

Benefit cost analysis of sub-surface drains for managing on-farm waterlogging in the Esperance Port Zone

Report prepared for:



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Executive Summary

South Coast Natural Resource Management have conducted a three-year trial to determine the cost-effectiveness of sub-surface drainage in the Esperance Port Zone of Western Australia. The trial is part of a project that is an investment by the Grains Research and Development Corporation and aims to support growers and advisors make more informed management decisions to address waterlogging on-farm. This report presents a Benefit Cost Analysis of the sub-surface drains to determine their cost-effectiveness and the timeframes associated with economic returns.

The trial was conducted in two locations near Esperance; Dalyup and Neridup. The total length of drains used in the Dalyup sub-surface drainage system is 19km across 56ha in area. The Neridup drainage system has a total length of 2.6km over 8.0ha in area. Both drains have 36m spacings so that the length (in metres) to area (in hectares) ratio is 1.3. The cost of installing the drains ranged from \$2,990/ha - \$5,190/ha, with the lower cost of installation attributed to lower labour costs (the grower installing the drain rather than subcontracting installation) and the use of a perforated sock to surround the pipe rather than limestone aggregate.

All three years of the trial, 2021 – 2023, experienced high growing season rainfall. The yield response due to the drains ranged from 1.13-1.49t/ha for wheat, 1.36t/ha for barley and 0.07-0.72t/ha for canola.

Results of the Benefit Cost Analysis suggest that subsurface drains are likely to be a cost-effective way for growers to manage soils that are susceptible to waterlogging in the Esperance region of Western Australia.

The net present value of the trial drains ranged between \$2,000 - \$2,500/ha for the two sites, with a return on investment between 31 - 68% and an internal rate of return of 12-16%. The time to break-even is estimated to be between 9 and 12 years with drains lasting at least 20 years and possibly more than 30 years without significant repair and maintenance costs. The drains at the Dalyup trial site had lower installation costs and was found to be more cost-effective than the drains at the Neridup site, even though yield responses were lower. **Minimising installation costs is key to maximising the profitability of subsurface drains.**

A Sensitivity Analysis found that the cost-effectiveness of the subsurface drains is robust to a range of realistic changes to future economic and environmental conditions. It is likely that subsurface drains will remain profitable unless future conditions are significantly more pessimistic than expected. This is especially true if installation costs increase significantly or if real grain prices reduce rather than increase through time. On the other hand, the profitability of subsurface drains is expected to be higher than expected if prices and crop yield productivity improvements through time are higher than expected.

This analysis is limited by the number of trial years (3), the homogeneity of trial years (all had relatively high growing season rainfall), the number of trial sites (2), and the number of years for which crop types were tested (wheat = 2 years, barley = 1 year, canola = 2 years). **Our results need to be validated with further trial sites, over a longer period of time to consider a range of years and where the yield responses of different crops types are repeatedly tested.**

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1. Background

Waterlogging occurs when there is excess water in a plant's root zone which leads to decreased oxygen availability to roots impeding plant growth (DPIRD 2023). It can also create poor trafficability, loss of nutrients, soil structure decline and recharge to saline watertables (DPIRD 2021). About 1 million hectares, or 5% of agricultural land in South West WA, has either high or very high susceptibility to waterlogging, and a further 2 million has moderate susceptibility (DPIRD 2022). Areas prone to waterlogging are those with relatively high rainfall (generally greater than 450mm/year) and are low in the landscape with low slopes. Soils particularly susceptible are shallow duplex soils, especially those with clay subsoil and on slopes less than 10% (DPIRD 2022).

Apart from using tolerant crops, pastures with suitable agronomy, or diverting surface water flows upslope using surface water management, the only suitable option in some areas is drainage. Drainage systems can include surface drains or subsurface drains. Surface drains can be installed along fencelines, laneways and depressions to control surface water. The buried pipe sits to the depth of the clay layer within the subsoil, the layer at which perched water becomes trapped in the root zone of the crop, reducing the prevalence of crop drownings and improving soil health (South Coast NRM 2024a). Surface drains are prevalent in Western Australia, but subsurface drains are scarce, and little is known about their cost-effectiveness.

South Coast Natural Resource Management have conducted a three-year trial to determine the cost-effectiveness of sub-surface drainage in the Esperance Port Zone of Western Australia. This project is an investment by the Grains Research and Development Corporation, and aims to support growers and advisors make more informed management decisions to address waterlogging on-farm. This report presents a Benefit Cost Analysis of the sub-surface drains to determine their cost-effectiveness and the timeframes associated with economic returns.

This report is a key deliverable in the statistical analysis for the trial, and directly delivers on the project's objective, "By 15 March 2024, key learnings and analysis of ROI of the trial sites will be extended to growers and advisers in the Western Region so that they have the knowledge and ability to implement on-farm sub-surface drainage and have a good understanding of time to return on this investment." Further findings and full project details are explored in the *Sub-surface Drainage Return on Investment Trial Final Technical Report: Esperance Port Zone*, by South Coast NRM (2024b).

2. Design of the sub-surface drainage trial

The trial involved the construction of two subsurface drainage systems, one in Dalyup and the other in Neridup (Figure 1). Both sites have relatively high rainfall, and shallow sandy/gravel soils over clay, making these sites particularly vulnerable to waterlogging (DPIRD 2022).

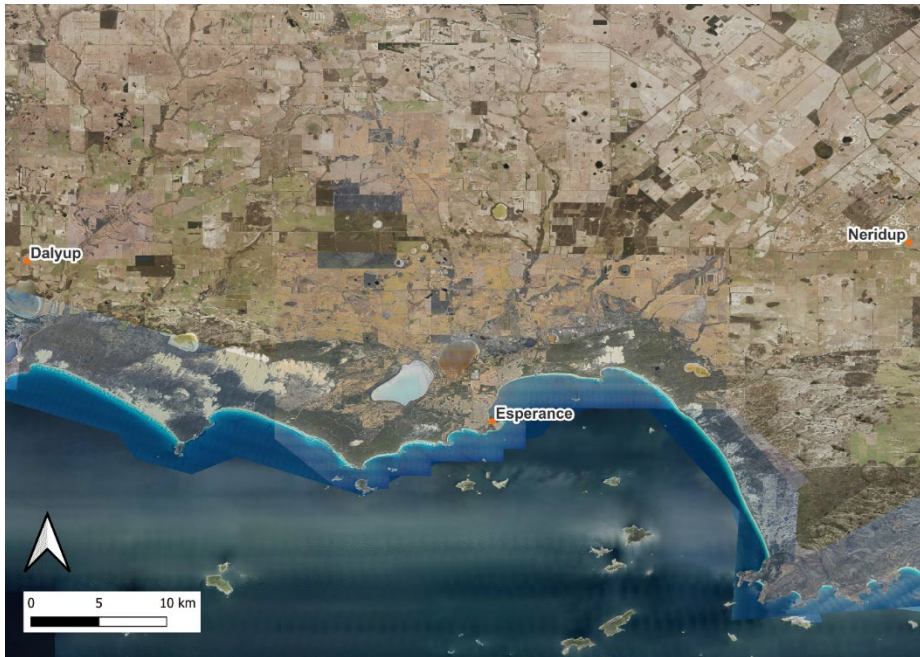


Figure 1: Trial locations for the subsurface drainage trial in the Esperance Port Zone (Source: South Coast NRM 2024b)

The subsurface drainage plan for the Dalyup site is shown in Figure 2. The site includes the 56ha area of the drain of which 66ha is affected by the drain. This area of affect is considered to be the drains “zone of influence”. The landholder installed a total of 33 individual pipes that ranged from 450m - 700m in length, running with the natural elevation of the paddock.



