11th
Australian Wine Industry
Technical Conference
Adelaide, October 2001

Workshop W14

Precision Viticulture – Principles, opportunities and applications

Presenters: Rob Bramley, CSIRO Land and Water / CRC Viticulture
Tony Proffitt, Albert Haak & Associates
Richard Hamilton, Southcorp Wines
Jonathan Shearer, Simeon Wines
Dennis Ormesher, Advanced Soil Mapping
David Lamb, National Wine and Grape Industry Centre / CRC Viticulture
James Taylor, Australian Centre for Precision Agriculture / Univ. Sydney

Introduction

Precision agriculture (PA) technologies improve the degree to which process control can be applied to agricultural production and promote the ability for agriculture to be managed in a way that recognises that the productivity of land varies in space, often over very short distances. The recent commercial availability of yield monitoring equipment for winegrape harvesters presents grape and wine producers with opportunities to tailor production of both grapes and wine according to expectations of vineyard performance and desired goals in terms of both yield, quality and the environment. This workshop will discuss the opportunities offered by precision viticulture and report the results of recent research. The topics to be covered will include a general discussion of what precision viticulture is and how it might work, the use of ancillary technologies such as remote sensing, EM38 surveying and GIS, and the experiences of the early adopters.

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Program

0830: Welcome, introduction and some background philosophy – Rob Bramley

0845: Yield Mapping – Company experiences

Southcorp Wines – Tony Proffitt and Richard Hamilton
Simeon Wines – Jonathan Shearer

0930: Remote Sensing – A tool for vineyard managers ? – David Lamb

0955: EM38 surveying in vineyards – A pragmatic overview – Dennis Ormesher

1020: Morning tea

1035: Digital terroirs - Their part in precision viticulture and environmental management - James Taylor

1100: Precision Viticulture – Research supporting the development of optimal resource management for grape and wine production – Rob Bramley

1125: General Discussion

1140: Close

Precision Viticulture - Technology to Optimise Vineyard Performance

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Introduction

Southcorp Wines, as with all wine producing companies, aims to optimise production to specification in quality as well as quantity, whilst ensuring minimal impact to the vineyard environment. The application of precision viticulture (PV) technology offers opportunity to better understand vineyards in order to optimise their performance within environmental constraints. Although PV is relatively new to the Australian Grape and Wine Industry, it is becoming increasingly apparent that established vineyard blocks vary substantially in both the quantity and quality of wine grapes produced (Bramley 2001). Southcorp Wines sees the advent of PV as a potential means by which the company can facilitate the tailored production of grapes and wine to meet its economic and environmental demands. This paper reports on recent findings and potential benefits of the technology, and briefly refers to the use of other instrumentation that is complementary to precision viticulture.

Assessing and working with vineyard variability

1998 vintage
During the 1998 vintage, we began efforts to determine the extent of spatial variability in our Coonawarra vineyards. As grape yield monitors were not commercially available at that time, we used a gondola that had been adapted to incorporate load cells. Signals from the load cells were relayed to a weighing indicator located in the towing tractor and grape mass was recorded manually at pre-defined ground positions. From this work we found that there was considerable spatial variability in yield both within and between rows.

1999-2001 vintages
Following the purchase of a HarvestMaster™ yield monitor and differential GPS in 1999, and the development of a mapping protocol (Bramley and Williams 2001), we have been able to produce yield maps for numerous company vineyard blocks within a number of key South Australian wine producing regions. In some cases we now have two and three years consecutive data for individual blocks. The findings to date verify our preliminary surveys and indicate that within-vineyard variability in yield is typically large and in the order of 8-10 fold. Although this is greater than expected, we have indications that the spatial pattern in yield is relatively stable over time. For example, a site in Coonawarra has shown that the difference in yield at any given location over the past three years is predominantly ± 0.5 standard deviations of the mean yield. This is good news since this makes it possible to identify discrete management zones. In this case, a targeted harvesting plan has been developed for the block, with batches of fruit from each of three different yielding parcels kept separate in the winery. Sensory and spectral analyses of finished wines indicate that there are differences in quality.

As we are also interested in understanding the spatial variability of grape quality as well as yield, data for a number of vine and berry characteristics has also been collected from geo-referenced vines within the same Coonawarra block. These have been mapped and, as for yield, their spatial pattern appears to be relatively consistent between years.

Economic analysis of yield data collected in 1999 from a Coonawarra block has demonstrated the power of PV technology with the production of maps showing gross margins and estimated value of production following winemaking (Bramley and Proffitt 1999). In this example, approximately one third of the block operated at a loss as a grape producing entity under uniform management, with a small area also making a loss after value adding through winemaking. The introduction of a targeted management plan could make this vineyard block a more cost-effective entity.

Multiple layers of information to support precision viticulture

We see the need for overlaying additional information to support yield and quality maps in order to gain a better understanding of the causes of vineyard variability so that block performance can be optimised. Such information may already be available in the form of soil surveys or aerial photographs for example. In recent years we have used GPS-equipped electromagnetic sensing equipment (EM38) which has proved to be invaluable in providing insight into the reasons for low production at a number of sites both in Coonawarra and the Clare Valley. In Coonawarra, soil depth variation has been shown to be the principal cause for yield variation at one site (Bramley *et al*. 2000), whilst at the Clare Valley site, soil salinity is thought to be the underlying cause for poor productivity (Bramley *et al*. 2001).

The use of aerial photography in company vineyards at Padthaway has provided management with confidence that the variation in yield using PV technology is indeed real due to the apparent resemblance of the two forms of information. Although useful, aerial photography does have its limitations compared with the more recent multispectral and hyperspectral imagery that is now available. The use of this more advanced technology is currently being investigated in company vineyards in Coonawarra and McLaren Vale in an effort to determine whether it can shorten the time required for the identification of management zones.

The potential benefits of spatial information

Following three years of yield mapping, we now see that there are a number of potential benefits associated with a detailed knowledge of vineyard performance. These include:

- Improved understanding of vineyard characteristics enabling targeted approaches to vineyard sampling (eg. maturity assessment), vineyard monitoring (eg. pest and diseases, soil moisture status), and crop forecasting.
- Improved efficiency in the use of inputs such as irrigation water and possibly fertiliser and chemicals, thereby improving cost effectiveness, as well as providing an opportunity to demonstrate that best practice procedures have been followed (eg. QA audits).
- Improved targeting of cultural practices both before and during the growing season (eg. mulching, mounding, and crop and leaf removal).
- Improved ability to batch fruit to defined specifications and tailor harvesting to winery storage capacity.
- Improved ability to capture vineyard knowledge in a form that is translatable to succeeding management, rather than the traditional need for learned experience.

Conclusions and future directions

- Yield maps from established vineyards have demonstrated that precision viticulture technology provides more detailed information on vineyard performance than is currently available. This has a number of practical applications both in the field and in the winery.
- The temporal consistency in spatial variation allows management zones to be identified. More targeted management demonstrations are now needed to fully evaluate application of the technology.
- The magnitude and ultimate cost associated with block variability is now better understood. This information provides incentives to devise strategies that will help optimise vineyard performance.
- The ability to overlay data sets in GIS (eg. yield and quality information, soil characteristics, aerial photographs and digital images) is providing significant opportunity for a more informed understanding of vineyard performance.
- Instrument calibration, ground truthing and correct data interpretation is essential since there needs to be absolute confidence in the technology. Data interpretation must be conducted in close liaison with all interested parties to ensure that apparent differences are quantifiable.
- Yield mapping is not necessarily expensive or confined to large wine companies - contract harvest operators should be able to offer the information.
- Manufacturers need to continue with product improvement and develop sensors that are more 'quality' based.

In summary, there is a need to focus on the causes of variability together with the development of strategies to improve vineyard performance. These are the key steps that are required to confirm whether precision viticulture is a tool that will enable optimisation of vineyard performance both economically and environmentally.

Acknowledgments

The support of the CRCV for project work in Coonawarra is gratefully acknowledged.

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DGPS Yield Monitoring to Assist in Managing Vineyard Variability

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General Information

- Simeon Wines has been involved in Yield Monitoring since the 1999 season at its Coldridge Vineyard located in Loxton in the Riverland, South Australia.
- Coldridge Vineyard is approximately 470 ha in size and is planted with premium winegrape varieties including Chardonnay, Semillon, Shiraz, Cabernet Sauvignon, Merlot and Petit Verdot.

Aims

- The major aim of this project is to analyse the amount and the extent of yield variation within and between vineyard blocks and to examine the reasons for this variation.
- After a basis of three year's worth of data, we hope to target those blocks (or parts of blocks) with high amounts of variation and be able to manipulate vineyard management practices to reduce such variation.
- By better understanding the factors that affect vineyard variability and its effect on grape quality, it will be an important tool in the future to assist in producing better quality winegrapes.

