The Use of EM38 and Precision Viticulture Techniques to Improve Water Use Efficiency (Coonawarra SA)

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Coonawarra SA

Source: Proftt et. al 2006, *Precision Viticulture, A new era in vineyard management and wine production*, p51

Figure 48(a) (left). Schematic diagram showing how an Electromagnetic Induction (EMI) sensor works. The current produced as a result of the first magnetic field generated by the transmitter creates its own magnetic field which is then detected by the receiver. The intensity of the second magnetic field reflects the conductivity of the soil. Figure courtesy of Terry Evans, Rural Solutions, South Australia.
Acknowledgements:

This report has been prepared with the support of a South East Natural Resources Management Board (SENRMB) “Innovation grant.” The author acknowledges the contributions from members of the SENRMB, Department of Water, Land and Biodiversity Conservation (DWLBC), Department of Primary Industries and Resources South Australia (PIRSA) and Rural Solutions South Australia throughout the period of this trial.

In particular, the author would like to thank Rob Palamountain (SENRMB), Glenn Bailey (PIRSA Struan House), Tim Powell & Colleen Bernie (DWLBC) along with Michael Zerk (Rural Solutions SA, Struan House) and Chris Brodie (Wingara Wine Group) for their technical input, advice, helpful comments and insights.
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1.0 Introduction & Project Design:
The South East (SE) of South Australia is fortunate in having a large, low salinity, ground water resource. With an increasing demand on this resource and an upcoming conversion to a volumetric licensing system, there is a community expectation that irrigators use this resource in an efficient manner. Efficient irrigation requires an understanding of the interrelationship of the factors: soil, climate and crop, along with the accurate assessment\measurement of variables such as soil moisture.

This project targets water use efficiency by analysis of Readily Available Water (RAW) and plant water use, in the form of a comprehensive review of irrigation practices in a Wingara Wine Group Pty. Ltd. vineyard. Although an established vineyard, assessment will follow a standard process for assessing any proposed irrigation development:

- Soil-Plant-Water Interaction
- Soil Moisture Measurement & Monitoring
- Irrigation Scheduling & Management
- Impact of Irrigation

The trial focus since inception has been to achieve water use efficiency gains, by improving understanding of soil – plant interactions and soil monitoring equipment to improve irrigation efficiency and effectiveness.

The project has completed all actions as planned:

- EM38 Survey
- Adjustment of Enviroscan probes
- Soil pit mapping
- Soil Nutrient Sampling
- Irrigation system review
- Petiole sampling
- Vineyard Scoring
- Plant Cell Density Mapping
- Yield Mapping
2.0 Benchmarking:
The first stage of the project focussed on benchmarking irrigation usage and vineyard characteristics. It was intended that irrigation in the first season be scheduled in a similar manner to past seasons, with analysis creating a benchmark of irrigation practice.

Results of the soil survey, however, dictated an immediate change. Ultimately, this response in itself, along with comparatively excellent vineyard performance (to past years) over the two years of the trial, could be taken to assume that vineyard performance was improved, through implementation of better irrigation management practices.

Petiole sampling and soil nutrient analyses were undertaken to provide a baseline of plant nutrient status. Furthermore, vine based measures of pruning weight and canopy architecture were also planned.

3.0 Trial results & Discussion:
3.1 Soil Survey
Compilation of an EM38 soil survey was contracted to Farmworks Pty. Ltd. (Meredith Vic.) who along with a suite of maps typical of a soil survey (Electromagnetic Response, Topography, pH, Soil Water Holding Capacity etc.), compiled both a Depth to Limestone and Percent Gravel map (Appendix 1). Finally, information relating to necessary modifications to the Enviroscan network was also provided. Interpretative maps compiled from these are detailed in figures 1 & 2:

Glenn Bailey (PIRSA Struan) compiled a soil summary from details collected in a soil pit study. Findings relating to soil readily available water, hydraulic conductivity, bulk density and water holding capacity have been particularly useful (Figure 3). Results can be found in the Rural Solutions SA report titled: “What is happening to the water in South East Soils? (2009)”

Ultimately, a vastly improved understanding of soil variability, in particular depth to limestone has been an essential management tool and results of both the soil survey and soil pit enabled several conclusions to be reached relating to the trial vineyard site:
Key Findings:

- Soil depth has a greater effect on vine performance than any identified soil horizons.
- Irrigation should be targeted to an appropriate depth, in this trial to a depth of 40cm, to prevent deep drainage or lateral flow along the calcrete capped limestone.
- Irrigation needs to account for a high hydraulic conductivity of 70 - 180mm/hr.
- % gravel can have a significant effect on overall soil water holding capacity.

