FIRE RECOVERY CASE STUDIES



FINAL REPORT TO WINE AUSTRALIA

Project Number: **PIN 2201**

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We sincerely thank owners of the trial vineyard sites and other industry participants who recognised the value of the project in the wake of the Adelaide Hills bushfire and contributed their time and inputs generously to the project.

Abstract

In the summer of 2019-20, Australia was devastated by a significant bushfire season that affected large areas of the country. The Cudlee Creek bushfire in the Adelaide Hills in December 2019 directly damaged around 1,100ha of grapevines as well as causing concerns with smoke damage to grapes.

The Department of Primary Industries and Regions, South Australia (PIRSA) and Wine Grape Council of SA released funding obtained under the Local Economic Recovery program for a project to establish and monitor bushfire recovery trials in Adelaide Hills vineyards over two vintages – 2021 and 2022. Wine Australia partnered with PIRSA to provide funding for a third season of trials (2023) and to generate extension materials for the grape and wine sector on the results of the project.

Trial work was established over several sites in the Adelaide Hills. Results provide evidence-based advice for growers on management of vines which have been directly damaged by fire and the best ways to return a vineyard to productivity.

Executive summary

The Cudlee Creek bushfire started on Friday, 20 December 2019. Around 1,100ha of vineyard in the northern part of the Adelaide Hills wine region were burnt. For grape and wine businesses affected by the fire or smoke, the impacts were significant. The fires not only destroyed sheds, machinery and equipment, they also directly damaged vineyards, trellis and irrigation infrastructure.

Vineyard owners and managers with moderate to severe damage were faced with three choices to manage their grapevines: begin revival immediately, wait until dormancy to review vine recovery from fire damage before commencing remedial action, or remove damaged vines and re-establish new plantings.

However, the fact that these events have been rare in the past means that there has been very little opportunity to study the recovery of vines after fire and to determine the best course of action to return a vineyard to productivity.

A multi-year demonstration trial was established in the Adelaide Hills by Colin Hinze (Pinion Advisory) and Richard Hamilton (Hamilton Viticulture) to take advantage of the opportunity. The aim was to provide data to determine the optimal time to begin vine recovery (immediately after the fire or once dormant) and the best method for winter pruning (spur, cane or trunk renewal) for recovering vineyards.

The project showed that accelerated economic recovery and return to full production is best achieved by taking time to fully understand the damage to vines, so that high-cost solutions are not implemented when unnecessary. The following actions are recommended:

1. Restore the irrigation system as soon as possible to optimise vine recovery and maximise carbohydrate reserves for dormancy
2. Thoroughly assess the impact of fire on the vineyard (mild, moderate or severe) to inform subsequent action. Vineyard variability combined with uneven fire impact can mean that the level of damage will vary between individual vines within a vineyard. Guidelines were developed to assist with the classification
3. Wait while the vines recover. Don’t remove any regrowth - let the vines maximise carbohydrate storage as they enter dormancy. In the meantime, continue operational management to maximise vine health, and take the opportunity to critically assess the vineyard viability, profitability and other production issues (e.g. block performance, varietal desirability, trunk disease incidence). Consider layering to replace any missing vines.
4. For mildly and moderately damaged vineyards, continuing with spur pruning in the winter following the fire is a reasonable economic option and likely to be the most effective strategy over the medium term. Conversion to cane pruning or trunk replacement is only necessary where there are other advantages, such as the influence on grape quality (e.g. bunch architecture) or remediation of trunk disease.

Background

The Cudlee Creek bushfire in the Adelaide Hills in December 2019 directly impacted vineyards in the region. As well as concerns with smoke damage to grapes, fires caused direct damage to grapevines across large areas. The dilemma winegrape growers faced was to determine what action should be taken to optimise vineyard recovery and which management options will give the best response, according to the severity of the fire damage sustained (Figure 1).



Mild damage
Evidence of damaged basal leaves Majority of grapes are not damaged Green rachis if berries are picked and/or eaten

Moderate damage
Major bunch zone damage, grapes desiccated, shrivelled rachis
Retained leaves and/or new growth above cordon
May have been considered 'severe' on initial inspection after fire

Severe damage
Total canopy desiccation
No regrowth from cordon
Watershoots only
Wide range of watershoot vigour

Figure 1: Examples of mild, moderate and severely damaged vines.

