Precision Viticulture: Cutting Edge Solutions for Vintage Problems

“How to move the curve on grape production and quality to maximise vintage returns”

A special report prepared by Total Viticulture Solutions
August 2014
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Introduction

As a vineyard owner, you want to manage your crop to achieve the highest possible yield of the best quality grapes. The objective is to achieve a higher grade and price at the winery, with minimum possible cost, hassle and stress. Likewise, if you are a viticulture consultant you want to always be ahead of the adoption curve on the latest science and technology-based methods and approaches to maximize grape production outcomes, and provide the best advice available to vineyard owners and managers.

From a winery perspective, having an improved understanding of factors affecting variability in grape production, and developing more sophisticated means of predicting grape quality, crop tonnage, and the timing of harvesting, are important in improving winery processing efficiencies and wine quality outcomes.

The major factors affecting the fundamental economics of grape growing and wine production, vineyard production and viability, and factors of grape quality and yield, range from global and national factors, to regional and local influences and vineyard specific factors. While some of these aspects are out of grape growers’ control, and apply to everyone in your region, others you are able to influence, manage, or control to varying extents.

Factors Influencing Grape Production Outcomes

- Global supply and demand
- Wine consumption trends and consumer tastes
- Government controls and regulation
- Industry structure, productive capacity
- Control that wineries exert over the industry (including grading, pricing and contract volumes)
- Terroir – topography / terrain / climate / weather / soil / water
- Availability of labour
- Available technology
- Financial resources
- Application of scientific knowledge and viticulture practices

The ability to understand, respond to, and exploit these factors determines how successfully you achieve optimal grape production outcomes. You can choose to either ignore, monitor, mitigate or proactively manage these factors.

Success Factors

Success comes from mitigating the risks applying to the factors over which you have little or no control, in part through long range planning, and maximizing your effectiveness in managing short term factors that are largely under your control.

In the past, traditional rule of thumb practices based on conventional wisdom and practice may have been the best available means for decision-making, and good enough in previous times when margins were much better, and the latitude for error greater. However, these practices can soon become outmoded and risky, as new advances in technology push back the boundaries of our understanding to give greater certainty in managing key viticultural variables.
Over the last decade significant advances in viticultural science and developments in many technology applications now make it possible to collect, collate and analyse an array of data for increasingly sophisticated decision-making, and more precise management of key grape production variables.

As a viticulturist, simply managing your crop on a year by year basis may give you a reasonable result over the shorter term. But having this sole focus year in and year out, without a broader and longer term view, will leave you vulnerable to climatic, market and technological change over time. Focusing on effective management of your current crop is important, but it is also critical to keep abreast of changes and to introduce new practices and technologies that come along, so that you can continue to improve your efficiencies, cost structures and quality outcomes over time.

So the key questions you really need to ask yourself are:

- What can you control, and what can you manage, to achieve the best outcomes sustainably over time; and,

- What is the current state of play in your vineyard, compared to the current set of viticulture best practices, and on the horizon improvements in technology and scientific management practices?

The reality is that the more precisely you are able to manage the variables and the risks, the greater are your chances of achieving optimal outcomes. Who wouldn’t want to achieve that?

**Purpose of this Report**

The reason we have written this report is to build greater awareness of how market leading vineyards and viticulturists apply the latest, best of breed technology and science to improve their crops and financial results. We will show you how to move the curve on yield and quality by better management of the risk factors and primary drivers that are under your control. By analyzing the latest trends and developing a case for applications of precision viticulture, or some of its crucially beneficial components, we will also show you how to take advantage of specific elements of these processes in a cost effective, simplified and stress free manner.

There are many misconceptions in the marketplace about new science and technologies that are applicable to the grape-growing industry. We will present the facts and analysis to clear up some of these myths, and demonstrate how to economically and sustainably utilise best practice precision viticulture to your best advantage.

**Current Market Situation**

The Australian wine industry has almost tripled in size since 1991. Most of this extraordinary success has come from growing its export markets. However, despite developing a reputation for being one of Australia’s most significant globally competitive industries, the last decade has been challenging for the wine industry with the viability of grape growers and wine producers coming under increasing threat. Over the last ten years we have seen a major reduction in grape prices, a significant increase in costs of inputs across the board, and consequent rapidly shrinking margins.
Stark Choices

In the meantime growers are faced with some stark choices. If you want to stay in the game you need to work smarter to improve competitiveness and margins. This may involve adopting new technologies and applications appropriate to your vineyard operations that impact yield and quality, or looking at new business models, or ways of structuring your business to create more cost effective means of production and better crop outcomes.

The reality is that to remain viable in the future, the only option is to look to premium grade production. If you’re in a (premium), cool-climate wine-growing region and are producing C-grade, or lower quality grapes you are likely to be uncompetitive or marginal at best. It’s obvious that the profits are in the premium end of the market (ie A and B grade), and unless you develop “premiumisation” strategies to move toward that end of the market the future will be tough, if not terminal. *(Expert Report on the Profitability and Dynamics of the Australian Wine Industry, Centaurus Partners, 2013; Wine Restructuring Action Agenda: Supporting Report, WMFA, 2009)*

Just to illustrate how the economics of grape production have changed and how margins have deteriorated consider the example below. A decade ago 10 tonnes of chardonnay was worth $2200 a tonne at the winery gate. Today you might get $1400, or as low as $1200 per tonne. Over the same period costs of production have risen around 20-50%, placing major pressures on growers to remain viable.

### Changing Economics of Grape Production - Squeezed Margins

<table>
<thead>
<tr>
<th>Chardonnay 10 tonnes/ha</th>
<th>2004 Harvest</th>
<th>2014 Harvest</th>
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<tr>
<td><strong>Price per tonne</strong></td>
<td>$2,200</td>
<td>$1,400</td>
</tr>
<tr>
<td><strong>Revenue</strong></td>
<td>$22,000</td>
<td>$14,000</td>
</tr>
<tr>
<td><strong>Costs</strong></td>
<td>$9,000</td>
<td>$13,000</td>
</tr>
<tr>
<td><strong>Margin</strong></td>
<td>$13,000</td>
<td>$1,000</td>
</tr>
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### Taking Action

The point here is that macro-economic factors are conspiring to create increasing downward pressure on grape prices and margins. So in this context taking action to do whatever you can do to improve yields or quality in a cost effective way is a necessity. The reality is that there is a need to do more than just reduce costs. More than ever, growers need to get on the front foot in responding to these circumstances, and find ways to maximize yield and quality. Improving ability to manage local variations in the vineyard offers vineyard owners the biggest upside.

