Soil mapping technologies

Precision agriculture in vegetable systems

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Why soil map?

Mapping changes in soil properties across a production area can assist with making important agronomic management decisions.

Soil sensing technologies are used to measure how soil characteristics vary across a field or farm.

Soil mapping can be used to:

- devise management zones,
- plan soil sampling points in the field,
- create variable rate prescription maps for fertiliser or soil amendments,
- develop irrigation prescription maps,
- assist in infrastructure planning, e.g. field or irrigation layout,
- assist with drainage planning.

Soil mapping systems

There are a number of commercially available soil mapping technologies. These technologies vary considerably so one sensing method may be more suitable than another in different situations.

One thing that is common to all soil sensing methods is that in-field soil sampling or ground-truthing is critical. In some systems, this is done 'on-the-go' with the sensor directly measuring the soil characteristic in question. In other systems, the sensor measures variability in a related characteristic, which is 'ground-truthed' using targeted soil sampling.

The most common soil mapping technologies are outlined in the table and further explained in later sections of this factsheet.

Interpretation and ground-truthing

The data collected by soil sensors is processed to generate a spatial map showing variability in soil characteristics within a field.

A level of interpolation is required to 'fill the gaps' between sample points on maps prepared from grid or zone sampling.

Soil sensing technology	Soil characteristic measured	Sampling and ground-truthing
EM38	Apparent electrical conductivity (ECa) as an indicator of soil type differences and soil constraints	Tow-behind sensor plus soil samples for laboratory analysis
Veris®	ECa, organic matter and pH	On-the-go sensing plus soil samples for calibration through laboratory analysis
Soil Information System™	Soil texture, topography, pH and macro and micro nutrients	On-the-go sensing plus on-board soil cores collected for laboratory analysis
Gamma radiometric	Soil type and texture	On-the-go sensing plus soil samples for laboratory analysis
Grid mapping	pH, EC and nutrient	Samples collected for each grid point for laboratory analysis

The 'gaps' are unsampled areas and the computer must estimate these values when the data is being processed. The higher the density of sampling the less interpolation is required, however higher density sampling comes at a higher cost and may not be practical (Figure 1).

Targeted and replicated soil sampling and analysis is required to ground-truth and calibrate the data collected using soil sensing systems. This sampling can confirm the reasons for variability or identify other factors that may influence crop performance.

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In contrast to the traditional method of sampling and bulking soil along field transects, ground-truthing of soil sensing data relies on the spatial soil information to identify sampling points to best understand differences in soil characteristics.

Data formats

Data can be obtained in a range of file types, including raw data, PDF, KMZ and shape files.

Specify up-front the file types you want the service provider to supply.

- It is important to request the raw data so it is available for future analysis or to upload into spatial data software.
- PDF files are very useful for viewing your maps and communicating with others. PDFs cannot be read by computer or GPS programs for future spatial use.
- KMZ files are necessary for location services and platforms such as Google Earth for targeted site-specific sampling in the field.
- Shape files can be uploaded into a range of third-party software packages for further analysis of the spatial data.

EM38 SOIL MAPPING

What does it measure?

EM38 surveys involve a vehicle-towed sensor operating in a fallow or low crop residue field situation (Figure 2). The sensors measure the apparent electrical conductivity (ECa) in the soil at designated depths. Soil texture (in particular clay content), soil salinity and moisture levels influence electrical conductivity, so EM38 mapping will indicate differences in soil types and salinity.

To interpret the map it is essential to collect and analyse soil samples to determine if the variation in ECa is due to differences in soil texture or soil salts, or both. Key analyses to ground-truth EM38 data include EC, soil texture (particle size analysis) and exchangeable cations. The EM38 survey usually also captures elevation data, which can be used for drainage modelling.

Resolution

Swath widths can be customised to the enterprise. In vegetable cropping a 5 to 10 m swath is generally used.