Materials & Methods

- Both of our machine harvesters have a yield monitoring system attached to them which consists of a Differential Global Positioning System (DGPS) antenna and receiver, a Profile Yield Sensor, belt speed sensor and a mobile field computer/datalogger.
- The DGPS measures the position of the harvester every few seconds (approximately every 3 metres) and the ground speed of the harvester.
- The Profile Yield Sensor is mounted above the harvester conveyor belt and consists of five sensors that effectively measure the height of fruit above the conveyor belt.
- The volume of fruit can be calculated due to the height of fruit on the conveyor belt and the speed of the conveyor belt. This can then be converted to mass flow assuming a constant density of fruit over the conveyor belt.
- The positional data and yield data are stored in the mobile field computer and can be transferred to a desktop computer for interpretation and analysis on a Geographical Information System (GIS).
- After much research into the use of a GIS, we came to the conclusion that the ESRI products ArcView 3.2 and the Spatial Analyst extension would best suit our requirements.
- Raw yield data sets are sorted in Microsoft Excel, then initially viewed and edited in ArcView prior to interpolation.
- The raw yield data is interpolated using block Kriging, which is the most appropriate method to interpolate data sets that show a correlation between the distance and direction between the sample points and the surface they represent.

- The interpolated yield data is then imported into ArcView and displayed as a grid theme with an appropriate legend that depicts the range of yields attained from that block.
- For the 1999-2000 season, ArcView initially acted as a tool to display, interpret, manipulate and evaluate our yield monitoring data sets. After the 2000 harvest, we wanted to expand our GIS to include vineyard features and points of interest.
- By using ArcPad and a portable DGPS unit in the field, we were able to capture specific points, lines and areas of interest. Such data includes property boundaries, vineyard block boundaries, buildings and sheds, natural vegetation areas, soil moisture logger and probe sites, weather stations, truck loading bays and main roads and tracks. With the addition of ArcPad, we are able to directly input these other field data sets into ArcView.
- ArcView also gave us the ability to display AutoCAD files from our existing soil survey. Such data sets included contours, soil pit locations and an array of soil identifiers including soil pH, depth of topsoil, readily available water content (RAW) and predicted rootzone depth.
- In effect, we now have a complete account of all features in and surrounding the vineyard in one database. There is a base geo-referenced aerial photo, with additional layers including the property boundary, all vineyard block boundaries, contours, interpolated yield monitor data and a range of interpolated soil identifiers.

Results

- By evaluating yield maps over many season's, trends in yield variation can be attained across blocks and between blocks. These trends can then be examined and reasons for the variation can be established. Contour and topographical maps and a range of interpolated soil identifier data sets can be overlayed and similarities and/or dissimilarities can be seen between these data sets and the yield data.
- If correlations can be seen, appropriate vineyard management practices can be changed to account for this variability and hopefully have a direct affect on the subsequent season's harvest (i.e. decrease yield variation).
- The following example is of a 3-year-old Shiraz block (block code – N5SHI). Irrigation type is undervine micro-sprinkler. Two seasons worth of yield data has been collected from this block (2000 – first harvest, and 2001 harvests). It should be noted that this particular Shiraz block is situated on a sandhill running east-west. The central eastern section of the block is situated directly on the peak of the sandhill, whilst the topography falls away to the west, north and south ends of the block.
- Yields attained from N5SHI were significantly up in 2001 (mean yield: 29t/ha; yield range: 19t/ha to 50t/ha) compared to 2000 (mean yield 18t/ha; yield range: 7t/ha to 37t/ha). Whilst the extent of the yield variation remained constant for both 2000 and 2001 (i.e. approximately 30t/ha yield range from the mean), the distribution of the yield across the block was more variable in 2000 compared to 2001 (Figure 1 and 2).
- The 2000-harvest yield map (Figure 1) shows a distinct lighter yielding patch along the central eastern portion of the block (east-west in direction) and in the north-western corner of the block. There is also a heavier yielding patch towards the southern end of the block, in particularly the south-west portion. One can instantly see that the first harvest from this block was extremely variable as one may expect.
- The 2001-harvest yield map (Figure 2) still shows a lighter yielding patch along the central eastern portion of the block, although not to the same extent as in 2000. There is definitely an increase in area of the lighter yielding portion of the block in the north-

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Coldridge Vineyard - Block N5 Shiraz (4.62 ha)

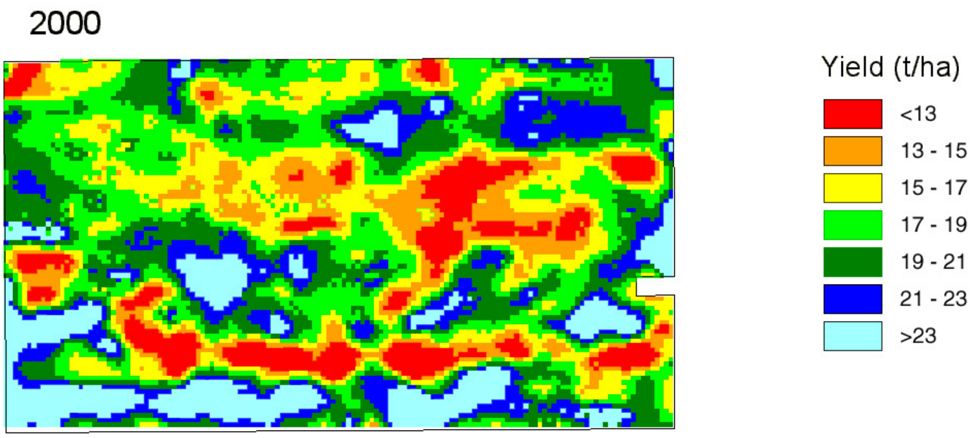


Figure 1: 2000 Yield Map indicating a variable yield distribution across the block

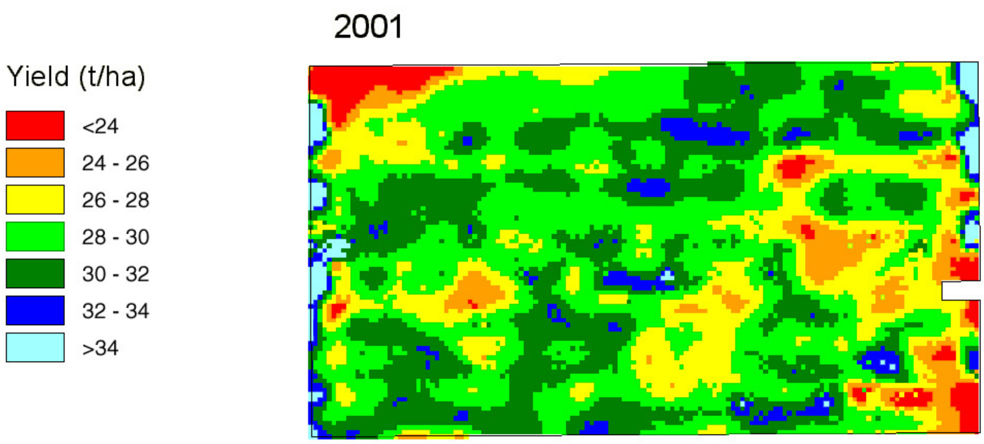
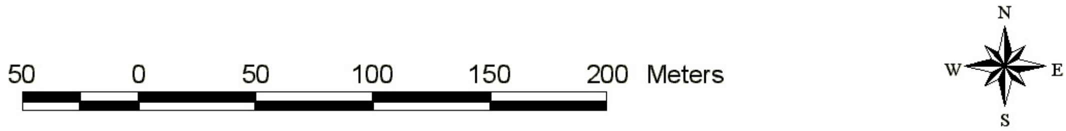


Figure 2: 2001 Yield Map indicating less variable yield distribution across the block than in 2000.



western corner. In addition to this, a lower yielding patch is evident in the south-eastern corner of the block also.

- To compare yield data between different seasons, normalised yield maps must be created. By normalising the yield data sets, the data is then expressed with a mean value of zero and a degree of standard deviations from the mean (which indicates the distribution of data from a common mean). It is important to remember that for a normally distributed data set, 95% of the values should lie within +/- 2 standard deviations from the mean. From Figure 3, it can be seen that both in 2000 and 2001 the yield attained across the majority of the block can be classed as normally distributed.
- When comparing the two years (i.e. subtracting 2000 normalised yield map from 2001 normalised yield map), areas of yield increment and decrement from the 2000 to the 2001 season can be attained. Figure 4 indicates that the performance across the majority of the block was relatively consistent from 2000 to 2001.
- Addition of the 2000 and 2001 normalised yield data can identify areas of relative performance within the block. This in effect will identify areas within the block that are of consistently good or poor performance from 2000 to 2001. Figure 5 indicates that the north-western corner of the block has performed consistently poor, whilst the portions of the block highlighted in blue have performed consistently well in 2000 and 2001.

Conclusions

- The assessment of yield maps and their correlation to topographical, contour and soil identifier data sets serve as an additional management tool to identify problem areas in the vineyard. They can assist in assessing the effectiveness of vineyard management programs such as the pest and disease spray program, nutrition/fertiliser program, irrigation scheduling and soil and canopy management.
- It is still very early days in the development of this technology for use in viticulture. Our early findings must be taken in context, with a minimum of three years data a sufficient basis to assess reasons for yield variance in vineyards.
- Precision Viticulture can and will act as an important additional management tool to Vineyard Managers to fine-tune their management. They are able to use Precision Viticulture to assess the efficiency of many of the vineyard management programs they implement, use it as a tool to account for and potentially reduce yield variability and assist in the production of better quality and more cost-efficient winegrapes.