Figure 2: Dalyup sub-surface drainage trial in the Esperance Port Zone (Source: South Coast NRM 2024b).

The sub-surface drainage plan for the Neridup site is shown in Figure 3. The site is comprised of 9 lateral lengths of sub-surface drainage pipe across an 8ha area (with a 9.2ha zone of influence), as well as two control areas within the same paddock. One control is an area that is not susceptible to waterlogging (Control D) and the other is an area susceptible to waterlogging but not affected by the drains (Control W). Excess water transmitted by the drains was not harvested for secondary use for either site. Specific details regarding the trials are provided in Table 1.

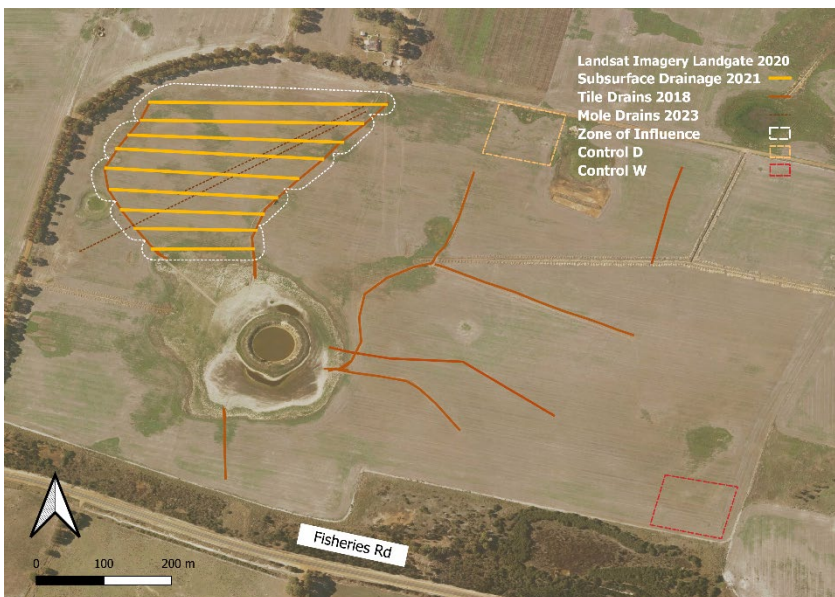


Figure 3: Neridup sub-surface drainage trial in the Esperance Port Zone (Source: South Coast NRM 2024b).

Table 1: Specifics about the sub-surface drainage trial sites

	Dalyup site	Neridup site
Length of drains	19km	2.6km
Area of drains	56ha	8.0ha
Area affected by drains	66ha	9.2ha
Drain spacing	36m	
Length to area ratio	Both sites have a drain length (km) to area (ha) ratio of 1:3 based on 36m spacings.	
Depth of drains	0.6-0.8m (to depth of clay layer within the soil profile)	
Installation	The landholder completed the installation using a soil-max tile drain machine and materials purchased from US distributor, Farm-Xport.	Installed by subsurface drainage contractor, Surface Water Management from Bunbury. The landholder did not need to purchase machinery or equipment.
Design	A mesh sock was used to surround the drain pipes	Limestone aggregate was used to surround the drain pipes

Source: Trial information

3. Methodology

Monitoring of the Neridup site by South Coast NRM began in February 2021 and ended in February 2024. The Dalyup trial site was included into the project following the first year's success at Neridup. Monitoring at the Dalyup site commencing in February 2022 and ending in February 2024. In total, three years of harvest data are analysed in Section 4 for Neridup, and 2 years are analysed for Dalyup.

Yield data was collected by the landholders annually following the subsequent harvest. The yield benefits were calculated by subtracting the yields of the drained site from the undrained (control) sites in the years of the trial. The undrained waterlogged control was used for comparison at the Neridup site.

To appropriately determine what parts of the paddock were being affected by the drains, the project established a zone of influence. The zone of influence is determined by adding a buffer to the perimeter of the drainage network with an extent of half the spacing width. For both trial sites, the spacing of the drains was 36m, creating an 18m buffer around the drains. The zones of influence for each trial site are mapped in Section 2 (Figures 2 and 3).

A Benefit Cost Analysis is performed to determine the cost-effectiveness of the drains, and the timeframes associated with economic returns. It employs standard discounted cashflow methodology. The steps involved in conducting a Benefit Cost Analysis include (adapted from Australian Government (2020)):

1. **Specifying the set of options to be evaluated.** In this case, the options include the Dalyup and Neridup sub-surface drainage systems.
2. **Identifying the impacts and select measurement indicators.** The impacts of this project include increased yields at each site. Other select measurement indicators include drain installation and maintenance costs, and additional crop related costs.
3. **Predicting the impacts over the life of the innovation.** In this case, expected yield increases due to the drains are predicted over a 20-year time horizon, with associated maintenance costs and crop related costs.
4. **Monetising (place a dollar value on) the impacts.** In this analysis, yield responses due to the drains are multiplied by the price of grain to estimate the value of yield responses.
5. **Discounting future costs and benefits to obtain present values.** The importance and methodology for discounting future cash flows is discussed in the paragraph below.
6. **Computing Benefit Cost Analysis statistics for each innovation.** In this case, we compute the following statistics:
 - a. The present value of the benefits (PVB, \$),
 - b. The present value of the costs (PVC, \$),
 - c. The net present value ($NPV = PVB - PVC$, \$),
 - d. The benefit cost ratio ($BCR = PVB / PVC$),
 - e. The return on investment ($ROI = NPV / PVB$, %),
 - f. The internal rate of return (IRR, %), and
 - g. The time to breakeven (years).
7. **Performing Sensitivity Analysis.** The purpose of the Sensitivity Analysis is to measure how uncertainty about specific assumptions of the Benefit Cost Analysis affect predicted impacts and their associated monetary valuation.

The process of discounting is important due to what is known as the time preference of money. The time preference of money states that money received now is worth more than money received in

the future. This is because we can invest money now and receive interest on that investment. To take into account this time preference of money, we need to reduce the amount of money received in the future to a present value by a process called 'discounting', using the following formula:

$$PV = \frac{FV}{(1 + r)^n}$$

where PV = Present value (\$)
 FV = Future value (\$)
 r = discount rate (%), and
 n = number of periods (in this case, the number of years).

The discount rate reflects the interest rate we think we could get on money we invest over the period of analysis.

4. Results

This section presents information and data on the climate of the two trial sites (subsection 4.1), the impacts and costs of the drains (subsections 4.2 and 4.3, respectively), as well as the findings of the Benefit Cost Analyses (subsection 4.4) and associated Sensitivity Analyses (subsection 4.5).

