AARES
AUSTRALIAN AGRICULTURAL & RESOURCE ECONOMICS SOCIETY

Economic and financial risks in under-vine management alternatives to herbicide in four South Australian wine-grape districts, 2016 & 2017

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Contributed paper prepared for presentation at the 62nd AARES Annual Conference, Adelaide, 6-9 February 2018

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Abstract
We calculate financial risk profiles for representative vineyards of 50-ha in four wine grape regions of South Australia using straw or living mulches as alternatives to herbicides for under-vine management. Calculations are based on replicated experiments in a commercial vineyard in each district with the most representative vine variety of each; the grape yields were measured in 2016 and 2017. Published district grape prices and yields for the years 2006 through 2017 form the basis for novel stochastic analysis. The herbicide (Control) treatment in Barossa Shiraz (BS) and Riverland Merlot (RM) showed greater median Gross Revenues ($/ha) than the other two districts: Eden Valley Shiraz and Langhorne Creek Cab-Sav. After subtraction of operating costs, and assuming alternative treatments produce grapes of equal quality and price as the Control in a district, the alternatives gave median Gross Margins ($/ha) greater than the Control in BS but lower than the Control in RM. Gross Margin results were mixed in the other two districts. The Gross Margin results above are magnified in financial Risk Profiles based on variations in Gross Margins times 50 ha across multiple ten-year periods after subtracting taxes, drawings, recurrent capital costs and interest on accumulating debt, for decadal cash margins. The Risk Profile of a treatment in a district is its cumulative distribution of decadal cash margins ($M). We show that choice of under-vine treatment can significantly affect a vineyard's financial viability.

Key words Farm financial risk, Risk profile, Decadal cash margin, Simulation, Under-vine treatments, Wine-grape production, South Australia

1. INTRODUCTION

The present study is a major up-date and supplement to a previous paper presented at AARES 2017 (Nordblom *et al*., 2017), which considered only a single year's harvest (2016) and only two wine-grape districts (Barossa and Langhorne Creek). The present study considers two years of harvest data (adding 2017) across four wine-grape districts (now including Eden Valley and Riverland districts). We make more direct use of district price and yield records published in the 12 most recent annual "***South Australian Winegrape Crush***

Survey" reports (Wine Australia, 2006 through 2017). From these reports it was possible to base a stochastic analysis of jointly correlated district by district yield and price variations to support simulations of baseline frequency distributions of Control treatment gross revenues.

Section 2 of this paper defines the basis for our stochastic analysis of district **Gross Revenue** distributions for the Control (herbicide) under-vine treatment. This allows consideration of simulated gross margins both as jointly-distributed random variates and as cumulative distribution functions. These are the distributions taken as the basis for simulating the other treatment outcomes.

Section 3 considers treatment and other operating costs for the calculation of distributions of **Gross Margins** for the Control treatment and nine alternative treatments applied variously in the field trials in the four districts. From among the nine alternative treatments, three were chosen for more detailed comparisons with the control (herbicide) treatment in each district. These show contrasts among treatments and between districts.

Section 4 focusses on financial consideration of all other costs at the level of an operational 50-ha vineyard over multiple ten-year periods. Using the treatment by treatment Gross Margins for each of the districts, **Risk Profiles** are generated. These contain long-run effects of different levels of opening debt at the farm level on the treatment outcomes.

Section 5 discusses the novel step-wise methods taken for several stages of preliminary results to reach the study's assessments of financial risk profiles on the basis of a 50 ha vineyard model under four levels of opening debt in each district for each treatment.

Section 6 concludes, noting limitations of the present analysis given the incomplete nature of our information so far on differences among treatments regarding **grape quality** (affecting prices, $/t), regarding changes in the under-vine **soil biome** (affecting vine health), and regarding efficacy of under-vine **weed suppression**.

2. GROSS REVENUE DISTRIBUTIONS

In this section, methods for determining gross revenue distributions over time are discussed as the first stage of our analysis, to produce the intermediate results forming the basis of the next section of the paper on Gross Margins.