Acknowledgments

I would firstly like to thank the Simeon Wines Coldridge Vineyard Management team for their input and assistance during this project. I would also like to thank Dr. Rob Bramley (CSIRO Land and Water) for his technical advice and training in producing yield maps. Additional technical support, training and expertise was greatly appreciated from Karen Hansen (ESRI Australia – Adelaide) in using the ESRI GIS products ArcView and ArcPad, Rob Ferguson (Ultimate Positioning – Benchmark) in the use of GPS equipment and DeVon Labrum (Harvestmaster) in the use of the yield mapping hardware.

SIMEON Wines

Coldridge Vineyard - Block N5 Shiraz (4.62 ha)

2000 2001

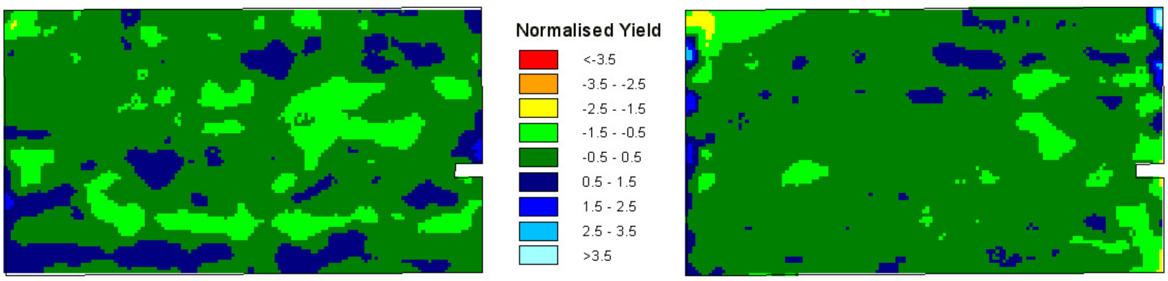


Figure 3: A comparison in vineyard yield between 2000 and 2001 in which the yield data has been normalised to a mean of zero and a standard deviation of one.

2001-2000

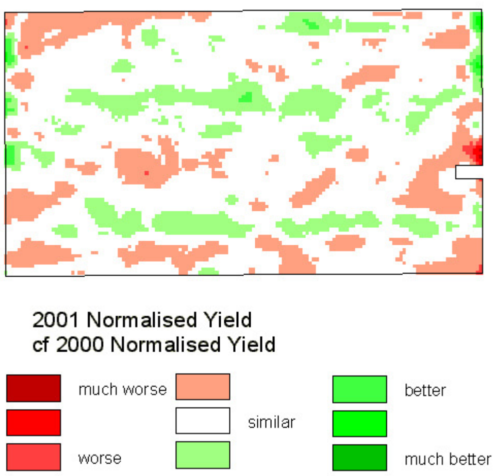


Figure 4: The difference between the normalised yield from 2001 compared to 2000 indicates areas of improved or declining yield from 2000 to 2001.

2000+2001

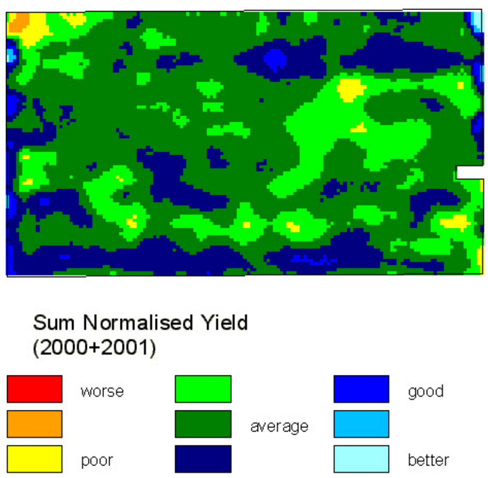
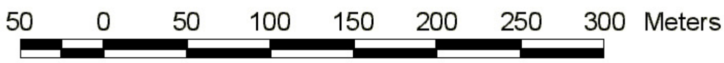
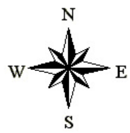


Figure 5: The sum of the normalised yield in 2000 and 2001 identifies areas of relative performance in the block.





Remote sensing - a tool for vineyard managers ?

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How does it work ?

Optical remote sensing works on the fact that all objects on the earth's surface reflect sunlight. The colour of plants, for example, is related to the fact that they tend to absorb all the incident blue and red sunlight (absorbed by chlorophyll) and reflect and transmit the green and near-infrared (often called far-red) sunlight (Figure 1).

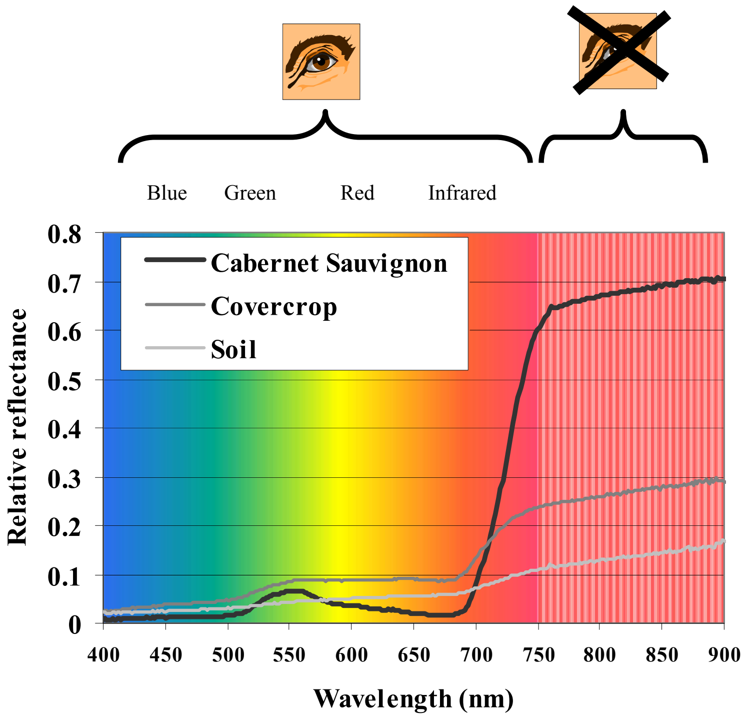

Figure 1 Spectral reflectance profiles for Cabernet Sauvignon, covercrop (chick-peas) and exposed red-brown soil. (Percentage of reflected sunlight = 100 x Relative reflectance). Data acquired from Charles Sturt University's vineyard in Wagga Wagga, NSW.

We humans only see the green light reflected from plants (which is why they appear green to us). We do not see any of the vast amounts of near-infrared sunlight reflected from plants. Ironically it is this near-infrared light that tells us most about plant vigour as a plant's near infrared reflectance is controlled by the structure/shape of the leaf cells and the water contained therein. In fact, the combination of near-infrared and red reflectance is a powerful tool for estimating plant vigour or leaf density (often inter-related) when viewing plants from overhead, say from a small plane or by a satellite.

What does vine canopy vigour/density tell us from overhead ?

Viticultural research conducted over the last ten years has demonstrated that the density and vigour of grapevines have a profound affect on the yield and quality of grapes due to a combination of microclimate and sunlight-illumination of fruit/buds. In cool-climate red varieties, for example, increased canopy vigour and density is often linked to higher yields and lower phenolic and colour concentrations. An overhead image of grapevines, in particular when using a sensor that is capable of detecting the near-infrared as well as red reflected sunlight, is capable of differentiating between areas of high or low vine vigour/density that are also presented to incoming sunlight. After all, an overhead plane or satellite is looking at the same structural differences that the sun is. More vigorous/dense vines will tend to have a higher near-infrared reflectance (more leaves containing more water and "stronger" cell structure) and lower red reflectance (due to stronger chlorophyll absorption). It is therefore no surprise that the latest research has shown that, for red varieties in regions where canopy management is important for yield and quality, colour-infrared imaging of the vine canopy can be a useful means of mapping differences in yield, colour and phenolics (Figures 2 and 3).

