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Yield Forecasting

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Introduction

Within the context of increasing competition on the international wine market, there is an emerging recognition in the Australian Wine Industry that the quality and reliability of its grape supply must continue to improve during this decade and beyond. Substantial cost savings and revenue gains could be realised if the volume of grape intake did not fluctuate so much and the intrinsic composition of grapes could be more reliably matched to desired wine styles, which are shifting towards better-flavoured, premium and super-premium (particularly red) bottled wine. In pursuit of these aims, major growers and purchasers of grapes are stipulating that particular yield targets should be met, in the belief that this will improve and maintain wine quality. Accurate yield prediction is an essential first step to successful yield regulation. Consequently there is a strong demand for improved systems to forecast yield.

Here we

- Discuss how to aassess forecasting performance
- Describe sources of variation in yield
- Outline what is needed to make and evaluate best practice vineyard forecasts

Assessing performance

To judge the performance of a forecasting system fairly, one needs to assess it over many vineyard blocks and preferably over a number of seasons. Table 1 compares actual crop forecasts made in January with deliveries at harvest for four patches of wine grapes. For instance, the vineyard manager forecast a delivery of 20 tonnes from patch 1 but at harvest delivered 22 tonnes to the winery. This represented a difference of –2 tonnes or a 9% underestimate. If the % differences for the four forecasts in Table 1 are added together, underestimates cancel out overestimates and the total delivery forecast is only 5% higher than actual. If assessed over many forecasts the average % difference is a measure of the bias in the system, that is whether the system tends to overestimate or underestimate actual yield. However, fruit from each of the four patches of vines below may be destined for different products in the winery or each patch may even be a different variety. Therefore, the impact that a collection of forecasts has on a winery is better described by the average of the absolute differences between forecasts and deliveries irrespective of whether they are underestimates of overestimates (column 6). Average absolute difference is a measure of the precision of a forecasting system. In the example below average absolute difference equated to 31%.

Table 1. A comparison of four crop forecasts made by a vineyard manager in January with actual deliveries at harvest.

Patch	Forecast (tonnes)	Actual (tonnes)	Difference (tonnes)	% Difference	Absolute % Diff.
1	20	22	-2	-9	9
2	15	9	6	67	67
3	18	17	1	6	6
4	18	32	-14	-44	44
Mean				**5**	**31**

Measures of forecaster performance commonly used by industry are the mean difference and the mean absolute difference between forecast and actual production, expressed as a percentage of actual delivery. The absolute difference is probably the most useful single measure of performance, because under- and over-estimates do not cancel each other out and the total impact on the winery at a batch-by-batch level can be quantified. In 2000 and 2001 the mean absolute difference achieved by grape growers in Australia was around 30% (Dunn and Martin 2003), who suggested after analysis of many grower forecasts, that although growers have a good appreciation for average production over time they fail to adjust forecast as much as production actually deviates.

The task is made more difficult by large variations in yield from season to season. So where is all the variation coming from? When analysed across many varieties and sites, in a broad range of climates in Australia, bunches per vine was consistently the largest source of season-to-season yield variation, with berries per bunch being the 2nd most important component and berry weight being the least variable *(GWRDC 2001, e.g. Figure 1)*. So, if one is to expend one's resources wisely, it would make sense to focus first on getting an estimate of bunches per vine right. After that, it important to get accurate estimates of berries per bunch to further improve forecasts. However, not much is to be gained from spending a lot of time measuring weight per berry. It can probably be predicted adequately in most cases from historical measurements at harvest.

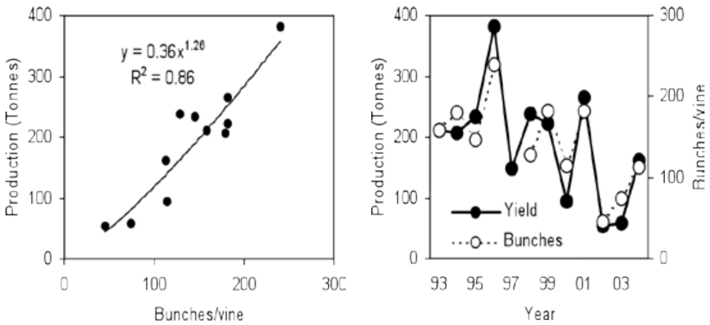

Figure 1. Yield and bunches per vine for a block of Cabernet Sauvignon at Coonawarra 12 seasons (left hand side). The relationship between bunches per vine and yield is depicted on the right hand side