Aims and Method

Three key knowledge gaps were identified, and this project undertook the following activities to address them:

1. **Timing** – what is the best time to undertake remedial pruning to optimise vine recovery; immediately after the fire (summer), or in the following dormancy (winter) period?

    - Two vineyards which were moderately to severely damaged by the fire were selected for this evaluation.
    - The first was a Pinot Gris vineyard, east of Woodside, and the second was a Chardonnay vineyard, east of Lobethal.
    - Within four weeks of the fire event, a section of vineyard at each site had the vine trunks cut 20-30cm above ground to promote new growth for a fresh trunk. New growth was trained to a single trunk and cordon during the autumn period following the fire.
    - In July of the same year (2020), an adjacent section had the vine trunks cut 20-30cm above ground, which provided the opportunity to establish side-by-side demonstration sites for evaluation (Figure 2).



Figure 2: Interface between summer (left) and winter (right) regrowth in Pinot Gris prior to shoot selection of the winter section on November 24, 2020.

    - Over the following three growing seasons (vintages 2021, 2022 and 2023), the demonstration vines were monitored and measured for:
        - Timing and duration of key phenological stages (budburst, flowering and veraison)
        - Key yield components including bunch number, yield per vine, bunch weight, berry weight and grape maturity.
        - Vine canopy size of the Pinot Gris site was measured using high resolution drone imagery in March 2021 and March 2022.

- Trunk diameter and overall vine survival was measured at both sites after the third vintage (May 2023).

2. **Pruning method** – what is the best remedial pruning to undertake to optimise vine recovery?

    - One vineyard was selected for this trial (Figure 3).
    - Three treatments were applied in two randomised plots: one in the mildly damaged lower section and the other in the moderately damaged upper section. Treatments included two industry-standard spur and cane pruning methods in comparison with trunk replacement (Figure 4).
    - All treatments were established during dormancy (winter) of 2020.

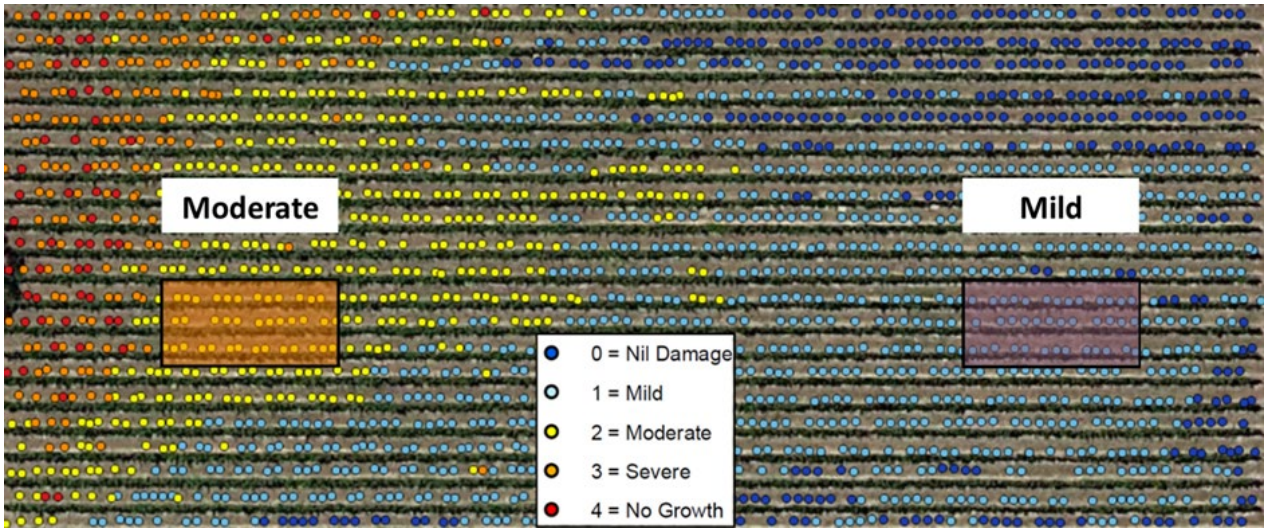


Figure 3: The distribution of damage sustained to the Chardonnay vineyard, with the location of trial plots overlaid.