By identifying the controllable factors amongst the many variables, and making (smarter) decisions in the vineyard based on careful collection, tracking and analysis of data, growers can arm themselves better with information and vineyard management options. If you’re not able to track and measure key production variables, how can you effectively manage them? It will be hit and miss, or just guess work. Innovative technologies and scientific research now make this viable.
What Do Vineyard Owners Want?

So in the face of all this challenging global and industry news, what do vineyard owners really want? Basically, most growers will have three main objectives:

1. **Increasing quality and quantity of grapes to achieve a better grade and price from the winery**
   Wine growers are re-evaluating the idea that there needs to be a trade-off between quality and quantity of production, and the science supports this notion.

2. **Ensuring the quality of grapes is good enough to secure renewal of contracts with the winery**
   With the current oversupply in grape production, delivering higher quality grapes is a much needed point of difference in securing better prices and on-going contracts for supply to wineries.

3. **Increasing margins and achieving a better ROI**
   While market forces determine the demand for wine, the vineyard owner can still improve margins and achieve a better ROI through strategic investment and cost reduction.

Managing Viticultural Risk

Consider the alternative perspective. In the end, achieving optimal grape production outcomes is essentially about managing viticulture risk. The question is how can you minimise that risk? What factors do you need to monitor and which elements of the grape production environment can you manage and influence, with greater precision than before? And what will it cost to achieve the best return?

The Quality - Quantity Trade Off - Moving the Curve & Managing Risk

With technology and management solutions that achieve greater yields and higher quality, at lower risk, it is no longer necessary to move along the curve, it is now possible to move the curve.
Major Challenges Facing Today’s Vineyard Owner

While major global and industry factors are beyond the control of vineyard owners, the sorts of operational challenges facing most vineyard owners in achieving their objectives include:

1. Time
   
   As a vineyard owner you could be a third generation wine grower, a younger college educated viticulturist, a doctor or dentist, or perhaps a wine enthusiast, who always wanted to run their own vineyard and create their own vintage. Many of you may be time poor because you have professional responsibilities or business commitments elsewhere. Whether the vineyard is your main source of income, or supplemental, it is nonetheless a commercial imperative to make it as profitable as possible and get a return on your investment.

   However, whatever the situation, it’s getting harder for anyone to find the time required to carry out all the day to day operational activities in the vineyard, then keep up with the latest technologies and science in viticulture.

2. Knowledge and expertise
   
   Producing quality grapes requires knowledge and skill. But keeping abreast of the latest advances in viticultural science and technology application can be a real challenge, if not impossible. It involves the kind of investment in time and effort that only a small percentage of owners successfully manage. Having the confidence to make critical decisions throughout the grape production cycle, which ultimately play out in yield and quality dividends, reputation and effective ROI, requires significant experience and expertise.

   Alternatively, ensuring you have access to the necessary and best advice based on the latest science, and access to available leading edge technologies and processes is the best insurance policy you can have for avoiding costly mistakes, and in managing risk and optimising your grape production outcomes.

3. Access to modern machinery, equipment and technology
   
   New technology is driving significant improvements in viticulture management and production. However, grower attitudes to adoption of new technologies may be the critical difference to many remaining viable and sustainable.

   To stay ahead there is an ongoing need to keep abreast of the latest trends and methods, determine their suitability for adoption in each circumstance, and make informed decisions on whether to invest. Purchasing and maintaining the necessary infrastructure, equipment and machinery to run a vineyard is a major investment, and apart from labour, represents the main ongoing operational impost.

   So there are three vital questions to understand here:

   1. How to stay up to date and informed about new technology options?
   2. How up-to-date and effective is your current equipment and machinery in actually doing the job?
   3. How do you determine the potential value and cost effectiveness of new technology to justify investment?
For many, the cost of replacing warn-out or outdated equipment may be significant, and you may well have been hesitating or putting off upgrade decisions, because they are not economically justifiable, in the current climate. You may even have cast your mind to the fact that inevitably, most equipment probably lies idle for months at a time, leaving you with a lot of ‘lazy capital’ sitting around tied up in equipment, when it could be well deployed elsewhere.

But finding a cost effective alternative that would relieve the burden of ongoing investment in infrastructure, machinery and equipment, as well as providing access to the latest technologies, until now may have seemed unlikely. Overcoming the uncertainty or risk of not having equipment on hand, or more importantly knowing the job will always get done on time, and to your required specifications and standards, regardless, are key issues to be weighed up.

The speed at which machinery, equipment and technology is advancing and changing means early adopters of new technologies will be able to create a competitive and cost advantage that will position them to get ahead of the pack in terms of quality, yield and margins.

Mechanisation and innovative technology brings new capabilities. Being technology shy or believing it is unaffordable are factors that need not limit success if you know how to overcome the knowledge deficit and bridge the gap in accessing the latest technologies and scientific applications in viticulture.

The real question to ask is, what is it costing you to not have access to the latest equipment and technologies to run your vineyard?

4. Quality people - labour resources

Not only is grape production capital intensive, but traditionally there is also a high dependence on labour, especially at critical times in the production cycle. There is competition amongst vineyard operators for often limited resources. Finding the right people, at the right time, with the necessary knowledge and skills to assist in running a vineyard can prove difficult. Finding people with the right motivation and commitment to doing a quality job, who will reliably turn up and perform, can be a frustrating, and often, a hit and miss exercise, which creates a good deal of stress.

So finding ways to either attract better people, or reduce the dependence on labour, and at the same time achieve a similar, if not better quality result, would be a highly desirable outcome. Eliminating wasted time and effort, and reducing associated stress levels would be welcome.

5. Logistics and coordination (and data for decision-making)

Running a vineyard is complicated. Keeping track of all aspects of the operations from scheduling daily and seasonal activities, working with the vagaries of the weather, managing people, equipment, maintenance and logistics, monitoring vine health and growth and all the other variables affecting grape quality and yield, can be time-consuming and challenging, not to mention the compliance and paper work. The potential for error is high. Operational tasks don’t get done precisely when they should, you don’t have access to the right information to assist in making optimal decisions, or some things simply get neglected or fall between the cracks in an effort to just keep the critical things operationally on track.
So there are two key challenges here for vineyard owners:

1. How to plan, track, monitor and manage the operational activities and co-ordinate vineyard logistics for more efficient production; and

2. How to collect, collate and analyse key viticultural data about variables that directly impact grape yield and quality, and evaluate and interpret this information for better decision-making to achieve superior production outcomes.