Cost

Costs range from $40/ha to $120/ha depending on the swath width used and the area covered. Service providers may charged separately for travel. Ground-truthing analysis costs are additional.

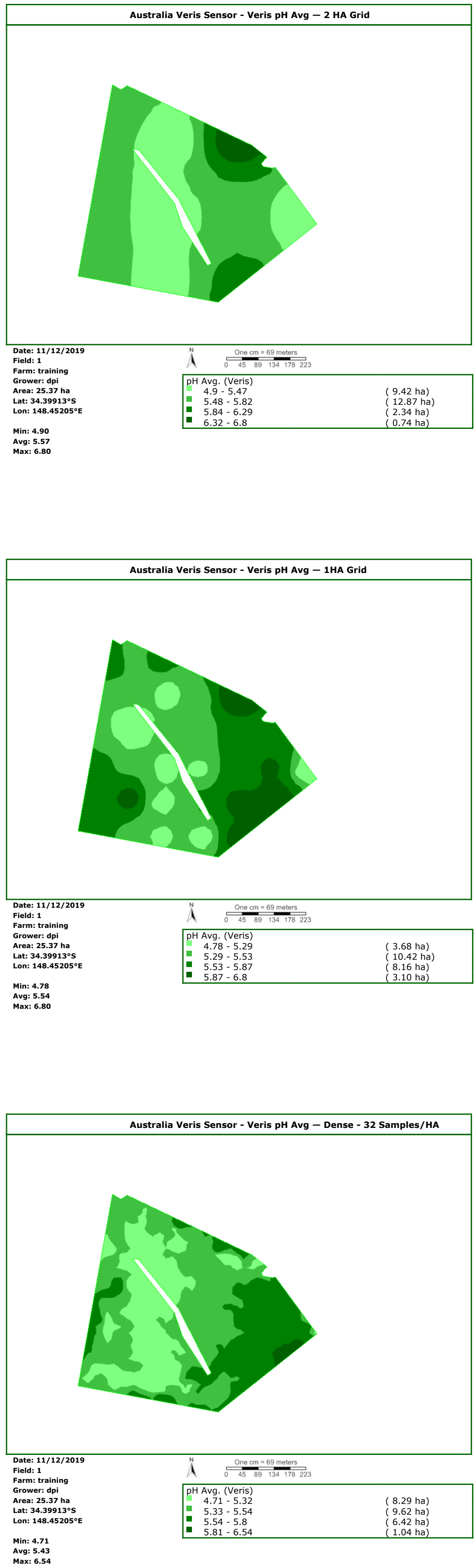

Figure 1. *Data density/resolution comparison of 2 ha grid sampling (top), 1 ha grid sampling (middle) and 0.03 ha grid sampling (32 samples per ha) (bottom). Source: NSW DPI*

Figure 2. *EM38 sensor (close-up inset) being towed behind a tractor to map soil electrical conductivity variability across a mixed vegetable farm in NSW. Source: Precision Pastures*

Pros

- Excellent for creating soil 'zones' for the layout of new blocks and placement of soil moisture probes.
- Combined with strategic soil sampling, EM38 maps can be used to understand soil type differences and subsoil constraints (e.g. sodicity and salinity) (Figure 3).
- Relatively cheap soil sensing operation.
- Can choose the level of resolution for ground-truthing and can be based on zones or grids.
- Digital elevation and waterflow maps can be constructed using the elevation data. These maps can be used for both drainage design and variable rate irrigation.

Cons

- Cannot be used in isolation to develop variable rate application maps, especially when aiming to manage topsoil constraints. Grid soil mapping is preferred in this instance for accuracy in prescription map development.
- EM38 maps need to be ground-truthed with additional soil sampling and analysis.

