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Evaluation of the least cost option to manage pastures in a wet winter in south-eastern Australia[1]

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Abstract

Extended wet winters present a challenge for grazing management for some farm businesses. Extended wet winters can cause waterlogging of pastures and when such pastures are grazed, soils and pastures are damaged. This research analysed, for two representative dairy farm businesses in south-eastern Australia with 100 hectares affected by a wet winter: (i) the cost of doing nothing differently to grazing management to manage pastures; (ii) the cost of actively managing wet pasture through 'on-off' grazing if the case study farm had a stand-off area; and (iii) the maximum amount of capital that could be invested in a stand-off area for wet pasture grazing management, if the farmer wants to earn a 10 per cent annual return. To do this analysis both biophysical modelling and economic analysis was used. It was found that, if the representative dairy farm businesses did nothing differently to grazing management during an extended wet winter, this could result in extra costs between $9,000 to $50,000 depending on the likelihood of a wet winter. However, if the representative farmer had a stand-off area and practised on-off grazing then the annual cost of this grazing strategy could be between $300 to $2,600. The maximum amount the representative farm business could invest in a stand-off area to earn a 10 per cent annual return, and be no worse off than doing nothing differently to manage wet pastures, was found to be from $50,000 to $250,000, depending on the frequency of the extreme wet weather. If the capital cost of the stand-off area was less than this amount, then the representative farmer would be better off investing in a stand-off area and using on-off grazing rather than doing nothing differently. A key conclusion from this analysis is that the representative farmer may be better able to manage the risk of a wet winter through active grazing management because the annual costs of an unchanged grazing management regime during a wet winter are more volatile than the costs of actively managing an extended wet winter. Lastly, a cost framework has been developed that other farm businesses could use to consider the costs of different wet winter pasture grazing management strategies for their businesses.

Key words: pasture management; cost analysis; wet winter; climate change

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Introduction

The changing climate is likely to increase the frequency of extreme, out-of-season rainfall events with periodic wetter-than-usual early- and mid-Spring conditions following a wet winter in south eastern Australia (Bureau of Meteorology, 2022). These extreme events will mean more waterlogged pastures, for longer times.

On dairy farms in the higher rainfall regions of south-eastern Australia pastures can be damaged and profits reduced when waterlogging of soils occurs during the winter and early spring (Ward, 2002). Waterlogging of pasture has longer-term adverse effects on soils when pastures on wet soils are grazed. Grazing waterlogged pasture crushes, bruises and buries herbage in mud, making it difficult to eat and unpalatable to stock, reducing pasture utilisation by up to 50 per cent (Ward, 2002). Cow intake of pasture is reduced at the time of grazing, and the quality of the feed offered to cows in subsequent grazing periods is also reduced while un-grazed clumps reduces subsequent pasture availability for grazing. Grazing and the associated pugging of a wet pasture causes serious long-term damage to the density and botanical composition of that pasture. Wet soils are at risk of structural damage and a decline in soil physical health by compaction or pugging when grazed. It is well documented that when a soil is pugged the soil structure is damaged (White, 2005).

Compaction from grazing occurs at a soil water content below full saturation when pressure from the animal's hoof compresses the pore space in the soil. This compression of pore spaces reduces the large macro pores and reduces soil aeration and water movement and increases soil bulk density. Taken together, the effect is that the growth potential of the pasture is severely restricted. The resulting deformation and remoulding of the soil causes undulation of the soil surface (Beukes et al., 2013). This process is self-perpetuating because the soil compaction at the bottom of the pug marks restricts downward percolation of water and causes ponding of water and reduced root penetration. After a soil is pugged in winter, it is a different, damaged soil compared to the soil at the start of the winter. Pasture accumulation is reduced for the remainder of the growing season (mid spring-early summer) for the pugged pasture, compared to a less damaged pasture, as the additive effect of both the physical damage to the soil caused by the pugging and the physical damage to the pasture plants and sward (Ward, 2002).

Essentially, under excessively wet conditions the pasture is growing in a more hostile soil environment with a loss of macro-porosity (reduced air-filled porosity at field capacity) leading to a poorer structure with zones of compaction. There is usually a thinning out of the pasture, with significant increases in the areas of bare ground and a decline in pasture composition, such as the loss of improved species and the ingress of weedy species. Nie et al. (2001) found yield reductions of 40-42 per cent in spring-early summer pasture dry matter (DM) following late winter-early spring pugging events (see also Ward et al., 2003). Pasture damage from wet soil pugging can necessitate the resowing of the pasture or some other form of pasture renovation.

Waterlogging and soil pugging have wider effects on the natural environment. Waterlogging increases denitrification of plant available nitrogen in the soil, increasing emissions of the powerful greenhouse gas nitrous oxide (de Klein and Eckard, 2008). Nutrient losses to the environment occur, especially of nitrogen, through surface runoff and nitrate leaching to groundwater. This increases eutrophication of waterways and ground water is contaminated (Eckard et al., 2004). Increased soil erosion from land with siltation of drains and waterways occurs too.

Waterlogged soils and the associated pugging of pastures affect farm operations and management by restricting access by stock and vehicles, damaging farm infrastructure (such as tracks, gateways and lanes) and creating additional challenges and stresses for management and staff (Nie et al., 2001). The opportunity to make silage can be lost or delayed which reduces the quality of the silage and the subsequent regrowth of the pasture. Fertiliser applications (especially of N) can be delayed, reducing pasture responses, or requiring more expensive application methods (such as by air). There is increased risk to animal welfare and health with increased stress, lameness, and mastitis, along with the need to increase supplementary feeding to compensate for reduced pasture intakes.

A range of strategies and management practices are used on farm to reduce the impact of waterlogging of pastures (Ward, 2002; DairyNZ, 2011). These include:

- Spreading the stock over the whole farm to reduce grazing pressure, or grazing only the well-drained paddocks. These strategies are minimalist management strategies;
- Using engineering options such as surface and subsurface drainage to drain excess water more quickly; and
- Actively managing grazing through reduced grazing time or pressure, such as the 'on-off' grazing method in rotational grazing management systems.

A strategy of avoiding grazing vulnerable paddocks (minimal management) results in faster rotations and ultimately reduces pasture growth rates as well as risking overgrazing and damaging the better-drained paddocks. The engineering options (for example 'hump and hollow' or 'ridge and furrow' sub-surface drainage) are costly options, often not viable for grazing activities. The 'on-off' grazing strategy is used and recommended on dairy farms in the higher rainfall areas of southern Australia and in New Zealand (Drewry, 2003; Laurenson et al., 2016; Agriculture Victoria, 2022).

The aim of this research was to explore the costs of doing nothing differently to grazing management in response to a wet winter and to explore the costs of taking steps to manage the wet conditions. That is, the strategy of grazing all paddocks in rotation during winter regardless of how wet it is (no adjustment for the extended wet winter) is compared with the costs of actively managing a wet winter using an 'on-off' grazing strategy.

Using on-off grazing strategy means cows are provided access to graze the wet pasture for a restricted time, usually 2-6 hours in a day, and then moved to a standoff area. For this strategy to be successful, it requires a suitable area to hold the cows in for several hours each day. Based on the research of Ward (2002), a stand-off area could include:

- Holding cows on farm infrastructure such as farm tracks. This can only be a short-term measure given the likely subsequent damage and repair costs, together with animal management issues;
- Using 'sacrifice paddocks', usually better-drained paddocks or areas. The pasture in this area is sacrificed and soils damaged, and the area will usually require a full renovation. This method also has potential increases in animal health issues, nutrient and soil losses to the environment and animal welfare issues (with potential consequences for the social licence to farm animals);
- Purpose-built containment areas such loafing, standoff or feed pads that can hold the entire herd for extended periods. This method involves a significant initial capital cost and the use of these structures involves operating and maintenance costs such as the labour and equipment to feed cows and remove manure. This was the option considered for the research discussed in this paper.