Most vineyard operators would want to have a way of knowing in advance what needs to be done and means of monitoring, and managing all these factors. Access to information and data about operational activities, vineyard variables and vine health help minimize risks and provide the means for more effective and efficient vineyard operations and achieving viticultural excellence.

A Compelling Future

In addressing these current challenges however, we are entering a brand new future for viticulture that embraces and takes advantage of the full range of precision tools, techniques, and applications currently available to vineyard owners and wine producers.

Given the current state of the industry and declining margins for all, and threatened viability for many, the imperative of adopting this brand new vision is all the more urgent.

So let’s explore this desirable new future and the possibilities of precision viticulture in a modernised industry using the latest information technology, systems and applications. It is a compelling future where the most advanced machinery and equipment, and sophisticated decision-support and management capabilities, together with a range of alternative outsourced solutions, provide significant opportunities for grape growers to more effectively reduce costs and move the quality-yield paradigm for maximum results and profits.

The future is here…
The New Vision

The Proposition of Precision Viticulture

Precision Viticulture is fundamentally about enabling viticulturalists and wine producers to make more informed, targeted management decisions to optimise vineyard performance – maximising grape yield and quality (outputs), and minimising costs of production (inputs) and environmental impacts.

Precision viticulture is based on the premise that there are significant variations within vineyards, and precise management customized to local conditions can reduce this variability and lead to increased yield and quality.

It enables the grape producer to first of all understand variations spatially and over time, and to identify specific “terroir units” which can then be treated individually. Once these individual variations are understood we are then able to develop adaptive viticultural techniques and targeted management strategies for specific blocks or sub-blocks to achieve optimal yield and quality outcomes.

By applying appropriate viticulture management practices (e.g. trellis design, pruning and other canopy management strategies, fertiliser and spraying applications, irrigation, differential harvesting, etc.), vineyard owners are able to respond more precisely to local variations in conditions and factors that influence grape yield and quality. This enables them to then institute “differential” (as opposed to uniform) management practices targeting zones of similar performance for specific treatments.

Precision viticulture technologies are a suite of diagnostic technologies, tools and techniques employed to more effectively assess and manage vineyard variability. PV depends on the application of new and emerging technologies such as global positioning systems (GPS), geographic information systems (GIS), meteorologic and other environmental sensors, and satellite and airborne remote sensing to capture and record high resolution spatial data for analysis and interpretation.

PV technologies are used to assess variations in grape yield and quality by monitoring and measuring local variation in the factors that influence grape production outcomes, including soil, topography, climate, vegetation and vine health. These factors of “terroir” are the primary drivers of grape production and vintage outcomes.

The purpose of PV is to locate areas within blocks which have similar (or dissimilar) growing characteristics, quantify how zones or areas perform, use this information to understand cause and effect, i.e. reasons for differences in performance and take appropriate action. This information empowers more soundly based decisions with the objective of reducing production costs and increasing efficiency, profitability and/or sustainability.

Essentially, PV is about risk management. Through use of spatial information vineyard owners can make more informed, fact based decisions with a greater likelihood of achieving

Objectives of Precision Viticulture

1. Appropriate management of the inherent variability of grape crops
2. Increased economic benefits (efficiencies, improved production outcomes, greater profitability and ROI)
3. Reduction of environmental impacts
the desired outcome, compared with a similar decision made in the absence of such information. By effective and precise management of these variables, you can optimize vineyard performance while minimizing environmental impacts and risks. Precision viticulture is about doing the right thing, in the right place at the right time.

**Vines and Variability**

Understanding variability and its impact is key to precision viticulture. So let’s consider some important facts about grape production.

Firstly, typically within any vineyard, grape yield varies considerably. Research shows this variation can be up to eight to ten times within a single parcel of land. When you consider that potentially, yield in one part of a crop may be ten tonnes per hectare, and in an adjacent area as little as one tonne, the upside to reducing or eliminating this variation is significant.

“Grape growers have known for ever and a day that vineyards are variable. Precision Viticulture gives them the tools to see that variation and to do something about it.”

Dr. Rob Bramley
(Leading authority on precision viticulture in Australia)

Secondly, patterns of yield variation are relatively stable over time, and driven by a number of factors including soil and topographic variation, soil moisture and micro-climate. Thirdly, there is a spatial correlation between patterns of fruit quality and grape yield.

While it has been known for some time that these variations of quality and quantity within vineyards exist, until recently there have been no ways of effectively managing them. Now, not only have there been considerable advances in development of technologies and decision systems, but the economics of employing these advanced precision viticultural techniques are becoming increasingly attractive.

**Wine Production Systems - Traditional Methods**

Traditional wine production systems have not recognized the inherent spatial variability of vineyards, as well as blocks within vineyards, and the resulting uniform management has been at odds with differential yield and quality outcomes. In other words it is customary to treat the whole vineyard the same, wanting a uniformly good result, but inevitably ending up with a variable, and often unexplainable result. For example soil maintenance and pruning are applied with equal intensity, regardless of varying soil conditions within the vineyard; and fertilisers and crop protection products are applied in identical concentrations.

Where once variability was treated as an inconvenient truth, it can now be approached as an actively manageable factor in viticulture. The key conundrum has forever been
determining “cause and effect.” Causes giving rise to crop variability are identified, which can then be proactively dealt with on a differential or site specific basis. **Variability is now an opportunity not a drawback.**

What this means is that there are major opportunities for innovative vineyard owners to take advantage of the range of technologies now available that can permit significant gains to be made in both operational efficiencies as well as quality and quantity improvements in grape production. And who wouldn’t want that?

**Moving The Curve**

Precision viticulture enables vineyard owners to “move the curve.” The only choice until now has been to go along the curve. Growers have been subject to conditions (in particular limitations on availability and application of appropriate and affordable technologies) that have limited the choice in deciding between grape production outcomes focusing on quality versus quantity. But what if you could better control the variables that affect both grape yields and quality? What if you could have both better quality without the traditional trade-off with quantity? PV makes this all possible now.

