Getting the Most Out of your Spatial Data

Yvette Oliver[1], Michael Robertson[1], Bindi Isbister[2], Ian Maling[3]
[1]CSIRO Sustainable Ecosystems, [2]DAFWA , [3]Silverfox solutions

INTRODUCTION

Low uptake of Precision Agriculture (PA), despite evidence of economic benefits, is partly due to the uncertainty of how to use spatial data to make management decisions. There is a range of inputs or management which can be varied spatially, such as started fertiliser, top-up fertiliser, herbicides, pesticides, lime, clay or dolomite. The difficulty most farmer face is determining what to vary and where to vary it.

There is a large range of spatial information available which can assist with making these decisions but the key is to understand what the data measures, its pros, cons and costs. The greatest value from the spatial data is gained when it is added to farmers' spatial knowledge and management information and targeted soil sampling. To provide some of this understanding to farmers we have produced a table explaining the value of the more commonly used spatial data for application to PA (Table 1). We have been trialling this process with farmer in workshops, field days and farmer visits and will discuss the process and comments from the workshops.

METHODOLOGY

In 2006, workshops were held with 8 farmers in the Liebe and Mingenew-Irwin Groups in the northern agricultural region of the Western Australian (WA), and at a field day with the Kellerberrin Demonstration Group, located in the central wheatbelt of WA. Farmers were assisted in creating management zones in their paddock by drawing a "mud map" which integrated their own knowledge about the variability of soils and yield across a paddock with other precision agriculture spatial data such as yield maps, electromagnetic survey (EM), gamma radiometrics, biomass imagery, stability analysis, soil testing and interpretation. During the process the farmers were asked to consider the following questions in relation to their own knowledge or "mud map":

- Do they have spatial variation with in their paddocks and by how much does it vary?
- Is the crop performance stable over time i.e. good yielding areas always perform well?
- What do they think is causing the spatial variation and stability?
- What other information do they need to make a management decision?

RESULTS AND DISCUSSION

Do you enough have variability and where is the variability in yield? (See Table 1)

There needs to be >1.5t/ha difference in yield, between the highest 1/3 and lowest 1/3 of the paddock, to manage areas differently (Robertson *et al.* 2006). This information can be obtained from yield maps, monitoring as you drive over the paddock or gut feel. In the workshops the majority of farmers thought they had yield variation greater than 1.5t/ha every year.

Management zones can be created using yield maps and NDVI maps over a number of years of cereal rotations, not using drought years in the analysis. Commonly paddocks are divided into three zones of high, average and low yielding areas, but more or less can be used. In the workshops, the most common form of spatial information associated with PA was yield mapping. Even though 75%

farmers at the workshop had yield maps (some over 5 years worth) and all thought this was the most reliable data source, very few could overlay or manipulate the maps. At the start of the workshop 50% had biomass imagery or considered paying for it, but by the end 90% would buy it.

Where is the variability in soil/landscape – does this relate to yield performance? (Table 2)

Yield potential is related to soil plant available water capacity (PAWC) (Oliver *et al*.2006) which is affect by soil type and rooting depth. Soil type and soil type boundaries are often determined from EM, gamma radiometrics and elevation, but it was found in the workshops that these were the least understood spatial data layers. The rooting depth can be determined from soil depth estimated from a calibration of the gamma signal in lateric landscapes or rooting depth is influenced by subsoil salinity which can be detected by EM. However care must be taken with both methods, as they often require calibration and expert knowledge to validate the data. Soil information is less accurate at determining performance zones but can assist in determining why areas perform they way they do (Table 2).

How stable is the performance in your paddock?

The stability of the paddock can be determined by using a few years of yield maps of biomass images (Adam and Maling, 2005) and areas which have a high coefficient of variation are considered unstable. Areas that are unstable perform well in one year (relative to rest of paddock) and poorly in other years (relative to rest of paddock). If areas are not stable it is difficult to determine how to manage nutrients, however you may still mange other factors spatially such as soil ameliorants.