This research used the technical findings of 'on-off' grazing from Ward (2002) about effects on pastures of wet-soils and grazing to evaluate the cost of active wet soil management compared to the cost of a wet winter if a farmer did not actively manage for the wet conditions. The strategy that is the lesser cost option is the better strategy. The research questions were:

I. What is the cost of a wet winter to a grazing farm business if management does not actively manage for the wet winter (that is, makes no adjustment to usual winter management strategies for an extended wet winter)?;

II. What is the cost to a grazing farm business if management actively manages for the wet winter by using on-off grazing (assuming in this case that the farm business already has a stand-off area)?;

III. Where a stand-off facility is not already in place, what is the maximum amount of capital that could be invested (to earn a 10 per cent annual return[2]) to set up a stand-off facility, such that the cost to the business of having the stand-off facility would be the same as the cost to the business of managing in a 'business-as-usual' way? The decision comparison is what is the breakeven capital sum where the farm business is no better or worse off? It follows that, if an effective stand-off area can be established that enables the wet pasture to suffer less damage and for less than this break-even sum, then the farm business is better off setting up a stand-off area than incurring the costs of grazing their wet-area pastures in the excessively wet winters.

Method

To answer the research questions, desktop analysis of the costs of 'doing nothing differently' and of the costs of active wet winter management was done for a dairy farm located in Allansford (Western District in Victoria) and another located in Fish Creek (South Gippsland in Victoria). These representative case study farms had two different soil types. It was assumed that 100ha of the farm was affected by a wetter than usual winter.

As part of this cost analysis, it was assumed that output from the farm case study farm would be maintained at the same level in the extra wet winter regardless of which management approach was adopted. That is, if pasture DM was reduced because of a wet winter, then it was assumed the pasture 'lost' is replaced with extra supplementary feed. In doing so, the cost of the extra supplementary feed needed to maintain output at the same level as in usual winters can be interpreted as a proxy for the cost of wet winters on pasture under the business-as-usual management method. In practice other costs may be incurred because of an unusually wet winter, but extra supplementary feed is a valid indicator of the degree to which farm profit would decline under an extra wet winter and so is a good proxy of the potential cost of damaged pasture to the business.

There are three key variables in this analysis of the costs of the different options to manage a wet winter:

- Kilograms of DM consumed from the pasture per hectare (DM with 10MJ ME/kg);
- Life of pasture (years from establishment to replacement);
- Cost of stand-off area (establishment capital and annual operating costs).

Estimate of kilograms of dry matter consumed

The amount of pasture that would be grown on the case study farms during a La Niña year[3] was estimated using simulation modelling. The study used a soil water and pasture growth simulation, as developed by Christie et al. (2018) in the DairyMod/SGS model. The simulation was run with two soil types; a poorly drained duplex soil and a loam sand representing a more freely drained soil type (Table

[2] It was assumed that the opportunity cost of capital invested in the pasture and the stand-off area was 10 per cent p.a. as the capital could be used elsewhere on farm and earn 10 per cent p.a. or it could be invested in another similarly risky venture, the stock market for example, and could earn approximately 10 per cent p.a (Sullivan and Curry, 2022).

[3] La Niña years: the wetter extended spring periods were selected in years 1910, 1949, 1950, 1975, 2010; the simulation was run for those actual years and then the average yield was calculated. La Niña years and associated climate data were accessed from the Bureau of Meteorology web site (www.bom.gov.au).

1 and 2). Grazing management was based on commencing grazing when there was 2.5 t DM/ha in the grazing area and after grazing a residual pasture of 1 t DM/ha remained.

Table 1. Key soil parameters used for modelling a poorly drained duplex soil

Horizon	Surface	A	B1	B2
Depth (cm)	2	0-20	20-70	70-100
Ksat (mm/hr)	21	21	1.2	1
Bulk Density (g/m3)	1.3	1.3	1.5	1.5
Saturated VolSWC (%)	49	50	49	49
Field Capacity VolSWC (%)(pF2)	38	38	45	45
Wilting Point VolSWC (%)(pF4.2)	14	14	27	32
Air Dry Content VolSWC (%)	13	13	13	13

Ksat = Saturated hydraulic conductivity; VolSWC = Volumetric Soil Water Content

Table 2. Key soil parameters used for modelling a free draining, sandy loam soil

Horizon	Surface	A	B1	B2
Depth (cm)	2	0-20	20-70	70-100
Ksat (mm/hr)	69.1	69.1	69.1	69.1
Bulk Density (g/m3)	1.35	1.35	1.35	1.35
Saturated VolSWC (%)	38	38	38	38
Field Capacity VolSWC (%)(pF2)	20	20	20	20
Wilting Point VolSWC (%)(pF4.2)	9	9	9	9
Air Dry Content VolSWC (%)	6	6	6	6

The DairyMod/SGS simulation model was used to estimate the herbage DM accumulation (kg DM/ha.month) from the pasture for each month from the 'average La Niña' years for the poorly drained duplex soil and the loam sand at both locations. The results of the SGS modelling (Tables 3 and 4) were used as inputs into the economic analysis. It was assumed that 70 per cent of the pasture growth that was simulated was utilised.

As discussed, grazing a waterlogged paddock reduces the herbage available in winter and spring. Pastures and soils can suffer serious pugging damage during the winter months and an extended wet soil period in September and the first half of October. Research has found that pugging caused by rotationally grazing on water saturated soils in a 'business-as-usual' manner, without employing any active wet soil management strategies such as "on-off" grazing is likely to cause:

- A 35 per cent reduction in herbage accumulation (growth) over the wet soil period (June to September); and
- A 28 per cent reduction in herbage accumulation for the remainder of the growing season (mid Spring to early Summer), after the wet soil period has finished (see Ward, 2002; Ward et al., 2003; and Ward and Greenwood, 2002). Similar findings were reported in Pande et al. (2000).

The DairyMod simulations do not account for the physical damage from grazing under these waterlogged conditions. To estimate the cost of damage from pugging with no change made to grazing management during an extra wet winter, the estimates of pasture growth in average La Niña' conditions, shown in Tables 3 and 4, were reduced accordingly based on these research findings. This assumption applied regardless of whether the soil was poorly drained or well drained.

Table 3. Allansford pasture growth during June to December[4] in a La Niña year, based on DairyMod simulations (kgDM/ha.month)

	June	July	August	September	October	November	December
DM growth poorly drained soil type	202	307	528	1043	1756	1931	1473
DM growth well drained soil type	243	295	676	1370	1927	1944	1217

Table 4. Fish Creek pasture growth during June to December[5] in a La Nina year, based on DairyMod simulations (kgDM/ha.month)

	June	July	August	September	October	November	December
DM growth poorly drained soil type	181	167	258	554	1142	1563	1614
DM growth well drained soil type	207	248	593	1267	1846	2226	1955

The economic analysis also involved estimating the cost of 'on-off' grazing, which restricted grazing to either 2 hours or 4 hours per day. Reducing grazing time can still cause pasture damage from under-grazing and subsequent senescence (Chapman & Lemaire, 1993). Cows typically consume 70 per cent of their daily pasture intake in the first 2 hours of grazing, and up to 88 per cent after 4 hours (Ward, 2002). To take account of these factors, it was assumed:

- If a wet winter is managed by restricting grazing to 4 hours each day, then 12 per cent of pasture was 'lost' due to under-grazing; and
- If a wet winter is managed through restricting grazing to 2 hours[6] of grazing each day, 30 per cent of pasture was 'lost' due to under-grazing.

On-off grazing was assumed only to occur during the winter months (when there was risk of pugging). It was assumed that some pasture consumption was forgone between June and August for the on-off grazing strategy.

Pasture that was 'lost' because of pugging damage or under-grazing was valued. Pasture grown and used in a livestock grazing system in a single production period can be valued using information about the value of equivalent sources of metabolizable energy (ME), using competitive animal feed markets as a guide (see Meyer et al., 2021 and Lewis et al., 2020). The value of extra ME produced and used on a farm lies between the market value of equivalent ME off the farm, such as barley, and the value placed by buyers of ME that is available on the farm in the form of agistment or standing hay (Hardin and Johnson, 1955). During times when pasture is in short supply on the farm relative to animal demand for it, the pasture available on the farm and used on farm has a maximum value equal to its equivalent off farm value, or replacement value (barley). During times when there is a surplus of pasture on the farm relative to animal demand for it, pasture available on the farm and used on farm is given a minimum value equal to standing hay or agistment value (if it not used on the farm at this time, it is called salvage value). The true value of pasture grown and used on a farm lies between these two upper and lower values. Thus, winter pasture grown and used on the farm has a maximum value

[4] Selected because these are the months that damage from pugging and post pugging is expected to occur.
[5] Selected because these are the months that damage from pugging and post pugging is expected to occur.
[6] In practice, 2 hour on-off grazing is not applied, but it was modelled to represent the costs of under-grazing from applying this management practice.

to a farm system that is higher than the minimum value placed on spring pasture that is grown and used on the farm. In this analysis, winter pasture that is lost as a result of the management strategy is valued at its replacement value (the maximum value it could have in the farm system) and spring pasture is valued at its salvage value (the minimum value it could have in the farm system) (see Table 5).