4.1 Climate

In 2021, Dalyup received a below average annual rainfall of 573mm, although most of this fell between April to November leading to an above average growing season. Neridup's total annual rainfall for the same year was above average reaching 631mm. Hence, the growing season had above average rainfall for both sites (Figures 4 and 5) (Bureau of Meteorology 2024a).

In 2022, with La Nina encouraging high rainfall for the South Coast, both Dalyup and Neridup recorded decile 10 annual and growing season rainfalls, reaching an annual rainfall of 732mm and 677mm, respectively (Bureau of Meteorology 2020).

El Nino and a negatively charged Indian Ocean Dipole led to drying conditions for the South Coast in 2023, dropping Dalyup's annual rainfall to a very low level (479mm), and Neridup's to a low level (487mm) (CSIRO 2023). However, much of 2023's rainfall was received during the growing season with Dalyup and Neridup both experiencing a high growing season rainfall.

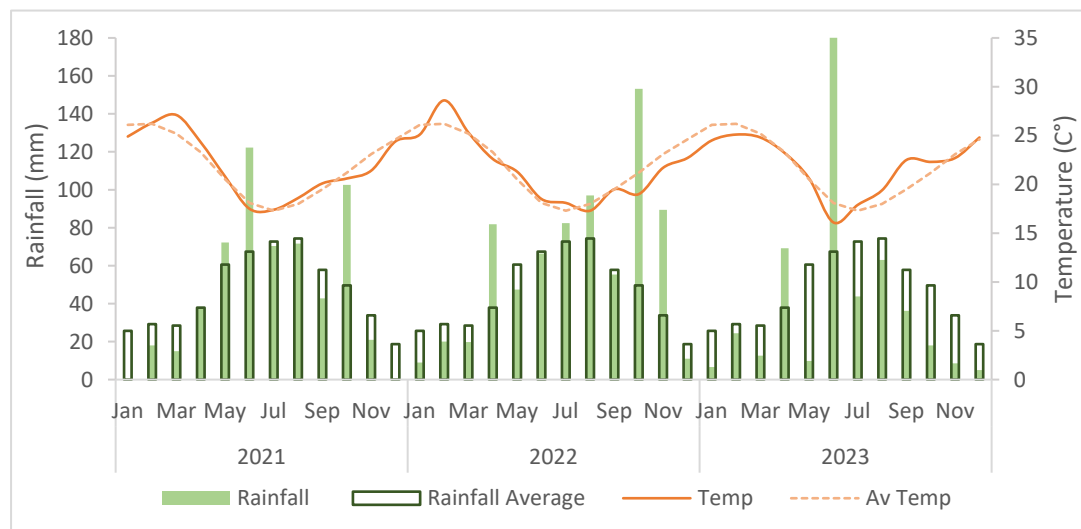


Figure 4: Monthly Climate Data for Dalyup, 2021 - 2023. Source: Bureau of Meteorology (2024a)

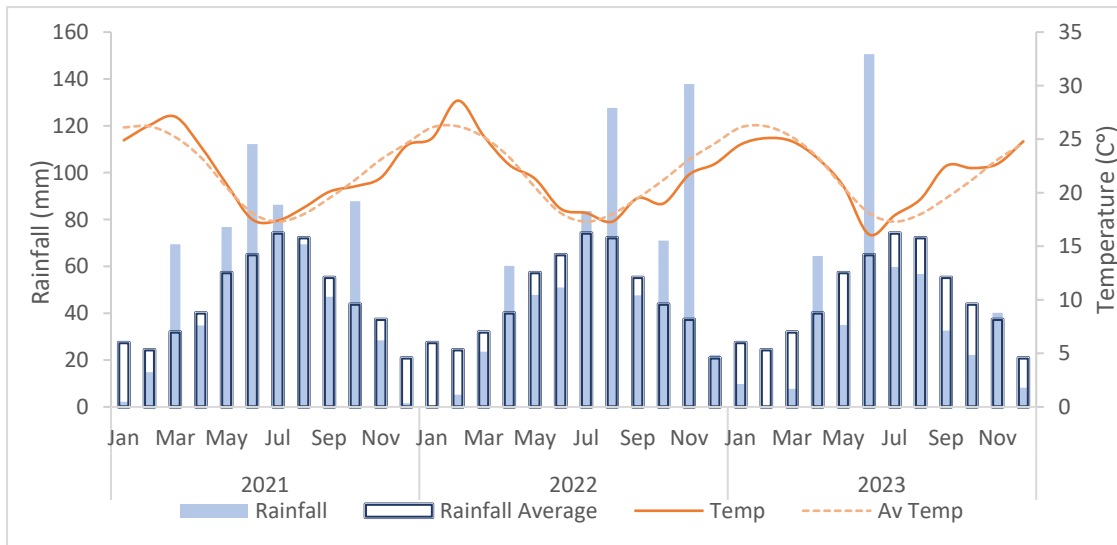


Figure 5: Monthly Climate Data for Neridup, 2021 - 2023. Source: Bureau of Meteorology (2024a)

4.2 Impacts of the drains

The impacts of the drains are considered in terms of yield benefits observed between the drained and undrained crops.

The Dalyup site

Dalyup grew canola in 2022, and wheat in 2023. The Dalyup trial yield data for 2022 and 2023 is summarised in Figure 6. Crop yields were higher for the drained compared with undrained areas of the trial. The 2022 canola yields in the drained area were 26% higher than in the undrained area. The following year, wheat yields increased by 44% due to the drain.

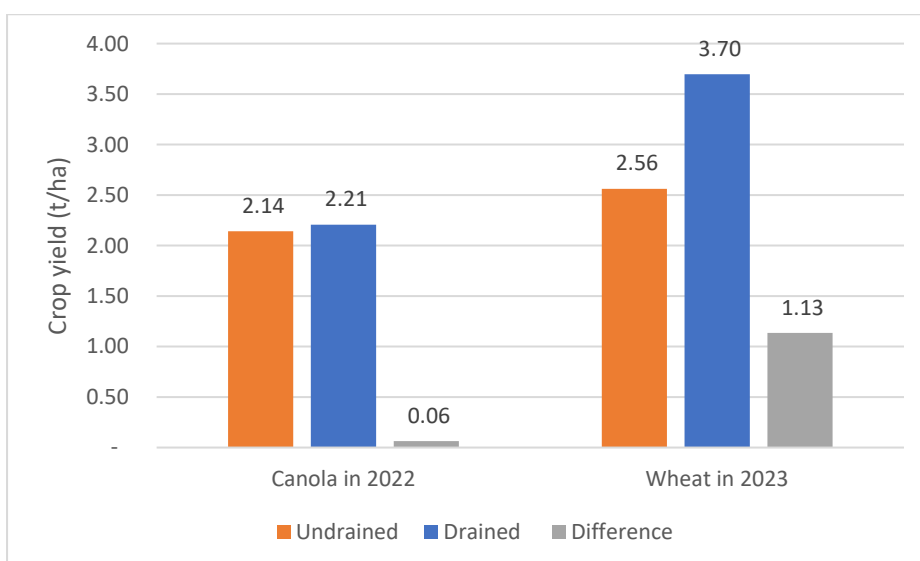


Figure 6: Grain yield data for the undrained and drained sections of the drained area at Dalyup for 2022 and 2023 (Source: Trial data)

Growing season rainfall was high in 2022 and 2023 compared with previous years (Figure 7). In the case of cereals, while similar yield benefits from the subsurface drains may be expected in future years with high and medium growing season rainfall, the benefits of the drain are expected to be lower in future years with low growing season rainfall. The Benefit Cost Analysis assumes average growing season rainfall in future years with yield responses that are 20% lower than the trial results for wheat (0.88t/ha). As the trial yield response for canola was very low because the extent of rainfall at key times meant that the drain had minimal effect, a higher yield response for canola is expected in future years. The average canola yield response is expected to be half that of the average wheat yield response at 0.44t/ha.