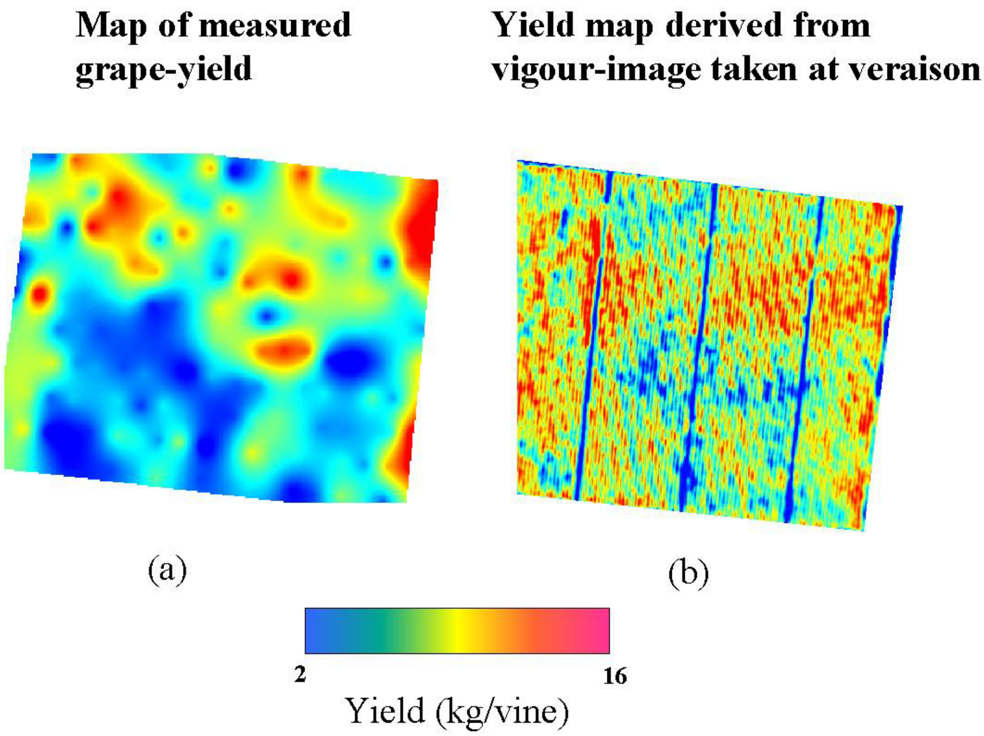

Figure 2 Yield maps generated from (a) approximately 200 measurements of vine yield, and (b) a vine-vigour image acquired at veraison 2001. This vineyard block is approximately 7 ha of Cabernet Sauvignon in the Coonawarra Region.

It is a matter of resolution and timing !

Spatial resolution of an image, or the size of the smallest object detectable on the ground, is important. However, research has demonstrated that the smallest resolution (ie centimetres), which incidentally is hardest to acquire, is not necessarily the best. In fact, image resolution only needs to be comparable to the inter-row spacing between vines and this may be 2-5 metres. This coarse-resolution helps to remove much of the fine detail of a vineyard which may actually confuse someone trying to interpret their imagery (Figure 4).

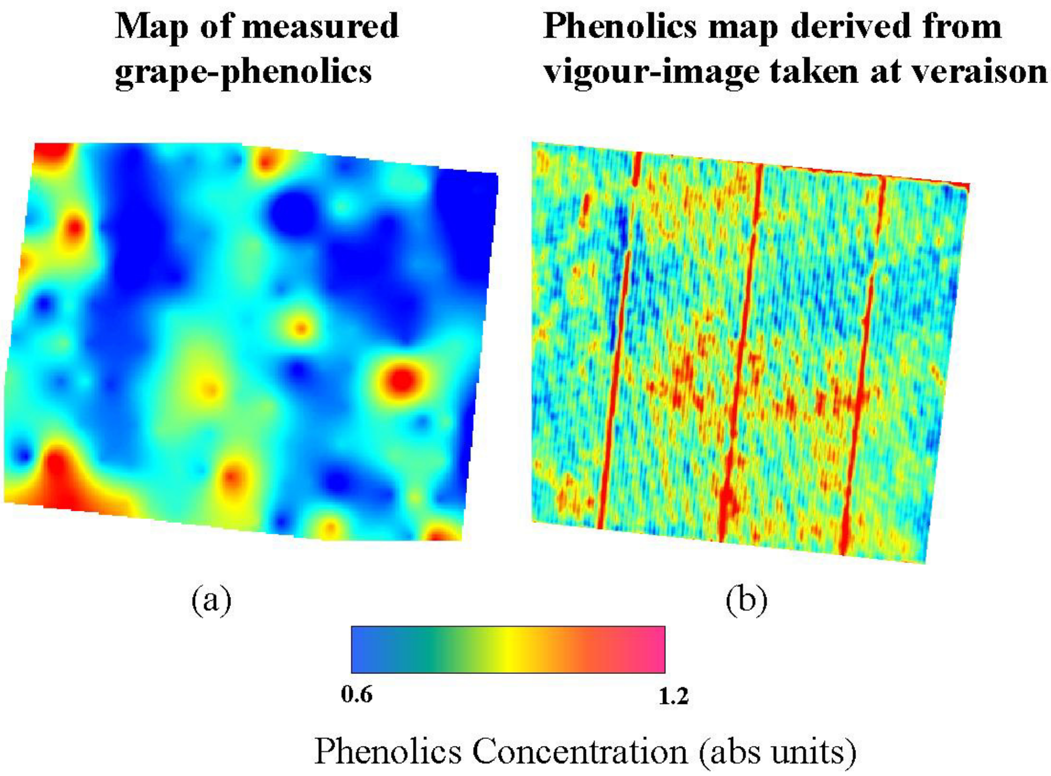

Figure 3 Maps of grape-phenolics generated from (a) approximately 200 measurements made on individual grape samples, and (b) a vine-vigour image acquired at veraison 2001. This vineyard block is approximately 7 ha of Cabernet Sauvignon in the Coonawarra Region.

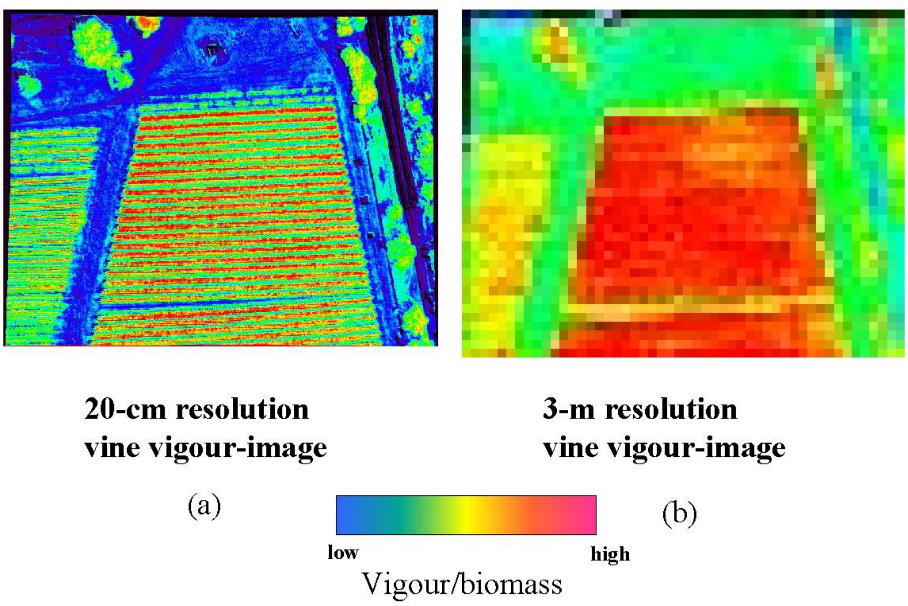

Figure 4 Vine vigour-images of a 1 ha Cabernet Sauvignon block in the Riverina taken at (a) 20-cm resolution, and (b) 3-m resolution. While greater spatial detail (individual rows, trees and fence posts, are visible in (a), it is much more difficult to "see" the patch of high-vigour vines in the top right-hand corner of the block that is clearly evident in (b).

It is important, if deciding to proceed with remote sensing of your vineyard, to select the best time for imaging in order to maximise your chances of observing something of value. Our research has indicated that the correlation between remotely-sensed vigour images of vines starts off very small at bud-burst, increases to a maximum at veraison and, depending on the type of irrigation strategy employed, drops off again to harvest or will remain strong (Figure 5).

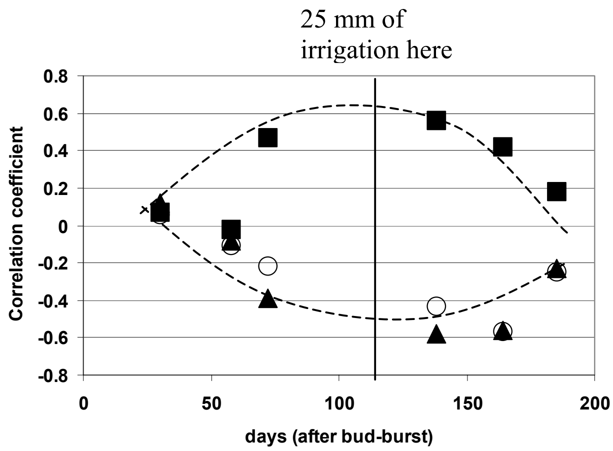

Figure 5 Measured correlations between vigour-images and on-ground parameters (yield, colour & phenolics) for a block of Cabernet Sauvignon in the Coonawarra Region with only a single irrigation event (approximately 120 days post bud-burst). Note the decrease in correlation occurring with the onset of vine stress after irrigation.