Table 5. Assumptions for the value[7] of pasture during the year

	Probability distribution of the value of pasture ($/kg DM)[8]		
	Minimum	Most Likely	Maximum
Value of pasture during winter (replacement value)	0.23	0.28	0.35
Value of pasture during spring (salvage value)	0.097	0.15	0.31

Assumptions about longevity of pasture

Pugging and under-grazing have a high likelihood of reducing the average life of the pasture and increase the annual and total depreciation cost of the capital invested in establishing the pasture. The loss of plants resulting from pugging is one of the major causes of reduction in pasture yield in the following season. It is not uncommon for pastures with a history of pugging damage to require resowing earlier than is the case for undamaged pastures. In some such cases, the bare spaces that were previously occupied by sown perennial ryegrass become colonized by poorer volunteer grasses and weeds. To account for the cost of longer-term damage to a pasture from pugging damage and under-grazing, the life of a pasture was reduced if pugging or under-grazing occurred. The life of the pasture, with pugging damage of varying degrees, ranged between 4-6 years (Graeme Ward, pers. comm.) compared with the undamaged expected pasture life of 7 years. Thus, in the economic analysis it was assumed:

- the renovation interval (life of the pasture) without pugging damage would be 7 years;
- if grazing was unchanged (no active grazing management), the long-term impact on pastures from pugging was a reduction in the average the life of the pasture from 7 years to 4 years;
- if grazing was restricted to 4 hours, it was assumed that the life of the pasture would remain at 7 years;
- if grazing was restricted to 2 hours, the long-term impact on pastures from under-grazing was a reduction in the average the life of the pasture from 7 years to 5 years.

This cost of loss of life of pasture was included in the budgets as the annual depreciation and interest cost of the capital invested in the pasture. This sum is an annuity that accounts for the annual depreciation cost plus interest cost (at 10 per cent p.a. opportunity interest cost) for the life of the pasture. In the analysis the capital cost of re-establishing the pasture at the end of its shorter life was $430/ha (for fertiliser, seed, sowing costs, lime and sprays) (Ben Reeves, pers. comm.).

Cost of a stand-off area

In one scenario of the analysis it was assumed that the case study farm already had a stand-off area and so no additional cost was included for a stand-off area. If there was no suitable existing stand-off area, then an estimate was made of the maximum sum that could be invested to set up a stand-off

[7] Based on the distribution of prices from 2011 to 2022 for feed barley and pasture hay (less the cost of conserving the feed) (Grain and Graze, 2022).

area to earn 10 per cent p.a. return and be just as well (or badly) off as operating under the business-as-usual management approach.

First, the *difference* between the annual cost incurred by using the no change to grazing management method and the annual cost of using an active grazing management method was calculated, before including a capital cost for setting up a stand-off area. This difference is the maximum annual dollar sum that could be used to provide a stand-off area (the opportunity interest cost and depreciation costs). If this total sum was used to enable the standoff area for on and off grazing, the farmer would be equally as well off with either system.

Refining this, the present value of the annuity (the difference in annual costs of the two systems described above) was calculated. This represented the maximum cost, to earn a 10 per cent p.a. return, of investing in a stand-off area. It was assumed the life of the stand-off area (n) was 10 years and the opportunity interest cost (i) of investing capital in this use was 10 per cent p.a.

Maximum cost of stand-off area =

$$\text{Difference in cost between no change in grazing management and active grazing management} \times \frac{(1+i)^n - 1}{i \times (1+i)^n}$$

This is the maximum cost a farm business could invest in a stand-off area for wet winter management (to earn 10 per cent p.a.) and be no worse off than under the business-as-usual management regime. If the actual annual capital (depreciation and opportunity interest cost) and operating cost of investing in a stand-off area was less than this breakeven annuity sum, the farm business is likely to be better off investing in a stand-off area and practising active grazing management. A grazier would be better off doing something about the wet-soil grazing problem than doing nothing differently, regardless of the conditions.

It is noteworthy that a stand-off area will have other uses beyond being used for wet winter management. This break-even annuity value is only focussed on the loss of pasture avoided by using a stand-off area. Once other potential benefits from using it for other uses are available, more could be invested in a stand-off area to reap these other benefits as well.

A summary of each option is presented in Figure 1 and a summary of assumptions behind each scenario is summarised in Table 6.

To account for the volatility of the value of pasture foregone during the winter and during the spring, a probability distribution of possible seasonal pasture supply was used (see Table 5). The cost of a wet winter to a farm system depends on how frequently a wet winter is expected to occur. It is expected that extreme wet winters are likely to increase under future climate change scenarios. According to the Bureau of Meteorology (BOM, 2022), heavy rainfall events are expected to continue and to become more intense as the climate warms. For these reasons, three scenarios of the likelihood of wet winters were explored:

1) occurring every year;
2) occurring 4 years in 10;
3) occurring 2 years in 10.

As part of this research a cost framework has been developed to demonstrate how to evaluate these questions. This framework was used in this study for a representative farm business, but equally could be applied for any farm business thinking through this problem (see Tables 7 to 10)[9].

[9] The costs and assumptions have been peer reviewed by the project team, beef and dairy farmers in Gippsland as well as by Department of Agriculture livestock advisors.

Figure 1. Costs of two strategies to manage a wet winter: doing nothing differently and active grazing management

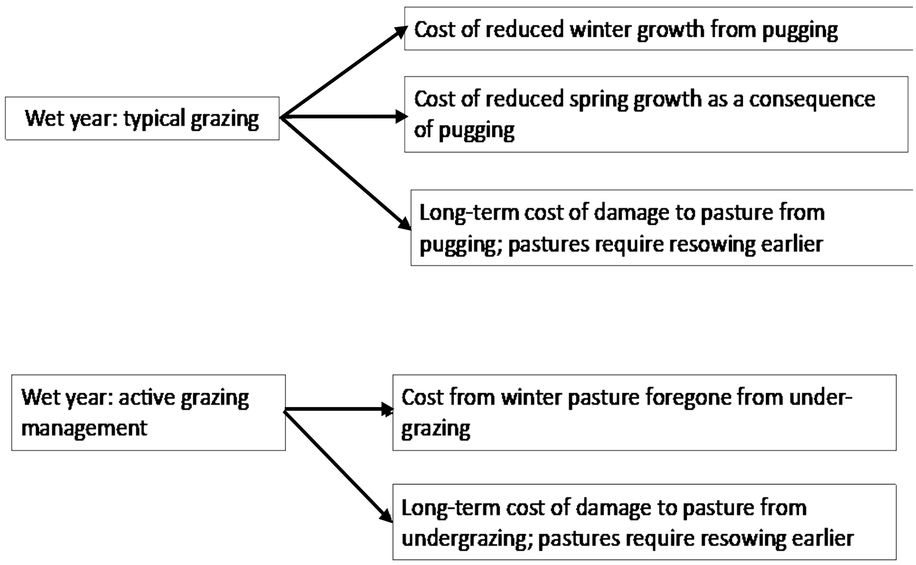

Table 6. Farm system assumptions for contrasting scenarios

	No active wet soil management	4hr on/off grazing	2hr on/off grazing
DM foregone due to pugging damage or under-grazing	28%-35%	12%	30%
Supplement wastage	30%	5%	5%
Life of pasture with no pugging damage and optimal grazing	7 years	7 years	7 years
Life of pasture assuming condition of scenario	4 years	7 years	5 years
Cost of pasture redevelopment	$430/ha	$430/ha	$430/ha

Results

If the case study farm already had a stand-off area, managing a wet winter using on-off grazing would be a lower cost strategy than the cost of doing nothing differently. For both locations (Fish Creek and Allansford) a 4 hour on-off grazing strategy was likely to be a lower cost option than a 2 hour on-off grazing strategy. If the farm business had more pasture grown in the winter (as result of the soil type and or climate) then the cost of doing nothing differently to manage a wet winter would be even higher (see Tables 11 and 12).