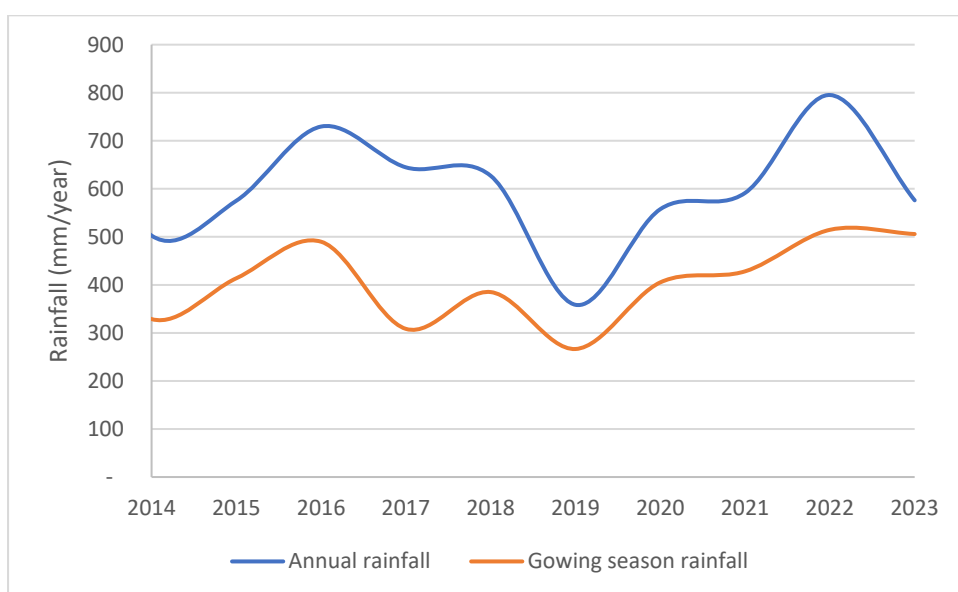


Figure 7: Farm annual and growing season rainfall at Dalyup, 2014-2023 (Source: Bureau of Meteorology 2024b)

The Neridup site

The crops sown to the paddock for the six years pre-trial and three years of the trial are shown in Table 2.

Table 2: Crop types sown in the Neridup trial paddock for the six years before the sub-surface drain trial (2015 – 2020) and the three years of the trial (2021-2023)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023
	Pre-trial						Trial		
Crop	Barley	Barley	Barley	Wheat	Wheat	Barley	Canola	Wheat	Barley

Source: Grower data

Yield data is provided in Figure 8 for paddock yield (the average yield across the whole paddock - blue columns), compared with the drained yield (the average yield for the drained area within the paddock - orange columns). The drained yield is on average significantly lower than the paddock yield for five of the six years before the trial, likely due to the effects of waterlogging.

The one year in which the drained yield was higher than paddock yield was a very low rainfall year (2019) where growing season rainfall was significantly lower than other years (Figure 9). On average, the yield at the drained site was 19% lower than the paddock yield before the subsurface drains were installed.

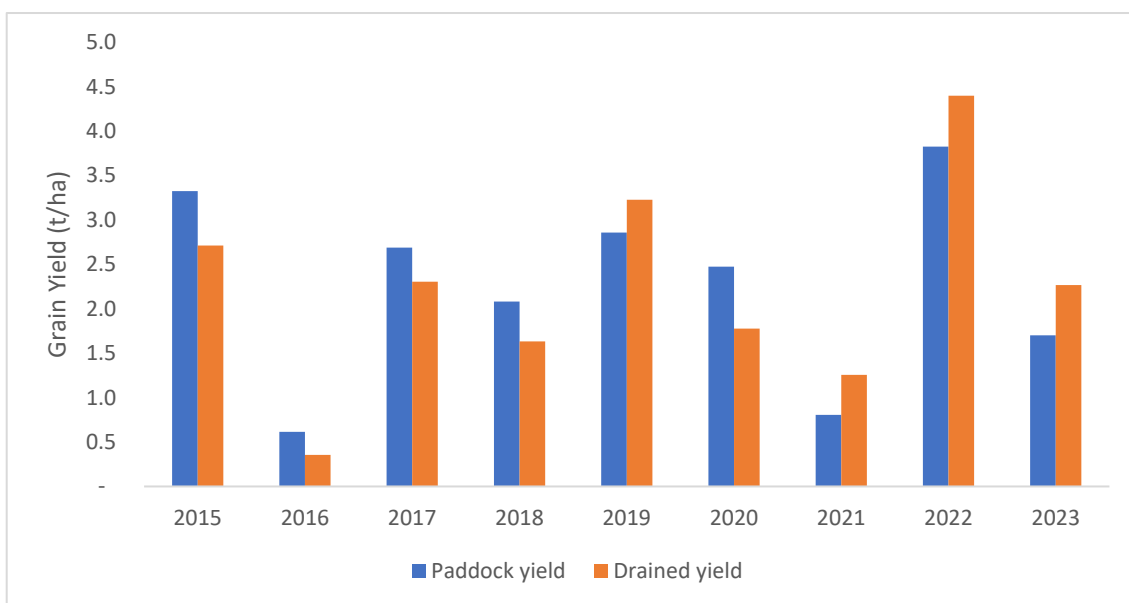


Figure 8: Grain yield data for the whole paddock and the trial area at Neridup for six years before the sub-surface drain trial (2015 – 2020) and the three years of the trial (2021-2023) (Source: Grower and trial data)

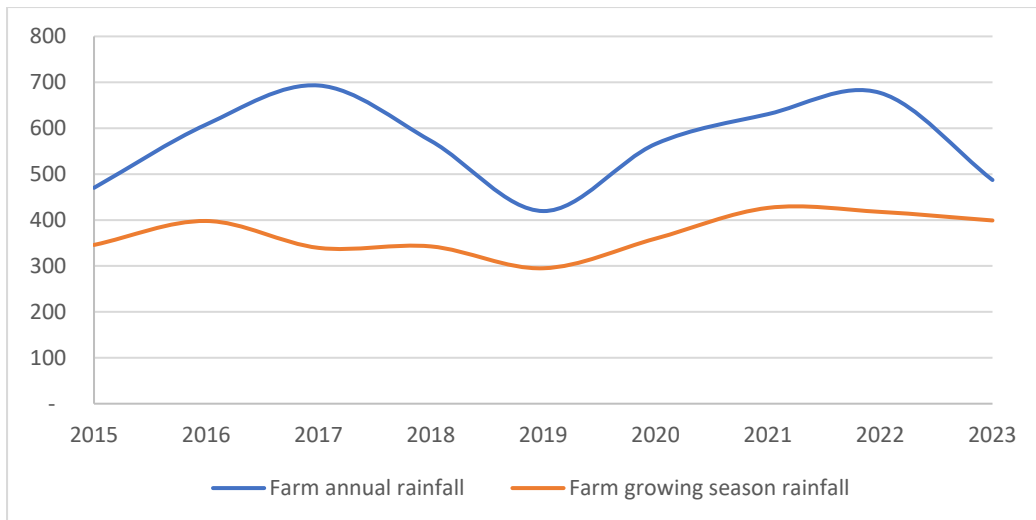


Figure 9: Farm annual and growing season rainfall at Neridup, 2015-2023 (Source: Bureau of Meteorology 2024c)