Figure 4: Adjacent examples of the three pruning treatments: left (white) = spur, centre (yellow) = cane, right (red) = trunk replacement. Taken 19th May 2022.

- Over the following three growing seasons (vintages 2021, 2022 and 2023), the treatments were monitored and measured for:
    - timing and duration of key phenological stages (budburst, flowering and veraison)
    - key yield components including bunch number, yield per vine, bunch weight, berry weight and grape maturity.

3. **Economic return** – what is the most cost-effective recovery strategy to return to productivity?
    - Eight commercial growers were prepared to participate in a survey and interview process to share their experiences, including:
        - Their specific scenario,
        - The recovery steps undertaken,
        - The labour hours required for each recovery step, and
        - The external costs encountered.
    - The data and information collected was highly variable, depending on each scenario, and created challenges for developing relevant benchmarks. Instead, a summary of the situation for each participant was written up as a case study, which included the damage sustained and the chosen recovery plan in each scenario.

Results and Discussion

1. Timing of Remedial Pruning

Results

No commercial crop was produced from either demonstration site in Year 1 (2021). High resolution imagery and calculation of vine canopy size (m2) by Airborne Logic provided quantification of our observation that the vines in the summer trunk removal were less vigorous than the winter trunk removal. The imagery capture was repeated in Year 2, with similar results (Figure 5).

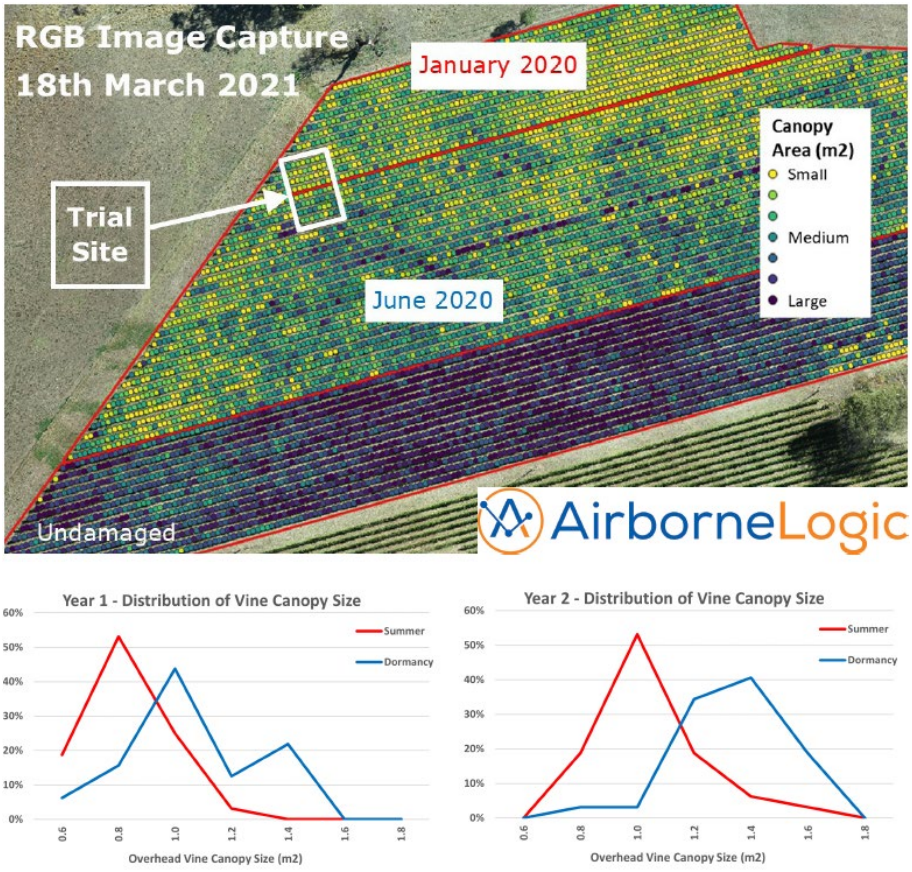


Figure 5: Vine canopy size measurement using high resolution imagery by Airborne Logic showing the difference in growth of vines rejuvenated soon after fire damage ("Summer", January 2020) compared to the following winter ("Dormancy", June 2020).

