

This article is an edited version of a paper presented at the 15th Romeo Bragato Conference, Hawke's Bay, New Zealand (20-22 August 2009), and published in the subsequent proceedings.

Further developments in precision viticulture and the use of spatial information in Australian vineyards

By Tony Proffitt¹
and Rob Bramley²

Introduction

Following the introduction of precision viticulture (PV) technologies to the Australian wine industry in the late 1990s, and associated research during the subsequent years, an increasing number of grape and wine producers are recognising the value of understanding the inherent biophysical characteristics and performance of their vineyards for improved viticultural management and decision-making. By definition, PV is viewed as a continuous cyclical process of observation, evaluation and interpretation leading to the implementation of a targeted management plan, followed by further observation and refinement of the management plan if required. The rationale behind this process is that through the use of spatial information,

any given viticulture decision has an increased likelihood of delivering the desired or expected outcome compared with a similar decision made in the absence of such information. However, it is important to realise that the use of spatial information alone also provides an opportunity to improve viticultural knowledge and management decision-making. Whilst this is not strictly PV-related, the use of spatial information in this way should be highlighted as the data is often acquired using the same technologies.

Technology adoption

Since the Australian grape and wine industry first looked at PV technologies, major progress has been made in its availability and affordability. In addition, research has continued to investigate new tools and to discover new uses for existing technologies. A useful review of PV is provided by Bramley (2009).

Whilst some would argue that the rate of adoption has been slow, the leaders in the field of PV have incorporated the acquisition and analyses of spatial information into their business models. This is demonstrated by the fact that high resolution maps are no

longer viewed only at vintage to help make harvest decisions, but are now being referred to throughout the year for a range of viticultural activities. Philosophically, as time goes by, there should be little difference between 'viticulture' and 'precision viticulture' and, in the case of these leaders, perhaps they are approaching that point.

A number of service providers offer various technologies and data acquisition, management, processing and viewing packages using geographical information systems (GIS). Within the range of PV tools currently available for the assessment of variation in vine performance, remote sensing of vine vigour and yield monitoring are the most readily available. Remote sensing using light aircraft is generally the 'entry point' for new adopters due to the potential high rate of return on investment; such imagery is available for about \$30-37 per hectare. Digital multi-spectral imagery (DMSI) is being acquired and used in vineyards for a range of applications including selective harvesting to improve the retail value of wine, the differential application of inputs to reduce vineyard heterogeneity and to reduce/maintain costs of production, the sampling of vine and soil

¹Viticulture consultant, AHA Viticulture/Precision Viticulture Australia, Dunsborough, Western Australia. Email: tony@ahaviticulture.com.au

²Principal Research Scientist, CSIRO Sustainable Ecosystems, Adelaide, South Australia. Email: rob.bramley@csiro.au

BUY AUSTRALIAN MADE

Mildura Victoria Australia www.spagnolo.com.au phone: (03) 5021 1933 email: sales@spagnolo.com.au



SG PRUNER

- Full electric over hydraulic controls from your tractor seat
- Totally adjustable for different cordon spacings
- Spur prunes between vine cordons
- Prunes single cordon in VSP trellise
- SG Pruner patent app no. AUS 780431 USA 652337



HEAVY DUTY TOOL BOXES

- Custom made
- Fully welded heavy duty
- Gas strut lid



VINEYARD & ORCHARD SWEEPERS

- Single and double sided
- Spring-loaded head enables it to glide around posts and vine trunks.
- Optional hydraulic lift, tilt and side shift cylinders.
- Ideal for cleaning up uneven terrain
- Durable powdercoated finish

phone: (03) 5021 193



Figure 1. Spatial information can now be displayed on yield monitoring consoles or ultra mobile personal computers (UMPC) to aid selective harvesting. As well as displaying information such as area covered, distance travelled and tonnage, different harvest zones can be displayed (i.e., the red, yellow and green areas) where the fruit is to be kept separate in the vineyard by changing receive bins.

related parameters to improve the accuracy in the measure of interest, and for vineyard design and field experimentation.

SpecTerra Services is a major company that provided DMSI and acquired data for 1800ha of vineyard in 2004. The area covered increased to 10,700ha in 2006 and then stabilised to between 7000-9000ha in subsequent years. The company also has airborne sensors available in Spain, France, Portugal, Argentina and Chile.

Given the low additional cost of yield monitoring over and above the cost of harvesting, there has been an increase in the number of contractors and winegrape producers that have installed yield monitors on their mechanical harvesters. Advanced Technology Viticulture has developed a weighing system that fits all harvesters and estimates that between 30 to 40 yield monitors currently get some use, with about 25 of these fully functional and being used regularly. The area of vineyard being mapped