The three years of data since the drains were installed were much higher rainfall years, particularly throughout the growing seasons of 2021 and 2022 which fluctuated between deciles 8 – 10. The average drained yield is significantly higher than the paddock yield for the three years, an average of 35% higher. Note that yield is lower in 2021 compared with most other years as canola was grown that year rather than wheat or barley. Canola typically has lower yields than cereals when measured on a tonne per hectare basis.

Yield data is provided in Figure 10 for the drained yield (orange line) compared with the two controls – the waterlogged control (blue column) and the dry control (grey column). On average, before the drain was installed, the drained site yields were 8% lower than the waterlogged control and 26% lower than the dry control. After the drain was installed, the drained site performed better than both controls – 112% better than the waterlogged control and 12% better than the dry control.

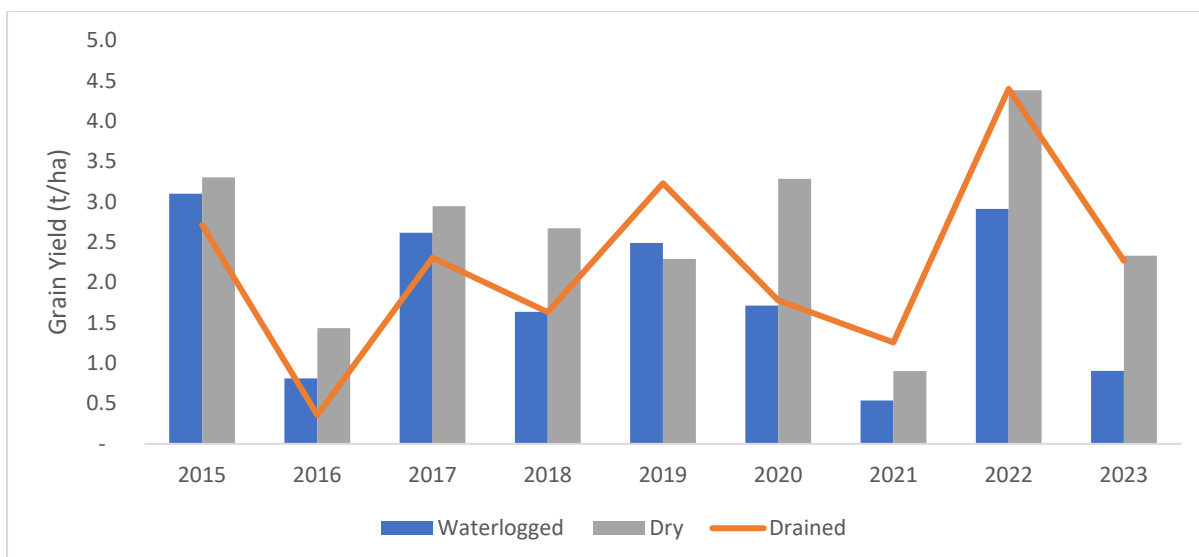


Figure 10: Neridup’s grain yield data for the control areas (waterlogged and dry areas) and the drained area for six years before the sub-surface drain trial (2015 – 2020) and the three years of the trial (2021-2023) (Source: Trial data)

The average difference in yields between the waterlogged and drained site before and after the trial are shown in Table 3. The expected benefits of the sub-surface drainage for cereals is estimated to be 1.55t/ha (a 59% benefit) and for canola is estimated to be 0.76t/ha (141%) for the Neridup site.

Table 3: Average difference between the waterlogged and drained sites at the Neridup site

	Before the trial (2015-2020)	After the trial (2021-2023)	Expected benefit of drain	
			Cereals	Canola
Average difference between waterlogged and drained sites (t/ha)	-0.06	1.19	1.48	0.76
Average difference between waterlogged and drained sites (%)	-8	112	109	141

Source: Author estimates

The three years of trial sites experienced high growing season rainfall (see Figure 9). The project results suggest the drain will provide benefits shown in Table 3 in years with high and medium growing season rainfall, but little yield increase is expected in years with low growing season rainfall. The Benefit Cost Analysis assumes average growing season rainfall in future years with yield responses that are 20% lower than the trial results. Yield responses to the drain in average years is assumed to be 0.61t/ha for canola and 1.18t/ha for wheat and barley.

4.3 Cost of the drains

The costs of installing the subsurface drainage systems for the Dalyup and Neridup sites are provided in Tables 4 and 5, respectively. Costs are divided by actual drain area, although the zone of influence

is larger. The Dalyup drain was more expensive in total than the Neridup drain, but cheaper on a per unit length and area basis.

Table 4: Dalyup subsurface drain installation costs

Activity	Total (\$)	Cost per unit length (\$/km)	Cost per unit area (\$/ha)
Soil Max machine	120,000	6,316	2,162
Pipe & sock (\$3/m in 2021)	40,500	2,132	723
Labour	3,240	171	58
Open drain for discharge point	1,900	100	34
Wages and administration	1,797	95	32
TOTAL	167,437	8,812	2,990

Source: Trial data

Table 5: Neridup subsurface drain installation costs

Activity	Total (\$)	Cost per unit length (\$/km)	Cost per unit area (\$/ha)
Aggregate	13,500	5,192	1,688
Travel and accommodation for team	7,000	2,692	875
Installation of 2.6km pipe (includes labour	21,000	8,077	2,625
TOTAL	41,500	15,962	5,188

Source: Trial data

4.4 Benefit cost analyses

A Benefit Cost Analysis is conducted separately for the Dalyup and Neridup sites, as presented below. The analyses use the following common assumptions:

- A 20-year time horizon. While it is likely that the drains will last longer than 20 years without significant repairs or maintenance, a 20-year time horizon is used for this analysis to be conservative,
- Real grain prices of \$350/ha for barley, \$450/ha for wheat and \$750/ha for canola. These prices are slightly higher than current prices (AWB 2023) as prices over the next 20 years are expected to rise (not including the impact of inflation),
- Grain yields in the future are expected to increase by 3%/year due to productivity improvements, such as improved varieties and crop management practices,
- To achieve higher crop yields due to the drain, additional agronomic costs will be required by way of increased fertiliser, chemical and cartage costs. These additional agronomic costs are estimated to be \$20/ha,
- Trial results show that annual repair and maintenance costs of drain are approximately 1.2% of the cost of drain installation, and
To comply with Western Australian state government guidelines, a discount rate of 7% is used (Pannell 2019).