Immediately prior to the commercial harvest of the host blocks in Year 2 and Year 3 (2022 and 2023), the demonstration trial vines were individually hand harvested to determine the bunch number and total weight of grapes (kg) per vine (32 samples per treatment). For reporting purposes, grape yield has been converted to kg/m to enable comparison.

A random 60-berry sample was then collected from the aggregation of grapes harvested from each panel within the trial, which provided eight samples per treatment for berry weight (g) and total soluble solids (Brix). Results are shown in Table 1.

	Pinot Gris	Yield (kg/m)	Bunches (per m)	Bunch weight (g)	Maturity (°Brix)	Berry weight (g)	Trunk Diameter (mm)	Vine Survival
Year 2	Summer	4.58	25.0	183	20.7	1.3		
	Winter	4.72	25.3	187	21.4	1.3		
	Summer Variance	*-3%*	*-1%*	*-2%*	*-3%*	*0%*		
Year 3	Summer	3.67	33.6	109	20.2	1.4	22.8	100%
	Winter	3.49	30.0	116	20.9	1.3	24.0	97%
	Summer Variance	*5%*	*12%*	*-6%*	*-3%*	*8%*	*-5%*	*3%*

	Chardonnay	Yield (kg/m)	Bunches (per m)	Bunch weight (g)	Maturity (°Brix)	Berry weight (g)	Trunk Diameter (mm)	Vine Survival
Year 2	Summer	2.23	18.3	122	19.4	1.7		
	Winter	2.00	18.6	108	19.4	1.7		
	Summer Variance	*12%*	*-2%*	*13%*	*0%*	*0%*		
Year 3	Summer	3.14	26.1	120	19.2	1.7	23.2	81%
	Winter	2.37	23.7	100	19.4	1.8	24.1	88%
	Summer Variance	*32%*	*10%*	*20%*	*-1%*	*-6%*	*-4%*	*-8%*

Table 1: Grape and vine measurements taken from the timing demonstration plots in the second and third seasons after fire damage and trunk replacement.

The key measurement for successful recovery after fire damage is yield. As can be seen in Figure 6, the timing of trunk replacement on the Pinot Gris block made little difference to the harvested yield in either year 2 (3% difference) or year 3 (5% difference). In contrast, the summer renewal treatment in the Chardonnay block produced a 12% higher yield in year 2, and a 32% higher yield in year 3. This variance in the Chardonnay block may be attributed to the compromised demonstration trial design which had different management inputs (primarily irrigation) imposed by the host vineyard manager for commercial reasons.

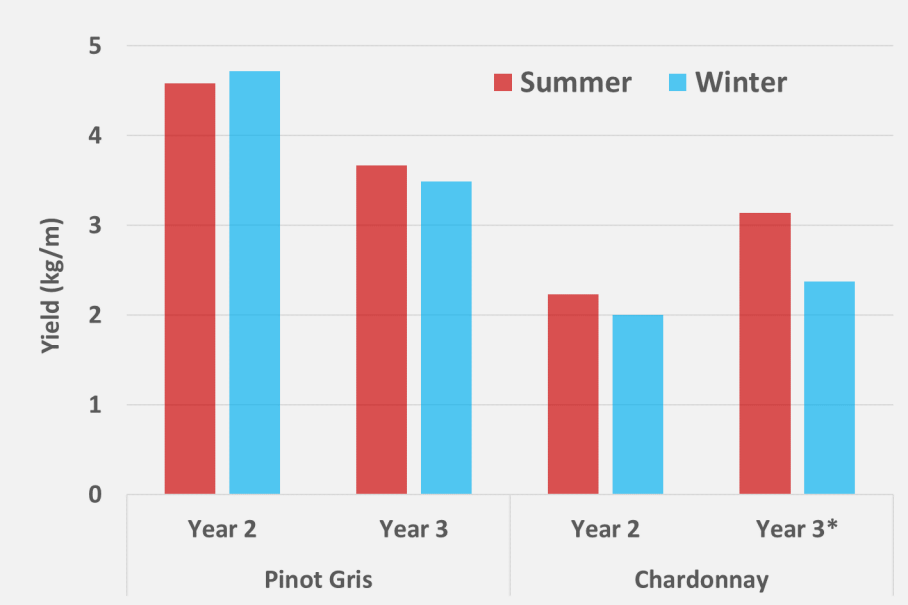


*Figure 6: Grape yield harvested from the demonstration plots in the second and third seasons after fire damage and vine renewal. *Note the unusual result for Chardonnay Year 3.*