Objective Forecasting Systems

Objective 'in-season' yield forecasting in the Australian Wine Industry began with Peter May in the 1970s. He understood that there were cardinal times during grapevine phenology when yield potential was set and advocated predicting yield by assessing crop components at these important phenological stages. He proposed a system based on (i) bunch counts made 4-6 weeks after budburst and (ii) berry counts made after fruit set (May 1972). Another forecast can be made close to harvest by destructively sampling vines or segments of vines. This forecast is important for intake scheduling. This system was improved by GWRDC, CSIRO and Victorian DPI research in the 1990s. If correct procedures are employed we suggest that for forecasts based on bunch counts in spring alone we can expect around +/- 20% (absolute average difference), for forecasts based on berry counts after set we can expects +/- 10-15% and for forecasts made prior to harvest based on harvesting segments we should expect +/- 5.This is not quite the 5% winemakers want but is better than the industry performance of around 30%.

Improved performance was due to

- incorporation of unbiased and representative sampling methods
- The determination of optimal sampling units for different yield components and viticultural systems.
- A flexible approach to sampling allowing forecasters to tailor sampling to vineyard block variability.
- Tighter definitions of yield components.
- The incorporation of important factors into forecasting formula (e.g. harvest efficiency).
- Software to facilitate simple, rapid random sampling, the calculation of variability and the assessment and subsequent improvement of forecasting performance.

These are discussed in more detail below.

Avoiding bias

When making any sort of forecast it is important to avoid any bias in sampling. It is important that each vine or vine space has an equal chance of being selected. This mean that weak and missing vine MUST be included. To ensure that each vine has an equal chance of being selected it is best to randomly select them before entering the block. This can be done using the spreadsheet or program referred to below. When there is no random selection of vines before entering a vineyard the situation depicted in Figure 2a can arise, where there is not adequate spatial coverage of the vineyard. Using a gridded system *(Figure 2b)* will result in better spatial coverage but should be avoided because of the risk it entails e.g. the shaded row may have a blocked irrigation dripper line or be situated on an old compacted road *(Figure 2b)*. Also, avoid random row, random vine selection techniques in all but regular blocks. In irregular blocks this will lead to clumping *(Figure 2c)*. Here we recommend 'stratified random' sampling where the block is split into split into equal sized segments and vines randomly selected within these *(Figure 2d)*. This process can be facilitated easily using the aforementioned spreadsheet or software.

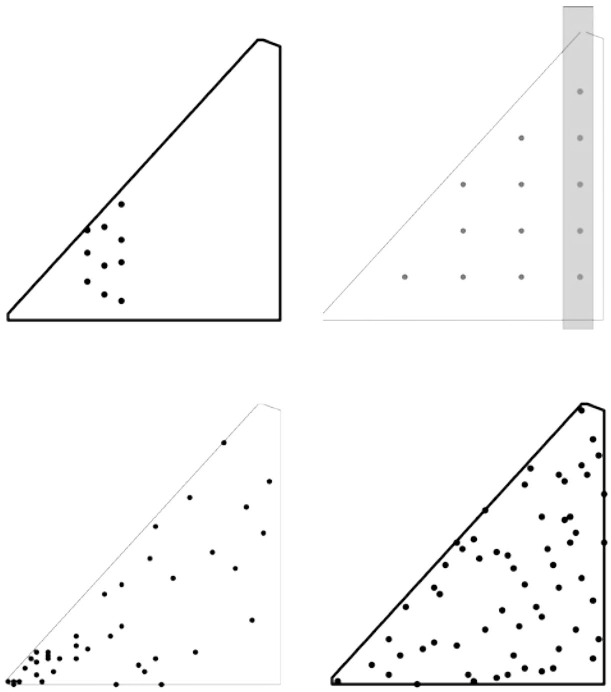

Figure 2. Human (a), gridded (b), random row – random vine (c) and stratified random sampling (d) in an irregular block. Note 60 vines have been selected in (c) and (d)

When sampling bunches, the same principal applies, i.e. each bunch must have an equal chance of being selected. It is important not to rule out any bunches from selection even if they have fewer than 10 berries or flowers. There is strong tendency for individuals to select larger than average bunches when asked to 'randomly' select bunches. Because of this and because most of the variation in bunch size is within vines rather then between vines we recommend visiting fewer vines and selecting multiple bunches from these vines. For instance, if 60 bunches are needed, visit 6 vines but collect 10 bunches from each vine. It is important to avoid bias in bunch sampling so we recommend randomly locating the first bunch and then taking it and the closest 9 bunches. This will force the selection of larger and smaller bunches.