**Precision Viticulture Technologies and Applications**

So let’s take a closer look at precision viticulture and the tools, techniques and applications that are currently available and within the practical grasp of those vineyard operators who are prepared to invest in order to optimise returns.

The following table (Table 1) shows the important elements of precision viticulture, the core variables, enabling technologies and applications that provide the platform for bringing together both vineyard and economic information, vineyard management responses to managing variability and the application of PV expertise.

Effectively managing variability within vineyards comes down to monitoring specific factors that make up the terroir for any vineyard block or parcel:

- climate and micro-climate
- topography
- soil
- water, and
- vine management

There are a number of enabling technologies which have been specifically applied to viticulture, including:

- geographic information systems (GIS)
- global positioning systems (GPS)
- meteorological stations for monitoring weather and climate
- remote and environmental sensing technologies
- soil sensors
- digital mapping models, and
- relational databases to organise all of the environmental and economic information collected for analysis and interpretation.
### Table 1: Precision Viticulture Technologies and Applications

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<tr>
<th>Vineyard Variables</th>
<th>Enabling Technologies</th>
<th>Applications</th>
<th>Adaptive Vineyard Management Practices (In-field technologies &amp; applications response to variability)</th>
</tr>
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</table>
| **Climate**       | Global positioning systems (GPS) | Satellite based geo-referencing for mapping vineyard environmental variability | • Vineyard design  
|                   | Geographic information systems (GIS) | Digital tools for map-based analysis | ➢ Layout, resource requirements |
| **Soil**          | Weather stations | Monitoring of climatic and meteorological factors important for vine growth & ripening - temperature, precipitation, humidity, and wind | • Trellis design  
|                   | Remote sensing from satellites, and airborne imaging (Digital Multi Spectral Imaging - DMSI) | Provide images depicting vineyard conditions (e.g., vine productivity – Normalised Difference Vegetative Index (NDVI) measures canopy size, density, biomass variability & shape; plant cell density (PCD), and grape quality & yield) | ➢ Re-orientation, geometry of vine support, light penetration  
| **Water**         | High resolution soil surveys | Detailed information about soil fertility (EMI) & hydrologic characteristics (water) | • Pruning practices/ regime  
|                   | Digital elevation models (DEM) | Detailed topographic mapping information | • Irrigation/fertigation  
|                   | Environmental sensors | Monitoring key bio-physical factors such as solar radiation, soil moisture, & temperature regimes | • Spraying  
|                   | Near infrared spectroscopy | Measuring grape quality, composition, colour, total solubles, solids & pH of red grapes, fungal diseases in grapes, wine fermentation, & wine quality grading | ➢ Variable rate application of herbicides & pesticides for pest & disease management  
| **Topography**    | Relational databases | Organise environmental and economic input and output data files and information | • Groundwork  
|                   |                      | | ➢ Fertilising, slashing, ripping, seeding - variable rate applications |
| **Vegetation**    |                      | | • Canopy management  
|                   |                      | | ➢ MSI, NDVI  
|                   |                      | | • Vegetation profiling and mapping  
|                   |                      | | ➢ Canopy density  
|                   |                      | | sugar levels, poor vine growth, nutrient and/or disease problems, irrigation effects  
|                   |                      | | • Selective-process harvesting  
|                   |                      | | • Yield mapping  
| **Integrated Technologies** | Distribution sensors networks | Real time monitoring of key factors such as water stress and temperature through strategic deployment of sensors throughout the vineyard | • Build a multi-dimensional picture of vineyard variables utilising science based, data rich analytics  
|                   | Vineyard models | 3-D modelling of vineyards based on accurate distance mapping and area measurement (block, plantings, infrastructure) | • Plan, monitor and manage to optimise vineyard performance  
|                   | Decision support systems | Bring together all vineyard and economic information and databases, vineyard models and geographic information systems into a single interactive software-based system to solve vineyard management problems and improve decision-making. | ➢ Maximise grape yield & quality  
|                   |                      | | • Minimise environmental impact & risk  
|                   |                      | | • Detailed analysis and reporting |
The specific ways in which these core technologies have been applied to viticulture enable the capture and collation of data on key vineyard variables. Multiple layers of information are brought together using a range of formats, databases, and vineyard models to build a multi-dimensional picture of the vineyard based on high resolution spatial data. Integrative technologies and software systems provide a single interactive platform (decision support system) for presenting and manipulating complex data in a usable format for analysis and interpretation. For example vineyard models can be developed to simulate microclimate, vine growth, grape ripening, and economic return on investment to evaluate management options.

This provides a detailed picture of within vineyard variability and a scientific basis for responding to and proactively managing these variations, solving specific vineyard management problems and improving the overall quality of decision-making.

**Software Applications for Managing Vineyard Operations**

Vineyard software is not novel but few growers in Australia use it. Usage is justified more often for business reasons (e.g. labour, pesticide use, budgets, equipment, and harvest tracking) rather than for technical viticulture applications (e.g. sampling, scouting, harvest forecasting).

So there are significant opportunities to utilise a range of software applications for both business and technical purposes that provide substantial benefits in monitoring and managing vineyard terroir, vine growth, grape development and operational activity. As well as the obvious regulatory requirements for tracking pesticides there is clearly a need for tracking the complex business of grape growing.

**Vineyard Operations**

- Spraying - chemical application and reporting
- Vineyard monitoring (pests, diseases, nutrition, water status etc.)
- Irrigation and fertigation scheduling and monitoring
- Tracking of phenology, yield components, fruit maturity, etc.
- Tracking of samples (petiole, soil, fruit) from vineyard block to lab
- Real time tracking and monitoring of all in field tasks performed in vineyard operations
- Tracking of harvested fruit from vineyard to winery with traceability back to vineyard block
- Decision support, expert systems (predict harvest date, yield estimation etc.)

**Vineyard Management**

- Labour tracking and payroll
- Vineyard economics and budgeting
- Resource (machinery and equipment) maintenance and management
- Farm planning and tracking (development of a calendar of operations)

PV technologies and applications provide a powerful suite of tools for vineyard owners to adapt their vineyard management practices and to respond with a high degree of precision to manage variability within their vineyards. This includes adoption of zonal management strategies, and differential or site specific treatments for in-field variability.
Economic Benefits of Precision Viticulture

But is the investment in precision viticulture likely to pay off? Perhaps a lack of data in the past has clouded the perceived cost-benefit equation. The ROI reported by leading researchers (CRCV, AWIRI, Bramley, Proffitt, Lamb, Winter, Dunn etc), viticulture experts and leading vineyard operators already using PV technologies leave little doubt about the economics of what other areas of agriculture have known and been practicing for years. The science, applied research and much in-field testing (which are all ongoing) have clearly established the base case for precision viticulture.