Recommendations

The first step after experiencing fire damage is to reinstate the irrigation infrastructure as soon as possible. Providing water to vines which are stressed and damaged from fire is the best immediate action which may be taken to aid their recovery. The best approach is then to wait and observe vine regrowth after the fire. Vines are naturally resilient plants, and their regrowth patterns will depend on the extent of damage sustained. Whilst the vines are responding to the fire damage for the remainder of the growing season, long-term plans should be reviewed. Taking no action until winter provides the opportunity to critically assess vineyard viability, profitability, and other production issues (e.g., block comparative performance, varietal desirability, Eutypa and other trunk disease infections, vineyard infrastructure, etc.).

During this period, leave all regrowth in place whilst maintaining soil moisture levels for active growth. Let the vines retain as much leaf area for as long as possible, so that they may maximise storage of carbohydrates going into dormancy. Continue operational management of the vines, such as basic fungicide applications and introduce fertigation to optimise leaf growth and vine health. Even where the crop is lost for the season, it is essential to maintain the long-term health of the vines.

Where vines are missing, consider layering to replace missing vines. The vigour potential from the root system of the beheaded existing vines have capacity to carry additional shoots, which may be used for layering in subsequent seasons to fill gaps.

2. Pruning Method

Results

Immediately prior to the commercial harvest of the host block each year, the trial vines were individually hand harvested to determine the bunch number and total weight of grapes (kg) per vine, providing up to 12 samples per treatment. For reporting purposes, grape yield has been converted to kg/m to allow for comparison.

A random 60-berry sample was then collected from the aggregation of grapes harvested from each pruning treatment within each row of the trial (up to four vines), which provided three samples per treatment for measurement of berry weight (g) and total soluble solids (Brix). Results for the three pruning treatments are presented in Table 2, with accumulated yield in Figure 7.

		Damage and Treatment					
		Mild			Moderate		
Season	**Attribute**	**Spur**	**Cane**	**Trunk**	**Spur**	**Cane**	**Trunk**
Year 1	Yield (kg/m)	3.79	3.22	-	0.47	0.15	-
	Bunches /m	42.9	36.4	-	6.3	2.6	-
	Bunch Wt (g)	88.4	88.4	-	74.4	59.1	-
	Berry Wt (g)	-	-	-	-	-	-
	°Brix	21.8	21.7	-	21.5	22.4	-
Year 2	Yield (kg/m)	2.56	2.56	3.10	2.27	4.04	3.82
	Bunches /m	31.9	29.1	27.9	24.8	37.2	29.7
	Bunch Wt (g)	80.2	88.0	111.3	91.8	108.8	128.7
	Berry Wt (g)	1.28	1.4	1.4	1.3	1.1	1.1
	°Brix	20.8	20.7	20.0	21.4	21.5	20.5
Year 3	Yield (kg/m)	3.39	2.69	2.76	4.14	4.32	3.80
	Bunches /m	37.2	26.7	27.8	39.0	34.8	32.0
	Bunch Wt (g)	91.1	100.7	99.2	106.0	124.0	118.8
	Berry Wt (g)	1.42	1.6	1.5	1.4	1.3	1.4
	°Brix	20.7	20.9	20.3	21.7	21.4	21.2

Table 2: Summary of grape production results from the pruning trial for the three years following fire damage.