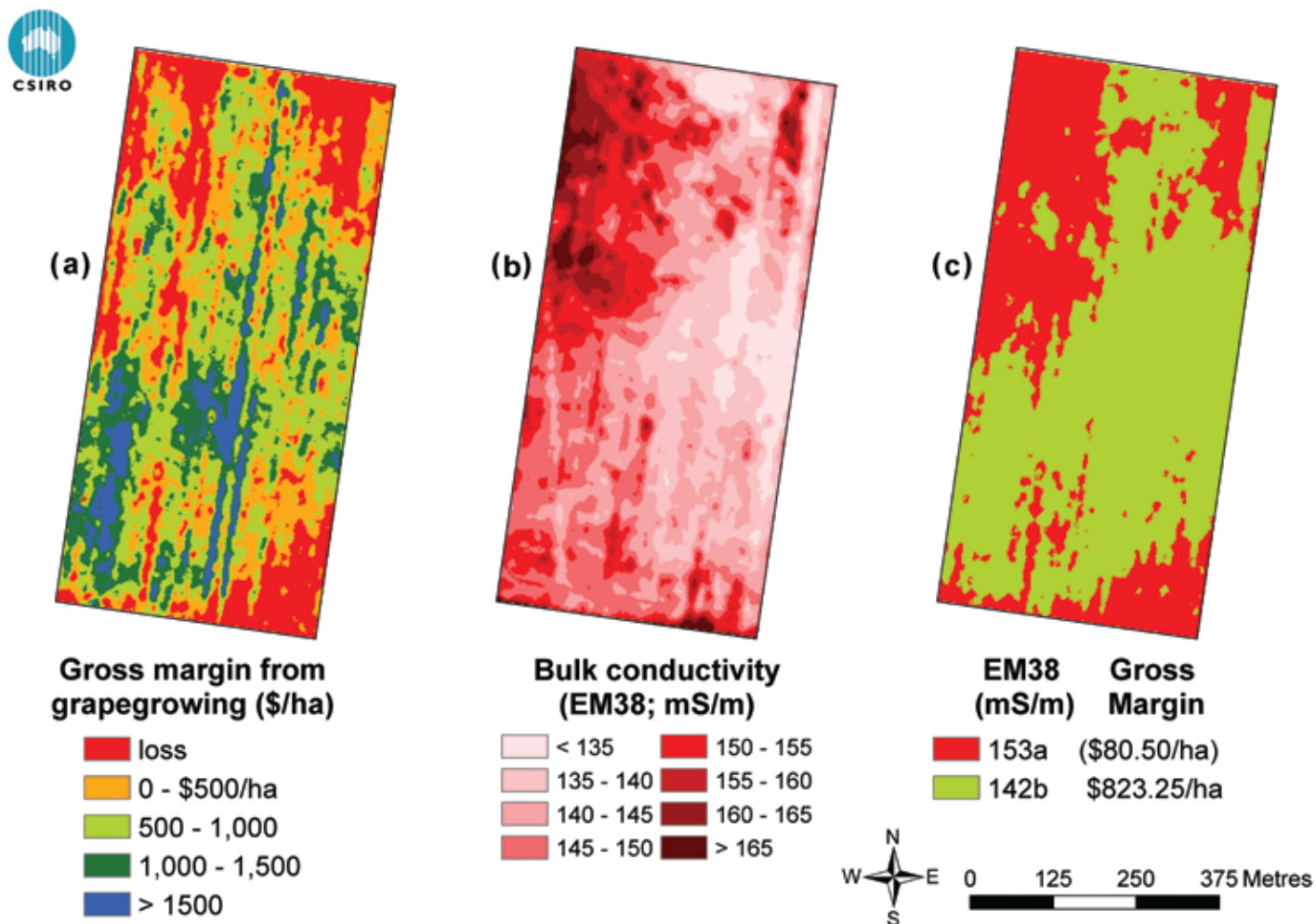


Figure 2. Variation in (a) gross margin obtained from producing Chardonnay, and (b) bulk electrical soil conductivity as determined using an EM38 sensor in a 33ha vineyard near Griffith, New South Wales. In (c), the map layers shown in (a) and (b) have been clustered together to identify two zones. The areas returning a loss are those with high conductivity suggesting that a soil constraint may be limiting productivity in these areas.

Table 1. Economic benefits of selective harvesting for grape production and/or wine production. Note that the benefits shown are based on the harvesting of fruit from different zones of the vineyard on the same day. Increased benefits are sometimes realised by harvesting zones on different days. Data of Bramley *et al.* (2005).

| Region | Variety | Income benefit (\$) - grape production | Income benefit (\$) - wine production |
|--------------------|--------------------|--|---------------------------------------|
| Clare Valley, SA | Riesling | 54,904 (+77.8%) | |
| Padthaway, SA | Shiraz | 4,657 (+3.2%) | 272,971 (+20.5%) |
| Margaret River, WA | Shiraz | 12,300 (+12.5%) | |
| Margaret River, WA | Cabernet Sauvignon | | 139,480 (+19.2%) |

has increased from about 850ha in 2004 to about 3000ha in 2009. In general, yield maps are being used in the vineyard in the same way that imagery is being applied. However, one of the main advantages that a yield map has over imagery, once it has been adjusted to match the tonnage recorded at the winery, is that it does not require ground truthing.

The acquisition of high resolution soil and elevation data is also becoming popular to help understand and better manage soil and topographical influences on existing and potential vine performance. The acquisition of such data is now at a spatial resolution and price that is often more cost-effective than using traditional manual methods. A range of proximal soil sensors are commercially available (e.g., electromagnetic induction via tools such as the EM38, gamma ray spectrometry and ground penetrating radar) which, when used in conjunction with a real-time kinematic global positioning system (RTKGPS), allow maps displaying changes in soil properties to be draped over three-dimensional digital elevation models (DEM) at scales that are relevant to vineyard managers. These data layers are being used for a range of applications including vineyard, irrigation and drainage design, soil amelioration, and the placement of vineyard infrastructure and equipment.

Applications in the vineyard

Harvesting

Selective sampling was one of the first applications of PV in Australian vineyards and, in the context of promoting uniformity in parcels of fruit delivered to wineries, continues to deliver significant commercial benefits. Selective harvesting is defined as the differential picking of grapes at harvest according to different yield and/or quality criteria with consignment to different product streams in order to exploit the observed variation in vineyard performance. Recently, there have been refinements in yield monitoring software. During vintage 2009 for example, operators of mechanical harvesters were able to view

pre-defined 'harvest zones' on the console, thereby negating the need for identification markers in the vineyard (Figure 1).

Numerous commercial examples of selective harvesting exist that demonstrate an increased profitability using this approach (Smart 2005; Proffitt *et al.* 2006). The economic benefits for four case studies are shown in Table 1.