Maintenance of a clean under-vine zone using herbicides and nine alternative under-vine treatments were established in randomised, replicated plots in one producing vineyard in each of four South Australian wine-grape districts. These focussed on the most widely grown vine variety in each district: Barossa, Shiraz; Eden Valley, Shiraz; Langhorne Creek, Cabernet Sauvignon and Riverland, Merlot. Useable yield data were obtained in the harvests of 2016 and 2017 for three of the districts but only for 2017 in Eden Valley.

The historical context of grape yield and price variations over time for the present analysis is represented by district yields and prices (calculated average purchase value) per tonne of the trial varieties in the four districts as reported in the ***SA Wine-grape Crush Survey*** by Wine Australia each year from 2006 through 2017. Over that period the consumer price index increased over 22%. Therefore, reported prices were adjusted to a constant (2017 dollar) basis (see Table 1). The consumer price indices (CPI) over that period for Adelaide (ABS 2017) were used for this purpose.

Taking the published grape harvest yield per ha for each year times that year's 2017 adjusted price results in a gross revenue value each year, as plotted for the four districts in Figure 1. Wide variations in gross revenues are evident in each district and these are taken to be representative of the common option of herbicide sprays for under-vine management, to define the Control treatment gross revenues in our analyses of the trials in each of the districts (Table 2). The variability in the Control gross revenues differ by district and these variations, as will be shown, are more or less correlated.

The 12-year yield and price sequences for the four districts were used to calculate the averages and standard deviations in each district. District means, variances and covariances among the yield and price sequences define the characteristic relationships among these measures. With these, it was possible to use the statistical program[1] **R** to simulate much longer sequences of random sets of values with similar statistical characteristics (averages, variances and covariances) to those found in the historical series. The extended series allows us to plot smoothed results over many more seasons than for the 12-year history. Examples are shown for 2,400 jointly-correlated (stochastic) random sets of simulated gross revenues from 2,400 sets of yields and prices for each district (Table 2). Here one may compare the simulated gross revenue values

[1] We wanted to draw samples from a specified multivariate normal distribution. Our approach was to combine Monte Carlo techniques with an eigen decomposition of the variance-covariance matrix of selected data. The statistical package **R** provides a convenient platform for these calculations. Specifically: we used the function 'mvrnorm' from the library MASS (https://cran.rproject.org/web/packages/MASS/MASS.pdf). We acknowledge the critical assistance provided by Dr David Luckett (Graham Centre) for this step of our analysis.

to those of the original 12-year historical series in terms of their statistical characteristics.

<<<< insert **Tables 1 and 2** about here >>>>

2,400 sets of simulated of gross revenues for the four districts (from which the samples shown in Table 2 were drawn) are plotted as Cumulative Distribution Functions (CDFs) in Figure 2 in terms of thousands of 2017 dollars per hectare. Here, considering the wide ranges of variation in gross revenues due to price and yield variations, one can appreciate the levels of riskiness in the vineyard business. Visually, Figure 3 captures the great year to year variability of gross revenues in the historical variations that are mimicked in the longer simulated series. Unsurprisingly, strong positive correlation (r=0.88) is captured between the Barossa and Eden Valley districts in gross revenue variations; these districts are geographically adjacent and therefore experience similar storm events and droughts through time; both grow Shiraz grapes and therefore also share a market. Positive correlation (r=0.74) in gross revenues can also be noted between Langhorne Creek Cab-sav and Riverland Merlot, though these districts are separated by over 150 km.

As mentioned above, the district yields and prices reported from 2006 through 2017 are taken to represent those associated with the most common method of under-vine management: one or more sprays of herbicide each year. Alternatives such as ploughing, cultivating and mowing, can be found around the world but are not part of the present study. Spraying under-vines has been relatively fast, easy, effective and is common across Australia as well as many other countries around the world; so much so that 35 confirmed reports of herbicide resistant weeds in grape vines have been documented around the world (Heap, 2018). Four of these confirmed reports are for multiple resistance to two herbicides; three further reports are for multiple resistance to three herbicides. A short review on these subjects is found in Nordblom *et al*. (2017).