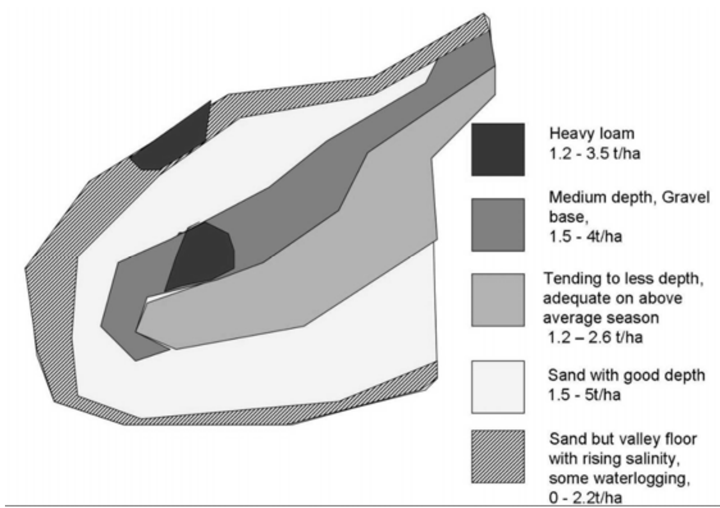

Figure 1. Example of a farmer mud map

What is causing the spatial variation and stability (Table 3)?

The zones were then compared to farmers "mud maps" which included their knowledge on zone locations, range of yield, soil types, soil constraints and management issues in that paddock (example in Fig 1). In the workshop, most thought the variation in yield was related to soil type and some mentioned plant available water capacity. Other reasons included weeds, frost and subsoil constraints. Despite no farmers having a soil survey of their paddock or farms, all could draw a soil map if asked but 62% thought they would acquire a soil map after the workshops.

Some validation of NDVI or yield maps with your mud map is required before they are used to create management zones. These spatial data can have errors due management issues such as double sowing or changing variety mid paddock or seasonal factors such as poor establishment, frost, areas which finished poorly, weeds, disease. Understanding of the season, soils and constraints coupled with a "mud map" can assist in spatial management. For example water logging will affect the yield in wet years which can cause unstable areas, non-wetting will cause establishment problems and low yield, granitic outcrops cause shallow rooting depth and obvious salinity reduced yield.

Do you need to understand the causes of variability?

No – means you will manage the zones according to the current yield potential. It may mean there are no constraints to production, and the areas (zones) are performing to their yield potential based on the soil type. The next step is to soil test in each zone, as this can assist with better macro and micronutrient management compared to bulk soil test for the whole paddock, and then determine the nutrient requirements for your yield potential target.

Yes – means you want to understand why the yield varies as to change management practice or improve yield. Using your knowledge and PA tools to determine poor performing areas, you then target soil and plant sampling in these areas (Table 3).This will help you to understand the yield potential for different soils (or PAWC's) with and without the constraints and then decide whether it is worth ameliorating or not. If the low yield is due to a site which cannot be ameliorated, is soil types such as shallow soils or acid to depth, then the best option is to match input to yield expectation.

Creating management zones

The creation of management zones can start with your knowledge of the paddock, add a yield maps or two, then bring in other spatial data and targeted soil sampling. The management zones can then be refined as more data (or yield maps) are available and with improved the understanding about constraints to production. This process means that farmers do not need to wait 5 years before managing their paddocks variably, so with farmer knowledge and 1 yield map (or biomass images) variable rate or spatial management can start in year 2.

CONCLUSIONS

The workshop activity to hand-draw a management zone map was to highlight to the participants that managing the paddock spatially does not need a highly technical approach. Often the best tool to start with is an aerial photo and the farmer knowledge of soils and productivity. This can help the farmer make a decision on whether it is worth investing in more technology based information or equipment, for example yield maps. By adding yield maps and biomass map we can add more confidence in these zones or be able to improve historic knowledge by overlay a number of years of information. After the workshop, the main actions by the farmers to improve confidence in zone management were: to find out about soil types (and boundaries) and yield potential, use a number of years of yield maps and overlay other data to create zones, conduct strip trials, and to investigate the cost and ease of yield mapping.