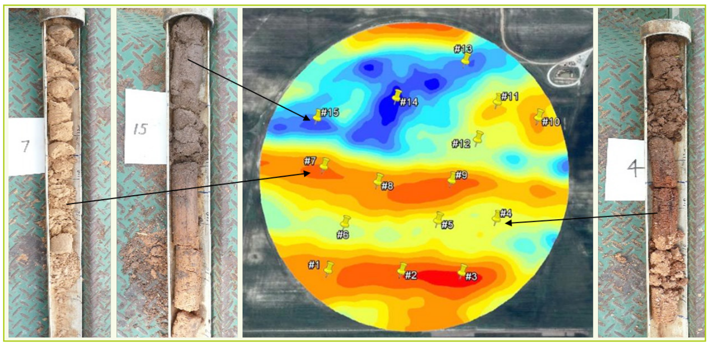

Figure 3. *EM38 map (centre) and soils samples from different zones (left and right) for a carrot field in SA. Source: PIRSA*

VERIS® SOIL MAPPING

What does it measure?

Veris® soil mapping uses on-the-go soil sensors that geo-reference each data point. Although a range of sensors have been developed, most platforms are set up to map apparent electrical conductivity (ECa), organic matter (OM) and pH from proximal sensors, along with topography or elevation data. The Veris® machine is towed across a field with either a tractor or 4WD under fallow or low crop residue levels (Figure 4).

Figure 4. *Veris® soil mapping rig. Source: Tasmanian Institute of Agriculture*

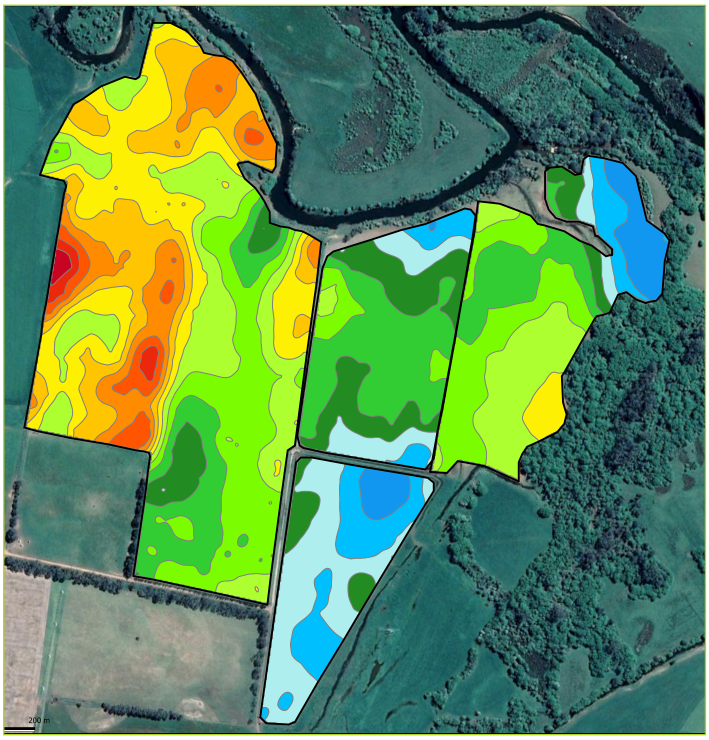

Figure 5*. Soil pH map from Veris® machine.*
Source: AgriLogic

The most common application for Veris® is to generate variable rate prescription maps for the application of lime based on pH measurements to a depth of 8 to 10 cm (Figure 5).

ECa can generally be mapped to two depths (most commonly 30 and 90 cm), but requires the soil to be moist. The data is processed into a spatial map similar to those generated from EM38 soil mapping.

While Veris® uses on-the-go sensors, some physical soil samples are required for laboratory analysis to calibrate the readings from the sensors. The more calibration points sampled, the greater the confidence or accuracy in the spatial map.

There are two options for calibration:

1. collecting cores from the machine and analysing these in a laboratory, or,
2. processing the data then ground-truthing the zones with more comprehensive soil analysis, such as pH, CEC and aluminium, to correct zone values and prescribe accurate application rates.