As Figure 5 suggests for this particular vineyard, and indeed similar red variety vineyards in the Riverina, canopy vigour-images are positively correlated with yield and negatively correlated with colour and phenolics.

What about spectral resolution – multispectral versus hyperspectral ?

The extraction of plant biophysical data from remotely-sensed imagery relies on the ability of the sensor to detect changes in the on-ground plant spectral signature. The ability of a sensor to distinguish small differences in the spectral or colour characteristics of vines is dictated by its spectral resolution. Figure 6(a) and (b) shows synthesised reflectance profiles of grapevines (Similar to Figure 1). Superimposed on these profiles are a set of wavebands corresponding to the sensitivity of a hypothetical instrument and the reflectance profile that would be inferred from the response of that instrument to the ground target.

In Figure 6, the hypothetical instrument measures the spectral signature of the target in four wavebands. While an accurate measure of the target reflectance would be extracted at the four specified wavebands, the shape of the reflectance profile of the vegetated target is only poorly described. Using thirteen closely-spaced wavebands (Figure 6(b)), the reflectance of the target is recorded for each waveband and the shape of the entire spectral profile is more accurately described. However, our research has suggested that identification of vine vigour levels only required wavebands which provide good discrimination between vines and underlying covercrop, and to date we have found near-infrared, red and green wavebands to be adequate for this purpose. In short, multispectral imaging is sufficient.

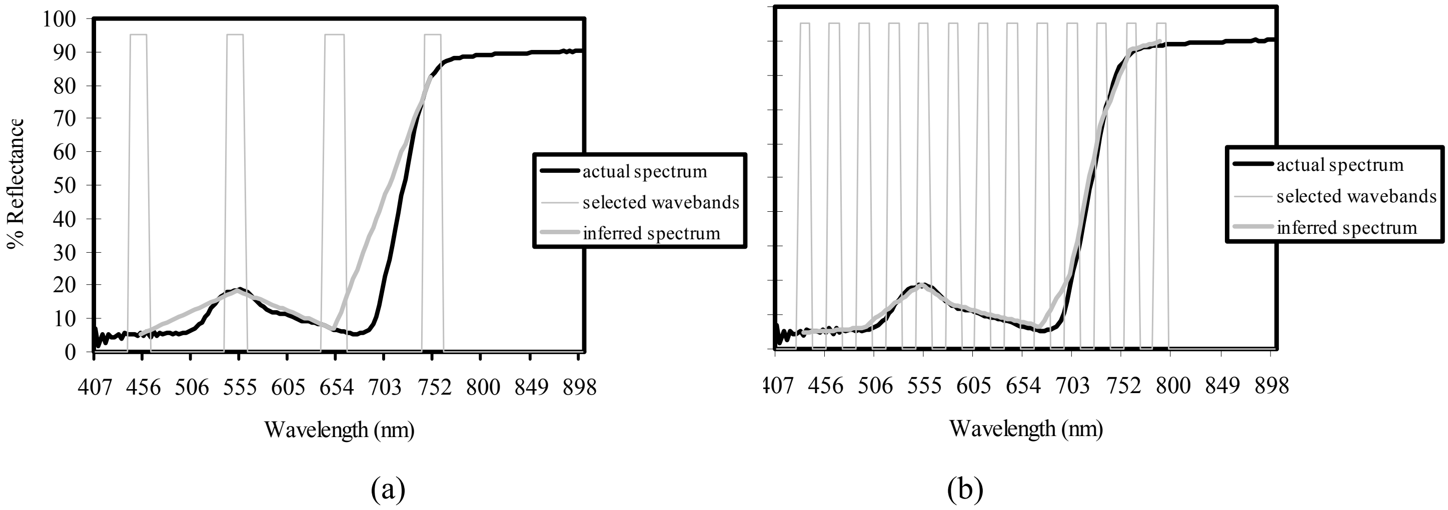

Figure 6 Comparison between an actual vegetation reflectance profile and an inferred reflectance profile using (a) 4 wavebands (multispectral), and (b) 13 wavebands (hyperspectral). (Data of Lamb, 2000).

The above notwithstanding, many more wavebands are available with hyperspectral compared to multispectral imaging systems, although with the both systems, the user can specify which bands are required. Where hyperspectral imaging, with its additional wavebands, has proven useful, is in difficult tasks such as identifying different grape varieties from the air.

Factors when considering remote sensing

1. The fundamental assumption in applying remote sensing to vineyards is that canopy characteristics will influence yield and quality. Under growing conditions where canopy management is an important determination of yield and quality, in particular for red varieties, remote sensing may be a useful method of identifying regions in a vineyard of significantly different levels of yield or colour/phenolics.
2. What information are you after ? If you simply want canopy vigour, which at this stage has been successfully linked to yield and quality in red varieties, then you most likely will not require hyperspectral imagery. Bare in mind that with hyperspectral imagery you will still get the wavebands necessary for vigour mapping, but you may be paying for the many other wavebands that you may not need.
3. Centimetre-resolution imagery is not necessary- rather a resolution comparable to the vine-row spacing will suffice to allow identification of different levels of vine vigour in a vineyard. This means a sensor can fly higher, and cover larger areas in single images - this keeps the flying time down, and the unit cost will drop if you can include other growers.
4. What is your pruning regime ? Images rely on the assumption that differences in vine vigour will appear as differences in canopy density and size. Images taken soon after pruning will be unlikely to give any indication of different vigour levels.
5. What is your irrigation regime ? Preliminary research indicates there is little value in imaging vines too early in development, certainly before flowering. However, you can leave imaging too late (as figure 5 suggests in the case of a single irrigation event) if you are planning to start stressing your vines soon after veraison.

Further reading

Current Australian and Overseas remote sensing research projects

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Acknowledgments

The data used in this workshop paper have been produced as part of Project 1.1.1 (Precision Viticulture) conducted by the CRC for Viticulture and supported by the Commonwealth Cooperative Research Centres Program.

EM38 Surveying in Vineyards -A Pragmatic Overview

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Introduction

The advent of Global Positioning Systems (GPS) has invigorated new interest in the use of the EM38 electromagnetic technology. Previously, the EM38 was generally used in a stop and go fashion, recording electromagnetic (EM) readings at strategic stations on a predetermined grid (See Fig 1). This mode of operation, although successful for its intended purpose, limited the instrument's capabilities due to the lack of spatial resolution. The recent GPS revolution has alleviated this problem, allowing the EM38's soil sensing qualities to be utilised in a manner that is suitably applied to precision viticulture (PV). By matching the spatial qualities of the GPS to the capabilities of the EM38, rapid and intense EM38 soil conductivity surveys can be easily performed (See Fig 2).

Figure 1.

Figure 2.

Precision viticulture application

EM38 surveys are generally used as the first step to PV when developing and redeveloping vineyards. A properly conducted EM38 survey delineates soil and salinity boundaries with a very high degree of spatial resolution. While the output from an EM survey clearly shows variability, the EM survey will need to be ground-truthed to determine specific soil characteristics. That is, areas of EM differences are targeted for soil surveying and by analysing the soil survey results and the spatial EM data, a map of soil variability can be created. Defining soil variability plays a significant role in implementing a management strategy for a vineyard. Once a vineyard is established periodical EM38 surveys are used to monitor problem areas initially identified in the principal EM survey.

This presentation will provide a pragmatic overview on EM38 surveying, with the following issues being discussed.

- What is an EM38 ?
- What does it look like ?
- How does it work ?
- What is required to perform an EM38 survey ?
- How is an EM38 survey conducted ?
- How is a vineyard mapped out ?
- What does an EM38 survey give you ?
- What are the benefits and limitations ?

Digital terroirs - their part in precision viticulture and environmental management

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Terroir is a unique term specific to viticulture and œnology. It is used to classify vineyards according to their social and historical background as well as their physical environment. For this paper the term "digital terroirs" differs from terroir in the fact that "digital terroirs" are classified solely on the physical environment. Digital terroirs are simply management zones - areas that require similar or identical management to maximise productivity and sustainability. Digital terroirs do not need to be contiguous – thus, a particular digital terroir may contain numerous discrete areas within a catchment. This paper seeks to illustrate the potential use of "digital terroirs" at two different scales, regional and sub-vineyard.

The Regional Case

Identifying a vineyard location
Obviously if a grower is looking for a new vineyard site he/she wants to pick a block that has high potential and low risk (both production and environmental). Therefore, there exists a potential to develop catchment or regional based "terroir" maps to identify areas with similar terroir and classify them according to production potential. As part of the new irrigation scheme located in the Lower Hunter Valley, the University of Sydney has undertaken the establishment and collection of baseline data for a local GIS. This data includes satellite imagery, existing Department of Land and Water Conservation (DLWC) soil data, a commissioned EM34 survey, cadastre data and a digital elevation model. As a sideline to this work the Australian Centre for Precision Agriculture is looking at using this data to develop a model to predict "digital terroir".