3.2 Enviroscan Probes

Re-location of Enviroscan Probes and sensors was planned to address the issue of mis-representative information provided by relatively “random” location of probes and their sensor levels.

A key goal was to have soil moisture probes located in areas of the vineyard with soil of low RAW and average to high RAW (as dictated by soil depth). For the purpose of this trial, it was decided that the location of probes was already satisfactory. However, for future installations it was concluded that with soil details to hand (and due to the variable depth to limestone), it would be possible to monitor both deep and shallow soils, whilst keeping probes relatively close to each other. This has the advantage of reducing the amount/length of cable in the vineyard and enabling probes to share loggers/transmitters. This has the advantage of reducing setup costs, along with potential damage to exposed cables.

In the case of the trial, in spite of satisfactory probe location, the quality of data from these was improved by “clustering” of sensors within the “terra rossa” soil horizon. One sensor on each probe was placed in the limestone to check for any “through flow” beyond the target (feeder) root zone. Cumulative “moisture” traces were subsequently adjusted to indicate moisture content of the terra rossa soil only.

In spite of promising results, during the two years of the trial probes were dogged by technical issues. Primarily these were traced back to cabling problems, which were both time consuming to identify and costly to repair. This reinforces the argument that an EM38 soil survey provides details which can make siting of probes a longer term and more economical proposition.

Key Findings:

- The EM38 map provided details necessary for the representative siting of monitoring probes.
- Details of soil depth enabled informed configuration of probe sensors.
- Setup costs and exposed cable runs can be reduced through judicious site selection.
3.3 Vine based measures:

3.3.1 Petiole Sampling

Key Findings:

No significant differences in vine nutrient status were observed by petiole sampling over seasons 2007/08 and 2008/09 (refer to table 2). For the purposes of this trial, it is felt that this excludes vine nutrition as having an effect on vine performance between seasons.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Year</th>
<th>N (%)</th>
<th>NO₃-N (mg/kg)</th>
<th>K (%)</th>
<th>Ca (%)</th>
<th>Mg (%)</th>
<th>S (%)</th>
<th>Na (%)</th>
<th>Cl (%)</th>
<th>Zn (mg/kg)</th>
<th>Mn (mg/kg)</th>
<th>Cu (mg/kg)</th>
<th>Fe (mg/kg)</th>
<th>B (mg/kg)</th>
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<td>Cabernet Sauvignon</td>
<td>2007</td>
<td>0.78</td>
<td>46</td>
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<td>3.56</td>
<td>1.64</td>
<td>0.27</td>
<td>0.23</td>
<td>0.08</td>
<td>0.49</td>
<td>32</td>
<td>45</td>
<td>25</td>
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<td>2008</td>
<td>0.73</td>
<td>43</td>
<td>0.26</td>
<td>3.57</td>
<td>1.47</td>
<td>0.27</td>
<td>0.22</td>
<td>0.07</td>
<td>0.41</td>
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<td>36</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Chardonnay</td>
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<td>41</td>
<td>0.46</td>
<td>2.99</td>
<td>1.59</td>
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<td>0.2</td>
<td>0.25</td>
<td>0.81</td>
<td>56</td>
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<td>41</td>
<td>0.34</td>
<td>3.13</td>
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<td>0.25</td>
<td>0.15</td>
<td>0.1</td>
<td>0.6</td>
<td>48</td>
<td>17</td>
<td>9</td>
<td>15</td>
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3.3.2 Point Quadrat Measures

Point quadrat measures are used to assess the proportion of leaves and fruit, which are positioned either at the exterior or interior of the vine canopy. This is assessed using a “point quadrat” rod inserted into a vine canopy, with the rod representing a beam of light (Smart & Robinson, 1992). This method was established for assessment of vines in cool climate regions and optimum values are therefore skewed towards an open canopy and exposed fruit.