While the economics of each situation is different, let’s look at a few examples. A combination of high resolution soil surveys (eg using EM38 data) accompanied by elevation mapping, targeted sampling of soil and/or plant tissues, some on-ground data through careful vine and fruit inspection, and complemented with yield mapping for targeted management may cost as little as 0.5-2.0% of the price of fruit received, but have the potential to increase the value of wine production by over 15%. *(Bramley et al, Aust NZ Grapegrower & Winemaker 2003).*

Managing Inputs As Well As Outputs

Traditionally wine growers have concentrated on managing production outputs ie. grape yield and quality, but the development of new innovations such as variable rate application (VRA) technology, increasing production costs, and environmental constraints eg. lack of water, are allowing producers to use spatial information to minimize expenditure by applying inputs such as irrigation, fertilisers, herbicides & fungicides, labour and machinery, more efficiently. Targeted differential application of inputs to specific areas across blocks reduces input costs and improves overall uniformity of crop yield and/or quality.

"Viticulture is an input-output process. Whilst some inputs to viticulture production cannot be controlled (eg the incidence of sunlight, rainfall etc.) resulting in some noise in the system, other inputs can be controlled and the outputs measured. Understanding of the relationships between the controllable inputs and outputs and their spatial variation promotes the development of targeted management."

*Bramley, 2001, CSIRO Land and Water and Cooperative Research Centre for Viticulture*
The following table provides typical examples of the bottom line benefits from precision viticulture applications.

**Table 2: Bottom Line Benefits from Precision Viticulture**

<table>
<thead>
<tr>
<th>Variable</th>
<th>PV Application</th>
<th>Economic Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inputs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Use of airborne crop vigour imagery to delineate zones for differential application of irrigation water to manage vine vigour as a means to: 1. Increase fruit quality across block 2. Reduce canopy management costs</td>
<td>Cost reduction of $700 per ha</td>
</tr>
<tr>
<td>Labour</td>
<td>Use of airborne crop vigour imagery to delineate vegetative zones for differential pruning. Setting of pruning wages based on vine vigour in order to: 1. Reduce costs 2. Increase morale</td>
<td>Cost reduction of $290 per ha</td>
</tr>
<tr>
<td>Sunlight / fruit zone</td>
<td>Targeted management using GPS mapping to identify zones for differential removal of vine leaves (leaf plucking) by hand to increase fruit exposure.</td>
<td>Improved the overall uniformity of crop yield and quality</td>
</tr>
<tr>
<td>management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertiliser</td>
<td>Differential application of fertiliser, lime and mulch by varying tractor speed according GPS mapping utilising soil profile and other vine data</td>
<td>Improved the overall uniformity of crop yield and/or quality</td>
</tr>
<tr>
<td>Spraying</td>
<td>Differential application of sprays using variable rate application technology (VRA) utilising GPS, GIS and crop data to determine within vineyard disease vulnerable areas and targeted dosages</td>
<td>Reduction in spray volume, reduced environmental impact, and reduced overall disease management costs</td>
</tr>
<tr>
<td>Frost</td>
<td>Strategic installation of frost fans based on crop data, geo-spatial information, frost impact data, wind break locations, modelling of airflow movements and susceptibility to frost damage. Reduce risk of crop loss in high value blocks. Project cost = $250k (installation of fans)</td>
<td>Cost savings – crop protected from frost event preventing predicted loss of &gt;$250,000 Payback – 14 days (first major frost attack after fans installed)</td>
</tr>
<tr>
<td><strong>Outputs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grape yield &amp; quality</td>
<td>Selective Harvesting for grape production &amp; wine production Digital Multi Spectral Imagery (DMSI) data were shown as plant cell density (PCD) for a 3.3 h Cabernet Sauvignon block and ground-truthed against canopy vigour, Baume, pH, and titratable acid (TA) to confirm PCD differences translated into real differences on the ground. As a result the block was divided into two zones and harvested differentially, using a mechanical harvester fitted with a yield monitor and differential GPS. (“Adding value to the wine business: using precision viticulture technology in Margaret River”, T. Proffitt &amp; B. Pearse, ANZGW, pp40-44, Dec 2004)</td>
<td>By using PCD, splitting the block into different management zones, and differentially harvesting each, the wine made from both zones (yields 16 t /h v 8 t/h) were allocated to higher and lower end products resulting in a net benefit of $140,000 compared to harvesting the block as a single unit.</td>
</tr>
</tbody>
</table>
On the outputs side PV technologies are assisting with differentiation of fruit quality and
differential harvesting of fruit parcels of uniform quality, and to improve disease and pest
monitoring, precision in vineyard sampling techniques, crop forecasting, fruit maturity
assessments, and scheduling of harvesting and production planning at wineries. Geo-
referencing down to individual vine level permits specific sampling points and carrying out
differential actions/treatments ie. site-specific management.

New vineyard developments and re-design projects are also using spatial data to understand
underlying topography and micro-climate, identify soil boundaries and drainage patterns, and
incorporate other factors affecting vegetation, orientation and logistics, to plan and design
vineyard block layouts.

**Mechanical Harvesting - Benefits**

Nowhere is the opportunity to adopt PV more apparent than in the case of harvesting. The
latest selective-process mechanical harvesters now deliver a better quality result than hand
picking, maintaining berry integrity, with virtually zero MOG or petioles, and minimal bruising
or juicing. They do so at a fraction of the cost of hand-picking, and without the stress and
time consuming tasks associated with assembling and managing labour crews. Using
mechanical harvesters with a combination of GPS tracking, GIS and grape yield monitoring
technologies on board to deliver detailed yield mapping data provides powerful information
on yield variations for future decision-making.

Modern harvesters have numerous advantages with speed, flexibility, differential in-field
harvesting, yield monitoring and timing (night harvesting) which deliver maximum benefits to
growers and wineries alike. Consider the following example.