<<<< insert **Figures 1, 2 and 3** about here >>>

3. GROSS MARGIN DISTRIBUTIONS

In this section, methods for determining Gross Margin distributions are shown, which produce results forming the basis of the subsequent section of the paper on Risk Profiles.

Production cost estimates have been provided by cooperating vineyard owners for each of the four districts. These are summarised for the Barossa farm in Table 3 (please see Appendix Tables 1, 2 and 3 for details on Eden Valley, Langhorne Creek and Riverland districts, respectively). We distinguish between the annual costs of the under-vine treatments: triticale straw mulch sourcing and spreading costs; seed and sowing costs of the living mulch treatments; and material and application costs for the herbicide treatment (Table 3). Also listed are the other annual operational costs common across all treatments, which are considered in calculating the sum of all annual vineyard operating costs for each. Obviously, there are differences in cost between the straw mulch (spread over 4 years) and annual herbicide treatments. In Table 3 the reader will also see there are differences among seed and seeding costs spread over 5 years for the alternative living mulches.

We assume the historical 2006-2017 yields and prices in the grape varieties of the four subject districts apply to the Control (herbicide only) under-vine treatments in the field trials. We further presume the **ratio** of the **average grape yield of an alternative under-vine treatment** to **that of the control (herbicide spray)** times **the gross revenue of the Control** will **give an estimate of the gross revenue of the alternative treatment**, assuming no differences in grape price per ton within a season and variety. The grape yield ratios found in the trial harvests of 2016 and 2017 are averaged at the top of Table 3 (and other district tables in the Appendix, except Eden Valley where only 2017 data are used).

Further, assuming these yield ratios hold across all periods, we recorded random draws from the baseline distributions of Control Gross revenues simulated in Figure 2 for the four districts, to define a probability distribution of gross revenues for each alternative under-vine treatment as its yield index times the Control Gross revenues. Table 2 indicates the generation of the 2,400 randomly drawn Control Gross revenues. Those for Barossa are carried into the 2nd column in the lower part of Table 3 (those for the other districts are likewise carried into Appendix tables 1 to 3). From each of the Control gross revenues the alternative treatment gross revenues are calculated (using the 2016 and 2017 yield indices), from which the annual operating costs of each under-vine alternative are subtracted to arrive at the distributions of **Gross Margin** values shown in the lower part of Table 3 for Barossa Shiraz (Appendix Tables 1, 2 and 3 for the other districts).

<<<< insert **Table 3** about here >>>

By design in Figure 4, the simulated Control treatment gross margin CDF for Barossa Shiraz is in the same relative position with the same median (50th percentile) values in both the 2016 and 2017 charts. Estimates of the three example alternative treatment CDFs shifted positions somewhat between the two years relative to the Control treatment. In 2016, Kasbah cocksfoot had lower gross margins than the others, which were clustered near the Control treatment. In 2017, the Control treatment had the lowest gross margin, with that of Kasbah cocksfoot being greater. The triticale mulch performed better, while the ryegrass/medic treatment was the best. Wide separation of results in 2017 contrasts with 2016.

At the Riverland district trial site, the Control treatment gave the highest gross margins in 2016 and second best in 2017 among the four treatments considered in Appendix Table 3 and Figure 4. The Kasbah cocksfoot treatment did least well in gross margins, assuming no differences in quality/price. The triticale straw mulch treatment was not included in the Riverland trial, but replaced with a living mulch of Governor ryegrass/Predator fescue (mix of perennial pasture grasses). This treatment did slightly best in 2017 but just better than Kasbah cocksfoot in 2016. However, our Botanal study of plant populations indicated this ryegrass/fescue treatment established very poorly in Riverland; thus, any yield differences are unlikely to be true treatment effects.

Eden Valley treatment grape yields, gross revenues, operating costs, and gross margins are simulated in Appendix Table 1. Only the results for 2017 are used as the 2016 yield results were compromised by delayed harvest due to a regional shortage of contract harvesters. In 2017 the ryegrass/medic treatment performed best, with median gross margins over $2,000/ha greater than the Control or triticale mulch treatments (Figure 5). The Kasbah cocksfoot performed only slightly better than the latter.