In consideration of poor canopy development in past seasons and issues of fruit exposure, this method was used in a “reverse” manner, aiming to measure increases in shoot length, interior leaves and reduction in the number of interior clusters (bunches). As per Smart and Robertson (1992), description of parameters measured and their “optimum values” are indicated below:

- % gaps: areas of no foliage (20 – 40%)
- Leaf Layer Number: total number of leaf contacts by the point quadrat (1.0 – 1.5)
- Percent Interior Leaves: proportion of leaves in the interior of the canopy (<10%)
- Percent Interior Clusters: number of bunches in the interior of the canopy (<40%)

Additionally, the method was used in a direct comparison of vine canopy structure between two vineyard “sub – zones.” These zones were identified in season 2007/08 by both the EM38 and Plant Cell Density (PCD) mapping, with changes in pruning management aiming to achieve uniformity between the two zones. Results are detailed in table 3 and the similarity between sub – zones indicates a degree of success. This is quite positive in light of a difference in soil depth (and subsequently RAW) of approximately 40% (refer to figure 1).

<table>
<thead>
<tr>
<th>Variety</th>
<th>Year</th>
<th>% Gaps</th>
<th>Leaf layer number</th>
<th>% interior leaves</th>
<th>% interior clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabernet Sauvignon</td>
<td>2008</td>
<td>6</td>
<td>2.1</td>
<td>21.4</td>
<td>92.3</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>10</td>
<td>2.26</td>
<td>54</td>
<td>75</td>
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<tr>
<td>Chardonnay</td>
<td>2008</td>
<td>28</td>
<td>3.2</td>
<td>40.5</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>4</td>
<td>2.62</td>
<td>64</td>
<td>89.6</td>
</tr>
<tr>
<td>Chardonnay Frosted</td>
<td>2008</td>
<td>22</td>
<td>1.52</td>
<td>19.4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>4</td>
<td>2</td>
<td>59</td>
<td>84.4</td>
</tr>
</tbody>
</table>
Table 4: Point Quadrat results between shallow and deep soil “zones”

<table>
<thead>
<tr>
<th>Variety</th>
<th>Zone</th>
<th>% Gaps</th>
<th>Leaf layer number</th>
<th>% interior leaves</th>
<th>% interior clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabernet Sauvignon (Young)</td>
<td>North</td>
<td>4</td>
<td>3.62</td>
<td>52.5</td>
<td>77.5</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>4</td>
<td>3.92</td>
<td>52.6</td>
<td>88.1</td>
</tr>
</tbody>
</table>

Key Findings:

- % gaps has remained similar or decreased between years and indicates a denser canopy
- Leaf layer number has increased, meaning an increase in total leaf numbers
- % interior leaves has increased, indicative of longer shoot development
- % interior clusters has reduced, indicating good fruit exposure in spite of increased leaf number

Similarly, for the young Cabernet Sauvignon vineyard, a harder pruning treatment aimed at achieving vine “balance” (Northern, shallower zone), proved successful and resulted in fewer shoots of equal length when compared with the Southern zone (refer to Figure 1). Although not utilised in the context of reducing water use, it is worth noting that adjusting pruning level (down), is a further tool which can be used in dry seasons to conserve water; although as these decisions need to be made during winter dormancy, it does rely on accurate seasonal forecasts.

3.3.3 Pruning Weights

Pruning weights were taken as an additional measure to observe for any change on account of irrigation strategy. Table 5 details results for samples taken from the young Cabernet Sauvignon vineyard.

What can be seen from the table, is that a change in irrigation strategy and compensatory pruning has caused differing results depending upon soil depth:

Shallow Soil (North):
Individual cane weight and pruning weight per metre of canopy has increased to the upper end of the optimal range, this coinciding with a reduction in the ratio nodes\kg pruning weight. What this reflects is significantly improved cane length and weight, with a reduction in subsequent bud numbers retained to a more “balanced” pruning level.

