National Wine and Grape Industry Centre Report for Australian & New Zealand Grapegrower &
Winemaker
Developing precision technologies to improve grape yield forecasting

Andrew Hall¹,² and Jim Hardie¹

¹National Wine and Grape Industry Centre, Charles Sturt University, Locked Bag 588, Wagga Wagga, NSW 2678, Australia.
²School of Environmental Sciences, Charles Sturt University, PO Box 789, Albury, NSW 2640, Australia.

Introduction

This article provides an overview of the potential use of precision technologies to aid grape yield forecasting and describes progress at the National Wine and Grape Industry Centre toward improved techniques for estimating grape yields at the vineyard scale.

Background

The average absolute difference between grower estimates of seasonal winegrape production and winery deliveries has been reported to be 33% (Dunn and Martin 2003). The impact of this mismatch is high, not only for wineries, where preparations for the annual vintage and harvest logistics involve significant expenditure, but also for suppliers trying to match inventory to demand and for seasonal grape price negotiations that generally rely on accurate supply forecasts. One estimate puts the collective costs of uncertainty in grape supply volume to Australian wineries at $200m each year. Clearly, greater levels of accuracy in forecasting seasonal grapevine yield will be of considerable benefit to wine producers and other sectors of the industry.

National and regional grape yield forecasts are generally based on the area of bearing

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vines together with an estimate of seasonal factors on grape development. Improving forecast accuracy using that approach seems achievable but only with better information on the impacts of climate on grape development.

Individual vineyard yield estimates presently rely on random and/or stratified sampling of vines and their developing grape bunches between budburst and harvest (May 2004; Neja et al. 1977; Ollat et al. 2002; Smithyman et al. 1998). The average of the yield-indicating parameters, namely, bunch number and bunch weight per vine, of the sample set is then multiplied by the number of vines in the block to produce the forecast for the whole block. Dunn and Martin (2003) found that for forecasts made in January, the average absolute difference could be reduced to 20% and potentially to 10-15% by using improved protocols. However, they noted resistance to their current improvements due to the cost and effort required in the vineyard. These impediments may be overcome by reducing the number of sampled vines by segregating the vine population into zones of known variation using precision technologies such as electromagnetic (EM) surveying of soil conditions, aerial remote sensing of vine canopies or harvest yield monitoring, and, at least for sampling after fruit set, by substituting the total fruit load of each sample vine for the sub-sampling of the developing crop of the sample vine.

To further increase accuracy in yield forecasts we are attempting to relate vine canopy growth to yield using canopy data of whole vineyard management blocks. Previous research by our group (Hall 2003; Hall et al. 2008) and others (Proffitt and Malcolm 2005) indicated that canopy growth rates and canopy size and density at particular phenological stages may be linked to yield, not just in the current season but also in subsequent seasons. In order to make accurate inferences about yield in this way, canopy characteristics of whole vineyard blocks are required. Remote sensing offers a rapid and cost-effective method for providing the large amount of vine growth information required. Alternatively, recent progress toward regular on-ground imaging of vine canopies with on-ground vineyard implement-mounted imagers may provide a more accessible alternative to airborne sensing.

In other words, with detailed spatial knowledge of the whole block, yield forecasting can be improved in two ways: (1) the sample grapevines can be selected so as to best
represent variability in yield within the block and (2) the yield of each individual grapevine in the vineyard block may be estimable based on the relationship between canopy and yield component parameters of the sample vines.

**Forecasts Based on Improved Sampling Alone**

With knowledge of the spatial variability, greater efficiencies in selecting sample locations in the vineyard can be achieved. Vine yield estimated from zones determined using canopy size from remotely sensed imagery has been shown to produce a more accurate estimate than a simple random sample (Proffitt and Malcolm 2005). Rather than allocating the number of samples in proportion to the zone area, knowledge of variability in a parameter related to yield within each zone, such as canopy size, or soil type, allows for the determination of the ideal number of samples to be taken from each zone and their location. After all, if there is little variability in the block, only a few locations need to be sampled in order to characterise the vineyard. We are using both aerial remote sensing of grapevine canopies and EM soil survey to confirm and compare their benefits in the Hunter Valley and the Riverina. At the Hunter Valley site, grapevine sample locations were determined using a horizontal dipole EM-38 soil electrical conductivity survey. Three zones have been identified using a cluster analysis algorithm (Figure 1). Randomly-selected vines in each of these zones are now been monitored in experiments designed to test the value of this approach for forecasting yield.