### Economic benefits of selective harvesting for grape production &
wine production

**Selective harvesting:** differential picking of grapes at harvest according to different
yield and/or quality criteria with allocation to different product streams in order to
exploit observed variation in vineyard performance (Further developments in precision viticulture
and use of spatial information in Australian Vineyards, T. Proffitt and R. Bramley
Australian Viticulture, Jan/Feb 2010 v14n1)

<table>
<thead>
<tr>
<th>Region</th>
<th>Variety</th>
<th>Income benefit grape production</th>
<th>Income benefit wine production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Claire Valley, SA</td>
<td>Riesling</td>
<td>$54,904 (+77.8%)</td>
<td></td>
</tr>
<tr>
<td>Padthaway, SA</td>
<td>Shiraz</td>
<td>$4,657 (+3.2%)</td>
<td>$272,971 (+20.5%)</td>
</tr>
<tr>
<td>Margaret River, WA</td>
<td>Shiraz</td>
<td>$12,300 (+12.5%)</td>
<td></td>
</tr>
<tr>
<td>Margaret River, WA</td>
<td>Cabernet Sauvignon</td>
<td></td>
<td>$139,480 (+19.2%)</td>
</tr>
</tbody>
</table>

Based on scientific research and practical application of precision viticulture techniques in
the field, there is an extensive and growing body of evidence in support of the substantial
economic benefits resulting from their use. These benefits are available now to those who
want to take advantage of the current range of precision viticulture technologies. But what
are the challenges in implementing PV and how do you go about getting started?
Challenges In Implementing Precision Viticulture

In the drive to reduce costs, increase quality and yield, and achieve higher margins and ROI, vineyard owners are confronted with a number of challenges when it comes to finding and implementing precision viticulture solutions that will assist them to remain competitive and sustainable in the short term, as well as over the longer term.

Slow Uptake

Australia is one of the pioneers in precision viticulture research, but there has been relatively slow uptake of the available technologies and applications in viticulture, despite their rigorous adoption in many other areas of agricultural production.

While adoption of precision viticulture is on the rise in many other wine producing countries around the world it is yet to really gain traction in Australia. If this does not change there is a danger the economics of better returns associated with precision viticultural practices elsewhere may play a hand in determining the fates of those who choose to ignore this opportunity locally.

Barriers to Adoption

Reasons for this apparent reluctance to adopt new approaches include:

- Lack of knowledge about the extent of variability - being able to measure it and then practically manage it;
- A lack of understanding of the impact of such practices and the business case for their adoption i.e. a clear return on investment;
- Lack of available technologies, until recently; and
- Lack of a coordinated approach to overcome disparate application of various tools and techniques.

Until now, no one has brought all the technologies together in a single platform and made them available in a coordinated, affordable package with the expertise and knowledge required to deliver the kind of precision viticulture that producers would expect.

Practicalities

While precision viticulture offers opportunities, there are also practical challenges that might get in the way of vineyard owners implementing the advanced solutions now available, including:

- The costs associated with purchase and implementation of technologically advanced equipment and tools;
- Sourcing people with expertise or capability to operate equipment and utilise the technology;
- The need to train people up to use new systems and applications, involving a significant learning curve for vineyard managers/owners, consultants, and operators, and requiring a major investment of time, money and resources;
- Choosing which technologies to implement or utilise amongst many alternatives requires time and effort, and cost-benefit analysis of defined benefits or advantages accruing;
Weather Stations

Weather data collected via weather or meteologic stations enables comparison of growing seasons against one another.

Data can be tracked to create real-time information on accumulated growing degree days, diurnal temperature ranges, disease pressure, soil moisture and irrigation needs and frost alarms.

Automated weather stations can also provide alerts via text message, phone calls and emails and can even alert an operator or vineyard manager of frost danger or when heat reaches dangerous levels for workers.

Current smart technology allows these devices to measure conditions in the vineyard, as well as activate irrigation valves and pumps, control electric gates and capture camera images.

“Premiumisation” Strategy and Precision Viticulture

Apart from promoting more efficient use of inputs to the production system as a result of better knowledge of variability, and demonstrating best practice or quality assurance standards have been met, smart vineyard owners know that the best way to improving returns is through achieving the highest possible grading for their fruit. The ability to harvest differentially ensures the winemaker will get the best quality grapes, allowing for better planning at the winery and improved sampling, yield estimation and forecasting of pick times.

Implementing precision viticulture provides a market opportunity for grape producers to actively adopt a “premiumisation” strategy to capitalize on the higher returns for higher quality (A and B) grapes, the market for which is predicted to be increasing demand both locally and overseas. Precision viticultural techniques and the QA standards they intuitively promote represent the best way to actively follow this ‘pursuit of quality’ strategy.

Deciding What to Do – Being Strategic

Having the time to do the necessary research yourself, understanding the science and developing the expertise, and doing the cost-benefit analysis for each technology application can be onerous. Not only that, but piecemeal adoption of technologies will limit capacity to realise the full benefits possible when they are strategically deployed, and properly integrated across vineyard operations. The costs for individual vineyard owners may be prohibitive, unless there are ways of defraying the overall cost of adoption and application.

Nevertheless, precision viticulture now gives growers an alternative to more effectively managing their grape production outcomes – it enables you to move and improve the “quality-quantity equilibrium curve”. When looking at your vineyard management and production techniques you now have options to adopt a range of PV tools and techniques.
yourself. Alternatively, you can seek assistance from those already utilising PV technologies, and benefit from their economies of scale and experience, and specialised PV expertise. Such an outsourced solution could deliver a cost-effective way of tapping into resources and getting started with PV.

Remote Sensing Techniques for Precision Viticulture

Adopting a Precision Viticulture Approach to Vineyard Management

Utilising precision viticulture effectively requires planning, investment and expertise. It is a scientifically based approach which demands a level of commitment and rigour for best results. Whether you are investing in PV yourself or looking to outsourced assistance or solutions you need to have a structured approach to Plan, Monitor and Manage vineyard variability and the adoption of PV technologies, as outlined in the diagram below.

Quality viticulture service providers utilising PV technologies should demonstrate how they can assist you to build a multi-dimensional picture of your vineyard based on data rich analytics, and provide the detailed analysis and reporting to make informed decisions on how to maximise grape yield and quality, minimize costs and environmental impacts, and manage risk.

