Practising precision I: A basis for making precision pay

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Abstract
PIP (Precision in Practice) is a new tool enabling farmers to accurately and cost effectively identify management zones within paddocks or management units. PIP is a two phase process with this paper addressing Phase 1. PIP begins with developing an accurate set of farm maps, including total area, arable area and elevation. Onto this base, historic satellite imagery is used to generate NDVI values and spatial statistics used to identify areas of difference (zones). These are verified by in-field measurement and farmer feedback. Phase 1 facilitates Phase 2 (see Paper 2) where targeted soil sampling by zone provides a source of information that can inform variable rate application.

Key words: precision, zones, satellite imagery, spatial statistics, variable rate, cost effective

Introduction
The availability of spatial, soil and crop data has grown exponentially in the past decade; as have the ways in which they are analysed and interpreted. Industry experience has shown that not all data interpretation processes and services necessarily attempt to understand the underlying spatial variability of an area before attempting to implement 'improved' management actions.

Concern over the practical application of what many 'precision' products were delivering to their farming clients, led to a collaboration between Terrabyte and 3D-Ag with the subsequent development of an 'outcomes based' precision platform called Precision in Practice or PIP.

PIP Phase 1(PIP 1) is a cost-effective, scientifically based approach to developing zones within a paddock or management unit using a base of satellite imagery and spatial statistics. The zones identified are ground-truthed by in field measurement and farmer feedback. Reports include: accurately digitised farm maps; each paddock individually zoned; a landscape and soil summary plus the identification of issues for further investigation.

PIP Phase 2 (PIP 2) is where information can be converted to outcomes through opportunities for management such as: more targeted soil sampling and ultimately a sound basis for differential zone management within a field including variable rate application of ameliorants, fertiliser or seed for example – *see Practising precision II*.

Method
PIP is a two phase process tailored to an individual client's specific requirements. PIP 1 involves establishing an accurate base onto which zone development can overlain using a combination of satellite imagery, spatial statistics and on-site assessment. PIP 2 utilises the information gained from PIP 1 to target further investigations and ultimately effect implementation of spatial management practices, such as variable rate application of soil ameliorants, fertilisers or seed.

PIP 1 The development of relevant management zones within a paddock or management unit is based on a series of steps using standard mapping protocols and a variety of data sources to maximise accuracy and repeatability.

1. Client engagement. The management zone development process begins with engaging with the client to accurately identify the property or properties to undergo processing, hereafter referred to as the farm. In practice this may begin with a farm outline with GPS reference, Google image or shapefile for example.

2. Defining the farm. An often-overlooked component of precision agriculture processes is the accuracy of the background farm maps onto which all other data is overlayed. The PIP process utilises high resolution,

geo-referenced imagery (preferably with 50cm or better resolution) and state government property cadastral data, integrated with client supplied information as the basis for digitising farm, paddock and infrastructure layers.

At the completion of the boundary definition process the total farm area for the property is calculated by the GIS software resulting with an accurate farm outline and total farm and paddock areas– Map 1.

3. Arable area map – Map 2. The arable area of the farm is similarly digitised using the aerial imagery. The arable area is defined as the total area within the property with an apparent history of cultivation and typically extends to the outside edge of any firebreak surrounding the farmed area or to the fenceline. The areas excluded from the arable area definition include;

- Any observable permanent farm tracks or roads,
- Land associated with dams and water ways,
- Individual and groups of trees,
- Areas inaccessible to cultivation without removal of existing vegetation, rocks or infrastructure,
- Land associated with existing infrastructure such as buildings, windmills fences etc., and
- Land associated with environmentally sensitive or environment control measures such as erosion control banks etc.

To avoid data that may be influenced by an edge effect or that may unduly influence or bias data correlation and analysis, a buffer is used around the paddock boundary and non-arable areas.

4. Complementing the farm and paddock map details, an elevation map – Map 3 is generated using the most accurate available data source (machine based GPS, Lidar, satellite). Elevation is particularly relevant in understanding water and air flow across the landscape for example.

5. NDVI and Crop Vigour mapping. Once the arable area has been accurately identified, historical satellite imagery is utilised to generate a normalized difference vegetation index (NDVI) for as many years as is possible. Developing an understanding of management history is central to our bespoke process of refining the selection of the specific satellite images to be included in the analysis, as the images reflect different land use, seasonal conditions as well as management actions. In this case, 10 cloud-free images (each representing one season) from Landsat 8 at 30 metre resolution were used to generate both the individual period and multi-season average NDVI data and presented in both absolute and normalised classifications to accentuate differences in plant growth.

