Being profitable precisely - a case study of precision viticulture from Margaret River

Introduction

Precision Viticulture (PV) is an all-encompassing term given to the use of a range of information technologies that enable grapegrowers and winemakers to better see and understand variability in their production systems, and to use this understanding to better match the inputs to production to desired or expected outputs. At least, that is the claim, but is it true? This paper describes a small case study undertaken in part of a block of Cabernet Sauvignon owned by Vasse Felix, in Margaret River, Western Australia; the study demonstrates that adoption of PV can realise immediate economic benefits.

The adoption and implementation of a Precision Viticulture approach to vineyard management is a continual cyclical process (Figure 1) that begins with observation of vineyard performance and associated vineyard attributes, followed by interpretation and evaluation of the collected data, leading to implementation of targeted management. Here, ‘targeted management’ can mean the timing and rate of application of water, fertiliser or spray, or the use of machinery and labour for operations such as harvesting, pruning or just about any aspect of vineyard management. The key technologies involved in PV, aside from the ubiquitous desk computer, are the global positioning system (GPS), grape yield monitors that might be regarded as primary observation tools and have now been commercially available in Australia for five vintages, and geographical information system software (GIS). Also invaluable is access to a range of sources of ‘supplementary information’ that may be useful in helping explain the observed variation in vineyard productivity. These might be regarded as secondary observation tools, and include soil-sensing technologies such as the EM38 sensor, more traditional methods of soil inspection, plant tissue analysis and remote sensing (Lamb and Bramley, 2001; 2002); as we demonstrate in this paper, remote sensing may also be regarded as a source of primary observations.

Conventional wisdom from broadacre agriculture, for which precision agriculture has been available since the early 1990s, suggests that farmers would be wise to collect around five years of data before implementing targeted management. In the example used to illustrate Figure 1, a 7.3ha vineyard in Coonawarra (Bramley and Proffitt, 1999; Bramley, 2001), the pattern of yield variation has been shown to be temporally stable over a three-year period, with the wines produced from fruit harvested from the different ‘zones’ producing wines of differing characteristics (Bramley, 2002). Given the perenniality of grapevines, one might expect spatial variation in vineyard productivity to be reasonably temporally stable. Indeed, in the vineyard shown in Figure 1, yield variation in any given year has been shown to be driven primarily by variation in the amount of plant-available water which, in this...
instance, is predominantly controlled by variation in soil depth (Bramley et al., 2000; Bramley and Lanyon, 2002); of course, soil depth is unlikely to vary over time!

The vineyard shown in Figure 1 is the subject of a large study of vineyard variability being conducted by the Cooperative Research Centre for Viticulture (CRCV: www.crcv.com.au/research/programs/one/project1.1.1.asp). Whilst this research seeks to assist grapegrowers and winemakers wishing to adopt PV by identifying the key drivers of vineyard variation, the fact is that PV is available now, with many early adopters looking to target management sooner rather than later, and avoid at least some of the waiting associated with the early phase of data collection that Figure 1 and the preceding discussion implies. Certainly, this was the intention of Vasse Felix, early adopters of PV from Margaret River. On the other hand, like others interested in adopting this technology, Vasse Felix needed to be sure that targeting its management was going to deliver an economic benefit.

**Precision viticulture at Vasse Felix – Vintage 2002**

During 2001, Vasse Felix saw that PV offered an opportunity for better managing a recently-planted property it had acquired towards the northern end of the Margaret River region. Block boundaries were georeferenced using differentially corrected GPS (accurate in the x and y planes to about 50cm), and a high spatial resolution soil and elevation survey was conducted by local geotechnical engineers using real-time kinematic GPS (accurate to about 2cm in the x, y and z planes) and a range of soil sensors of which radiometrics proved to be the most useful (the use of steel posts in the vineyard mitigated against the utility of EM38 soil sensing). The data so collected were used as the basis for a GIS in which all spatial data are stored, analysed and displayed.

The use of remotely-sensed imagery in viticulture has been the subject of much recent research (e.g., Hall et al., 2002; Lamb et al., 2001; Lamb and Bramley, 2002) with early indications being that veraison +/- two weeks is the optimal time for image acquisition (Lamb and Bramley, 2002). Accordingly, Vasse Felix engaged the services of a commercial provider of airborne digital multispectral video (DMSV) imagery who acquired imagery of the site on 6 February, 2002. The DMSV system used collected images in four separate wavebands (e.g., Hall, 2002) corresponding to the infra-red, red, green and blue wavelengths. For this study, the so-called ‘plant cell density’ index (i.e., the ratio of infra-red to red reflectance) was used to generate the image shown in Figure 2. Variation in this index is thought to give an indication of variation in vine vigour.

Two weeks prior to the expected date of harvest, the imagery collected at veraison was used as the basis for targeted fruit sampling in 27 rows (3.3ha) of a block of Cabernet Sauvignon. Areas of apparently low and high ‘plant cell density’ were sampled and the fruit analysed for maturity indices; an assessment of fruit quality was also made (Table 1).