The Dalyup site

Specific assumptions for the Dalyup site include:

- A repeated wheat-canola rotation,
- Yield responses due to the drain for the first three years of 1.1t/ha (wheat), 0.1t/ha (canola) and 1.1t/ha (wheat) (see Figure 6),
- In future years, average growing season rainfall is assumed with wheat yield responses that are 20% lower than the trial results = 0.88t/ha. As canola trial yields are very low, a higher yield response for canola is expected in future years. The canola yield response is expected to be half that of the average wheat yield response = 0.48t/ha,
- Area of impact = 66ha. This is slightly greater than the area of the drain (56ha) to account for the zone of influence of the drain, and
- Installation cost of drain = \$167,437 (see Table 4).

The future stream of benefits and costs of the subsurface drains is shown in Figure 11. These benefits and costs are not yet discounted so they don't account for the time preference of money. The major cost is installation, with only minor drain repair and maintenance and additional agronomic costs accruing annually after installation.

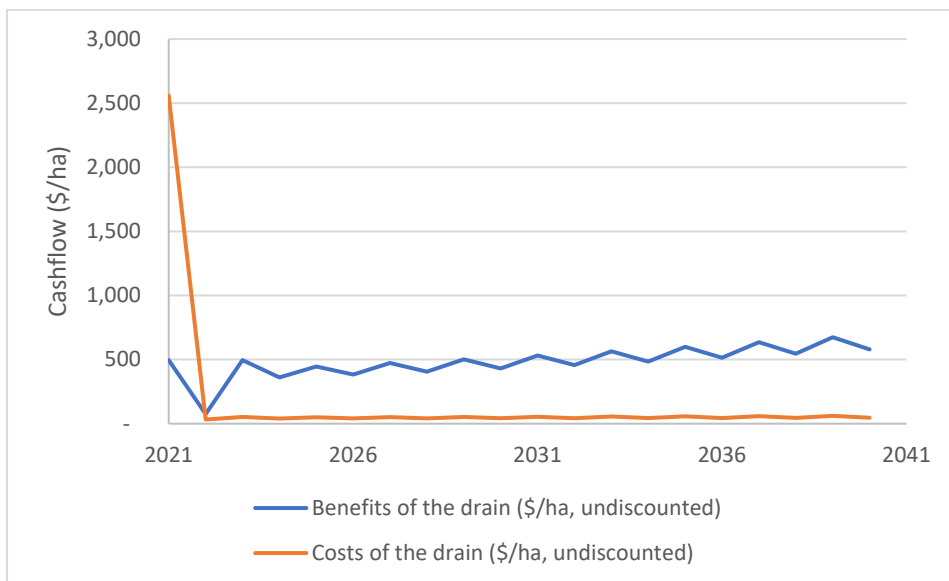


Figure 11: Undiscounted stream of benefits and costs of the sub-surface drains for the Dalyup site (Source: Author estimates)

The cumulative cashflow curve with and without discounting is provided in Figure 12. These results show that the project is cost-effective, with break-even expected to occur in 2030, 9 years after installation (see blue line that includes discounting to account for the time preference of money).

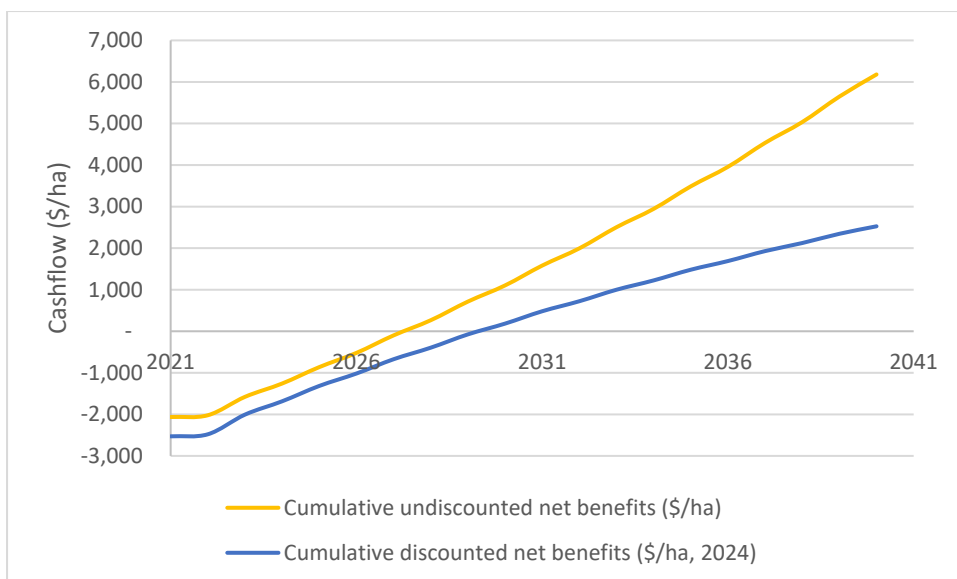


Figure 12: Cumulative cashflow from the subsurface drains for the Dalyup site (Source: Author estimates)

A summary of the results of the Benefit Cost Analysis for the Dalyup drains is provided in Table 6. The present value of the benefits is expected to exceed the present value of the costs, with the drains presenting a net present value of \$2,530/ha. The benefit cost ratio is estimated to be 1.68, indicating that for every dollar spent on the project, the grower receives \$1.68 in return. This represents a 68% return on investment – a 68% profit on investment. The internal rate of return is 16% suggesting that the project is expected to provide a 16% annual rate of growth, which is significantly higher than current interest rates.

Table 6: Benefit cost analysis results for Dalyup over a 20-year time period (\$, 2024 discounted)

	Total area (\$)	Per hectare (\$/ha)
Present value of the benefits (\$)	413,000	6,260
Present value of the costs (\$)	246,000	3,730
Net present value (\$)	167,000	2,530
Benefit cost ratio		1.68
Return on investment (%)		67.9
IRR (%)		16.4
Time to breakeven (year)		2030

Source: Author estimates

The Neridup site

Specific assumptions for the Neridup site include:

- A repeated canola-wheat-barley rotation,
- Yield responses due to the sub-surface drain of 0.76t/ha (canola), 1.55t/ha (wheat) and 1.42t/ha (barley) for the first three years (see Table 3),
- In future years, average growing season rainfall is assumed with yield responses that are 20% lower than the trial results – 0.61t/ha for canola and 1.18t/ha for wheat and barley,
- Area of impact = 9.2ha. This is slightly greater than the area of the drain (8ha) to account for the impact of the drain around its perimeter, and
- Installation cost of drain = \$41,500 (see Table 5).

The future stream of benefits and costs of the subsurface drains is shown in Figure 13. These benefits and costs are not yet discounted so they don't take into account the time preference of money. As was the case at the Dalyup site, the major cost is installation, with only minor drain repair and maintenance and additional agronomic costs accruing annually after installation.