Yield monitor data has been used in conjunction with knowledge of the costs of grape or wine production to construct gross margin maps (Bramley and Proffitt 1999; Bramley 2009). These are powerful and currently under-utilised tools for identifying and addressing poor and/or variable financial performance in vineyards.

Case Study 1

As part of a PV extension project involving a group of grapegrowers near Griffith in New South Wales, a 33ha block of Chardonnay was used to acquire yield monitor data at harvest. During the growing season, production costs were also recorded for this block. By integrating the yield and cost of production data, a map showing the gross margin for the vineyard block was produced (Figure 2a). Whilst the average cost of production (+/- \$15 per tonne) resulted in gross margins in the \$500-\$1000 per tonne range, the effective cost of production in areas returning a loss was more than \$45/t higher than the average for the block. Areas returning more than \$1500/t had effective costs of production that were more than \$45/t below the block average. The grower was particularly interested in addressing the areas of the vineyard that were operating at a loss or generating returns that were considerably less than what was required of the vineyard.

Figure 2b shows a map of apparent electrical conductivity for the same block obtained using an EM38 sensor. When the gross margin and EM38 maps are clustered together (Figure 2c), the poorly performing areas of the vineyard block appear to be those in which the values recorded by the EM38 are significantly higher ($p < 0.05$) than in the remainder of the block.

**When you need Reliability
Use RYSET Picking Snips.**



35mm Hardened Chrome Blade
(GT460) Straight Blade (GT470) Curved Blade



58mm Hardened Chrome Blade
(GT480) Straight Blade (GT480) Curved Blade



62mm Heavy Duty Picking Snip



Ryset Economy Grape Snip



Premium Japanese Chikamasa
58mm Hardened Carbon Steel Blade, Heavy Duty Handles Perfectly Balanced Spring



Premium Japanese Chikamasa
Hardened Serrated Blade for Wire Cutting



**Also ring about our large range of
15, 20, 25 litre Picking Buckets**

www.ryset.com

RYSET
AUSTRALIA

**TOOLS FOR AUSTRALIAN
HORTICULTURE**

FOR YOUR LOCAL SUPPLIER

Ph: (03) 9457 2982 Email: info@ryset.com

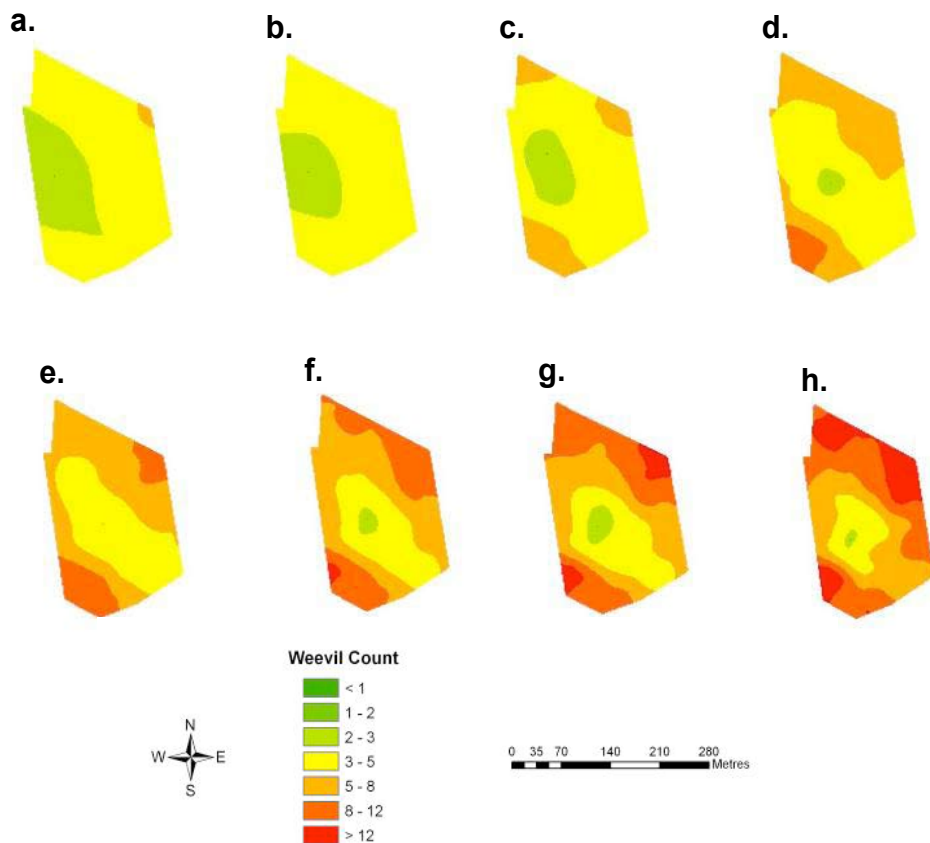


Figure 3. Monitoring the spatial distribution of garden weevil in a 4ha block of Chardonnay in Margaret River, Western Australia. Changes in weevil numbers monitored weekly on vines between December 2005 and March 2006 are shown in maps (a) to (h) which correspond to fortnightly recordings. Unpublished data of Mark Gibberd, Curtin University of Technology, Margaret River, Dean Lanyon, Arris, Adelaide, and Stewart Learmonth, Department of Agriculture and Food WA, Manjimup.

Although this does not prove that a soil constraint is limiting production, it does suggest that an examination of vineyard soil properties is warranted and that a targeted soil amelioration program may be economically beneficial.