These workshops/field days highlighted some farmers are managing their paddocks spatially without PA technology. The farmers have a wealth of knowledge about their paddock variability from their own experience and often have a collection of PA information under utilised. Following a process like this workshop can assist farmers to integrate their own knowledge with understanding of the PA tools, and increase their confidence to manage their paddocks spatially by thinking about applying the "right inputs" on the "right place" at the "right time" to increase profits.

ACKNOWLEDGMENTS

This work was funded by GRDC and CSIRO. We thank the participating farmers for their time.

REFERENCES

Adams, M.L., Maling, I. (2005). Simplifying management zones – a pragmatic approach to the development and interpretation of management zones in Australia. In: Mulla, DJ, Editor. *Proceedings of the 7th International Conference on Precision Agriculture*, July 25-28, 2004. Precision Agriculture Center, University of Minnesota, St. Paul, Mn.

Oliver, Y.M., Wong, M., Robertson, M.E., Wittwer, K. (2006). PAWC determines spatial variability in grain yield and nitrogen requirement by interacting with rainfall on northern WA sandplain. *Proceedings of the 13th Australian Agronomy Conference*, 10-14 September 2006, Perth, Western Australia. Australian Society of Agronomy.

Robertson, M.J., Lyle, G and Bowden, J.W. (2006). How much yield variation do you need to justify zoning inputs? *GRDC WA Crop Updates 2006.*

Table 1. Defining zones from plant performance – primary data layer in any development of performance zones in a paddock

Observation technique	How measured	Cost	Attribute estimated	Pros	Cons	General Pros /cons
Aerial photo	Aircraft	Orthorectified aerial photo costs approx $500 for a farm of about 1000 ha – or Google Earth	Some difference in crop performance or stubble can be seen Plant establishment/performance from stubble	Useful starting layer, readily accessible Easy to acquire, useful for farm overview	May not give a good indication of yield variation Plant establishment estimation requires the high resolution image which can be costly	Ideally have few years of yield maps or biomass maps to understand the variability both across the paddock and over time and between crops May not provide understanding as to causes of variation
Yield map	Harvester	One off cost for yield monitor (range $5,000 -10,000) GPS cost range $500-$10,000	Yield variation across the paddock	Records actual crop yield Valuable for variable rate This is the plant interpreting the environment	Will not explain why yield is varying Requires some data processing by computer to obtain the maps Will not explain low yield due to weeds or frost	
Visible/Near Infra Red (NIR) reflectance i.e. NDVI and biomass imagery	Aircraft/ or landsat satellite	~$500-600 imagery but analysis and interpretation cost ($5/ha) for standard resolution It can cost more for higher resolution images	Biomass variation across the paddock Other minor attributes are : Leaf area index, N status, physical damage	Valuable for variable rate as it is the plant interpreting the environment Can obtain a number of years of images without having to wait 5-10 years to get the yield maps Commercially available High resolution images can be useful for diagnosis small scale changes.	Biomass may not relate to yield particularly in poor finishing seasons Weeds may give a high biomass Need to be careful about the date the image was taken High resolution image is expensive. May not always be needed – depends on the scale of the management issue	
Zoning and performance analysis	Silverfox or Skyplan	Silverfox analysis $5-7/ha	Zone paddocks based on the variability and performance of the crops (from yield or biomass data) ***AND*** determine the consistency these zones	Can provide management zones to put into the controller. Can determine if a paddock is worth variable rating based on the amount of variation and consistency i.e. if inconsistent patterns occur over time then it may be difficult to variable rate	Correlation between soil parameters and plant performance can be weak	

Table 2. Defining zones from soil information –useful in explaining plant performance but not the primary layer in developing zones