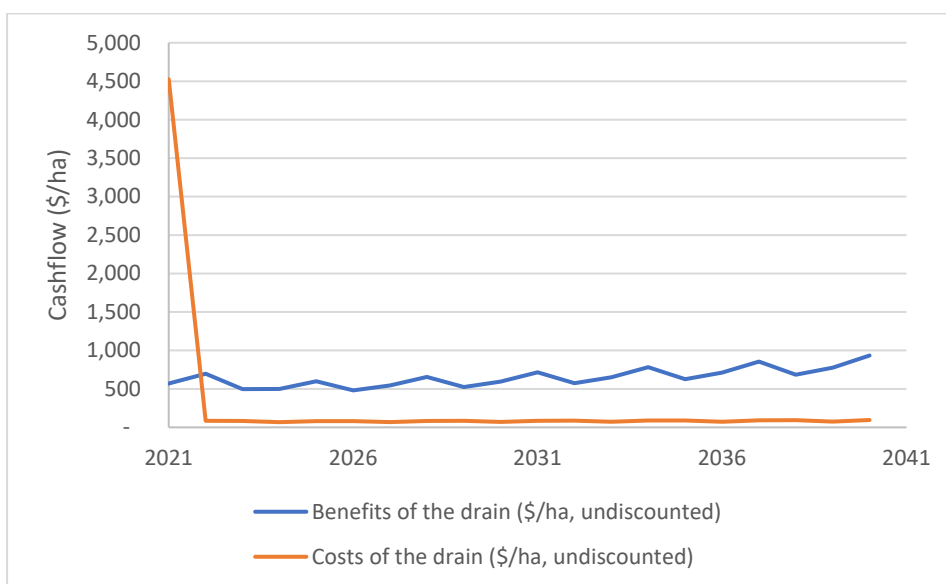


Figure 13: Undiscounted stream of benefits and costs of the sub-surface drains for the Neridup site (Source: Author estimates)

The cumulative cashflow curve with and without discounting is provided in Figure 14. These results show that the project is cost-effective, with break-even expected to occur in 2033, 12 years after installation (see blue line that includes discounting to account for the time preference of money).

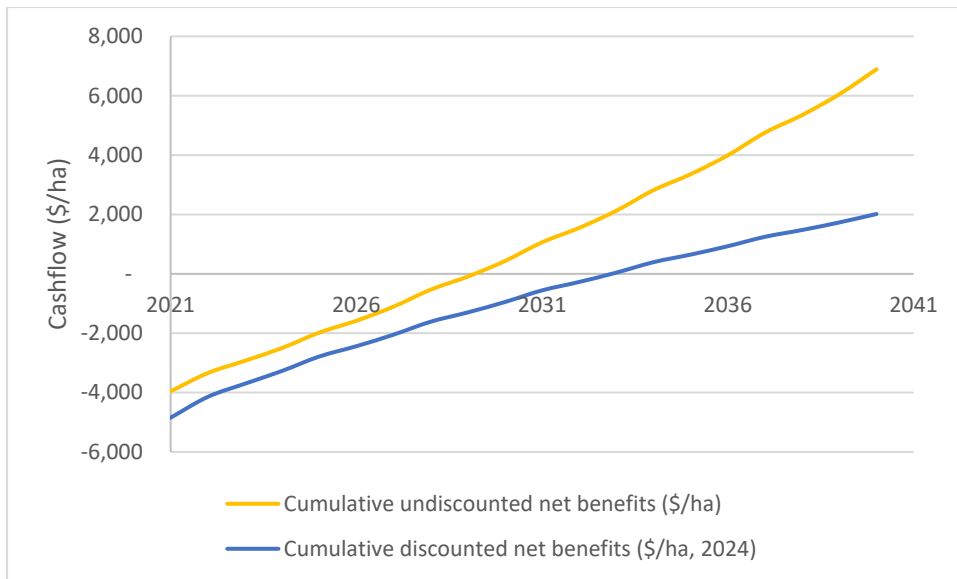


Figure 14: Cumulative cashflow from the sub-surface drains for the Neridup site (Source: Author estimates)

A summary of the results of the Benefit Cost Analysis for Neridup is provided in Table 7. The present value of the benefits is expected to exceed the present value of the costs, with the drains presenting a net present value of \$2,000/ha. The benefit cost ratio is estimated to be 1.31, indicating that for every dollar spent on the project, the grower receives \$1.31 in return. This represents a 31% return on investment - 31% profit on investment. The internal rate of return is 12% suggesting that the project is expected to provide a 12% annual rate of growth, which is significantly higher than current interest rates.

Table 7: Benefit cost analysis results for the Neridup site over a 20-year time period (\$, 2024 discounted)

	Total area (\$)	Per hectare (\$/ha)
Present value of the benefits (\$)	79,000	8,600
Present value of the costs (\$)	60,400	6,600
Net present value (\$)	18,600	2,000
Benefit cost ratio	1.31	
Return on investment (%)	30.8	
IRR (%)	11.7	
Time to breakeven (year)	2033	

Source: Author estimates

4.5 Sensitivity analyses

A sensitivity analysis is conducted on the net present value of each of the drains to determine whether the results are sensitive to key assumptions. Each of the key assumptions are adjusted one at a time, with all other assumptions held the same. Each key assumption is adjusted to a realistically low and a realistically high value, as indicated in the legend of the figures presented below.

The sensitivity analysis for the Dalyup site is presented in Figure 15. The net present value remains well above zero in all scenarios indicating that the subsurface drains are likely to be cost-effective under a range of future economic and environmental conditions. The results are least sensitive to changes in maintenance and additional agronomic costs, and most sensitive to future expected prices and the potential for higher-than-expected crop productivity improvements.