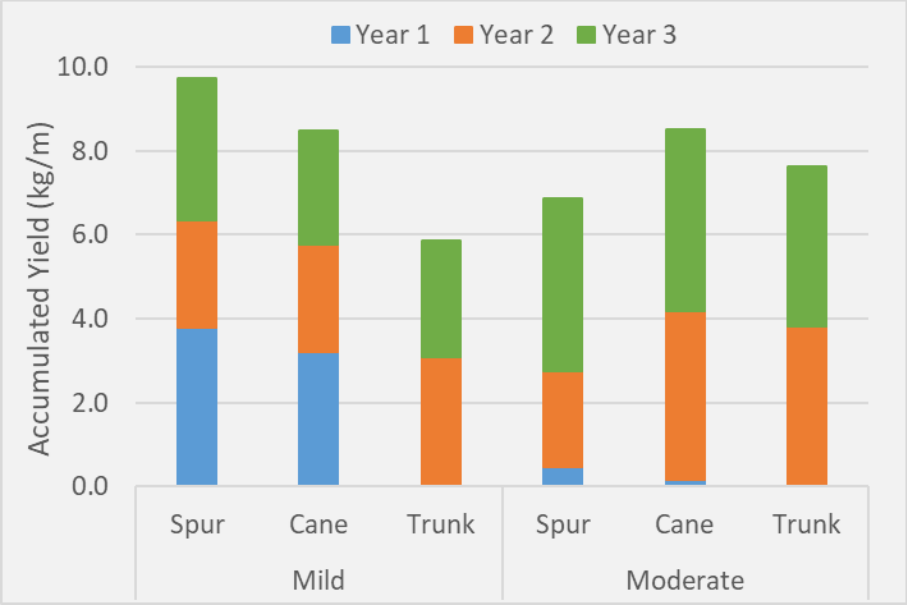


Figure 7: Accumulated yield over three seasons for each treatment in each section of the trial.

As may be seen in Figure 7, the continued practice of spur pruning in the mildly damaged area provided the highest yield over the three-year period. However, the practices of conversion to cane pruning and trunk replacement were more beneficial overall in the moderate damage area, as moderate damage to spur pruned vines reduced their productivity over this period.

Combination of grape yield data with economic modelling (Table 3) demonstrates that for vines that suffer mild fire damage, the most cost-effective management practice is to maintain spur pruning. The conversion to cane pruning and trunk replacement treatments were only beneficial for fire damage recovery of more severely affected vines.

Similarly, for vines that sustained moderate damage, spur pruning also provided the best economic return over three years, although the cost per kg of grapes was 40% higher compared to the mild damage area. The cost per kg of grapes from the conversion to cane pruning treatment was only marginally higher than the spur pruned treatment, however the trunk replacement treatment still resulted in the worst return from an economic perspective.

	Damage and Treatment					
Grape Production	**Mild**			**Moderate**		
Yield kg/m	**Spur**	**Cane**	**Trunk**	**Spur**	**Cane**	**Trunk**
Year 1	3.79	3.22	0.00	0.47	0.15	0.00
Year 2	2.56	2.56	3.10	2.27	4.04	3.82
Year 3	3.39	2.69	2.76	4.14	4.32	3.80
Cumulative	**9.74**	**8.47**	**5.86**	**6.88**	**8.51**	**7.62**
Economic Modelling						
Year 1 ($/m)						
Standard Pruning	$0.50			$0.50		
Extra Pruning	$0.20			$0.20		
Cane Conversion		$1.50			$1.50	
Trunk Renewal			$2.00			$2.00
Year 2 ($/m)						
Training			$1.20			$1.20
Pruning	$0.50	$1.20	$1.20	$0.50	$1.20	$1.20
Year 3 ($/m)						
Training			$0.80			$0.80
Pruning	$0.50	$1.20	$0.50	$0.50	$1.20	$0.50
	Damage and Treatment					
	Mild			**Moderate**		
	Spur	**Cane**	**Trunk**	**Spur**	**Cane**	**Trunk**
Total Cost ($/m)	**$1.70**	**$3.90**	**$5.70**	**$1.70**	**$3.90**	**$5.70**
Grapes Cost ($/kg)	**$0.17**	**$0.46**	**$0.97**	**$0.25**	**$0.46**	**$0.75**

Table 3: Assumptions and calculations for the cost of remediating the different damage levels and remediation treatments on a commercial scale, based on the information captured in Table 2.

Recommendations

Where vineyards have minor and moderate fire damage, continuing with spur pruning is a reasonable economic option. Consideration should be given to increasing spur bud numbers (say to 150% of the normal target) to compensate for the impact of fire on the permanent cordon.

Conversion to cane pruning or trunk replacement is only necessary where there are other advantages, such as the influence on grape quality (e.g. bunch architecture). In vineyards where cordon decline and trunk disease are impacting production, trunk replacement after a fire is justified, particularly as the crop in the following season has already been impacted.

Most critically, after the reinstatement of irrigation infrastructure, it is essential to wait and observe individual vine recovery, leaving all growth untouched to maximise carbohydrate storage for dormancy.