Targeted management

Selective harvesting may not always be the appropriate response to vineyard variability. For example, the available product/brand line might be limited or there may be logistical winery constraints such as processing and storage capacity. The opportunity therefore exists for viticultural inputs (e.g., irrigation water, fertilisers, soil amendments, sprays and labour) to be applied differentially (or 'targeted') to particular areas across vineyard blocks in order to improve the overall uniformity in crop yield and/or quality.

Broadacre cereal farmers have predominantly used high resolution spatial information in this way by means of variable rate application (VRA) technology. However, managing inputs has not been the major objective for winegrape producers who have generally concentrated on managing outputs (i.e., yield and quality). This is beginning to change due to the

development of new technology, increasing production costs and environmental constraints such as the lack of irrigation water. Two examples of targeted management are described in Proffitt *et al.* (2006). The first involves the differential application of irrigation water to manage vine vigour as a means of improving the overall quality of fruit across a vineyard block and reducing canopy management costs. The second involves the setting of pruning wages based on vine vigour in order to reduce costs and to improve staff morale. Input costs were estimated to be reduced by \$700/ha in the first example and by \$290/ha in the second. Both studies used airborne imagery to delineate zones of so-called 'high', 'medium' and 'low' vine vigour. Other examples of targeted management have recently been observed in vineyards, including the differential removal of vine leaves (leaf plucking) by hand to increase fruit exposure, and the differential application of fertiliser, lime and mulch by increasing or decreasing tractor speed. In all these cases, management zones have either been identified on the ground using markers or on-the-go by using maps that have been imported on to personal digital assistants (PDA) or UMPCs attached to GPS equipment.

Sampling and monitoring

Sampling and monitoring are key activities that are required in vineyards for much of the year and include crop yield forecasting, fruit maturity assessment, tissue and soil collection for nutritional analyses, fruitfulness assessment via bud dissection, and pest, disease and vine health assessment. It is critical that the sampling methodology employed for each of these activities is representative of the whole vineyard block because spatial variation in vine and/or soil characteristics may introduce a bias in the results. The traditional approach has been to target vines or areas within a block using a random sampling strategy and, in some cases, the number of samples taken is determined statistically in an attempt to achieve an acceptable degree of error.

The commercial availability of high resolution spatial data allows alternative approaches to be used. One example involving crop forecasting is described in Proffitt *et al.* (2006) in which a vineyard was divided into sampling zones based on vine vigour derived from airborne imagery. This strategy realised a 5% improvement in crop estimate compared with the traditional random sampling approach. However, more research is required to determine how PV technologies can improve crop forecasting since this is a topic of national importance (Hall and Hardie 2008). Using other sampling strategies based on spatial information, winemakers have observed improvements in fruit maturity assessments; an example is documented in Bramley (2001). Spatial information is also being used to improve sampling strategies when selecting vine material for bud fruitfulness assessment (bud dissection analyses). This is considered to be critical since the relationship between potential fruitfulness and actual fruitfulness recorded in the vineyard varies according to vine vigour (Wisdom *et al.*, 2004).

Pest, disease and vine health monitoring is an important activity that is required to be undertaken in the vineyard for much of the year. Once again, high resolution spatial information is being used to improve surveillance strategies. An example of this is the work that continues to be undertaken in monitoring and detecting phylloxera (*Daktalosiphaira vitifoliae*) (Edwards *et al.* 2004; Renzullo *et al.* 2004). Similarly, the

use of spatial data is proving to be valuable for research work investigating relationships between pests and their environment.

Case Study 2

The garden weevil (*Phlyctinus callosus*) is a vineyard pest that is a problem in the south western region of Western Australia. Up to 70% reductions in crop yield have been reported as a result of their nocturnal feeding habits. In addition, they are responsible for increasing botrytis infection through damage to individual berries.

Anecdotal evidence suggests that there is a relationship between soil type, ground cover species in the vineyard and the occurrence of high populations of garden weevil. A 4ha block of Chardonnay in the Margaret River region has been established as part of a research project aimed at addressing this issue. Across the block, 192 vines were selected and geo-referenced using a differential GPS. During the 2005-06 season, each vine was fitted with a waxed, cardboard weevil trap around the trunk, and the number of weevils caught in each trap were counted weekly over an 11-week period starting in December 2005 and finishing in March 2006.

Changes in the weevil population across the vineyard during the monitoring period are shown in Figure 3 (see page 34). Weevil numbers were low in December 2005 with little variation across the vineyard block (Figures 3a, 3b). However, the population started to increase in January, particularly towards the perimeter of the block (Figures 3c, 3d). This pattern continued during February (Figures 3e, 3f) and March (Figures 3g, 3h) suggesting that the pest was either moving into the vineyard from outside or that the pest preferred some aspect of the environment (e.g., plant species, soil type) closer to the edges of the vineyard block. The spatial distribution of plant species and soil properties across the vineyard are currently being acquired and will be correlated with weevil numbers, vine damage, crop yield and indices of fruit quality using clustering techniques and GIS.

Vineyard design

Variation in soil and topography is likely to have a substantial impact on variation in vineyard performance. High resolution soil maps generated through the use of proximal sensors are proving to be useful in providing insights into the spatial variation in soil properties at scales that are relevant to those responsible for designing new vineyards or re-developing older vineyards. The information is frequently being used as an alternative, usually cost-effective, methodology to position inspection pits compared with the standard, lower resolution 75m grid approach. Whilst this approach does not replace the need for skilled soil surveyors, it does provide a means of assisting them to target their efforts (Bramley *et al.* 2009). Accurate boundaries delineating changes in soil properties, coupled with topographical information, assist with matching grape varieties to desirable soil types, designing irrigation and drainage systems, and locating infrastructure (e.g., roads, dams, frost fans and buildings) and instrumentation (e.g., weather stations and soil moisture/salinity monitoring devices).