Adequate sampling

Research has shown that many forecasts are inaccurate due to insufficient sampling (GWRDC 2001). The best sample size is the smallest number of measurements that you need to make to meet your tolerance of doubt for a given variation. It is affected by variation and how much doubt you are prepared to tolerate (Percentage error or PE in the formula)

n = t2 x (CV)2/(PE)2

If you are looking for a high degree of accuracy you cannot tolerate as much doubt. With a low tolerance of doubt such as 5% at low levels of variation (e.g. 20%) your best sample size would be approaching 60. However, at more usual levels of variation (e.g. 40%) you would need hundreds of measurements. If you relax your tolerance of doubt to around 15% the best sample sizes are lower. Once again the spreadsheet or program referred to will easily allow you to do this for you at any tolerance of doubt you select. However, typical optimal sample sizes are presented below for a Percentage Error of 15%.

Table 2. Typical optimal sample sizes (PE = 15%, t = 2) for various yield components

Yield Component	Sample Size
Bunches per vine (or segment)	30
Berries per bunch or bunch weight	60
Berry weight	100

Optimal sampling units

In many cases it is not always necessary to sample whole vines or panels for bunch number counts. Research has shown that for most vine management systems used in Australia a segment (or slice) of the vine will suffice *(Figure 3)*. This will reduce time spent counting and also reduce counting fatigue with smaller numbers being collected. Guidelines for optimal segment lengths are given in Table 3 below.

Table 3. Advised segment lengths for bunch counting a range of vine management 'types'

Situation	Advisable segment length (m)
Young vines	Whole vine
Cane-pruned vines with low bunch densities	0.9 – 1.2 m
Most spur and cane pruned vines	0.6 m
Minimally and mechanically pruned vines	0.3 m

However, if using segments it is important to ensure that they are also randomly placed to avoid the bias of always selecting higher or lower yielding sections of the vine. Again, the spreadsheet and software allow this to be easily done.

Figure 3. A segment is a slice of the vine. In the inset a segment 'ladder' is being used for bunch counting.

Correct formula

It is critically important to use the correct formula and this involves making sure that the block dimensions use in the forecast are correct and that the forecast accounts for harvest efficiency. Harvest efficiency reflects the ratio of the actual delivery of fruit to the winery to the amount of fruit in the block at harvest time. Weight can be lost during harvest and transport. These losses can be due to the stalks or rachis of the bunch and some bunches not making it into the harvesting bin in machine harvesting. Weight per bunch usually considers the weight of the rachis. Approximately 5% of bunch weight can be attributed to the rachis. Losses can be attributed to transfers to bins and evaporative or spillage losses in the vineyard and during transit. Typical harvest efficiency factors for different situations are given in Table 4 below.

Table 4. Typical harvest efficiency factors for a range of conditions.

Conditions	Harvest Efficiency Factor
Meticulous hand harvesting very close to the winery	1.00
Hand harvesting, with transfer to a distant winery	0.95
Very efficient machine harvesting with small transport losses	0.90
Inefficient machine harvesting with transport losses	0.85

Software

To promote rapid uptake of improved crop forecasting techniques an MS Excel based spreadsheet and user manual was developed (available from GWRDC). The spreadsheet was improved and further developed into software called grapeforecaster (**http://www.fairport.com.au/grapeforecaster/**). The benefits of the new software are large. Because it is based on a database it has improved storage potential and can be easily interrogated (e.g. for historical yield component data). It is flexible allowing growers to make at least five different types of forecasts and to amalgamate patches of similar vines across the vineyard or vineyards (e.g. all of their Chardonnay). Furthermore, this flexibility would easily facilitate accurate regional forecasting.

Acknowledgements

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Further Reading

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