The cost of doing nothing differently to manage a wet soil also delivered more volatile annual costs (higher coefficient of variation and greater range of costs) than a strategy that actively managed a wet soil using on-off grazing (see Figures 2 and 3).

Additional scenarios were considered. These results showed that if a wet winter occured more frequently, the cost of each option would be greater – the position of the distributions of costs changed but the shape of the distributions did not change (see the supplemental data in the Appendix).

Table 7. Cost Framework Part A: Key assumptions

Inputs to the cost framework	Nomenclature to represent this input	Example (based on representative farm)
What area is vulnerable to damage with grazing because the area is wet?	AA	100 ha
kg DM expected to be consumed from vulnerable paddock over winter (June/July/August)	A	88,970 kg DM
kg DM expected to be consumed from vulnerable paddock early spring (September and early October)	B	157,290 kg DM
kg DM expected to be consumed from vulnerable paddock over late spring to early summer (second half of Oct/Nov/Dec)	C	241,360 kg DM
Expected life of the pasture without damage from pugging	D	7 years
Expected life of the pasture with damage	E	4 years (if pugging) 5 years (if under-grazed)
Cost of pasture renovation $/ha	F	$430/ha
Interest cost	G	10% p.a.
How many years in 10 likely to experience loss in pasture consumed due to wet winter	H	2 years
Percent of supplement wasted	I	30% (fed in paddock) 5% (fed on standoff area)
Value of pasture 'lost' in winter (c/kg DM)	J	$0.285/kg DM
Value of pasture 'lost' in spring (c/kg DM)	K	$0.18/kg DM

If the case study farm business did not have a stand-off area, and a wet winter was managed using 4 hour on-off grazing, a maximum capital investment of approximately $50,000 could be invested in a stand-off area. This is counting only avoided pasture-damage related costs as the total benefit of the stand-off area. Investing $50,000 in a stand-off area would mean that the business would be no worse off than if nothing different was done to manage the extra wet conditions (where a wet winter occurs in 2 years in 10 and the farmer wanted 10 per cent p.a. return on their extra capital invested). If the actual capital cost of a stand-off area was to be less than this break-even sum of $50,000, then active grazing management would be a lower cost option than doing nothing differently (see Table 9). If the frequency of a wet winter was higher, then the break-even or maximum amount a farm business could invest in a stand-off area would be greater (see Tables 13 and 14) and a more expensive stand-off area would be justified.

Table 8. Cost Framework Part B: Calculations if doing nothing differently to grazing management

	Equations	Example
If grazing management is unchanged, how much pasture (which is usually consumed) is expected to be 'lost' due to pugging damage during winter (kgDM)?	L = A*35%	31,140kgDM
If grazing management is unchanged, how much pasture (which is usually consumed) is expected to be 'lost' due to pugging damage during early spring (kgDM)?	M = B*35%	55,052kgDM
If grazing management is unchanged, how much pasture (which is usually consumed) is expected to be 'lost' due to pugging damage from late spring to early Dec (kgDM)?	N = C*28%	67,581kgDM
How much extra feed (kg DM) is required due to wastage of supplementary feed in winter?	O = I*L	9,342kgDM
How much extra feed (kgDM) is required due to wastage of supplementary feed in spring?	P =(M + N)*I	36,790kgDM
What is the cost ($) of pasture 'lost' because of pugging damage?	Q=((L+O)*J)+((M+N+P)*K)	$40,155
What is the annuity if life of pasture is 7 years?	R=(F*AA)*(G*((1+G)^D))/(((1+G)^D)-1)	$8,832
What is the annuity if life of pasture is 4 years?	S=(F*AA)*(G*((1+G)^E))/(((1+G)^E)-1)	$13,565
What is the extra depreciation cost?	T = S - R	$4,733
What is the annual cost of this management strategy if wet soil event every year	**U= Q + T**	**$44,888**
Expected value of the cost of this management strategy if wet soil event occurs in x years in 10	**V = U * (H/10)**	**$8,978**

Table 9. Cost Framework Part B: Calculations if practice 4 hour on-off grazing management

	Equations	Example
If grazing is reduced to 4hr/day, how much pasture (which is usually consumed) is expected to be 'lost' due to pugging damage during winter (kgDM)?	L = A*12%	10,676kgDM
If grazing is reduced to 4hr/day, how much pasture (which is usually consumed) is expected to be 'lost' due to pugging damage during early spring (kgDM)?	M = B*0%	-
If grazing is reduced to 4hr/day, how much pasture (which is usually consumed) is expected to be 'lost' due to pugging damage from late spring to early Dec (kgDM)?	N = C* 0%	-
How much extra feed (kg DM) is required due to wastage of supplementary feed in winter?	O = I*L	534kgDM
How much extra feed (kgDM) is required due to wastage of supplementary feed in spring?	P =(M + N)*I	-
What is the cost ($) of pasture 'lost' because of pugging damage?	Q=((L+O)*J)+((M+N+P)*K)	$3,191
What is the annuity if life of pasture is 7 years?	R=(F*AA)*(G*((1+G)^D))/(((1+G)^D)-1)	$8,832
What is the annuity if life of pasture is 7 years?	S=(F*AA)*(G*((1+G)^D))/(((1+G)^D)-1)	$8,832
What is the extra depreciation cost?	T = S - R	-
What is the annual cost of this management strategy if wet soil event every year	**U= Q + T**	**$3,191**
Expected value of the cost of this management strategy if wet soil event occurs in x years in 10	**V = U * (H/10)**	**$638**

Table 10. Cost Framework Part B: Calculations if practice 2 hour on-off grazing management

	Equations	Example
If grazing is reduced to 2hr/day, how much pasture (which is usually consumed) is expected to be 'lost' due to under-grazing during winter (kgDM)?	L = A*30%	26,691kgDM
If grazing is reduced to 2hr/day, how much pasture (which is usually consumed) is expected to be 'lost' due to undergrazing during early spring (kgDM)?	M = B*0%	-
If grazing management is unchanged, how much pasture (which is usually consumed) is expected to be 'lost' through pugging damage from late spring to early Dec (kgDM)?	N = C* 0%	-
How much extra feed (kg DM) is required due to wastage of supplementary feed in winter?	O = I*L	1335kgDM
How much extra feed (kgDM) is required due to wastage of supplementary feed in spring?	P =(M + N)*I	-
What is the cost ($) of pasture 'lost' because of pugging damage?	Q=((L+O)*J)+((M+N+P)*K)	$7,977
What is the annuity if life of pasture is 7 years?	R=(F*AA)*(G*((1+G)^D))/(((1+G)^D)-1)	$8,832
What is the annuity if life of pasture is 4 years?	S=(F*AA)*(G*((1+G)^E))/(((1+G)^E)-1)	$11,343
What is the extra depreciation cost?	T = S - R	$2,511
What is the annual cost of this management strategy if wet soil event every year	**U= Q + T**	**$10,488**
Expected value of the cost of this management strategy if wet soil event occurs in x years in 10	**V = U * (H/10)**	**$2,098**

Table 11. Expected value ($) of the cost of each management strategy for a dairy farm business with well drained soils and 100ha of grazing land affected by a wet winter in Allansford and Fish Creek assuming different likelihoods of a wet winter occurring

	Do nothing different	4 hour active grazing	2 hour active grazing
Allansford well drained (2 in 10 years)	8,978	638	2,098
Allansford Well Drained (4 in 10 years)	17,955	1,276	4,195
Allansford Well Drained (every year)	44,888	3,191	10,488
Fish Creek Well Drained (2 in 10 years)	10,024	526	1,818
Fish Creek Well Drained (4 in 10 years)	20,047	1,052	3,635
Fish Creek Well Drained (every year)	50,118	2,631	9,089

Table 12. Expected value ($) of the cost of each management strategy for a farm business with poorly drained soils and 100ha of grazing land affected by a wet winter in Allansford and Fish Creek assuming different likelihoods of a wet winter occurring