In Langhorne Creek results (Appendix Table 2), are available for two harvests, 2016 and 2017. Highest gross margins are calculated for the ryegrass/medic treatment in both seasons, above the Control treatment by a similar margin each time (Figure 5). The Kasbah cocksfoot had lower gross margins than the Control treatment in both seasons. Least consistent between seasons were the gross margins of triticale straw mulch … similar to the Control treatment in 2016 and to Kasbah cocksfoot in 2017.

<<<< insert **Figures 4 and 5** about here >>>>

In comparison to the gross revenue series plotted in Figure 2 for the four districts, the Control Gross margin series in Figure 6 differ by the subtraction of operating costs calculated for the Control treatments and three of the nine alternative treatments in Table 3 (and Appendix tables 1, 2 and 3).

Historical yield and price variations, and costs, differ among districts and vine varieties. Our simulated gross margin series sometime dip into negative values (below zero) in Figure 6, with the exception of Langhorne Creek in our examples. Analogous to Figure 2, which plots the CDFs of Control treatment **gross revenues** for each district, the CDFs of **gross margins** of the same Control treatments are given in Figure 6.

A median difference in gross margins of over $3,000/ha for the Control treatment (herbicide) between Eden Valley Shiraz and Riverland Merlot appears in Figure 6. Between these two extremes are the Control gross margin CDFs of Barossa Shiraz and Langhorne Creek Cab-sav.

<<<< insert **Figure 6** here >>>>

4. FARM FINANCIAL RISK PROFILES

We now have the basis for additional consideration of the farm financial costs: any recurring overhead costs, including interest on debts over time (such as those incurred in establishing the vineyard or in drought periods), machinery, depreciation and capital costs (the manager's wage, taxes on income).

Subtracting these costs from the treatment gross margins we arrive at the cash surplus, which we can now use to define long-run risk profiles for comparing under-vine treatments for a 50-ha vineyard in each of the four districts. These cash surpluses mirror the change in the bank balance resulting from each treatment, providing more complete whole-farm management information than is available from simple gross margin analysis.

To standardise measures across districts, we assume vineyards of 50-ha with equipment, fuel, repair and replacement costs of $8,820/year, additional recurring overhead costs (extra labour, vineyard repair and renewal) of $80K/year, manager's drawings of $120K/year, inflation of 3% per year on all the above costs, 6.5% interest payed on outstanding debt, 1.5% interest received on credit balances and 19% tax on farm income.

A ten-year (decadal) **cashflow budget** calculator is designed with five horizontal sectors in one worksheet, the first of which contains the above cost information. Below this is the key row (15) in the model where key cell **C15** contains a code that randomly generates a number from 1 to 2,391, which is an address in a lookup table on the next page of 2,400 sets of four treatment Gross margins that were generated in Table 3 for Barossa Shiraz. The limit of 2,391 represents the maximum number of 'decades' (10 year sequences) that can be drawn from a simulated sequence of 2,400 years. The four values at that address and the following nine addresses are copied into the cashflow worksheet, 10 across, in four rows, eight lines apart. Those four rows of Gross margin values are those from the Control (herbicide) treatment and the three alternative treatments, now multiplied by 50 ha to represent a ten-year sample of price and yield variations in that district. This analytical setup is designed following that of Hutchings (2013), allowing repeated simulations of decadal cash margins with the Excel add-in, @RISK 7.5 (Palisade, 2017).