How to Get Started with Precision Viticulture

The first step to getting started in precision viticulture is firstly to recognize that there is variability within your vineyard, and secondly to see this as an opportunity rather than a problem which can be responded to positively and managed effectively with the right science, data and technology that is now available. Then you need to start collecting data about the vineyard so that you can build up a picture to see exactly where the poorer and better performing areas are, and quantify these differences. This may surprise you.
Plan, Monitor and Manage - Implementing Precision Viticulture

**Plan**
- Business plan
- Vineyard design
- Plantings
- Operational management

**Monitor**
- Climate
- Weather
- Micro-climate
- Temperature
- Precipitation

**Manage**
- Soil
- Water
- Plant nutrition
- Vine health
- Canopy Vigour
- Yield
- Quality

**Terroir**
- Climate
- Soil
- Water
- Topography
- Vegetation

**Core TVS Viticultural Management Services**
1. Pre-Pruning
2. Pruning
3. Spraying
4. Groundwork – ripping, harrowing, fertilising, seeding, wire-lifting
5. Netting On/Off
6. Post and trellis repair
7. Labour crews

**Selective - Process Harvesting (SPH)**

**Total Vineyard Management (TVM)**

**Precision Viticulture (PV) for Site-Specific Crop Management (SSCM)**
1. Soil Analytics
2. Water monitoring
3. Crop Vigour Analysis
4. Yield mapping
5. Post condition analysis
   - Variable Rate Technologies (VRT)
   - Digital Application Mapping, GPS, GIS

**Vines**
- Canopy vigour, foliar pigments (chlorophylls), carotenoids etc, water stress

**Grapes**
- Brix, total acidity, PH, malic acid, polyphenols, colour index, ripeness etc
How Precision Viticulture Works

Precision viticulture should be seen as a continuous process of ongoing observation and collection of data on various grape production inputs (climate, soil, water, topography etc), and outputs relating to yield and quality. Based on analysis and interpretation of this information, different approaches or strategies can be developed on how best to respond more ‘scientifically’ and precisely to the variability within the vineyard to maximise grape yield and quality. Targeted management strategies will continue to be refined and improved as more information is added to build up a multi-dimensional picture of vineyard variability to assist with better decisions and actions.

Perhaps the easiest and most useful place to begin the process is with yield mapping and the addition of supplementary information such as soil testing and mapping. Ongoing analysis, interpretation and evaluation of the information provides further feedback for better targeted management of the vineyard parcel or block. Did it work? Was it useful? What changes are required?

Additional information gathered via airborne imagery to describe canopy characteristics using digital multi spectral imaging, collecting accurate boundary block data, and digital elevation mapping detailing topography are also important elements in building comprehensive block profiles. Ongoing data acquisition and constant testing and measuring leads to continuing refinement of data and more detailed understanding of the drivers of yield and quality, and how best to work with the underlying elements of terroir.

Ground truthing is also important to validate onsite soil maps and airborne remotely sensed images, before making decisions. Over time the growing volume of data begins to take on predictive value which leads to development of increasingly more sophisticated models for understanding and managing vineyard variation. Through combining various layers of spatial information, relationships between various spatial elements can be examined and management zones created for differential treatment ie targeted vineyard management.

Benefits of Precision Viticulture

Going forward then, by recognising and taking advantage of variations in-field, the main benefits to grape producers of adopting precision viticulture are:

- Reduced production risk;
- Capability to more effectively control or manipulate the variables associated with grape quality and quantity – the ability to ‘move the curve’;
- Reduced input costs and environmental impacts
- Improved return on investment due to better quality and prices
- Reduced management stress
- Reduced capital investment and cost of capital
The Cyclical Process of Precision of Viticulture - How to Get Started

1. Observation
   Data Capture & Collation
   • Yield mapping

2. Inputs
   • Digital elevation models (DEM)
   • Soil mapping
   • Soil testing (EM38, gamma radiometrics)

3. Outputs
   • Remote sensing
   • Airborne imagery (NDVI)
   • Fruit quality assessments
   • Yield mapping

The Process of Precision of Viticulture

Supplementary Information
• Remote sensing
• Soil & tissue testing
• Soil mapping
• Crop assessment

3. Analysis & Interpretation

4. Implementation of Targeted Management Plan

Zones
- Yield
- Baume
- Leaf area
- Nutrition
- Soil map
- Elevation

Targeted Management Zones
Differential applications of inputs
• water
• fertiliser
• canopy management
• sprays

Sampling & Monitoring
Representative sampling taking account of vineyard variability
• yield forecasting
• fruit maturity assessment
• tissue and soil collection for nutritional analysis
• fruit fullness via bud dissection
• pest, disease and vine health assessment

Harvesting (selective process harvesting)
Differential harvesting according to specific yield and/or quality criteria with delivery to different product streams in order to exploit variations in vineyard performance

Vineyard Design
Design and layout taking account of soil, topography and micro-climate

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How to Enjoy the Benefits and Rewards

Deciding what you want

Right now you have a number of choices before you. Going forward you can do nothing, do it yourself, or you can seek help from others with the expertise to assist you in beginning the process of implementing precision viticulture. Let's consider these options.

Do nothing

Well you can do nothing. You can risk staying stuck in the past, taking whatever comes your way, hobbled by out-of-date vineyard management practices and aging and outmoded equipment, and stay committed to the legacy grape producing ways of the past.

You may continue doing what you have done for some time, but without change, eventually the tide of technology and marching economics will get the better of your margins, and your vineyard will over time, be outpaced for quality and yield, and likely become uneconomic.

Do it yourself – in-house

Alternatively, you can look for options to bring precision viticulture expertise in-house and invest in the latest PV equipment and technologies, innovations, improvements and resources yourself. Now this is possible but requires significant planning and effort to implement the necessary changes, and it will be expensive requiring significant investment beyond what most individual vineyard owners could rationally justify. With a lot of time on your side and perhaps deep pockets you can start the process of implementing precision viticulture into your vineyard operations now.

Outsourced solutions – managed services

If you're like many vineyard owners you can clearly see the advantages of precision viticulture. You may even be feeling a little excited about the prospect of implementing precision viticulture, but are bit overwhelmed or hesitant about doing it on your own, and knowing exactly how to get started.