Case Study 3

The management team at Penfold's Robe vineyard has been using high resolution spatial data in a variety of ways over the past six

GRAPE HARVEST TIPPING TRAILERS

3 & 4 TONNE CAPACITY

**NOW
AVAILABLE**

**Optional
DIGITAL WEIGHING SYSTEM**

*The Ultimate in bulk handling of machine harvest
or handpicked grapes in the minimum of your time,
your fruit is delivered fresh to the winery,
in optimum condition the combination
of quality materials and experience in manufacture
all add up to a product to best serve your needs*

**ORDER
NOW**



- Now available in 3 tonne and 4 tonne capacity
- Outstanding features include:
 - Sturdy Duragal chassis frame
 - All other steel grit blasted prior to sealing and coating.
 - 2 mm stainless steel hopper with extension wings
 - Heavy fabricated boxed lifting arms with 32 mm greasable pins
 - Narrow 1610 mm width on 3 tonne unit ideal for narrow rows
 - Narrow 2050 mm width on 4 tonne unit ideal for narrow rows
 - Will tip load at any level up to 3m in height.

SAFETY FEATURES:

- Level Indicator
- Swivel drawbar
- Easy to operate from tractor's hydraulics.
- Safety restricter valves fitted.



WE ALSO MANUFACTURE:

- Deep-placement Fertilizer Rippers
- Undervine Hydraulic Weeders
- Pneumatic Pruners (Self Propelled)
- Bin Trailers

**SINCE
1960**

Serving the industry with quality products for Australian vineyards.

For further information contact



17 Magnolia Street TANUNDA SA 5352

Phone (08) 8563 2390 Mobile 0417 837 359

Fax: (08) 8563 3649 Email: fabroweld@bigpond.com

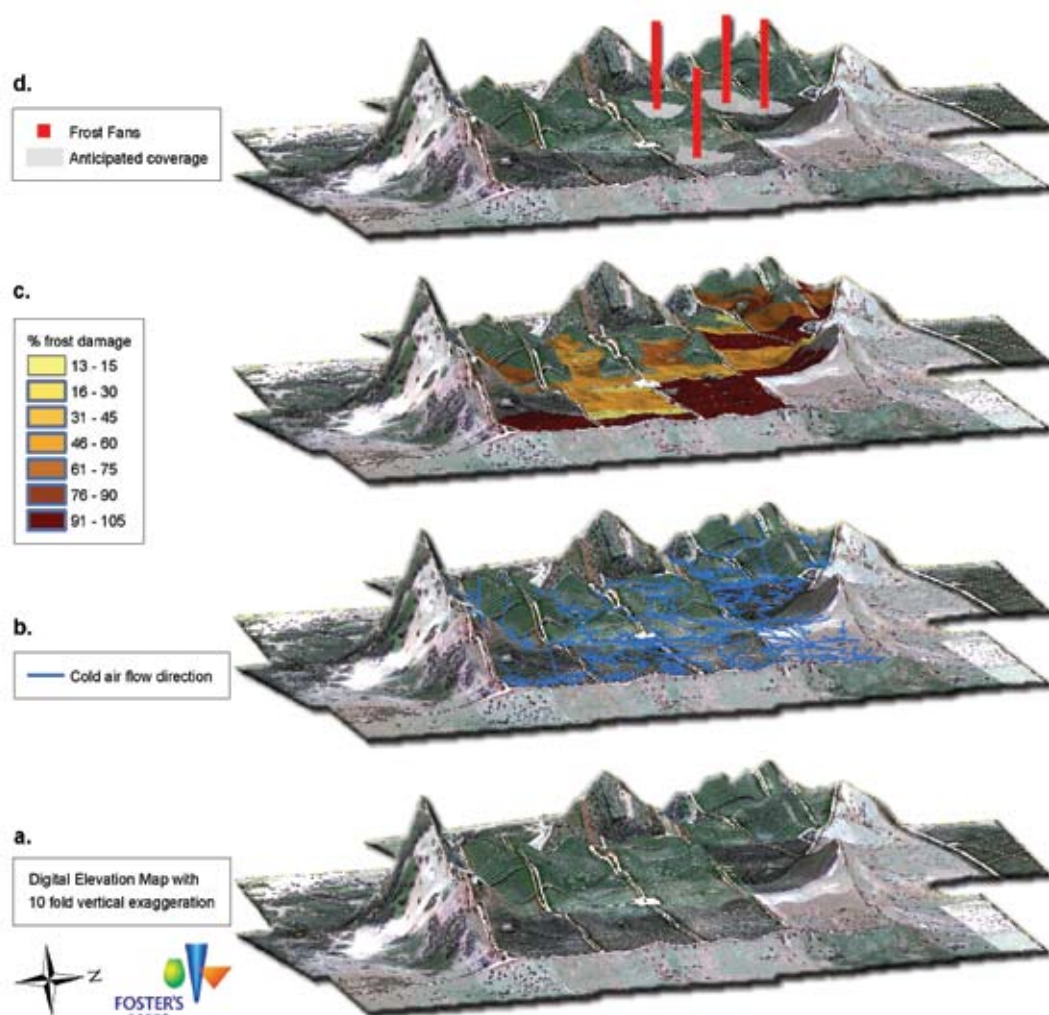


Figure 4. Using spatial information to locate frost fans at Penfold's Robe vineyard in South Australia. Unpublished data of Richard Hamilton and Suzanne McLoughlin, Foster's Group.

BIRD CHASER

SAVES YOUR CROPS

Tested by
Primary Industries
& Resource SA

- Cost effective
- Environmentally friendly
- Easy to erect
- Eliminates
- Reduces noise pollution
- No more killing birds
- No power required
- Designed for Australian conditions
- Long life performance
- Saves your crops

BUY 1 GET 1 FREE!