**Forecasting Yield from Grapevine Canopy Growth**

The complex relationship between canopy characteristics and yield is a major theme of investigation within the project. The impetus for our approach came from the observation that there was a particularly strong negative correlation between canopy size at flowering and yield in the following season (Hall 2003; Hall et al. 2008).

Canopy-related mechanisms affecting fruit development are likely to span the entire reproductive cycle of two years (see Watt et al. 2008). Successful development of canopy growth as a reliable indicator of yield, both within the current and following seasons, will require better understanding of the positive and negative relationships
between canopy growth and yield. Canopy size generally indicates the photosynthetic capacity of a vine and its ability to bear fruit. However, the published literature already provides a strong indication that other more specific relationships exist. Remotely sensed imagery of grapevine canopy may indicate future grape production through the following mechanisms.

Canopy Size and the Current Season’s Crop

• The poor light penetration associated with dense foliar canopies has a generally negative effect on bunch development, including the survival of flower clusters, fruit set, berry size and bunch size thus reducing the crop in the current season (Smart 1985).

• Shoot growth rate, and hence canopy size, is inversely related to the current season’s crop load (Hardie and Martin 2000).

Canopy Size and the Following Season’s Crop

• Canopy size and density is generally inversely related to light penetration and consequently, the initiation of the fruit bud primordia that become the following season’s crop (May 2004; Neja et al. 1977; Ollat et al. 2002; Smithyman et al. 1998).

• Canopy growth rate is positively related to the carbohydrate status of the vine and may reflect potential development of fruit bud primordia in the season of initiation (May 2004; Neja et al. 1977; Ollat et al. 2002; Smithyman et al. 1998).

Along with detailed information being collected for the sample grapevines, canopy information collected individually for each vine in a block is central to the project. This information is being derived from airborne remotely sensed colour-infrared images with a spatial resolution (pixel size) of about 0.5 m. Using a geographic information system (GIS) as well as computer programs previously developed at the NWGIC, imagery is being automatically processed to provide quantitative canopy descriptors at the individual grapevine scale (Figure 2). Quantitative descriptors of canopy size and density at different phenological stages as well as the rates of change in canopy are being added to databases containing information on every vine in each trial vineyard. Time series of canopy information about the vineyard block is being used to identify and explain canopy-yield relationships. Using simple models derived from the yield
data and the remotely sensed data of the sample vines, various yield estimates of the whole blocks are produced for further validation.

**Potentially Adding Value to Aerial Remote Sensing**

Remotely sensed vineyard imagery can be used to quantify the variability characteristics in the leaf canopy of entire vineyard blocks down to the individual vine scale (e.g. Hall et al. 2003). This technology is also being used increasingly in large vineyards to forecast spatial differences in grape composition and manage the quality of the vintage. The ability to identify yield variation and forecast yield in subsequent seasons will add considerable value to remotely sensed images of vineyards.

**Project Outputs and Outcomes**

Information resulting from this project is being used to guide the development of more accurate and/or cost effective protocols for grape yield forecasting. We envisage a much closer alignment of grape supply with expectations resulting in significant direct financial savings for wine producers, wine marketers, industry suppliers and others through savings in the costs associated with inaccurate forecasting of seasonal grapevine yields.

Further inquiries concerning this work are welcomed and should be directed to the project leader, Dr Andrew Hall (ahall@csu.edu.au), or Leo Quirk (lquirk@dpi.nsw.gov.au) at the National Wine and Grape Industry Centre, Wagga Wagga, New South Wales.

**References**


Figure 1 Soil electrical conductivity of the Hunter Valley study block used to determine sample grapevines.
Figure 2 Close-up of remotely sensed NDVI image of vineyard with computer generated vine location information. Spectral reflectance information describing canopy characteristics of each individual vine can be rapidly extracted by a computer.