	Do nothing different	4 hour active grazing	2 hour active grazing
Allansford poorly drained (2 in 10 years)	8,944	521	1,804
Allansford poorly Drained (4 in 10 years)	17,887	1,041	3,608
Allansford poorly Drained (every year)	44,718	2,604	9,020
Fish Creek poorly Drained (2 in 10 years)	6,763	304	1,263
Fish Creek poorly Drained (4 in 10 years)	13,526	609	2,526
Fish Creek poorly Drained (every year)	33,814	1,521	6,314

Figure 2. Likely range of the expected value of the cost of three different wet winter management strategies ($) if a wet winter occurred 2 years in 10 (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Allansford assuming business has a standoff area (well drained soils)

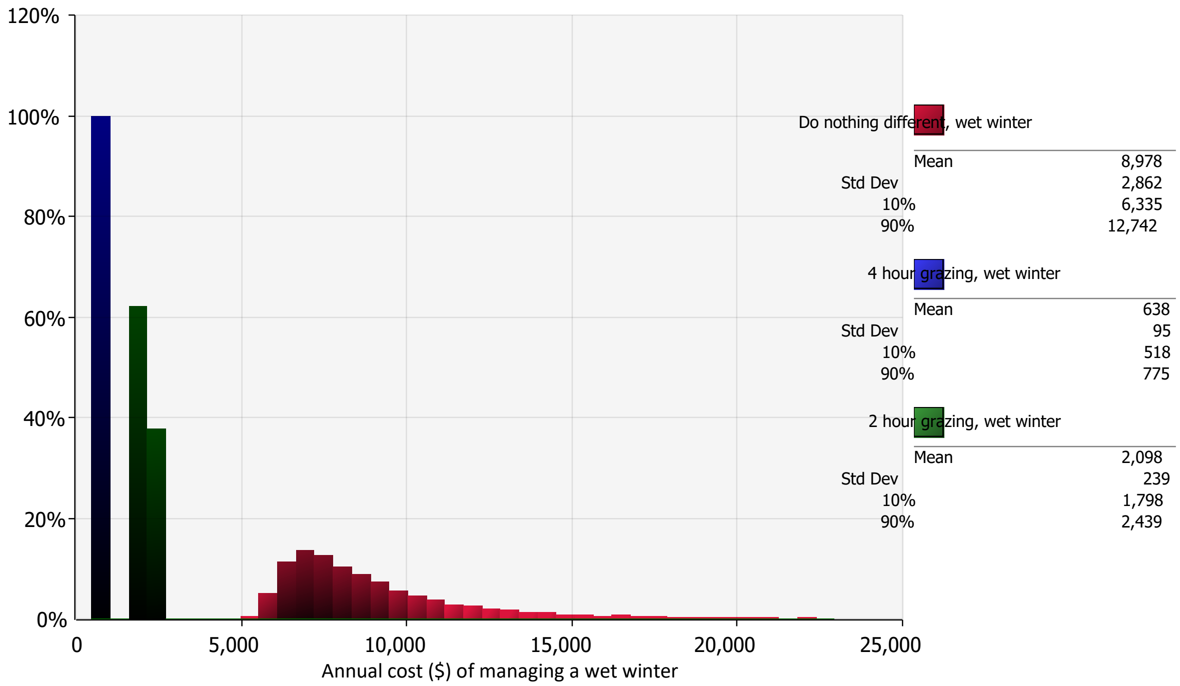

Figure 3. Likely range of the expected value of the cost of three different wet winter management strategies ($) if a wet winter occurred 2 years in 10 (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Fish Creek assuming business has a standoff area (well drained soils)

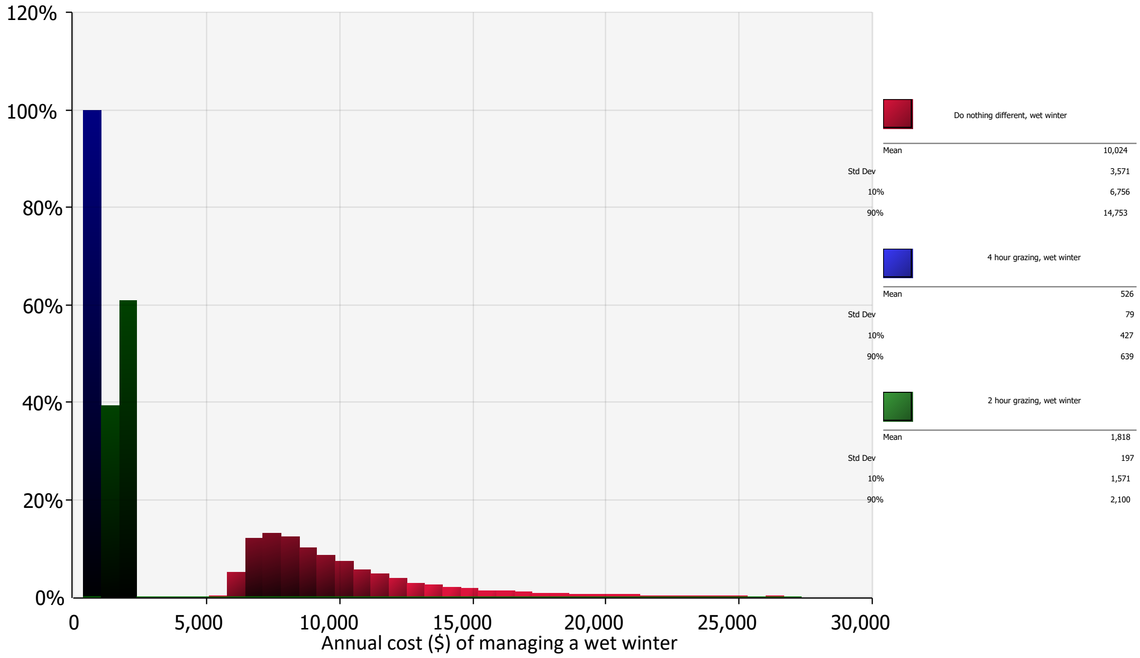

Table 13. The maximum amount ($) the representative case study farmer could pay for a stand-off area on a farm in either Allansford or Fish Creek with well drained soils to be equally well off from doing nothing differently and doing something differently (assuming 10 years life and 10% p.a. opportunity interest cost)

	4 hour on-off grazing strategy	2 hour on-off grazing strategy
Allansford well drained 2 in 10 years	51,242	42,274
Allansford well drained 4 in 10 years	102,484	84,548
Allansford well drained every year	256,210	211,371
Fish Creek well drained 2 in 10 years	58,358	50,422
Fish Creek well drained 4 in 10 years	116,716	100,844
Fish Creek well drained every year	291,789	252,110

Table 14. The maximum amount ($) the representative case study farmer could pay for a stand-off area on a farm in either Allansford or Fish Creek with poorly drained soils to be equally well off from doing nothing differently and doing something differently (assuming 10 years life 10% p.a. opportunity interest cost)

	4 hour on-off grazing strategy	2 hour on-off grazing strategy
Allansford poorly drained 2 in 10 years	51,755	43,871
Allansford poorly drained 4 in 10 years	103,511	87,741
Allansford poorly drained every year	258,777	219,353
Fish Creek poorly drained 2 in 10 years	39,684	33,794
Fish Creek poorly drained 4 in 10 years	79,369	67,589
Fish Creek poorly drained every year	198,422	168,972

Concluding Discussion

The aim of this study was to evaluate the cost of two strategies a dairy farmer could implement to manage an extended wet winter: the cost of doing nothing differently in extra wet conditions, versus the cost of doing something different through restricting grazing time and using a stand-off area. Past research has shown that active grazing management can reduce the damage to pastures and soils from pugging and consequently reduce loss to pasture dry matter. The question was: 'which of the two aforementioned strategies was likely to be the lowest cost -and most profitable – strategy?