ADELAIDE PLANT GROWERS
594 States Rd., Onkaparinga Hills
Ph: (08) 8186 0983 Fax: (08) 8384 1606
Ph: (08) 8384 7176 Mob: 0438 616 224
Email: adelplant@chariot.net.au

years to fine-tune vineyard practices. The vineyard is located close to the coastal township of Robe, about 320km south-east of Adelaide, in South Australia. Frost damage to vines and the subsequent loss of fruit has become an increasing problem in recent years. This case study demonstrates the use of spatial information to locate frost fans as a strategy to reduce the risk of crop loss in high value blocks. The basis of the capital cost evaluation was an expectation of two major and two minor frost events over a 10-year period resulting in 80% and 20% crop damage, respectively.

An RTKGPS was used to map elevation and the acquired data then used to construct a DEM (Figure 4a). Windbreak positions and areas exhibiting different degrees of frost damage to vines in the previous year were geo-referenced using a GPS. Loss of fruit and the degree of damage as a result of frost events was determined in the vineyard by undertaking intensive counts in each affected block. This data, together with the predicted air movement across the vineyard, were superimposed over the DEM (Figures 4b, 4c). Air movement was derived using GIS routines that predict water flow across the landscape and for the purposes of this work it was assumed that cold airflow dynamics are similar to fluid dynamics. An examination of Figures 4b, 4c identified several tree lines that were required to be removed to enhance the drainage of cold air. Fruit value was determined from grape purchase costs and estimated crop yields.

When coupled with the manufacturer's recommendation that a single fan will cover approximately 6ha, the spatial data enabled identification of the optimum sites for the placement of four diesel-powered frost fans (Figure 4d). The location of each fan was based on a number of factors including the incidence and severity of previous crop damage, the value of fruit in each

block and windbreak locations in relation to airflow movement and susceptibility to frost damage.

The total cost of the project was \$250,000 which included the purchase and installation of the frost fans in 2007, the purchase of a diesel tank and trailer, the construction of bunding, the modification of some trellis, and the removal of tree lines. Within 10 days of the fans being installed, a frost event occurred. An 11ha block of high value Sauvignon Blanc fruit, which was destroyed by frost in the spring of 2006, was protected and only received minimal damage on the fringes of the frost fan protected areas during the 2007 frost event. Indeed, the amount of fruit saved in 2007 across all protected blocks was estimated to be of a value similar to the total cost of the project. The frost fans, therefore, paid for themselves in the first year and consequently, plans to purchase an additional four frost fans were implemented.

Field experimentation

The marked spatial variability that has been shown to exist in vineyards presents problems for researchers and winegrape producers wishing to conduct viticultural field experiments. It also presents issues for vineyard managers faced with the problem of deciding how their management practices should be targeted within variable blocks. The classical approach to viticultural experimentation is to use randomised designs that attempt to accommodate the effect of underlying spatial variation by randomly allocating treatments to a number of plots. However, the merits of this approach are questionable given that the management units to which the results will be applied are likely to be variable. The commercial availability of high resolution spatial data, coupled with geostatistical methods, has led to new experimental approaches being utilised.

Case Study 4

Conducting experiments over whole blocks is an alternative approach to the plot-based one and several examples have been existence for a number of years in vineyards located in South Australia. A number of viticultural management strategies have been investigated including a range of mid-row and canopy management techniques (Bramley and Lanyon 2005; Panten *et al.* 2008; Panten *et al.* 2009) and the treatment of powdery mildew (Bramley *et al.* 2007).

Figure 5 (see page 38) illustrates an example in which the merits of a range of vineyard floor treatments for enhancing vine vigour were examined in an organic vineyard in the Clare Valley, South Australia. The vineyard manager was concerned that vine performance in this block was being constrained by inadequate nutrition and/or competition for soil water from the inter-row sward. A highly replicated design was implemented by vineyard staff with the manager being very positive about the opportunity it afforded him to see how responses to the treatments varied across the vineyard block. Whilst the analysis of such experiments is complex, Figure 5 shows that it promotes robust evaluation of differences between possible management strategies over the entire area in which they may be applied. In contrast to the classical approach which seeks to determine whether one treatment is better than another treatment, the whole-of-block approach recognises

that a particular treatment may deliver benefits in some parts of the block whilst another treatment may be more effective in other areas. If these treatment effects can be associated with a key variable (e.g., clay content, soil moisture), this approach also increases the opportunity for extrapolating the results to other vineyard blocks.

Conclusions

Through the acquisition of high resolution spatial data, Australian grape and wine producers are recognising that the inherent variability of land (predominantly topography and soil properties) results in variation in its potential productivity (i.e., crop yield and fruit quality). Its subsequent use in the vineyard has much to offer as a way forward to increasing knowledge about the integration of soil and land attributes on vines and seasonal impacts on grape and wine production. This knowledge, when coupled with appropriate experimental approaches, is helping to improve our understanding about a range of vineyard issues which, in turn, is helping to fine-tune management practices and business models as well as improving our ability to make proactive decisions.

Potential adopters of PV and spatial information, whether for production purposes or as a research tool, should be aware that all they need to start with is a single layer of information and to begin thinking about the meaning of that information and its relationship to variability in the vineyard.