The principle aim of the GIS is to establish an environmental monitoring system to measure the impact of the irrigation system on soil and water quality in the catchment, especially the threat of salinity, sodicity and soil acidification. The existing environmental data on the Hunter Wine Country Private Irrigation District (PID) has been used to create a new soil and predicted terroir map for the PID. Further classification of the soil map using k-means cluster analysis with other landform and soil properties has produced a digital terroir map. The terroir map and prediction model when ground-truthed and refined will hopefully be a useful tool in the selection of future vineyards, from both an environmental risk and grape quality point of view. The soil and digital terroir maps were generated from a "top-down" approach by the disaggregation and recombination of broadscale data (Figure 1). In this case a 25m^2 digital elevation model and the DLWC's landscape units. The DLWC data has no confidence measure associated with it to gauge the accuracy of the data and ground-truthing is therefore required to verify the model. This ground-truthing will be done from a "bottom-up" approach. The original soil and terroir maps will be used to identify small areas which represent the range of soil and terroir in the catchment. Intensive surveying will be done at these sites and the data aggregated to determine the actual soil and terroirs present and their spatial orientation (the means of this survey is discussed below). The intensive nature of these small surveys results in a high confidence in the final predicted terroirs. The "bottom-up" terroirs will be used to refine the original "top-down" model. A schematic of the model is given in Figure 2.

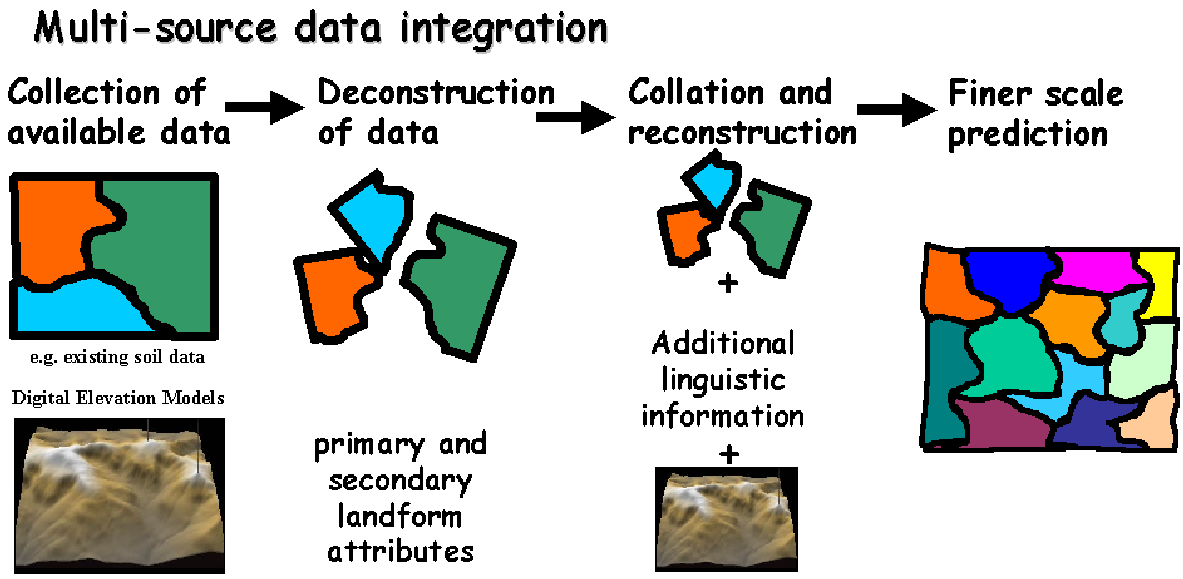

Figure 1 Schematic example of the deconstruction and reconstruction of broadscale data sources to produce a finer scale prediction.

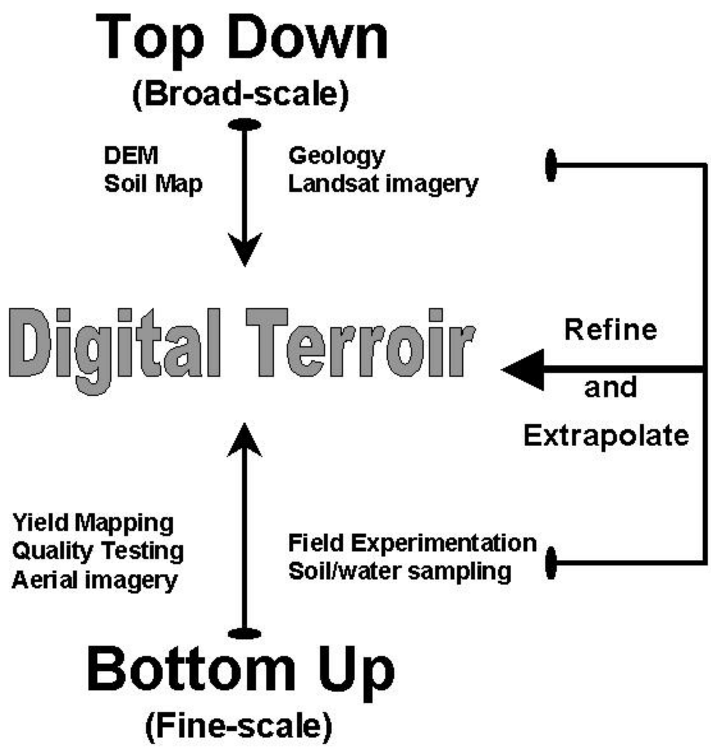

Figure 2 A model to predict local terroir for environmental management given a variety of different scaled data.

If a satisfactory prediction model can be developed, the "terroir" maps will have several potential uses. Perhaps the most economic use lies in the identification of premium winegrape country. If existing premium winegrape country is identified and classed, then areas of undeveloped country can also be classed to identify areas with premium winegrape production potential. If this is the case then the terroir map becomes very valuable. Alternatively, and possibly a larger issue, is the identification of environmental risk. If the environmental risk of viticultural production can be quantified, then vineyards can adapt their management strategies or utilise the information as a marketing tool. For example vineyards in a low environmental risk situation may be able to market their vineyard as environmentally sustainable in much the same way that organic food is marketed. It is also foreseeable that government legislation will be introduced to ensure environmental auditing of production processes. Digital terroirs may be one way of approaching this problem. Undeveloped high-risk areas may have more stringent development guidelines, especially in regards irrigation, or in severe cases no allowance for development. Finally, and the current aim of the development of the GIS, is the use of the derived information to strategically develop an environmental monitoring system by identifying environmental critical control points (ECCP's) in the catchment. These EECP's will be placed in sensitive locations where environmental problems may first appear. This will hopefully give an early warning of any deterioration in the catchment environment. The locations of ECCP's for different risks will vary according to the risk and the local land use. For more information on the "top-down bottom-up" model and the terroir prediction model see Taylor and McBratney (2001).

The Fine-scale Case

Sub-vineyard Digital Terroir - using ancillary data to plan your vineyard.
Once a vineyard site has been chosen, then the design of the vineyard becomes very important. The use of information technologies can greatly help in this. Given the current soil surveying protocols, the most important point to stress here is the current movement away from grid sampling across the world to a randomized, site-directed, sampling scheme based on existing production information. This leaves the ICMS/Wetherby system lagging behind. However, this is not to say that the current system is totally defunct or useless. The system has provided the industry with a strong starting point for the last decade and it has been a big step forward in farm design compared to other industries. Now, however, viticulture needs to respond again to changing technology and incorporate these new technologies into the ICMS/Wetherby system.

Many new vineyards are currently having soil electrical conductivity surveys (usually using electromagnetic instruments) prior to development. Other data sets in the form of elevation models, aerial imagery and photography also exist. There is, however, little appreciation of the potential of these technologies and little understanding of how best to use the information. This is not to say that these raw surveys are not valuable. Rather, using geostatistical techniques, spectral analysis and new methods such as pedotransfer functions that allow the prediction of soil properties as a continuum, the quality and value of this data can be greatly enhanced. We are concerned about the potential for the misapplication of these technologies. There have already been set backs in the adoption of these information technologies in other industries due to a lack of decision support system. Even though these technologies exist it is always important to dig holes. The combined sum of all proximal and remote sensing cannot tell you exactly what you will find until you turn some sods over. The point we are trying to make is that where the holes are dug is crucial to value of the information derived from the soil survey.

The most common method of deriving potential digital terroirs is through the use of cluster analysis (Hartigan and Wong, 1979). Clustering may or may not be weighted depending on the relative value of different data-sets. The cluster algorithm may take a wide range of different data sources e.g. aerial imagery, yield and crop information, soil survey (both pit and EM) provided that the data is interpolated onto a common raster (grid). Unless the data are on the same raster, analysis cannot be performed across data sets. Cluster analysis aims to divide the data sets into groups (clusters) such that the mean of each property in each cluster is maximally different to the other clusters. The optimum number of clusters is determined when the addition of another cluster does not produce a cluster that is statistically different from another cluster. The determination of statistical difference for this process has been outlined by Cupitt and Whelan (2001)

Figure 3 illustrates the clustering method. Two data sets - Readily available water (RAW) and elevation have been chosen as illustrative data sets. RAW has been chosen as an indicator of likely irrigation needs, whilst elevation gives an indicator of soil type (soil usually follows catenary sequences down slopes). RAW values derived from a 75m grid survey have been interpolated by kriging onto a 5m grid using Vesper (Minasny et al, 1999). The elevation survey was interpolated onto the same grid using the topogrid function of ARC/INFO®. Cluster analysis was performed in JMP®, in this case for four clusters. For each cluster the mean value of the original data within the cluster is given in the accompanying table. From the table, zones 1 and 4 have a similar RAW value but very different location in the landscape. By clustering only with RAW values these two zones are considered equal. In reality they are not with zone 1 characterised by heavy clays that is limiting RAW through root penetration and zone 2 lighter textured soil limited mainly by the soil moisture holding capacity. Two contrasting soils such as this will require different management strategies.