The least cost option for the case study farm businesses which already had a stand-off area would be to actively manage a wet winter through restricting grazing time. The expected value of the cost to the case study farm business that actively managed a wet winter (through restricting grazing to 4 hours a day) on average ranged between $300 to $2,600 (depending on the likelihood of a wet winter and the amount of pasture 'lost'). This was substantially less than the cost of doing nothing differently. The expected value of the cost to the farm business that did not actively manage a wet winter on average ranged between $7,000 to $50,000 (depending on the likelihood of a wet winter and the amount of pasture 'lost'). Actively managing a wet winter was a better strategy if the likelihood of more extended wet periods increased, as the cost of doing nothing differently is higher the more frequent a wet winter occurs. It is likely that extreme rainfall events over South-east Australia will increase in frequency and magnitude under a changing climate (Ashcroft et al., 2017).

Further, restricting grazing to 4 hours was a lower cost strategy compared with restricting grazing to 2 hours. It is a counter-intuitive, but at usual stocking densities and practices, having the cows on a wet pasture for 4 hours before taking them off to the feedpad or standoff area was more effective than a 2-hour grazing. The shorter grazing time meant less pugging damage, and initially less pasture damage during the wet soil period. However, pastures are being under-grazed with only 2 hours of grazing. This may not be an issue for the first one or two grazings but, ultimately, not grazing the pastures hard enough means pasture regrowth suffers through becoming more moribund, especially in post-wet soil periods (see Ward, 2002). Researchers in New Zealand (Beukes et al., 2013) concluded that minimal grazing of pastures to aggressively manage wet soils results in depressed pasture growth and therefore reduced farm profits. Past research has also shown that if grazing was longer than 4 hours then the rate of increase in pugging damage accelerated quickly, as did the severity of the pasture damage (Ward, 2002).

A conclusion from this analysis is that a farmer may be better able to manage the risk of a wet winter through active grazing management because the annual costs of an unchanged grazing management regime during a wet winter are more volatile than the costs of actively managing wet-soil grazing. In this study the cost of the extra supplementary feed was a proxy for the cost of doing nothing different in a wet winter. The volatility of the annual cost of the grazing management regime was reflected in the volatility of the cost of supplementary feed.

A key outcome of this research was to show that the cost of not doing anything differently to manage a wet winter results in 'losing' valuable winter feed. Pasture that was 'lost' in winter had a higher value than pasture 'lost' during the spring.

The maximum amount the representative farmer could invest in a stand-off area (and earn 10 per cent p.a. return), based on the pasture-related benefits alone, depends on how frequently a wet winter is likely to occur. If a wet winter is expected to occur in 4 years in 10, then, based on the assumptions in this analysis, the representative farmer could invest a maximum sum of $100,000 in a stand-off area and be no worse off than doing nothing differently. If, however, the cost of a stand-off area could be established for less than this amount, the representative farmer would be better off to set up a stand-off area and practise on-off grazing than incur the costs of grazing their wet area pastures in excessively wet winters. Capital needed to establish stand-off areas varies in cost and life span. The type of stand-off area suitable to use in a wet winter would be a semi-permanent feed-out area, which would have a life of 10 years and an initial establishment cost in the range of $60,000 to $90,000[10] (Scott McDonald, pers. comm. 2021). In addition to the capital outlay for this semi-permanent feed system, there is typically an annual repair and maintenance cost for damage from the herd around the troughs (Scott McDonald, pers. comm, 2021).

This study has practical application for livestock producers considering the question about whether to change grazing management of their herds in extra wet conditions. Key considerations are how frequently a wet winter will occur that will result in the added costs to the pasture and for extra feed, and whether a stand-off area would have other uses to their farm business. If a stand-off area would not be of value to a farm business at other times of the year or in other more typical years, and if the likelihood of a wet winter is relatively low then doing nothing differently may be the best strategy for a grazing farm business. If a stand-off area has value at other times in the year and in other years then actively managing a wet winter through 4 hour on-off grazing could well be an attractive option.

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[10] This is the cost of gravel, earthworks, land forming, drainage works, troughs, fencing, and cabling along the feed face.

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Appendix. Results for Each of the Other Scenarios

Figure A1. Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 4 years in 10 (red bars: no change to grazing management, blue bars: 4-hour grazing management, green bars: 2-hour grazing management) for 100ha in Allansford (well drained soils)

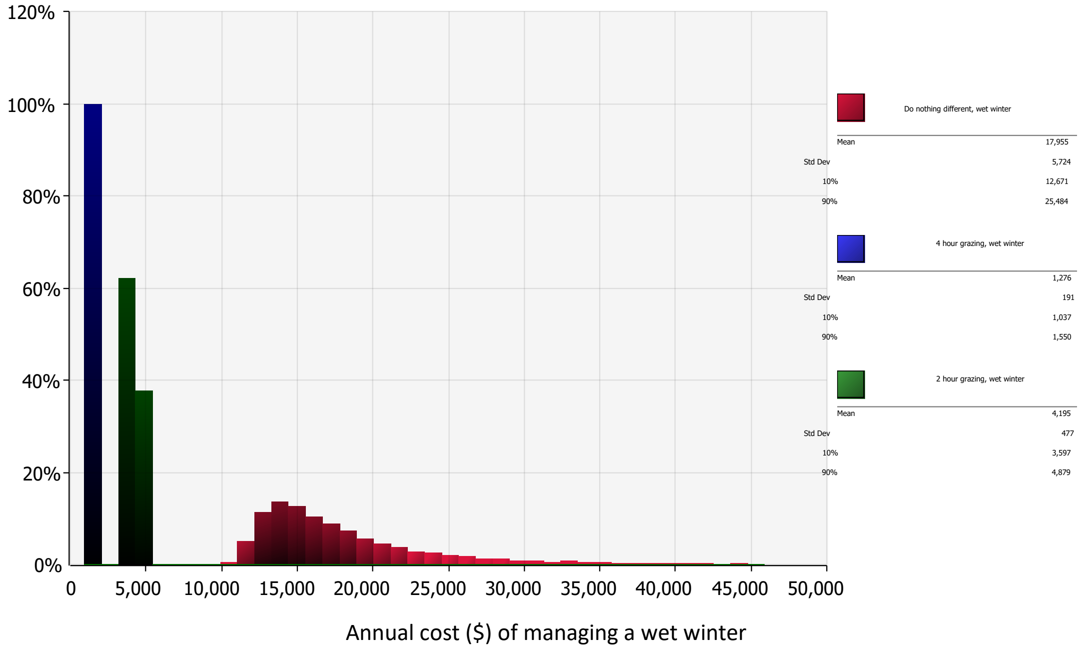

Figure A2. Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred every year (red bars: no change to grazing management, blue bars: 4-hour grazing management, green bars: 2-hour grazing management) for 100ha in Allansford (well drained soils)

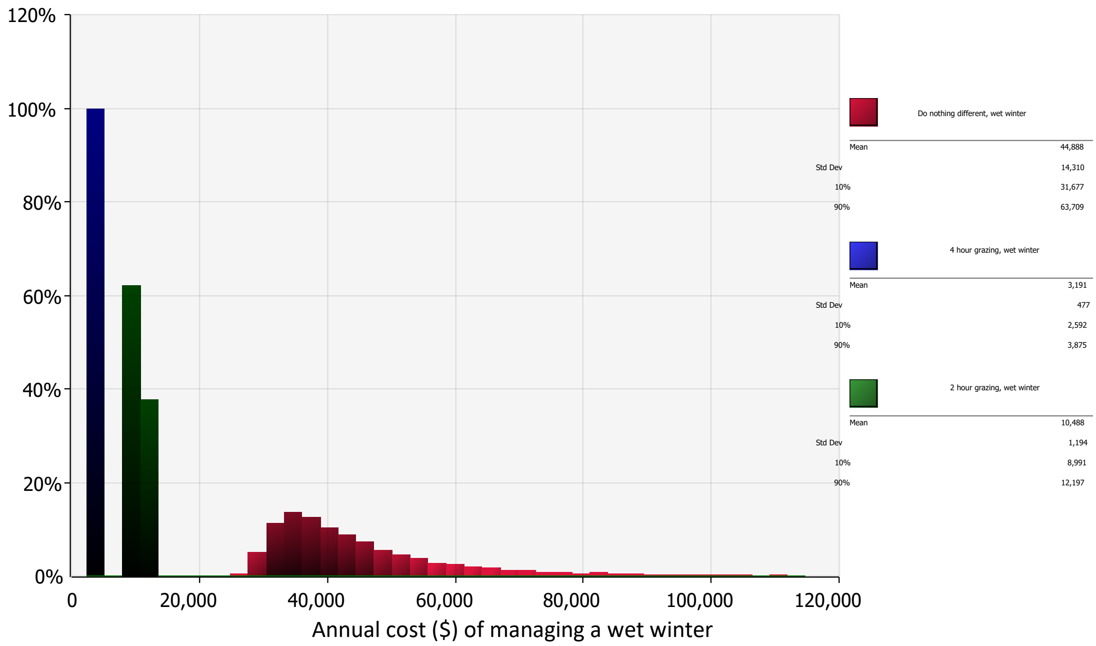

Figure A3. Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 4 years in 10 (red bars: no change to grazing management, blue bars: 4-hour grazing management, green bars: 2-hour grazing management) for 100ha in Fish Creek (well drained soils)