Phosyn Analytical

...turning soil and plant analysis

Fe Zn B Ca Co Cu NO₃-N Cl K Mg Mn Mo N Na P S

...into results within 5 days

Ph: 07 5568 8700
Megalab™ www.yaraphosyn.com ASPAC

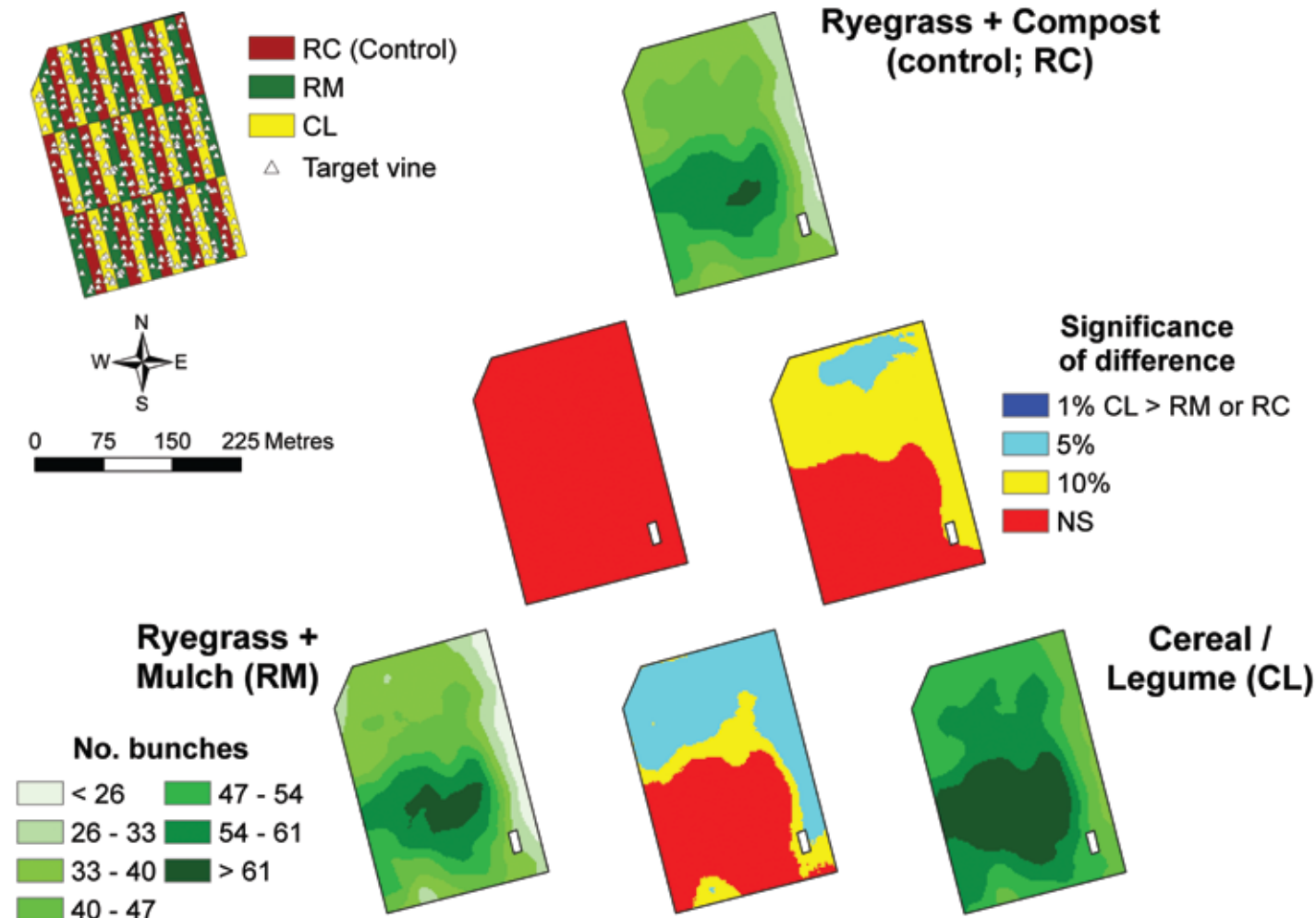


Figure 5. A whole-of-block experiment in which a replicated design (top left) was applied in 2004 over a 4.8ha block of Merlot to assess the merits of three mid-row management strategies (RC, ryegrass + compost; RM, ryegrass + mulch; CL, cereal + legume). Treatment responses are shown in terms of bunch number per metre of row on 378 target vines for vintage 2006. Significance of difference between the treatments is shown in maps positioned between each treatment map. Data of Panten *et al.* (2009).

Acknowledgements

We are grateful to the people who have allowed us to use their data for this article. In particular, we would like to acknowledge Mark Gibberd, Curtin University of Technology, Margaret River; Dean Lanyon, Arris, Adelaide; and Stewart Learmonth, Department of Agriculture and Food, Western Australia (Case Study 2); Richard Hamilton and Suzanne McLoughlin, Foster's Group (Case Study 3), and Kerstin Panten, JKI Institute for Crop and Soil Science, Braunschweig, Germany (Case Study 4).

References

- Bramley, R.G.V. (2001) Progress in the development of precision viticulture – variation in yield, quality and soil in contrasting Australian vineyards. In: Currie, L.D. and Loganathan, P. (Eds.). Precision tools for improving land management. Occasional report No. 14. Fertiliser and Lime Research Centre, Massey University, Palmerston North, New Zealand.
- Bramley, R.G.V. (2009) Precision viticulture: Managing vineyard variability for improved quality outcomes. In: Reynolds, A.G. (Ed.). Understanding and managing wine quality and safety. Woodhead Publishing. In press.
- Bramley, R.G.V. and Proffitt, A.P.B. (1999) Managing variability in viticultural production. *Australian and New Zealand Grapegrower and Winemaker* 427: 11-16.
- Bramley, R.G.V. and Lanyon, D.M. (2005) A new approach to vineyard experimentation – where and how? In: Blair, R.J., Williams, P.J. and Pretorius, I.S. (Eds.). Proceedings of the 12th Australian Wine Industry Technical Conference, Adelaide. pp. 241.