Moderate Depth (South)
Individual cane weight and pruning weight per metre of canopy has remained relatively unchanged and reflects the vine balance which was already in place. However, nodes\kg pruning weight has increased and this reflects that vines are capable of carrying slightly more shoots (resulting in slightly higher yield) than had been previously recognised.

Table 5: Pruning weight results between trial seasons and zones; Young Cabernet Sauvignon

<table>
<thead>
<tr>
<th></th>
<th>Nodes\kg Pruning weight</th>
<th>Mean cane weight (g)</th>
<th>Pruning Weight (kg/m canopy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South 2008</td>
<td>52</td>
<td>22.0</td>
<td>0.33</td>
</tr>
<tr>
<td>South 2009</td>
<td>41</td>
<td>42.8</td>
<td>0.62</td>
</tr>
<tr>
<td>North 2008</td>
<td>28</td>
<td>30.8</td>
<td>0.63</td>
</tr>
<tr>
<td>North 2009</td>
<td>33</td>
<td>35.2</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Note: Aim for 30 - 40 nodes\kg pruning weight
Aim for 20 - 40g cane weight (optimal)
Aim for 0.3 - 0.6kg pruning weight/m canopy
Yield mapping, although only possible in sections of the vineyard, provides a further layer to this interpretation (Appendix 3).

**Key Findings:**

- Shallower, more frequent irrigations proved effective in increasing overall shoot length and weight
- The irrigation strategy employed maintained shoot length and weight within an optimum range.

**3.4 IRES:**

Irrigation application was tracked by use of the ICMS & Rural Solutions SA Irrigation Recording and Evaluation Software (IRES) package.

Comprehensive entry of data including: applied irrigation (and in particular meter readings), rainfall, evaporation and Enviroscan Probe data, has indicated irrigation efficiency of 97% during the second year of the trial (as interpreted by Department of Water, Land and Biodiversity Conservation). A system check undertaken by Michael Zerk of Rural Solutions SA (Struan House), however, has indicated declining application uniformity during the irrigation season with system variability of 20% reported (Appendix 4). This was found to be primarily attributed to blockage of drippers resulting from:

- calcium carbonate build up in dripper lines
- infrequent flushing of irrigation lines
- ingress of sand into drip line due to infrequent cleaning of filters

**Key Findings:**

- IRES has proven useful in tracking a range of inputs, to enable interpretation of irrigation efficiency
- IRES outputs enabled observation of system efficiency (decline) over the course of the irrigation season
- Daily recording of meter readings proved invaluable in identifying declining output and missed shifts, among other things.
4.0 Management Review
There have been three major changes to management for this vineyard, as a direct result of the EM38 survey:

- Irrigation management has been adjusted, with shorter more frequent irrigations aimed at reducing through – flow and lateral flow beyond the vine root zone. Furthermore, irrigation scheduling has been adjusted to irrigate to the majority minimum soil depth (in this case 40cm), by applying more frequent, shorter irrigations. Although not perfect, this is a compromise that aims to deliver a constant supply of water to vines in shallow soil, whilst reducing deep drainage and lateral flow. Similarly, deeper soils are not over irrigated, nor do they receive additional water from lateral flow, ultimately reducing vineyard variability resulting from applied irrigation (refer to figure 3).

- Zonal management of the overall vineyard has been implemented, in consideration of clear areas of uniform soil depth. What this means is the creation of “sub zones” within what was previously regarded as “uniform” vineyard patches i.e. Cabernet Sauvignon 2004, which is now managed as two separate areas in regard to pruning level.

- Pruning rates have been adjusted for “low potential” areas, to improve uniformity of vine vigour (and fruit quality) across the vineyard, while maximising water use efficiency. A distinct management zone could be established for this treatment, by comparative assessment of EM38 soil data and plant cell density information.