There are options to outsource provision of individual services to a professional vineyard management services provider. Now many growers already do this with varying degrees of satisfaction and success. But if you’re committed to getting moving with PV, then to begin by outsourcing your harvesting may be a good place to start the process of collecting data about your vineyard.

Leading edge viticulture service providers with selective process harvesters and GPS, onboard tracking and grape yield monitors will get your grapes harvested quickly and economically, and most importantly give you yield and quality maps indicating the extent of variability in your vineyard blocks.

This is the start of the data collection and analysis process upon which you can now begin to build.
Fully Outsourced Solution - Total Vineyard Management

A next step beyond selected managed services, involves Total Vineyard Management, a fully outsourced solution requiring only executive (or no) input from the owner/manager, with full reporting and analysis. This is an opportunity where precision viticulture technologies can be progressively applied to build a more detailed picture of variability and how best to respond to it with targeted management practices.

Not only does this option give you a complete outsourced solution and peace of mind, but with a quality service provider you will get cost effective access to PV expertise and the latest PV technologies they employ across their operations.

Advanced Outsourced Solution

Data Analysis and Planning

Implementing precision viticulture is an ongoing process. It involves utilising PV technologies for observation and data collection, and consolidation and analysis of high resolution spatial data for better planning and decision-making.

Accessing this technology and expertise through viticulture service providers that have already invested in this technology and have it embedded in their processes can provide a cost effective solution to implementing precision viticulture.

Precision Viticulture

Precision Viticulture is the most advanced viticulture management solution utilising the full range of PV technologies, analytics and advice, designed to deliver optimal grape production outcomes (to manage costs on the input side, and to move the quality-quantity curve on the output side).

By applying precision viticulture techniques, utilising the data, and using outsourced professional expertise to bring it all together, you can move the curve, and sit back and enjoy the fruits of your labours, the smarter way.

More Information

If you would like to find out more about precision viticulture, or want to know more about whether it is an option, or you simply want to get started contact, Total Viticulture Solutions for a FREE cost benefit analysis to check if precision viticulture managed services (in full or in part) can work for you.

A Strategic Vineyard Assessment will look at your current vineyard management practices, technologies and potential to improve your grape production outcomes and vineyard ROI through precision viticulture. It will assist you in understanding how to access elements of PV, establish which aspects will be beneficial, and if it is economically justifiable to get started with utilising available precision viticulture technologies.
End Note

Accelerating The Perpetual Search For The Highest Quality Possible

Grape production and the winemaking process to produce high quality premium wines are complex activities, requiring many years, some would say a lifetime, to perfect. It takes years to understand vineyard vagaries and more than the basics of viticulture to produce quality grapes.

The purists describe the obligation of the vigneron as “... to be in a perpetual search for the highest quality possible”. In adopting a philosophy of wine production the moving force that underlies it is the notion of terroir and that the wine produced from any particular place has an identity that is merely in essence the expression of the sum total of the variables unique to that climate or terroir. Quality is usually the result of many years of observation and experience. (The World of Fine Wine, Issue 14, 2006)

Precision viticulture represents a paradigm shift in our “perpetual search for the highest quality possible”. It is a step which accelerates years of observation into identifiable variables and precise differences which can be managed to move the curve on quality and yield.

Ultimately, as time goes by, and the new wave of precision technologies and applications are integrated into vineyard operations best practice, there should be little difference between ‘viticulture’ and ‘precision viticulture’. We still have quite some time to go before we achieve this, and it will be the innovators and early adopters who reap the benefits well in advance of the rest.
References


Appendix 1

Wine Industry Analysis

Industry Oversupply

There is an oversupply of commercial grapes, notably in the lower grades (C-F) which is creating price distortions across the industry, and the burden of sunk costs in infrastructure based on the economics and projections of a decade ago remain an ongoing burden for many industry players. There is increasing penetration of foreign wines into the Australian market which has traditionally been dominated by local producers (peaking at over 90% market share) and offered higher margins than export. Trading performance in established overseas markets of US, UK and Canada, which have taken over 60% of our exports are declining, as global competition grows. Moreover, opportunities in Asia, particularly China, heading into the “Asian Century” are yet to be fully realized.

Implications of Restructure

The Wine Makers Federation of Australia’s industry restructure blueprint (Actions for Industry Profitability 2014-2016, WMFA Report, Dec 2013), which attacks both the supply and demand side, aims to hasten the correction to the supply base to improve and restore profitability and asset values to stakeholders. What this means is that with too many regions producing uneconomic fruit relative to high-grade cost structures, a shake-out is underway and some growers and wine producers will and must leave the industry. Still, there are many confounding factors that make the elimination of (lower grade) grape production over-supply and the corresponding uncompetitive surplus challenging but imperative in reinvigorating the competitiveness of the wine industry.

The core issue of oversupply is that 83% of total wine produced in Australia in 2012 was D, E or F grade. While A and B wines account for just 7% of the total domestic production (A = 2%, B = 5%, C = 10%, D = 39% and E and F = 44%) they reflect 28% of total revenue. (Expert Report on the Profitability and Dynamics of the Australian Wine Industry – Centaurus Partners, Dec 2013, p59)

Other Factors

While these global and industry-wide factors are not directly within the sphere of wine grower’s control, long range planning can help mitigate or manage risks, and assist more proactive responses to changing circumstances. In addition, IBIS World’s industry report “Wine Production in Australia 2013-14”, also points out that wine production has been impacted by other factors such as climate change and extreme weather events, pest and disease issues, and a range of input factors including water access, energy prices and labour costs. It notes as well, the importance of access to, and adoption of technology innovations and their implementation into production.

“Premiumisation” Strategy and Precision Viticulture

Currently, there is an opportunity in the market to adopt a “premiumisation” strategy to capitalize on the higher returns for higher quality (A and B) grapes, the market for which – both local and export, is likely to be sustainable into the foreseeable future. One key way in which growers can support this approach is to implement precision viticulture techniques to plan, monitor and manage more effectively the variables affecting grape quality and yield.
List of Abbreviations

DGPS (differential GPS)
DSS (decision-support systems)
GIS (geographic information systems)
GPS (global positioning systems)
GVI (green vegetation index)
NDVI (normalized difference vegetation index)
PA (Precision Agriculture)
PCD (plant cell density)
PV (Precision Viticulture)
PVR (photosynthetic vigour ratio)
SSCM (site-specific crop management)
VRA (variable-rate application),
VRT (variable-rate technologies).