SA Crate
Hire and Sales of Plastic Crates and Bins

Unit 3
 43-55 Produce Lane
 Pooraka SA 5095
 Tel: 08-8349 4556
 Fax: 08-8349 5316

No More Bending

Rigid Construction.
Easy Stacking.
No Need to Handle Produce/ Product.
Rotates Through 360° with Tipping Bar Fitted.
Many Applications.

Materials Handling and Storage
Your Need Our Solution

Bramley, R.G.V.; Proffitt, A.P.B.; Hinze, C.J.; Pearce, B. and Hamilton, R.P. (2005) Generating benefits from precision viticulture through selective harvesting. In: Stafford, J.V. (Ed.). Proceedings of the 5th European Conference on Precision Agriculture. Wageningen Academic Publishers, The Netherlands. pp. 891-898.

Bramley, R.G.V.; Evans, K.J.; Gobbett, D.L.; Panten, K. and Scott, E.S. (2007) Optimising strategies for control of powdery mildew through whole-of-block experimentation. In: Blair, R.J., Williams, P.J. and Pretorius, I.S. (Eds.). Proceedings of the 13th Australian Wine Industry Technical Conference, Adelaide. pp. 317-318.

Bramley, R.; Gobbett, D. and Hinze, C. (2009) Next steps in Precision Viticulture – spatial data for improved design of vineyard re-planting. Final Report on Project No. CSL08/01 to the Grape and Wine Research and Development Corporation. CSIRO/GWRDC, Adelaide.

Edwards, J., Lewis, M., Powell, K., Hackworth, P. and Lamb, D. (2004) Identification of phylloxera from high resolution infrared aerial imagery; a comparative study between airborne imagery types. *Australian and New Zealand Grapegrower and Winemaker* 488: 51-54.

Hall, A. and Hardie, J. (2008) Developing precision technologies to improve grape yield forecasting. *Australian and New Zealand Grapegrower and Winemaker* 538: 20-24.

Panten, K.; Bramley, R.; Bishop, T. and Gobbett, G. (2008) Further developments with whole-of-block experimentation. *Australian and New Zealand Grapegrower and Winemaker* 533a: 42-46.

Panten, K.; Bramley, R.G.V.; Lark, R.M. and Bishop, T.F.A. (2009) Enhancing the value of field experimentation through whole-of-block design. *Precision Agriculture*. In press.

Proffitt, T.; Bramley, R.; Lamb, D. and Winter E. (2006) Precision Viticulture – a new era in vineyard management and wine production. *Winetitles*, Adelaide.

Renzullo, L.; Held, A.; Powell, K. and Blanchfield, A. (2004) Remote sensing phylloxera infestation: current capabilities and future possibilities for early detection. *Australian and New Zealand Grapegrower and Winemaker* 485a: 126-130.

Smart, R. (2005) Tamar Ridge takes a bird's eye view for harvest planning. *Australian and New Zealand Wine Industry Journal* 20(5): 9-11, 102.

Wisdom, T.; Bennett, J. and Clark, N. (2004) Bud dissections: Crop estimation and achieving target yields in the Margaret River wine region. *Australian and New Zealand Grapegrower and Winemaker* 485a: 60-62.



Australian Viticulture Subscription Form



Australian Viticulture is the only magazine dedicated to the business of growing grapes in Australia. From the latest research extension and financial advice, to special reports from all Australia's grapegrowing regions, to chemical usage guides and tractor and equipment reviews, *Australian Viticulture* gives growers an insight into cutting-edge viticulture. **PUBLISHED BI-MONTHLY**



Please register my subscription to *Australian Viticulture* beginning with ☐ the next issue, or ☐ Vol _____ No _____

Rates (tick as required)

| | | |
|-------------------------------------|---|---|
| Australia | <input type="checkbox"/> \$66.00 one year (6 issues) | <input type="checkbox"/> \$121.00 two years (12 issues) |
| Student (Australian residents only) | <input type="checkbox"/> \$55.00 one year (6 issues) | |
| New Zealand | <input type="checkbox"/> \$70.00 one year (6 issues) | <input type="checkbox"/> \$130.00 two years (12 issues) |
| Overseas (Economy Air Mail) | <input type="checkbox"/> \$100.00 one year (6 issues) | <input type="checkbox"/> \$190.00 two years (12 issues) |

Prices inc GST

☐ Cheque enclosed (Australian dollars payable on an Australian bank) **or** Charge my ☐ Visa ☐ Mastercard (no other cards accepted)

Number Card Verify Code* Expiry _____

Name _____ Company _____

Address _____ Postcode _____

Email _____ Tel _____ Fax _____

Signature _____ Date _____

Subscribing to our print journals entitles you to free registration of our e-newsletter **Daily Wine News**.

For our records, please indicate your involvement with the wine industry

☐ Winemaking
 ☐ Grapegrowing
 ☐ Administration
 ☐ Cellar door
 ☐ Supply
 ☐ Distribution
☐ Retailing
 ☐ Wine marketing
 ☐ Education
 ☐ Student
 ☐ Other _____

Return with payment to: **WINETITLES PTY LTD**, PO Box 1006, Prospect East, South Australia 5082 *The Card Verify Code is the last three digits on the back of your card.

[w] winetitles

LEADING PUBLISHER TO THE WINE INDUSTRY

Winetitles Pty Ltd ABN 57 109 570 336

Ph +618 8369 9500 Fax +618 8369 9501

Email subs@winetitles.com.au Website www.winetitles.com.au/av/

630 Regency Road, Broadview, South Australia 5083 PO Box 1006, Prospect East, South Australia 5082



Visit www.winebiz.com.au to view our full range of publications · Gift vouchers are available for purchase by calling (08) 8369 9500