In vegetables, a calibration resolution of 1 calibration sample per 2 ha is recommended. The calibration data is then used to correct the Veris® field measurements before the data is mapped.

Resolution

The resolution is determined by the swath width, the speed of travel and soil type. The number of sampling points decreases when the machine travels faster or along paths wider apart. For example, 36 m transects at 12 km/hr in heavy clays gives 8 to 10 sample points per ha while 24 m transects at 10 km/hr in a loam gives 20 to 25 sample points per ha.

Cost

Costs range from $17/ha to $35/ha (for pH and ECa) plus travel. Veris® mapping in vegetable production is likely to be at a higher rate due to the higher number of calibration samples required per hectare.

Pros

- High-resolution mapping (e.g. a 36 m swath) can provide a resolution of 8 to 10 samples per ha, but this can be varied according to your requirements.
- Can tailor the sampling regime to suit the landscape.
- Measurements are done on-the-go.
- Laboratory analysis can be used to calibrate pH and ECa. Additional analysis such as CEC can assist with ground-truthing.

Cons

- Requires a supply of deionised or rain-water.
- Limited to a depth of 8 to 10 cm for pH (or 12 cm depth in some situations).
- Laboratory analysis of soil samples required to calibrate Veris® data.

SOIL INFORMATION SYSTEM™ (SIS) MAPPING BY TRIMBLE

What does it measure?

SIS™ mapping uses a range of sensors and geo-processing to measure soil physical and chemical characteristics (Figure 6). These include soil texture, topography, electrical conductivity, pH and a range of macro and micro nutrients. From these characteristics, additional parameters are calculated and spatially mapped.

The process begins with Dual EM38 mapping, which is used to identify points for soil physical measurements (e.g. tip compaction, sleeve resistance, resistivity, moisture, % of pore spacing and capacitance) to a depth of up to 1.2 m.

On-board processing of the EM38 data and the results from soil physical measurements determines the best locations for soil coring for chemical analysis. Two cores are taken at each sampling site at depths of 0 to 0.6 m and 0.6 to 1.2 m.

Results from laboratory soil chemical analysis and on-board physical measurements are used to develop a range of spatial data layers including, elevation, EM38, moisture-holding capacity, root zone depth, compaction characteristics, macro and micro nutrients and salinity (Figure 7).

Resolution

Data-point resolution can be varied from 2 m grid to 30 m grid.

Figure 6. *SIS™ rig with sampling cores. Source: DAF*

Cost

Costs range from $70/ha to $140/ha.

The lower rate is for EM38 and soil physical properties only and the higher rate also includes soil chemical analysis (analysis cost included). Travel costs are usually additional.

Pros

- Can generate numerous data layers.
- Measures soil physical characteristics, including soil texture, as well as chemical characteristics.
- Can vary sampling resolution to suit requirements and budget.
- Can be used to develop variable rate prescription maps and drainage models.

Cons

- The cost can be high, but offset against the detailed soil data obtained.
- Requires laboratory analysis.