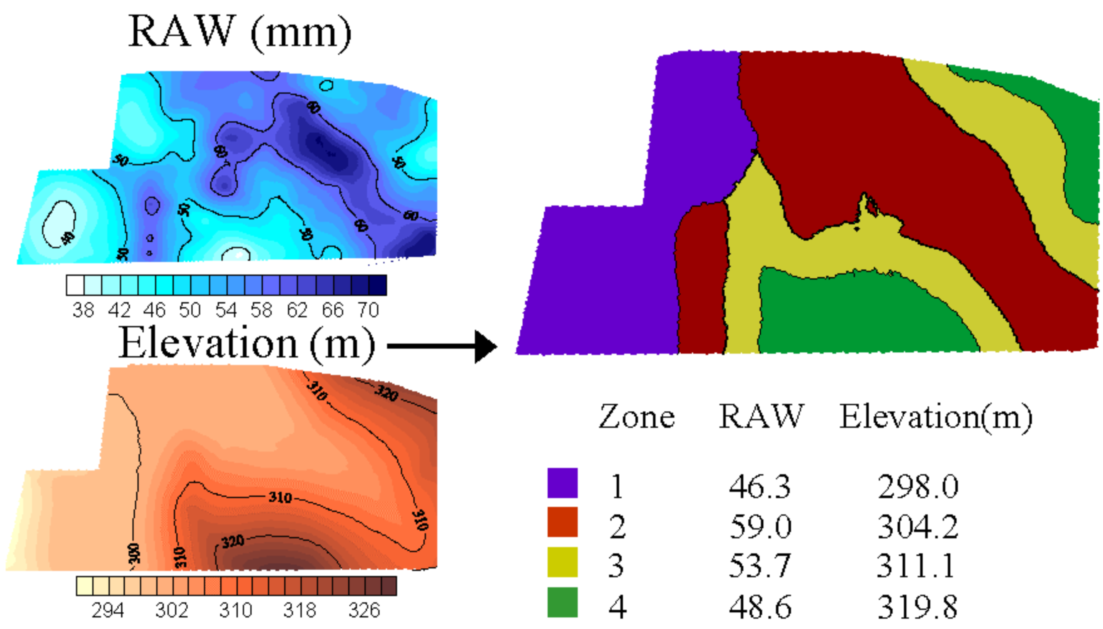

Figure 3 Derivation of 4 potential digital terroirs using RAW and elevation data for a 100 ha vineyard.

The above example highlights the advantage of larger numbers of data sets in producing accurate cluster analysis. However, some level of confidence in the data should be had before it is used. It is also important to remember that clusters require some strong spatial structure to be manageable. Thus, there is a trade-off to be made between the shape and size of the clusters and the difference between cluster means.

Conclusion

Viticulture is an industry that intensively captures and records information on the production system. With new technologies and methodologies now available, viticulturists can derive even more from these data sets. The ability to model and observe production variability across a vineyard and a catchment in the form of digital terroirs will allow growers to be more productively efficient and environmental conscious and accountable.

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Precision Viticulture – Research supporting the development of optimal resource management for grape and wine production

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Precision Agriculture (PA) is an all-encompassing term given to a suite of technologies which promote improved management of agricultural production through recognition that the potential productivity of agricultural land and the input-output relationships driving the production system can vary (Figure 1), often over distances of only a few m. The key technologies involved are yield monitors, the global positioning system (GPS) and geographical information systems. These enable farmers to see within-paddock variation, and to identify and implement management strategies in which the inputs to the production system are closely matched to the desired and/or expected outputs. 'Inputs' are often taken to infer fertilizers, but they also include irrigation water, pesticides and significantly, the timing of operations such as harvesting.

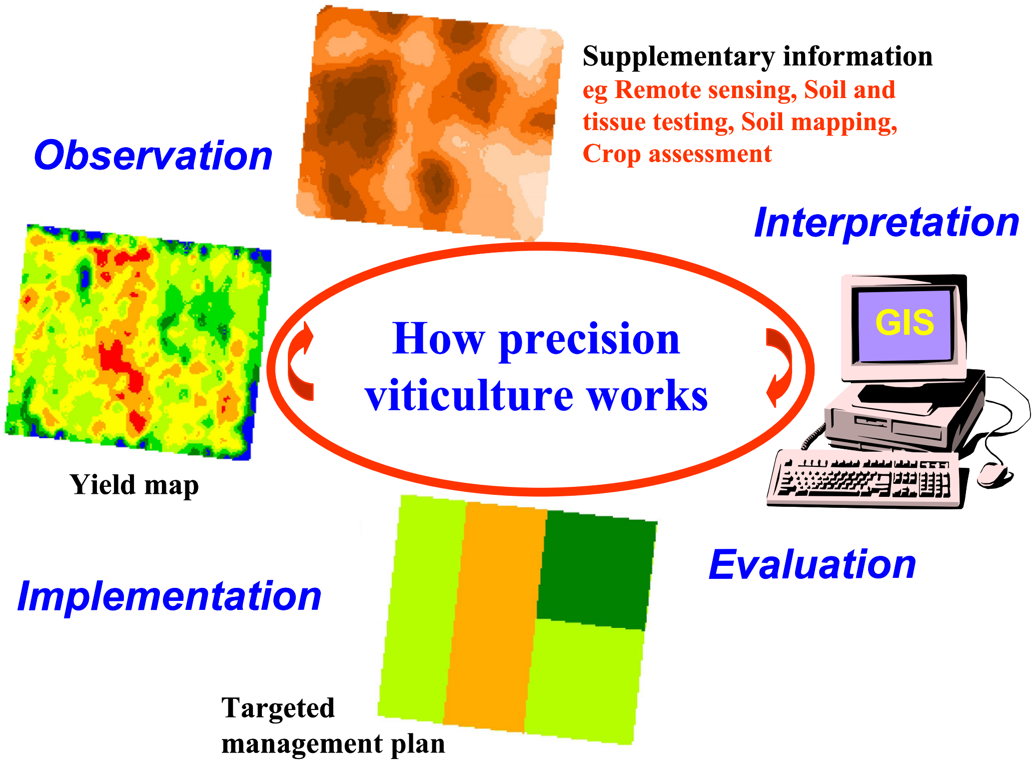

Figure 1 The process of precision viticulture. The process begins with yield (and/or quality) mapping and the acquisition of complementary information (eg a soil map) followed by interpretation and evaluation of the information leading to implementation of targeted management. This is followed by further observation (was the targeted strategy useful ?) etc… The process of data acquisition and use is therefore continuous, and improvements to management, incremental. Over time, data collected during the observation stage take on a predictive value.

The benefits of being able to implement such an approach to viticultural production include:

- Efficient use of inputs to the production system such as sprays, fertilizer and water, leading to improved cost effectiveness, enhanced sustainability and an ability to demonstrate that best practice has been followed or QA standards met.
- The ability to separate the crop at harvest and to harvest according to quality specification, leading to improved profitability through an ability to ensure that the quality of premium wine is not reduced through the inclusion of sub-optimal fruit.
- The ability to tailor harvesting according to market demand and expectations, or winery storage capacity.
- Improved crop forecasting. For vintage 2000 in Australia, the industry prepared for a crush of approximately 150,000 t more than was actually achieved. If it is assumed that 100,000 t of this can be ascribed to poor forecasting, and that the costs associated with processing fruit and storing bulk wine are around \$200 t^{-1}, the cost of poor crop forecasting industry-wide can be seen to be of the order of \$20M.
- Enhanced precision of vineyard sampling generally, such as might be required for decision making regarding the scheduling of harvest, or for mid-season operations relating to yield or quality control, such as crop thinning or leaf plucking.
- An improved basis for paying growers – based on both yield and quality. Growers who are able to demonstrate conformation to desired procedures or quality assurance schemes such as the ISO standards may also have a basis for attracting price premiums.

For these benefits to be realised, the industry will need answers to a number of key questions including:

- Is the pattern of variation constant in time ?
- Does spatial variation in fruit quality follow the same pattern as spatial variation in yield ?
- Can we identify the drivers of this variation and if so, are they manageable ?
- What are the implications for vineyard sampling (and viticultural research) ?