5.0 Conclusion:
Use of EM38 soil mapping targeting interpretation of depth to limestone, has proven effective in improving the efficiency of applied irrigation. The degree of variability in (Terra Rossa) soil depth (to limestone) had not been appreciated prior to the trial, nor had the shallowness of some parts of the vineyard. Furthermore, soil pit data revealed that the Terra Rossa soil, although being classified a clay loam, possessed soil hydraulic conductivity properties more akin to a sand.

Irrigation targeting the majority, minimum average soil depth has been effective in achieving vines of moderate vigour; in particular the changes in irrigation management have resulted in an improvement in canopy architecture for vines located on shallow soils (<40cm). This has primarily meant a change to shorter, more frequent irrigation, particularly in light of soil hydraulic conductivity.

The EM38 soil survey, when combined with other Precision Viticulture Imaging such as Plant Cell Density Mapping, enable management zones to be delineated. This has resulted in further irrigation efficiency improvements on a vine physiological level. This is in the context of vines on shallow soil ultimately being classified as having lower “potential.” Pruning these zones to fewer bud numbers subsequently takes into account this reduced “potential” and thereby reduces the water requirement of individual vines.

6.0 references:


Profitt, T., Bramley, R., Lamb, D. & Winter, E., 2006, “Precision Viticulture, A new era in vineyard management and wine production” Winetitles Adelaide, pp 24 - 76

Appendix 1: EM38 Depth to Limestone & Soil Pit Information

Shallow Soil overlying Limestone

Suspected Solution Pipe (deep soil feature)

Location of soil moisture sensors
Predicted gravel content of Horizon 1. Modelled using combined Margeaux data.

Gravel content in Margeaux:
- Depth of Horizon 1 samples ranges from 0-0.55m
- Model of predicted gravel content in Horizon 1

Margeaux (18 samples)
- Model Statistic
  - r=0.80, p=0.02
  - RMSE=2.3, Est.KCV=n/a

Max: 5.9%
Min: 0%
Mean: 1.2%
Median: 0.9%

Katnook Estate
Margeaux
Model of predicted gravel content in Horizon 1

Survey date: 21/02/2007
Surveyed with dual frequency RTK GPS & EM38DD

www.farmworks.com.au
Appendix 2: Plant Cell Density Mapping

- Low vigour due to shallow soil depth to limestone.
- Medium vigour
- Low vigour on account of spring frost damage
Appendix 3: Yield Mapping

Note: only the 2008/09 image complies with recognised yield map colouration guidelines.

Yield data for season 2007/08 (top):
It is difficult to conclude any definitive changes in yield in relation to irrigation strategy, although some association between soil depth and yield could be interpreted from the image.

Yield data for season 2008/09 (bottom):
Some association between soil depth and yield could be interpreted from the image. Complicating matters for the 2008/09 image, however, is that hand picking of premium bunches occurred in the central section of the block, prior to machine harvesting.
## Pressurised Irrigation System Auditing

### Irrigation Emitter Evaluation

<table>
<thead>
<tr>
<th>Emitter Location</th>
<th>Brand</th>
<th>Model</th>
<th>Nozzle Size(s) Colour/Nominal Flow Rate (L/h)</th>
<th>Emitter Spacing (m)</th>
<th>Pressure (kPa)</th>
<th>Volume (mL)</th>
<th>Time (sec)</th>
<th>Flow Rate (L/h)</th>
<th>Application Rate (mm/h)</th>
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*Refer to field sheet for locations

Averages: 126.6, 59.1, 1.77, 0.54

Select maximum and minimum values from the figures above - Midpoint will be calculated.

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<thead>
<tr>
<th></th>
<th>Maximum</th>
<th>Minimum</th>
<th>Midpoint</th>
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<tbody>
<tr>
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<tr>
<td>Flow Rate</td>
<td>65</td>
<td>51</td>
<td>58.0</td>
</tr>
</tbody>
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Target variation: Pressure ±10%, Flow Rate ±5%

<table>
<thead>
<tr>
<th>Variation ±%</th>
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<td></td>
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<td></td>
<td>26.1</td>
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</tbody>
</table>

System Application Rate: 0.5 mm/h