Figure 1: Management zones

6. Management Zone derivation
Utilising the NDVI data from the ten years concerned, reflects both the physical environment (soil, crop type, seasonal conditions) as well as management impacts on the plant growth assessed by the NDVI. -K-means cluster analysis is then used to further assess the spatial trends within the imagery data to identify potential management zone locations. Zone mean and standard deviation and multivariate correlation enable robust assessment of the differences between zones.

Unlike a simple average NDVI assessment PIP considers both temporal and spatial trends within the data. As such it is able to differentiate between areas that might have a similar long term average NDVI but achieve that value very differently. For example, one area may consistently produce the paddock average level of production while another area varies from high to low levels of production to arrive at that average result.

While the PIP process works well on the 'stand-alone' basis described above, other useful layers of data can be incorporated if available, such as: EM survey &/or yield or protein data for example, to further customise the process to the individual client's farm.

Typically, a minimum of three production zones are identified for each paddock/management unit, using the cluster analysis, differentiated as High, Average or Low performance (see Fig. 1).

6. Verification. At the completion of the initial production zone development process, in-field soil and landscape assessment are undertaken, involving targeted one metre deep soil cores across the study area and management zones to examine and compare the soils profile and characteristics.

Typically reported for each individual sampling point is a GPS reference, a description and photograph of the landscape and of the extracted soil core. Soil characteristics recorded include Munsell soil colour and texture, a measure of pH, EC, slaking and dispersion, together with any observations pertaining to rooting depth or the presence of compacted layer/s, and/or any inclusions for example.

7. Reporting. All data remains the property of the client and PIP 1 concludes with the delivery of a comprehensive report including: all maps and processed imagery produced; a zoned paddock map for each paddock or management unit; the results of landscape and soil assessment as individual sample points (with sampling map) and an overall summary of findings; plus discussion points for future actions. An outline of the methodology and background information is included to aid understanding.

Results and discussion

Early precision agriculture (PA) in Australia began with 'manually' looking at soil data, early yield maps and perhaps an electromagnetic survey, then subjectively identifying differences on a gross scale. Understanding how to address the issues required a deal of experience.

Now with the multitude of data available, an additional skill is required - to identify quality information, of value to decision making. Without due diligence to ensure that benefits outweigh the costs; sustainable improvement in the business' triple bottom line cannot be reliably achieved.

Too often PA programs respond to single layers or types of data to make spatial management decisions. For example, lime application based exclusively on pH data or Nitrogen application based on a limited number of soil cores.

Soil is highly spatially variable; taking more samples does not necessarily equate to a more accurate result. Grid sampling for example, while it produces a bulk of information it does not necessarily overcome the issue of the innate variability of the soil. (Condon 2019; Rossel and McBratney 1998; and Conyers and Davey 1990) and minimising sampling error is crucial to delivering useful information for decision making.

Better initial targeting of where to take the samples by building layers of relevant data that underpin productive potential is the approach taken by PIP to derive its management zones. From an accurate farm map base PIP uses NDVI as a measure of all the elements that are reflected as growth i.e. landscape, soil type and depth, water and management. In this way soil variability is not the only factor relied on in deriving the zones. PIP's addition of statistical analysis of the point data genuinely identifies points of difference (and similarity) to more robustly define zones. Finally in field observation of the 'big picture' influences of landscape in combination with soil properties is used to give confidence to the digital analysis.

In addition, as a final in-field verification we confirmed the land manager's experience of crop performance of a particular area within a field aligned with the derived zones (*without* their prior knowledge of the mapped zones). Feedback from land managers has been positive and resulted in actioning PIP 2.

PIP 2 uses the information gained from PIP 1 to target soil sampling by zone to help determine the reasons behind the difference and what actions are appropriate. 'Blanket' rates of inputs can be varied according to need; and potential savings made re-directing fertiliser from an area that consistently under-performs to an average or higher performing area where the additional fertility can be returned as higher yield.

The results of zone based soil testing from those farms that have progressed to PIP 2 have also shown definitive differences between the derived zones.

To this point the PIP process has focused on cropping properties however work is ongoing to adapt reliance on measuring peak growth at one point in the season to account for grazing or fodder production.

Conclusion

In this age of burgeoning data and remote sensing there is a need for a systematic and mathematically objective approach to organising spatial data in a way that leads to practical outcomes for growers. This is the foundation of the PIP process. Further, there is still relevance in including on-site observation, landscape assessment and measurement as part of a bespoke system tailored to the individual property and land manager.

References

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