Only with time can the grower assess the level of damage sustained to the vines and determine the best recovery treatment.

This study has shown that the intensive treatments of conversion to cane pruning and trunk replacement do not provide an overall economic benefit after three years, even for moderately damaged vines. Only in areas that have been severely damaged, where there is no or limited re-growth from the existing cordons, is the practice of trunk replacement justified unless there are other advantages (e.g., cordon decline and trunk disease management).

3. Economic Return

Results

To provide relevant guidelines for winegrape growers, we adjusted the reported labour hours according to the situation of each participant and applied a standard labour rate of $35 per hour. We then combined this result with the reported machinery costs to determine the combined labour and machinery requirement for each activity (Table 4).

	Range Reported # (per Hectare)
Vine Remediation	
Cordon Removal	$2,500 to $3,500
Trunk Removal	$1,200 to $2,400
Cordon/Trunk Disposal	$250 to $750
Irrigation	
Wire and drip removal	$400 to $2,200
Dripper tube replacement	$875 to $1,500
Dripper wire replacement	$875 to $1,500
Trellis	
Strainer replacement	$50 to $100 *(each)*
Intermediate replacement	$22 to $30 *(each)*
Cordon wire replacement	$875 to $1250

#labour and machinery costs only, excludes materials

Table 4: Calculated cost per hectare range required to undertake a variety of tasks related to recovery after fire damage.

To create further value for winegrape growers, we modelled four different scenarios that are likely to be encountered after a significant event such as the Cudlee Creek bushfire (Table 5). These estimations are designed to show the range of costs which may be required for different vine treatments, depending on the extent of fire damage. The scenarios modelled were for minor repairs, medium repairs, major repairs and full replacement of the vines and vineyard infrastructure.

The results show that conversion to cane pruning and trunk replacement add substantial costs to the recovery process, with a full vineyard replant requiring significant investment, as expected.

Adelaide Hills Vineyard - Typical Dimensions

Row Width	2.7 m
Vine Spacing	1.5 m

Attribute		Minor Repairs	Medium Repairs	Major Repairs	Full Replant
Area Damaged		10%	50%	75%	100%
*Efficiency**		*50%*	*75%*	*90%*	*100%*
	$/m	$/ha	$/ha	$/ha	$/ha
Trellis*					
Strainers	$0.45	$333	$1,111	$1,389	$1,667
Intermediates	$3.00	$2,222	$7,407	$9,259	$11,111
Cordon Wire	$0.25	$185	$617	$772	$926
Subtotal	*$3.70*	*$2,740*	*$9,135*	*$11,420*	*$13,704*
Irrigation*					
Laterals	$0.75	$556	$1,852	$2,315	$2,778
Dripper Wire	$0.20	$148	$494	$617	$741
Valves	$0.15	$111	$370	$463	$556
Subtotal	*$1.10*	*$815*	*$2,716*	*$3,395*	*$4,075*
Vine Remediation (100% of Area)					
Extra Pruning	$0.20	$741			
Cane Conversion	$1.50		$5,556		
Trunk Replacement	$2.00			$7,407	
Replanting	$4.00				$14,815
Subtotal		*$741*	*$5,556*	*$7,407*	*$14,815*
Vine Training					
Crop -3yrs	$1.60				$5,926
Crop -2yrs	$1.20			$4,444	$4,444
Crop -1yr	$0.80			$2,963	$2,963
Subtotal		*$0*	*$0*	*$7,407*	*$13,333*
Total per Ha:		**$4,296**	**$17,407**	**$29,629**	**$45,927**
Total per m:		***$1.16***	***$4.70***	***$8.00***	***$12.40***

** an efficiency factor is applied to trellis and irrigation repairs, given that smaller repairs tend to cost more per unit to repair.*

Table 5: Detailed financial modelling for recovery after fire damage in each of four scenarios for a typical Adelaide Hills vineyard design.

Recommendations

The outcome of the economic case studies and modelling reinforce the recommendation that, following reinstatement of irrigation, the best course of action is to wait and observe individual vine recovery. It is only by observing vine response to fire damage that vineyard managers may reliably assess the level of damage sustained to vines to inform the best recovery treatment option. Whilst there is a great temptation to act quickly and avoid delay, there is a high risk that vineyard managers may embark on a high-cost course of action that may not be warranted, such as trunk replacement in a mild to moderate damage scenario.