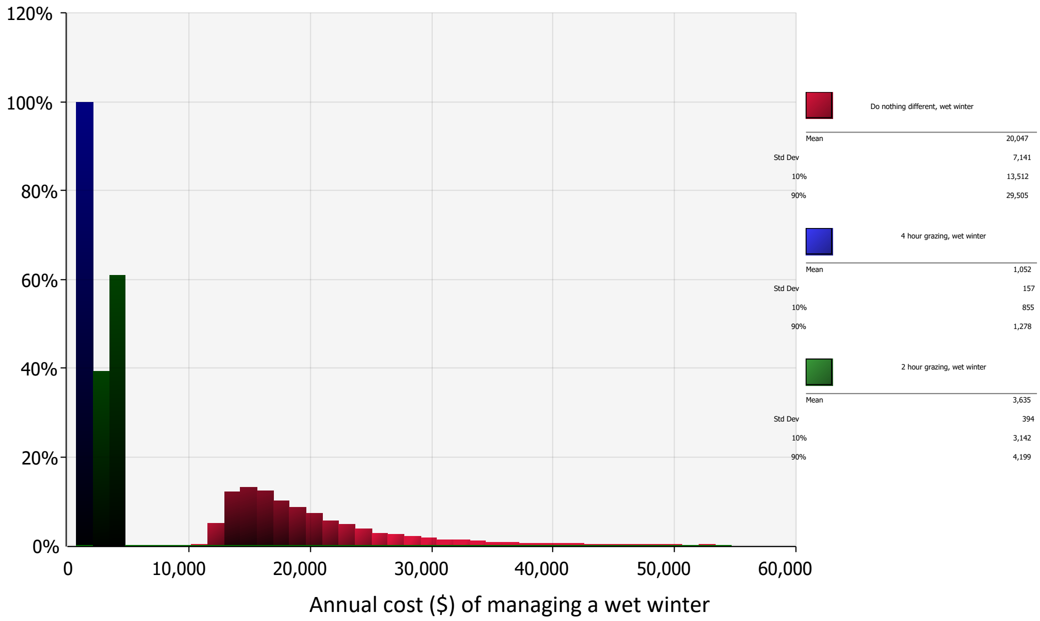

Figure A4. Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred every year (red bars: no change to grazing management, blue bars: 4-hour grazing management, green bars: 2-hour grazing management) for 100ha in Fish Creek (well drained soils)

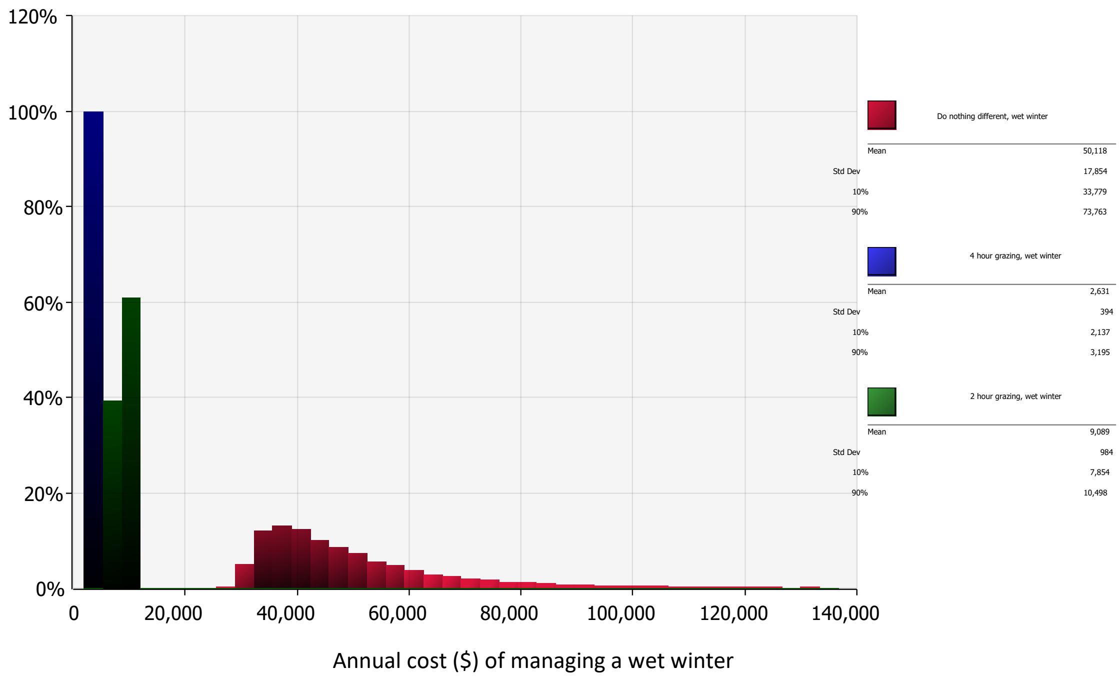

Figure A5. Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 2 years in 10 (red bars: no change to grazing management, blue bars: 4-hour grazing management, green bars: 2-hour grazing management) for 100ha in Allansford (poorly drained soils)

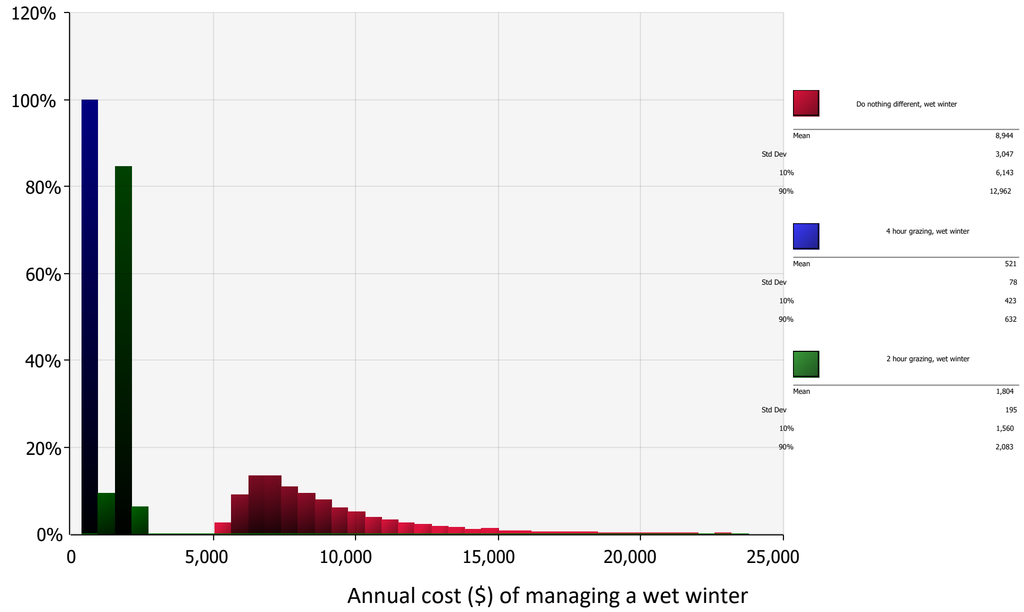

Figure A6. Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 4 years in 10 (red bars: no change to grazing management, blue bars: 4-hour grazing management, green bars: 2-hour grazing management) for 100ha in Allansford (poorly drained soils)