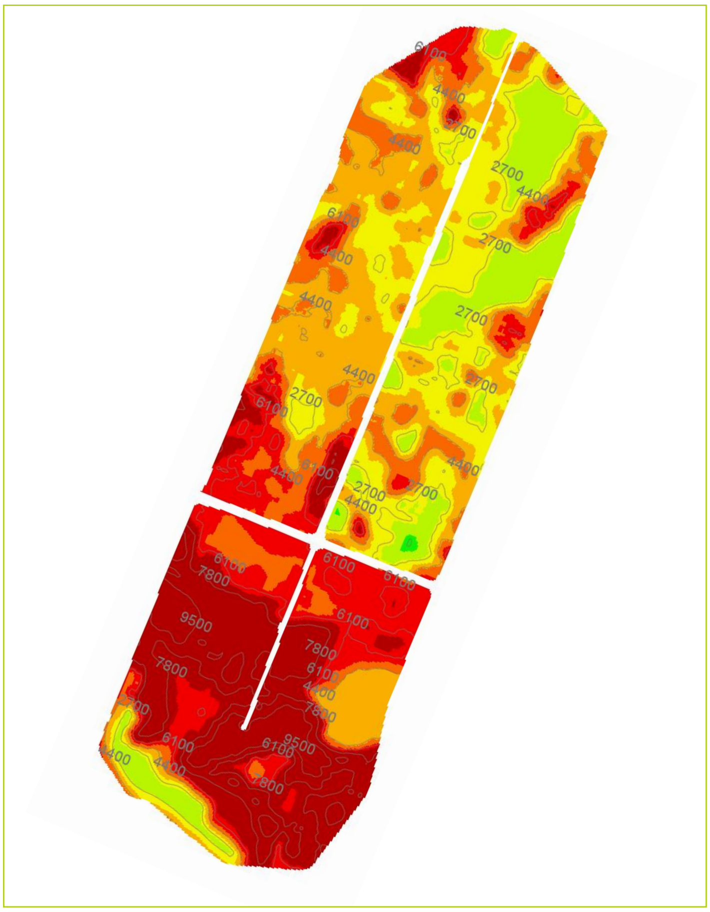

Figure 7. *Spatial mapping of surface compaction (kPa).*

RADIOMETRIC SOIL MAPPING

What does it measure?

Gamma radiometrics (Figure 8) is a method of measuring the gamma rays emitted during the radioactive decay of naturally-occurring radioactive elements found in soil and rock. Radioactive decay from potassium (K) and thorium (Th) are the most useful for indicating differences in soil type and texture as they tend to correlate well with clay and gravel content in the soil respectively.

Figure 8. *EM and radiometric soil mapping in action. Note radiometric sensor on the front of the vehicle. Source: Vegetables WA*

Radiometrics, in conjunction with EM38, can be helpful in identifying changes in soil type and to define soil management zones, particularly in sandy soils. Radiometric data only needs to be collected once, due to the unchanging nature of soil texture. As with all soil mapping technologies, ground-truthing is required to validate the data (Figure 9).

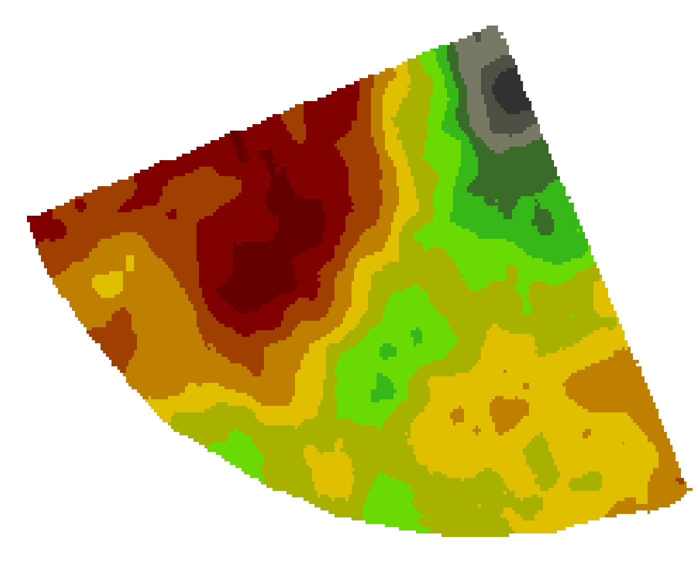

***Figure 9.** Radiometric Potassium count map for a carrot field in WA.*

Resolution

Typically, radiometric equipment collects data at a rate of 1 sample per second, or 1 Hz. Equipment is driven at 10 to 20 km/h and swaths vary from 12 to 36 m.

Cost

Gamma radiometric mapping is generally undertaken simultaneously with EM38 soil mapping and included in the EM38 mapping costs. Costs for both EM and radiometric data collection ranges from $7/ha to $12/ha, depending on the survey area. Data processing and interpretation costs are additional to collection costs and depend on the degree of analysis required. Travel costs are usually additional.

