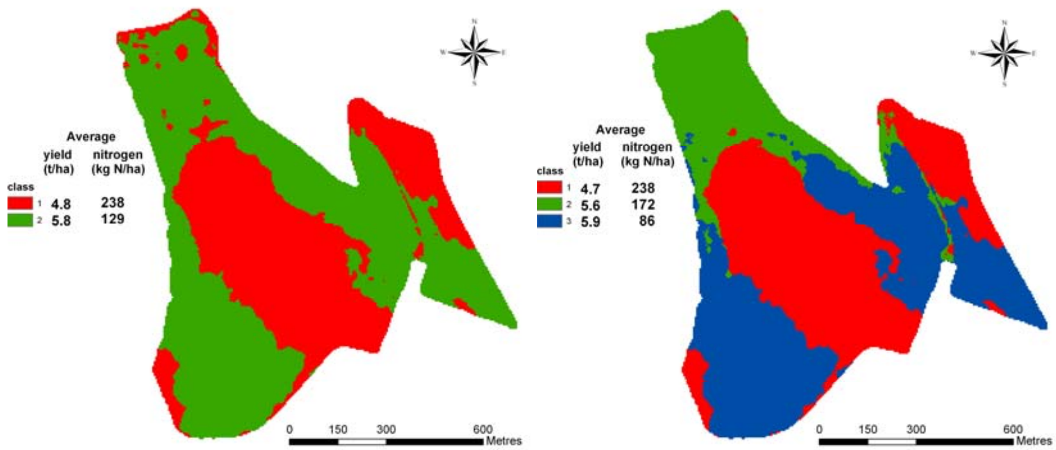


Figure 5: Two (a) and three (b) potential management classes built using the soil ECa, elevation and crop yield information for the field shown in Figure 4.

Application equipment

The smallest area in a field that can be treated differently is related to:

- the minimum independent section width of the application equipment;
- the speed at which a rate-change can be relayed to the equipment;
- the time it takes for the equipment to change up and down rates; and
- the speed of travel.

This means that each equipment set-up and its operation will provide a unique minimum area of application. So by choosing/changing equipment and speeds, growers have a variety of options available to them for controlling the scale of application. In general though, VRT can be divided into two categories:

Map-based

Maps of where, and how much input to apply are created prior to the application operation. These digital maps are loaded into a computerised variable-rate controlling system on board the vehicle being used in the application. Using a global navigation satellite system (GNSS), the system interprets map locations and desired rates and matches them with the changing position of the vehicle during application operations.

Real-time

Actual application rates are decided as the application operation is happening. These systems rely on sensors to collect data directly relevant to the rate decision 'on-the-go'. This data is relayed directly to a computerised variable-rate controlling system which responds by computing the desired rate and transmitting this to the application equipment.

Real-time VRT tends to be highly specific. One piece of equipment will only apply pesticides and another will be needed to apply fertiliser. However, each piece of equipment is usually self-contained so there is no need to buy several components. The specific nature of the equipment is driven by the different sensors needed and the different processing required for each input.

This technology does not require detailed maps or extensive decision making prior to application, but all systems allow the operator to set base rates. Some systems also provide the option of combining base-rate maps with the data from the real-time sensor.

VRA operations

The four main categories of VRA operations can be defined by the scale at which information on variability is gathered/treated and the category of VRT equipment that is used (Table 1). The categories are:

- map-based management class operations;
- map-based whole field operations;
- real-time management class operations; or
- real-time whole field operations

Map-based management class operations can be undertaken with a wide range of application equipment and applied to any input that is metered onto a field. Real-time, whole field operations need specific hardware to be used for the input being controlled. At present these types of operation are only used to apply nitrogen fertiliser and herbicide.

For more Information

Further detail and explanation of technologies and techniques specific to the Australian grains industry can be found in:

PA Education and Training Modules for the Grains Industry.
Produced by Brett Whelan and James Taylor
Australian Centre for Precision Agriculture, University of Sydney
for the Grains Research and Development Corporation
(2010).

These modules are available from the ACPA on CD at present (precision.agriculture@sydney.edu.au).

Your local agronomist and machinery dealers should also be able to help with locally relevant information.

	Management class treatment of variation	Whole field treatment of variation
Map-based	**A map of broad areas where different management is required is used to describe where rate changes will occur.**	**A map of variability across a whole field is used to determine continuous rate changes.**
	Examples o ***nitrogen applied at three different rates to three management classes.*** o ***lime only applied in areas previously identified as requiring pH adjustment***	***Examples*** o ***phosphorus applied based on the pattern of removal from previous yield map/s.*** o ***pre-emergent herbicides applied based on a map of soil organic matter content***
Real-time sensors	**A map of broad areas where different management is required is used to describe where base rates will change. Real-time sensors are then used to measure variability within each management class and vary application around the base rates.**	**Variability across the whole field is sensed and used to control treatment rates during application.**
	Examples o ***base nitrogen rates are calculated for each of three classes. A crop reflectance sensor is then used during application to measure variability in crop condition within each class and vary application up or down from the base rate.*** o ***maps of areas where broad-spectrum herbicide is to be applied are combined with reflectance sensors to deliver specific action chemicals to detected weeds.***	***Examples*** o ***only green weeds, which are detected in fallow using reflectance sensors, are treated with herbicide.*** o ***crop reflectance sensors are used to control nitrogen application rate variation around a single base rate***

Table 1: The four categories of VRA operations are defined by the scale at which information on variability is gathered and the category of VRT equipment.