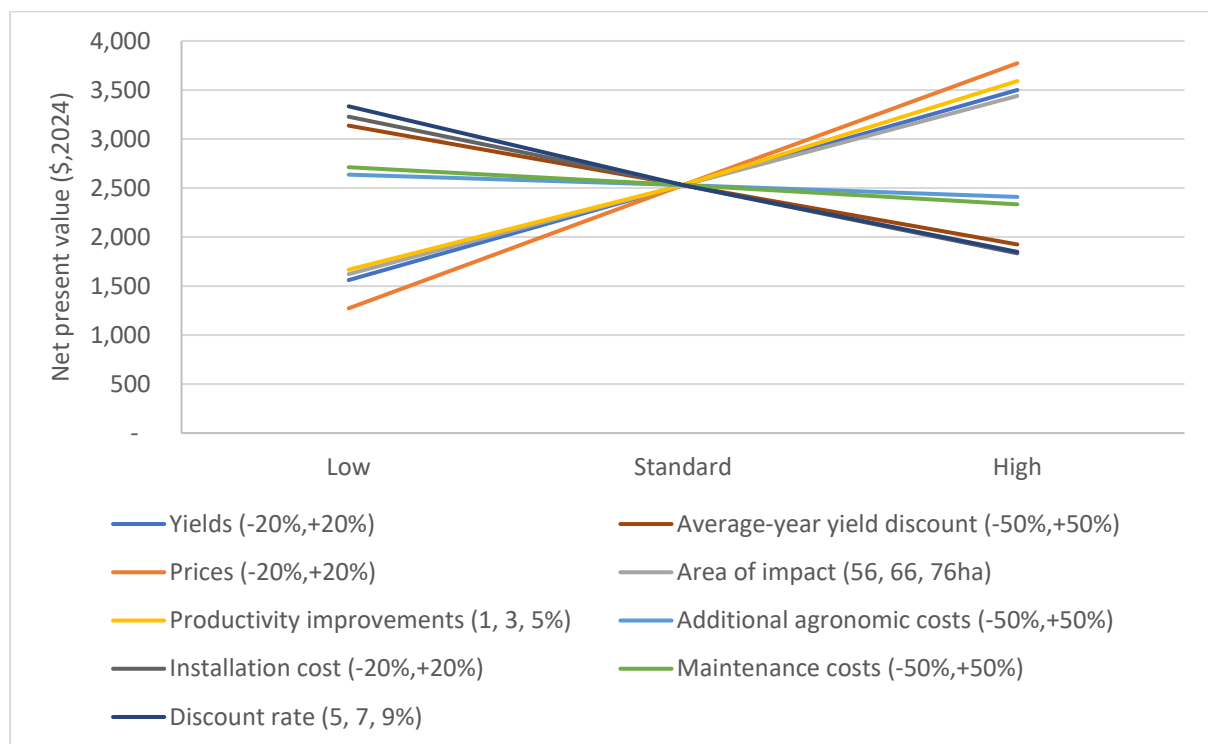


Figure 15: Sensitivity analysis of the sub-surface drains for the Dalyup site (Source: Author estimates)

The sensitivity analysis for the Neridup site is presented in Figure 16. The net present value remains above zero in all scenarios indicating that the subsurface drains are likely to be cost-effective under a range of future economic and environmental conditions. As was the case for the Dalyup site, the results are least sensitive to changes in maintenance and additional agronomic costs. The results are most sensitive to future expected prices, where results are reduced to close to zero if average prices are 20% lower than assumed in this analysis. The results are also sensitive to installation costs, crop yields and productivity improvements.

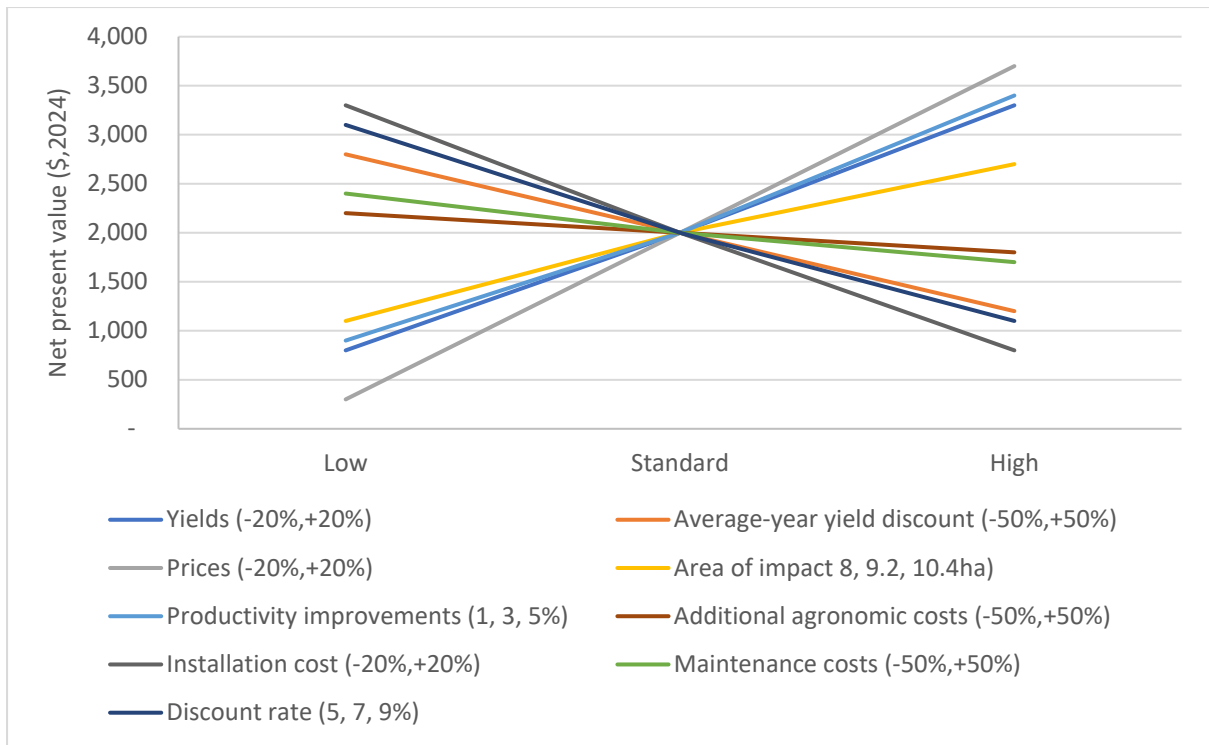


Figure 16: Sensitivity analysis of the sub-surface drains for the Neridup site (Source: Author estimates)

5. Conclusions

The results of trial suggest that subsurface drains are likely to be a cost-effective way for growers to manage soils that are susceptible to waterlogging in the Esperance region of Western Australia. The net present value of the trial drains ranged between \$2,000 - \$2,500/ha for the two sites, with a return on investment between 31 - 68%. The internal rate of return of the drainage systems is estimated to be 12-16% which is well above current interest rates. The time to break even is estimated to be between 9 and 12 years, with drains expected to last at least 20 years with minimal repairs and maintenance, and possibly more than 30 years.

The results were found to be robust when a sensitivity analysis tested the impact of a range of realistic changes to future economic and environmental conditions on the economic performance of the trial drains. The sensitivity analysis found that the drains remained profitable under all conditions tested. The results were not sensitive to realistic changes in maintenance and additional agronomic costs (such as increases in fertiliser, chemical and cartage costs due to higher yields achieved by the drains). The results were most sensitive to future expected prices, crop productivity improvements and installation costs. The sensitivity analysis considered one change at a time, keeping all other assumptions the same. It is likely that the drains will become unprofitable if a number of future economic and environmental future conditions are simultaneously and significantly more pessimistic than those we have considered in this analysis.

The Dalyup site had greater economic benefits than the Neridup site, even though the yield responses at this Dalyup were lower than those of Neridup. This is because the Dalyup site had significantly lower costs than Neridup - \$2,990/ha compared with \$5,190/ha respectively (including installation, maintenance and additional crop costs). The lower costs at Dalyup can be attributed to lower labour costs of installation as the grower installed the drains himself, as well as the use of perforated sock to surround the drain rather than limestone aggregate. At the time of installation, the Neridup site could not attain any cost-effective, local sources of limestone aggregate, and therefore, sourced the aggregate from Busselton, shipping it down via road train. It is noted that accessing limestone or other suitable aggregate more locally, or from locations on farm, would significantly reduce the costs associated with the Neridup site's installation.

The author understands that installation costs have increased since 2021 when the trial drains were installed. Minimising installation costs will be key to maximising the profitability of sub-surface drains for managing waterlogging in south-western Australia.

There are a number of limitations to this study. Trial data for the subsurface drains was only available for 2 – 3 years, all of which experienced relatively high growing season rainfall when compared over a 10-year period. We have reduced the expected yield responses from the drain in future years assuming average growing season rainfall. Our results rely on one year of data for barley and two years of data for canola and wheat across two sites. Our results need to be validated with further trial sites, over a longer period of time to consider a range of years with low to high growing season rainfall, and where the variety of crop types are repeatedly tested.

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