From these farm-level Gross margins are subtracted all the costs mentioned above as they accumulate over the decade, given a level of opening debt at one of four levels: Zero debt, -$250K, -$500K or -$1M debt. The level of opening debt is present in the cumulative cash balance in the first year and is subtracted from the closing cumulative cash balance at the end of 10 years to calculate the 'Decadal cash balance'. Of course, higher levels of opening debt require higher interest payments and increased borrowing in poor seasons, making it harder to achieve positive long-term cash margins. It is the burden of accumulating debts over time that amplify differences between treatments, largely because debit interest rates are three times greater than credit interest rates. Credit balances can also taxed, so that there is an inbuilt negative bias to long-term cash balances

In this model, decadal cashflow iterations can be repeated as quickly as new random numbers from 1 to 2,391 can be selected by cell **C15**. Running this model with the Excel add in @RISK completes 2,400 iterations in about 15 seconds. The brief explanation above may be sufficient for interpreting the results that follow, which are in terms of "distributions of decadal cash margins". More simply, we call these **Risk Profiles**. We now present the results district by district, each with four levels of opening debt.

<<<< insert **Figure 7. Barossa Shiraz Risk Profiles** about here >>>>

Here the reader is invited to compare the annual Gross Margin chart for Barossa (Figure 6) with the whole-farm risk profiles of the various treatments (Figure 7 A) with zero opening debt. Notice the horizontal axis expresses the ten-year closing bank balance of the vineyard in millions of dollars. The

Ryegrass/Medic and Straw mulch, which had higher gross margins than the other two treatments (Control and Kasbah Cocksfoot), have more than covered the whole-farm costs over time. The latter two treatments were able to cover the whole-farm costs in about 65% of decades. With $250K opening debt (Figure 7 B), the latter two treatments would only cover costs in about 50% of decades. Opening debt of $1M (Figure 7 D) would see the farm losing money in over 80% of decades, while the best treatments given the same opening debt would gain profits in 70 to 75 % of decades.

<<<< insert **Figure 8. Eden Valley Risk Profiles** about here >>>>

Comparisons are invited for Eden Valley's gross margins in Figure 6 with the risk profiles for that district in Figure 8. The spread between best and worst median gross margins is rather narrow and the best median gross margin is lower than the worst in the previous example (perhaps due to higher per hectare operational costs). With zero opening debt, subtracting the same 50-ha whole-farm costs from the lower gross margins for a decade shows all treatments to be loss-making; least so for the Ryegrass/Medic and Kasbah Cocksfoot treatments, but not enough so to save the farm. Increasing levels of opening debt send this vineyard into progressively deeper debt.

<<<< insert **Figure 9. Langhorne Creek Risk Profiles** about here >>>>

Here, readers are invited to compare Langhorne Creek gross margins (Figure 6) with the Langhorne Creek risk profiles in Figure 9. The median gross margin of the Control treatment is only slightly below that in Barossa. The Risk profile of the Control treatment in Langhorne Creek also shows the same tendency for accumulating debt with increasing levels of opening debt as in Barossa. Most promising among treatments in Langhorne Creek is that of Ryegrass/Medic, with an 85% chance of decadal profits given zero opening debts. Even with opening debt of $250K this treatment indicates a 70% chance of profitable operations.

<<<< insert **Figure 10. Riverland Risk Profiles** about here >>>>

The Riverland gross margins for the different treatments (Figure 6) may be compared with that district's Risk Profiles in Figure 10. Apparently most profitable among the under-vine treatments in the Riverland district is the Control (herbicide), with Predator Fescue and Ryegrass/Medic coming second and third (but recall, there is doubt these fescue results are true treatment results). Even with opening debts of $500K the Control treatment seems to indicate a financially viable vineyard. With opening debts of $250K the second and third alternatives also would be viable. It is interesting to recall that Ryegrass/Medic and Triticale straw treatments were best in the Barossa case while the Control was the poorest option there.