Precision Viticulture research in the CRCV seeks to address these questions. Thus far, the work has focussed on a 7.3 ha block of Cabernet Sauvignon in the Coonawarra region of South Australia and a 4.5 ha block of Ruby Cabernet in the Sunraysia region of NW Victoria. In the case of the Coonawarra site, harvesting over 3 years (1999-2001) was carried out with a mechanical grape harvester fitted with a yield monitor and differentially corrected GPS (dGPS). The pattern of yield variation was found to be sufficiently consistent over the 3 years to warrant production of a composite yield map (Figure 2). This information was interpreted with assistance of supplementary information (EM38 soil survey, remotely sensed multispectral imagery) leading to the development of a targeted harvesting strategy in which fruit from different parts of the block were separated into different bins for separate fermentation (Figure 2). Analysis of the wines produced from different parts of the block demonstrated the merits of this approach (Table 1), which was supported by a sensory evaluation of the wines conducted by Southcorp winemakers.

A precursor to all of this work has been the development of a protocol for yield map production (Bramley and Williams, 2001). Further research seeks to identify which layers of information describing various aspects of vineyard variability and performance are required for more robust delineation of management zones (Figure 3). Such layers could usefully

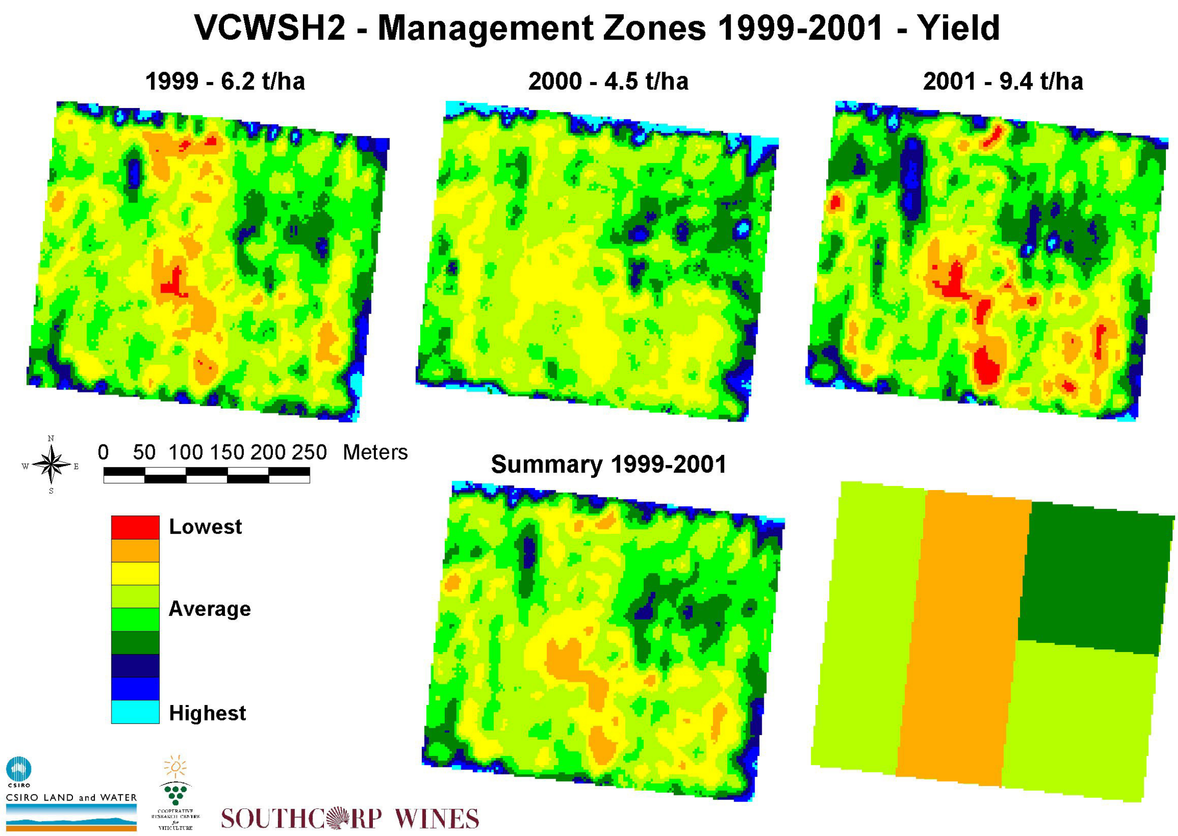

Figure 2 Development of a targeted harvesting strategy for a 7.3 ha block under Cabernet Sauvignon in Coonawarra. In spite of substantial differences in the mean yields obtained during the 3 years of this work, the pattern of spatial variation in yield was sufficiently similar for production of a composite yield map to be justified, followed by identification of a targeted harvesting strategy.

Table 1 Spectral analysis of wines produced from the zones identified in Figure 2 (Vintage 2000)[1]

	Yield Class[2]		
	High	Low	Medium
Total Anthocyanins	931 b	980 a	868 c
Total Phenolics	60 b	67 a	59 b
Colour density (-SO_2)	0.24 b	0.62 a	0.44 b
Colour density (SO_2)	0.49 b	0.99 a	0.43 b

[1]Values labelled with different letters are significantly different ($p<0.05$). Note that the sensory evaluation resulted in the low and medium yielding areas gaining the same score with the higher yielding zone producing a wine of "slightly lower" score based on winemaker preferences.
[2]The high and low yield classes correspond to the areas identified in Figure 2 in the NE and central portions of the block, respectively, whilst the medium yield class is made up by the remainder of the block.

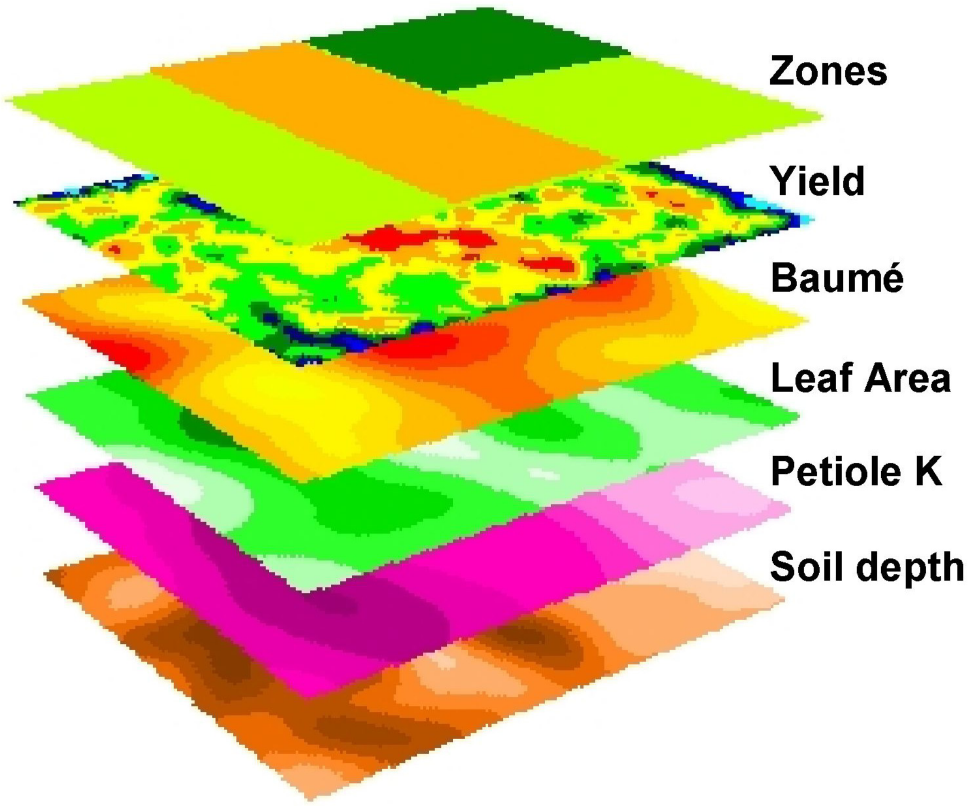

Figure 3 The development of vineyard management zones. This figure seeks to illustrate how different layers of information about variation in vineyard attributes might be combined as a means of identifying management zones based on a holistic consideration of the vineyard, rather than just yield as in Figures 1 and 2.

include information about the underlying soil and land resource, based on digital elevation models or soil survey using tools such as EM38 (Bramley *et al.*, 2001 – see poster at the end of this summary), and information about variation in vineyard attributes other than just yield (Figure 3). This information would promote better matching of vineyard management to the underlying land resource and desired production targets.

Acknowledgements

This work is jointly funded by CSIRO Land and Water, Southcorp Wines Pty Ltd and the Cooperative Research Centres Program under the aegis of the Viticulture CRC. I am most grateful to Dr Tony Proffitt (formerly of Southcorp Wines) for his valuable input to the work which included providing the data shown in Table 1, and to Susie Williams (CSIRO Land and Water / CRCV) for her excellent technical assistance.

Further reading / information

The following web pages, together with links identified on these pages, provide further information on precision viticulture research being conducted both in the CRCV, and by CSIRO Land and Water:

www.crcv.com.au/project1_1_1.html
www.clw.csiro.au/research/agriculture/southern/
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The following references may also be of interest:

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