Pros

- Helps identify gravel, rock and clay content at high resolution at a sub-paddock scale.
- When coupled with ECa, accurate soil management zones can be defined.
- Beneficial for better understanding sandy soils.
- Radiometric data only needs to be collected once.

Cons

- Relationships between radiometric data, ECa and soil properties are regionally-specific, not universal.
- Requires soil sampling to ground-truth.

GRID SOIL SAMPLING

What does it measure?

Grid soil sampling refers to the collection of soil samples on a standard grid to quantify spatial variability in soil characteristics across a field (Figure 10). The grid can be customised to suit the enterprise.

Grid soil sampling is most commonly used to measure soil pH, electrical conductivity (EC) exchangeable cations (CEC) and nutrients (mainly phosphorus). However, any analysis can be easily added to suit enterprise requirements.

Traditional soil sampling, based on the whole field or broad management zones, does not highlight the variability in soil properties across the field. Therefore it should not be used to generate variable rate prescriptions for the application of crop inputs.

Resolution

Resolution of sampling is variable, but 0.25 to 0.5 ha grids are recommended to suit the intensity and scale of vegetable production.

Cost

Costs depend on the resolution of the grid and the analyses requested. For vegetable cropping, based on single-depth sampling, costs range from $160/ha to $230/ha, depending on which analyses are requested. These costs include the analysis costs. Additional costs are also incurred if sampling multiple depths.

Pros

- Sampling resolution, depth and analyses are set to suit requirements and budget.
- Soil samples can be tested for any characteristics required (depending on laboratory capability).
- Soil characteristics can be analysed at various depths.
- Provides an understanding of distribution of nutrients and soil constraints.

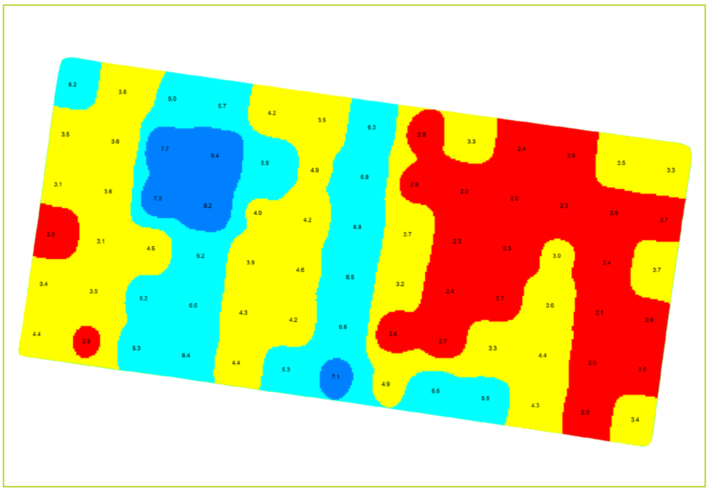

***Figure 10.** Grid mapping results for ECse (dS/m) for a vegetable field in Victoria.*

Figure 11. *Grid soil sampling. Source: Precision Pastures*

Cons

- The cost can be high, but offset against the detailed soil data obtained.
- Sampling design does not easily allow for landscape variation (flats v slope), however, this is rarely a problem in vegetable cropping, given the higher resolution grids used.

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Acknowledgements

The Queensland Department of Agriculture and Fisheries would like to acknowledge the contributions of Mel Fraser and Andrew Harding (PIRSA), Bryan Granshaw (Vantage-NEA), Matthew Roesner (Precision Agronomics), Ben Fleay (Precision Agriculture) and the Society for Precision Agriculture Australia (SPAA).

Funding and Project Partners

Hort Innovation Strategic levy investment | VEGETABLE FUND

This project has been funded by Hort Innovation using the vegetable research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au