5. DISCUSSION

The novel methodological steps in this paper included:

- Using the statistical characteristics of a 12-year historical series of grape yields and prices corrected for inflation for the four districts to generate a multivariate distribution from which to draw longer sample series with the same characteristics. This allowed us to define a set of baseline district by district distributions of 2400 gross revenues ($/ha). We took these distributions to represent the Control (herbicide) treatment, providing the basis for simulating gross revenue distributions for the alternative treatments in each district.
- Comparing treatments in terms of probability distributions of their gross revenues and (after treatment and other operational costs) their Gross Margins. Gross Margins are sometimes referred to as 'profits' but this is misleading as this does not account for other costs of sustaining a vineyard, including capital costs, drawings, taxes and interest.
- Introducing farm-financial risk considerations that are usually missed in typical analyses that stop with Gross Margins. Our Financial Risk analysis allows definition of Risk Profiles specific to a standard-sized 50-ha vineyard in each district and farm-level costs typical of these, including the risks of accumulating interest on debt when presented with several poor seasons in a row, or when starting with a low or high debt burden. A vineyard operation with a negative median decadal cash margin may not be financially viable. Our risk profiles indicate the **probability of a profitable vineyard** under different practices and conditions.

6. CONCLUSIONS

The surprising differences in financial rankings of the different treatments are 'explained' by district differences in yields, varieties and prices. However, these points do not explain the **causes** of yield differences, which are due to biological processes that are the main subject of the field experiments and biological measurements behind this work. There are unanswered questions that limit the present analysis given the incomplete nature of our information so far on differences among treatments regarding **grape quality** (affecting prices, $/t), regarding changes in the under-vine **soil biome** (affecting vine health), and regarding efficacy of under-vine **weed suppression** by the different treatments.

The present analysis sheds light only on the economic and financial consequences (opportunities) that face vineyard managers. These results were obtained given assumptions of fixed ratios of treatment yields to Control yields, based on yield ratios observed in field trials over only two years. We also assumed constant grape quality across treatments at a given trial site in this preliminary analysis.

For grape prices we used the calculated average purchase value per tonne of the trial varieties as reported in the ***SA Winegrape Crush Survey*** reports (Wine Australia, 2006 – 2017). Thus, we have ignored the distributions of grape prices within a district for a variety, which change from year to year based on quality judgements in the market. As a result, we have certainly under-stated the profitabilities of vineyards consistently producing the highest quality grapes.

In only one of the districts (Riverland) did the Control (herbicide) treatment appear to be the best. In the other three districts the Control treatment appears only second best (Langhorne Creek), third best (Eden Valley) or the worst option (for Barossa).

Of course, one should be cautious about results from only two seasons at only one location in each district, even results that appear to be consistent over the two seasons. The evidence of highly volatile grape yields and prices in the study area is so pronounced that taking any two years as representative is somewhat naive. Nevertheless, our results are sufficiently provocative that we feel confident some alternatives to under-vine herbicide spraying may be financially superior to herbicide in some districts. The studies to date therefore justify investment in continued field studies on one hand and drawing farmers' attention to the alternatives where they seem best suited.

As of this writing, the European Union has only extended the licence for five years for glyphosate (herbicide) to be used in production of goods imported to the EU for human consumption. This lends a sense of urgency to the need for finding effective alternative under-vine treatments.

ACKNOWLEDGEMENTS

The co-authors acknowledge **Wine Australia** for providing a research grant which funded (1) the field trials carried out in South Australian vineyards by Chris Penfold, University of Adelaide; (2) the analysis of soil chemistry and microbial populations under the different treatments carried out by Melanie

Weckert, National Wine & Grape Industry Centre, Charles Sturt University and NSW DPI Wagga Wagga; (3) participation of Mark Norton (NSW DPI and the Graham Centre for Agricultural Innovation) and Jake Howie, University of Adelaide, in 'Botanal' measurements of the composition of under-vine plant populations at the trial sites; Jake Howie also conducted much of the statistical analyses of field trial measurements of vine and grape parameters. Tom Nordblom (Graham Centre, Charles Sturt University) participated as corresponding author, with Tim Hutchings (Graham Centre) in assembling this preliminary analysis. The authors alone are responsible for the assumptions, observations and interpretations in this study and any errors remaining in it.

Special thanks are extended to two Graham Centre Scientists:
Prof James Pratley, for help on the underlying issues of herbicide resistance.
Adjunct Prof David Luckett for timely help in use of **R** for multivariate simulations of yields and prices to mimic the statistical behaviour of the published historical series.

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