Observation technique	How measured	Cost	Attribute estimated	Pros	Cons	General Pros /cons
Aerial photo	Aircraft or Satellite imagery	Orthorectified aerial photo costs ~$200 for a farm of about 1000 ha for an or Google earth	Soil colour/ boundaries	Readily accessible Simple way of defining soil boundaries that are visible in summer Can show trees, creek lines which may explain yield variability	Poor indication of crop performance as boundaries may not match biological performance May not show all soil types	
DEM (digital elevation model)	Ground survey	Collected when EM or farm surface water control layout is done	Topography	Related to (but does not measure) soil types, water flow, frost, soil depth, water logging potential.	Topography may not always relate to yield	Might define soil zones but does not indicate performance in the zones
- Elevation	Aircraft	Low precision but easy to access		When combined with other information such as soil type or EM, it can be used to explain some of the variation in yield		
	RTK GPS on farm e.g. autosteer	High accuracy and low cost if your controller is capturing data				
EM (Electromagnetic Induction)	Aircraft or ground survey	$5-7/ha to + $7/ha	Soil salinity or Boron content after calibration with soil samples	Can determine the extent of salinity or boron toxicity which are subsoil constraints	Needs to be calibrated with soil sampling	
- Measured bulk soil electrical conductivity (ECa) down to 1.5m			Soil type (clay content), Soil depth and plant available water capacity (PAWC)	May indicate soil type boundaries and this can help determine where to sample Yield potential can be estimated when soil depth, soil type is linked to estimate of PAWC	Requires calibration by soil sampling as high EM could be clay soil or saline soil. Needs marked range of soils or soil depths (i.e. clays and sand).	May assist in determining why areas perform they way they do, but there is often little you can do to ameliorate (e.g. salinity, boron toxicity, soil depth) but you can manage differently
Gamma ray Emission Measures the emission of radioactivity from the top 30 cm of soil	Aircraft or ground survey	$8,000-$12,000/farm depending of mobilisation cost of aircraft without interpretation	Soil type, soil depth and PAWC	Gamma signal is related to mineralogy and clay content User can combine the inferred soil type and soil depth information to estimate PAWC Can obtain data for a larger area easily	Requires specific calibration for different geographical regions Needs a lot of interpretation and calibration	
Other geophysics surveys – ground penetration radar, gravity	aircraft		Geological information such as dykes and faults	Can indicate geological structures which effect water flow across farms. Can relate to areas of saline seeps.Often used in salinity management plans	Needs some interpretation by a hydrologist about what to do	

Table 3. Integration - management zones from plant or soils + farmer knowledge+ targeted soil sampling + analysis

Observation technique	How measured	Cost	Attribute estimated	Pros	Cons	General Pros /cons
Create zones +	**From yield, NDVI, soil or farmer knowledge+**					
Farmer knowledge/ mud map +	Farmer	Your time making observation and driving over paddock in car or tractor	Approximate soil type, boundaries and performance in areas across the paddock Information on weeds, water logging, poor establishment, management etc	Information that all farmers relate to. Can explain variation in yield maps and biomass maps due to management and season such as weeds, frost etc.	If new farm or are not driving over paddock may not have this knowledge May not differentiate plant performance	Provide zones based on understanding the reasons for the variation in yield in a season and how stable these zones are over a number of seasons
Soil and plant survey - Assessment of the performance of crop and soil constraints by point sampling +	Ground/ person with GPS	Agronomist time (~$160/200/hour) Soil analysis from $40-$80 per site Plant analysis – tissue test ~$x	Soil type, PAWC and rooting depth → Soil chemistry → Soil nutrition → Crop performance survey →	PAWC related to yield potential and therefore appropriate fertiliser rate. A simple observation of rooting depth may indicate suitability of soil for plant growth. Soil chemistry can assist with understanding subsoil constraints if sampled to at least 60cm depth. Nutritional data to determine appropriate rates for N,P and K Can explain variation due to management and season such as weeds, frost and nutrition Ground based observation is at a scale which is appropriate to manage.	May be time consuming and costly Looks only at a point and is difficult to relate to a paddock i.e. does not look at the spatial variation of the yield	Requires some expert knowledge of data processing and agronomy and is complex to interpret the large amount of information
=						
Combination of all the tools and methods	Knowledge of zones and stability c***ombined*** with other data layers to ***target*** soil and plant sampling to diagnose the causes of the variability to make informed management decisions			Provides understanding of the reasons for variation to determine if amelioration is possible to increase yield or what the target yield should be.	Can be expensive and time consuming	

Note : Farmers do not need to wait 5 years before managing their paddocks variably.
The addition of farmer knowledge 1 yield map (or biomass images) can allow farmers to start variable rate in year 2 – As more data (or yield maps) are available then the zones can be refined