In light of the differences shown in Table 1, a targeted harvesting strategy was employed at harvest (19 March, 2002). The crop was harvested by a ‘tow-behind’ Gregoire G65HD mechanical harvester fitted with a Farmscan grape yield monitor and differential GPS. On the basis of the imagery and subsequent analysis (Table 1), the study area was split into a northern and

<table>
<thead>
<tr>
<th>Plant cell density</th>
<th>Baumé</th>
<th>pH</th>
<th>TA</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>10.4</td>
<td>3.20</td>
<td>8.40</td>
<td>Medium</td>
</tr>
<tr>
<td>High</td>
<td>10.8</td>
<td>3.24</td>
<td>8.35</td>
<td>Medium</td>
</tr>
<tr>
<td>Low</td>
<td>11.9</td>
<td>3.33</td>
<td>5.77</td>
<td>Good</td>
</tr>
<tr>
<td>Low</td>
<td>12.3</td>
<td>3.37</td>
<td>6.53</td>
<td>Very Good</td>
</tr>
<tr>
<td>Low</td>
<td>11.7</td>
<td>3.29</td>
<td>7.87</td>
<td>Good</td>
</tr>
</tbody>
</table>
greater significance, however, was the quality of the fruit different yields (mean yields of 16 and 8t/ha, respectively). Of veraison (Figure 2). The mean yield for the whole study area was can be seen from Figure 3, the yield map bears a strong mapped using the protocol of Bramley and Williams (2001). As which the ‘boundary’ between the sections is delineated on a collecting the fruit. However, a system is currently being tested in alongside the harvester for each section; the other bin could move flagging tape, with the appropriate chaser bin then moving with the fruit from the southern section going into the other. southern section (Figure 3). Two chaser bins were used such that the fruit from the northern, higher vigour, area went into one bin, with the fruit from the southern section going into the other. Operationally, this required the two sections to be delineated by flagging tape, with the appropriate chaser bin then moving alongside the harvester for each section; the other bin could move out of the way by either moving ahead, or dropping behind the bin collecting the fruit. However, a system is currently being tested in which the ‘boundary’ between the sections is delineated on a harvest plan and identified automatically by the GPS.

Following harvest, the data collected by the yield monitor were mapped using the protocol of Bramley and Williams (2001). As can be seen from Figure 3, the yield map bears a strong resemblance to the remotely-sensed image collected close to veraison (Figure 2). The mean yield for the whole study area was 13t/ha, but the higher and lower vigour areas had substantially different yields (mean yields of 16 and 8t/ha, respectively). Of greater significance, however, was the quality of the fruit harvested from the two areas, and the implications of this quality difference with respect to final product. Table 2 presents the results of analysis of bulk samples delivered to the winery. As can be seen, the differences in fruit character noted two weeks prior to harvest for samples taken from the areas identified in the imagery collected at veraison (Figure 2, Table 1) carried through to harvest (Table 2) and were large enough to warrant allocation of the different batches to different end products. Thus, fruit from the higher yielding northern area (higher plant cell density) was deemed suitable for the Vasse Felix ‘Classic Dry Red’ (retail price of approximately $19/bottle), whilst that from the lower yielding area was assigned to the Cabernet Sauvignon varietal (retail price of approximately $30/bottle); had the block been harvested as a single unit, it would have all been assigned to the lower value wine.

**Precision viticulture is profitable**

A total of 12.68t fruit were harvested from the higher quality southern portion of the block. Assuming a simple conversion of 1t fruit producing 750L wine, we estimate that the gross retail value of production from this area was approximately $285,300. The lower quality northern portion produced a total of 25.5t with a gross retail value of $363,375. Thus, the total gross retail value of production using the targeted harvesting strategy based on remotely-sensed imagery was approximately $648,675. Had the block been harvested into single bins and the fruit used to make the cheaper ‘Classic Dry Red’, the 38.18t would have produced wine with a gross retail value of $544,065 – that is, a PV approach to harvesting of this 3.3ha block has yielded an increase of $101,610 in the estimated gross retail value of production, equivalent to $2661/t fruit harvested or $30,791/ha.

It is recognised that wine retail pricing is a less satisfactory basis for assessing the merits of adopting PV than would be provided by the true costs and value of production of grapes and wine. However, for reasons of commercial confidentiality, this is the only indicator of the benefit:cost that we can provide. Further, we have assumed that the costs of winemaking for the two products are comparable. With respect to viticultural operations, since the block was managed uniformly, the cost of grape production for the two products were the same, although the targeted harvesting incurred the additional cost associated with running the second chaser bin that enabled segregation of the fruit. Thus, in spite of its obvious shortcomings, we suggest that this analysis provides an indication of the level of increase in revenue that might accrue to a grapegrowing and winemaking business through the adoption of PV.