Growers impacted by fire should also take advantage of community volunteer and government-provided resources after major fire, as these opportunities considerably ease the burden and stress of the initial cleanup phase.

Outcomes and Conclusions

Managing fire-damaged grapevines in the past has been largely by trial and error, with little knowledge of best practice to return vines to productivity as quickly as possible. This project has provided practical information to winegrape growers on the best ways to manage recovery of grapevines from fire damage. This recent experience will support winegrape growers to make informed, evidence-based decisions in the event of a major fire in the future.

This project has shown that accelerated economic recovery and return to full production is best achieved by taking time to fully understand the damage to vines, so that high-cost solutions are not implemented when unnecessary. For mildly and moderately damaged vineyards, we have shown that the lowest cost recovery method is likely to be the most effective strategy over the medium term. The project also showed that even badly-damaged vines can be restored to productivity under best practice treatment.

Economic impacts are likely to be realised in future bushfire events, when the results of the project can be directly employed by growers and vineyard managers to return damaged grapevines to full productivity in the fastest and most cost-effective way.

Recovery from bushfire continues to be a topic of discussion amongst the Adelaide Hills grape growing community. This funding has enabled a positive outcome from a very negative situation, and the outcomes will be applicable across any grape-growing regions of Australia which are affected by fire in the future.

Key findings

- Trials across three seasons have demonstrated the most effective treatments for returning fire-damages grapevines to productivity
- The most critical action is to wait and observe individual grapevine recovery from fire damage before committing to a high-cost recovery option
- The most economical solution for vineyard recovery is likely to be the lowest input option
- Even badly-damaged vines can be restored to productivity under best practice treatment
- Video production has proved to be a highly effective method of engaging with members of the viticulture industry. The video has been viewed 361 times since it was published at the end of 2022.

Key challenges

- Inconsistency of economic data available from growers proved to be a hurdle
- Variability of vine damage and recovery makes it difficult to provide unequivocal recommendations for individual situations.

Legacy and next steps

- The digital resources generated through this project (video and podcast) are readily accessed and freely available to assist vineyard owners respond to bushfire damage to vineyards in the future
- Findings are also being incorporated into industry articles and factsheets which will be published and made available to the grape and wine sector
- All resources will be housed on the Wine Australia website.

Recommendations

- Ongoing promotion and communication of project outcomes, particularly in the lead-up to a high-risk fire season, will raise awareness of the resources available, including the video, podcast and factsheets

Concluding statement

Major bushfire events are only expected to increase in frequency in future with the effects of climate change. All Australian vineyard managers therefore face the increasing risk of damage to grapevines by fire. Findings from this project will be invaluable for vineyard managers if (when) they face the scenario of recovery from fire damage in the future.

Communication

This project has achieved the core objective of filling knowledge gaps relating to the best timing of vineyard recovery activities, the most suitable recovery method, and the expected economic value of each strategy. Significant extension materials and digital content were generated, with findings communicated through the following avenues:

- Presentation at the SA Central Expo, 23rd September 2020
- Presentation at the National Wine Sector Bushfire Conference, 25th May 2021
- Poster presentations (x2) at the Australian Wine Industry Technical Conference (AWITC), 26th-29th June 2022 (including being awarded the prize for best industry impact)
- Wine Australia RD&A News article 26 August 2022 Acting after a bushfire: what to do, and when | Wine Australia
- Presentation to NE Wine Zone (Vic) grower group, 23rd Nov 2022
- Production of a 10-minute resource video for industry containing key findings from the project, December 2022 https://youtu.be/RyMgjoFbn-0 or *via* Vine recovery following a fire | Wine Australia
- Recording of a podcast as part of the ASVO's 'Grower Maker Researcher' series, February 2023 Managing vineyards damaged by fire | Grower, Maker, Researcher - Wine Industry Insights
- Publication of three feature articles in the Australian and New Zealand Grapegrower and Winemaker journal, intended for spring 2023
- Future publication of downloadable fact sheets, based on the feature article manuscripts, which will be made available after the articles are published *via* the Wine Australia website: Vine recovery following a fire | Wine Australia

Feedback from live presentations and AWITC activities were extremely positive and supportive of the project objectives and findings.