The cost of a grape yield monitor with supporting software is approximately $9050 excluding GST. Grape yield monitoring requires the use of a differentially corrected GPS of which there are a range of models available; purchasers may also choose whether to access the differential correction from a commercial provider to whom an annual subscription is payable, or the signal that is available free of charge from the chain of marine beacons operated by the Australian Maritime Safety Authority (www.amsa.gov.au/ns/dgps/dgps.htm) which, depending on the location and intended application of the user, may or may not be suitable. A GPS unit similar to that used by Vasse Felix costs approximately $9000 and the annual subscription to differential correction is $2500. If these costs were spread over five years, the cost of yield monitoring amounts to $6110/year. If we assume that the true costs and value of production of grapes and wine are a range of models available; purchasers may also choose whether to access the differential correction from a commercial provider to whom an annual subscription is payable, or the signal that is available free of charge from the chain of marine beacons operated by the Australian Maritime Safety Authority (www.amsa.gov.au/ns/dgps/dgps.htm) which, depending on the location and intended application of the user, may or may not be suitable. A GPS unit similar to that used by Vasse Felix costs approximately $9000 and the annual subscription to differential correction is $2500. If these costs were spread over five years, the cost of yield monitoring amounts to $6110/year. If we assume that average grape yields in Australia are of the order of 10t/ha (note that on average, the block at Vasse Felix was higher yielding than this), and that during a vintage, a harvester covers about 0.4ha/hour for a vintage total of 450 hours (a total of 180ha or 1800t), the cost of yield monitoring amounts to about $3.40/t. This equates to about $13.60/hour of harvester operation. Of course, for harvesters operating at faster speeds (i.e., covering larger areas per hour), this cost will go down.

**Table 2. Analysis of fruit delivered to the winery from areas harvested separately on the basis of ‘plant cell density’ at veraison.**

<table>
<thead>
<tr>
<th>Plant cell density</th>
<th>Mean yield (t/ha)</th>
<th>Baumé</th>
<th>pH</th>
<th>TA</th>
<th>Quality</th>
<th>Winemaker comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>16</td>
<td>12.35</td>
<td>3.56</td>
<td>6.23</td>
<td>Medium</td>
<td>Light in colour, some simple berry fruits, greener leaf edges, tobacco, herbal, medium intensity with starchy finish. Acid balance not too back. Greener palate than low vigour/yield.</td>
</tr>
<tr>
<td>Low</td>
<td>8</td>
<td>13.0</td>
<td>3.55</td>
<td>5.40</td>
<td>Very good</td>
<td>Darker red colour, rhubarb, smoky, dark cherry nose, shows more intensity of flavour and riper notes than higher vigour/yield.</td>
</tr>
</tbody>
</table>
Remote sensing services are now available in Australia for about $25/ha, equivalent to $2.50/t fruit harvested. The costs of the sort of high resolution soil survey conducted at Vasse Felix, which is not required on a repetitive basis, are of the order of only $1/t when spread over five years. Thus, the total costs of the data acquisition elements of PV amount to approximately $6.90/t. If a consultant were employed to construct the GIS and carry out the sort of data analysis required in this study, which is probably the most appropriate way for early adopters to gain a benefit from PV rather than trying to learn the necessary spatial statistical, image analysis and associated techniques themselves, the costs of PV would increase to around $11/t. Clearly, this is a trivial expense in relation to the increase in the gross retail value of production achieved in the Vasse Felix study simply by targeting harvesting based on aerial imagery. It should also be noted that the targeted harvesting employed in this study was a simple straight-line delineation of the block into two zones (Figure 3). A more sophisticated approach could have involved a more complicated zonation, not necessarily based on straight lines, and with greater differentiation in terms of target product; note that the top part of the range ‘Heytesbury’ wine, which the very best fruit in this block may have been suitable for, retails for about $65/bottle.

The success of this example from Vasse Felix might lead some readers to wonder why yield monitoring was used; surely the same result could have been obtained more cheaply through use of a GPS and the remotely-sensed imagery alone? On the face of it, this is true. However, as Figure 1 infers, the adoption and use of PV involves a continuous cyclical process of data acquisition and use, each data layer building on those already collected. Such an approach allows the merits of targeted management to be evaluated and, if necessary, for the “management zones” to be modified and the differences between them understood – “you can’t manage what you can’t measure” is an old, but very true adage! Importantly, and assuming temporal stability in the patterns of vineyard variation, data collected annually will acquire a predictive value. Thus, managers will be able to tune their management in the increased expectation that any given decision will indeed deliver the desired outcome, leading to increased control over the whole production and supply chain. Importantly to Vasse Felix, the PV approach also ensures continuity and retention of information and knowledge about the production system; the departure of key staff certainly leads to a loss of experience, but given the data storage implicit in the use of PV and GIS, it need not lead to a loss of expertise.

Overall, the simple study detailed here suggests that PV offers grapegrowers and winemakers the ability to acquire valuable information about their production system, the cost of which is far outweighed by its value.

Acknowledgments

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References


From May 2003, Master Winemakers will offer state-of-the-art bottling services to our valued contract clients and to external wine producers. Winemaker in charge of the bottling line is Peter Florance.

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