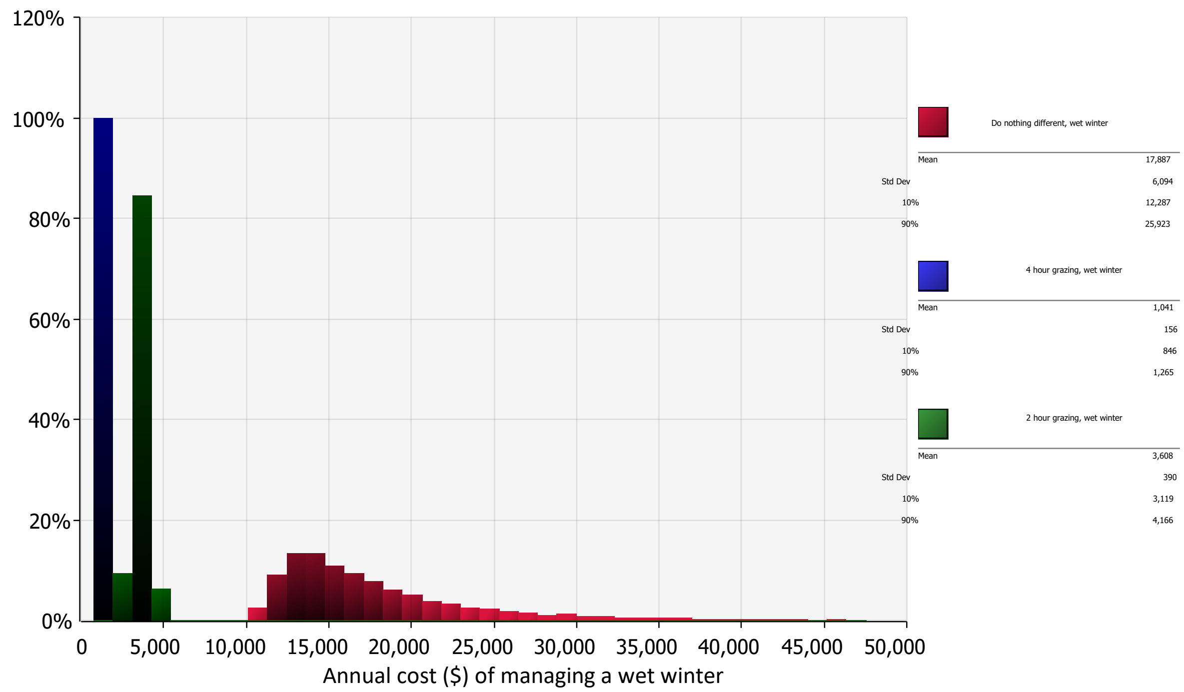

Figure A7. Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred every year (red bars: no change to grazing management, blue bars: 4-hour grazing management, green bars: 2-hour grazing management) for 100ha in Allansford (poorly drained soils)

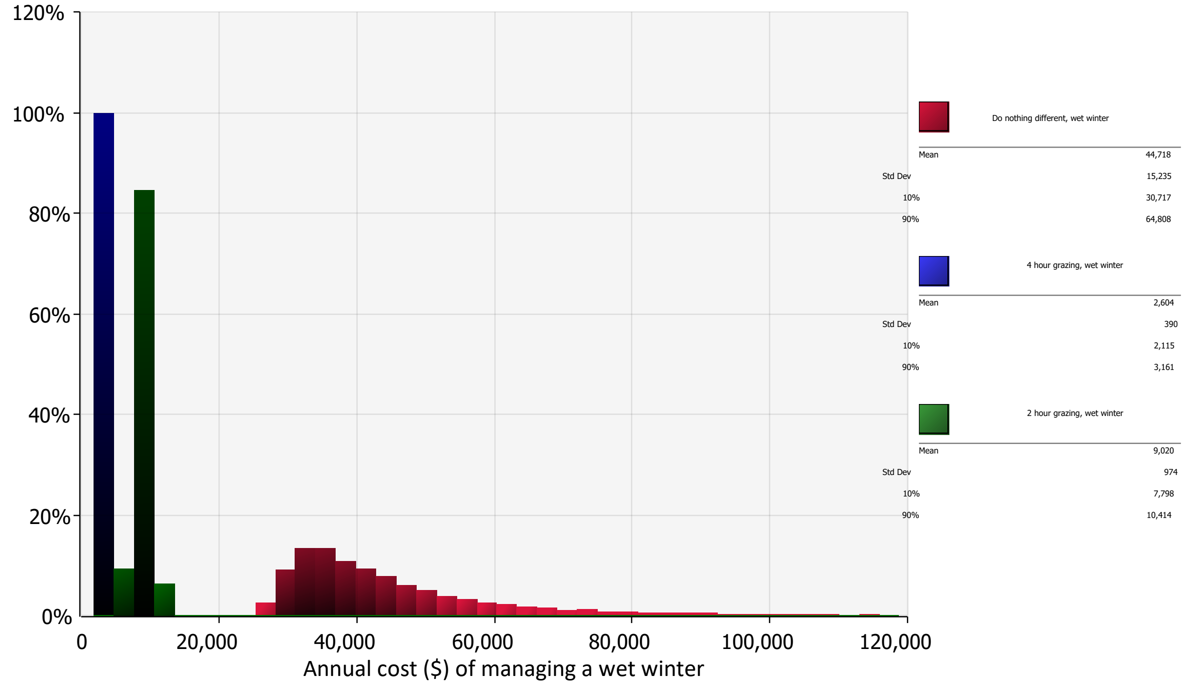

Figure A8. Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 2 years in 10 (red bars: no change to grazing management, blue bars: 4-hour grazing management, green bars: 2-hour grazing management) for 100ha in Fish Creek (poorly drained soils)

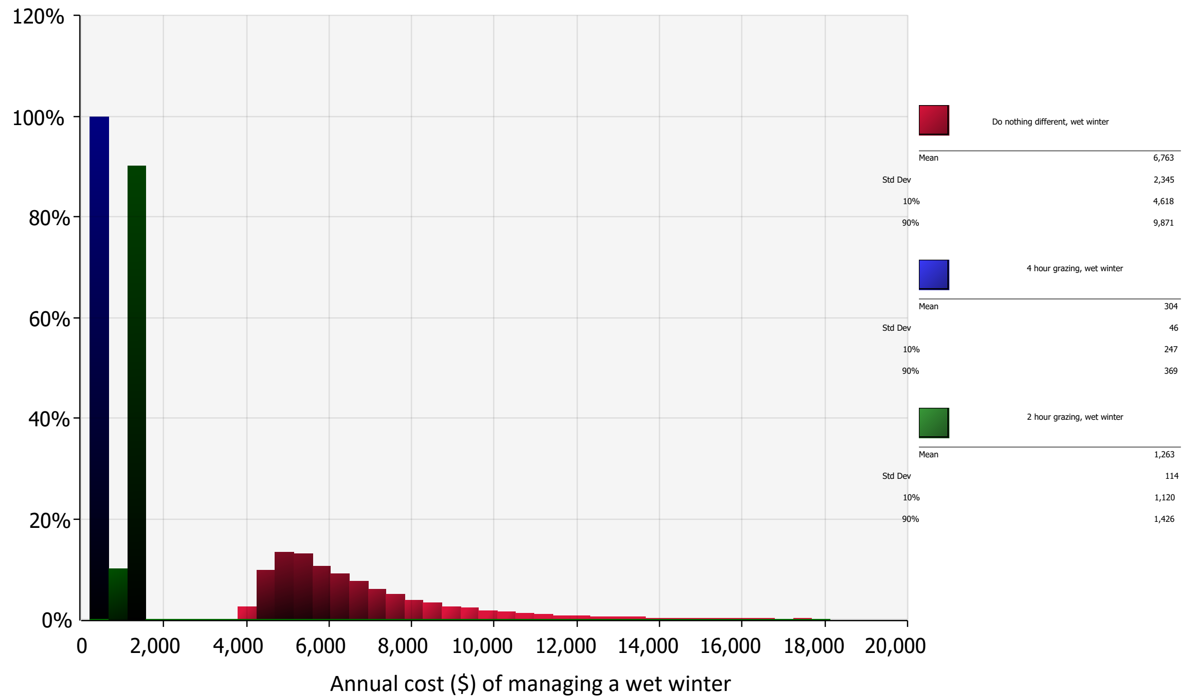

Figure A9. Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 4 years in 10 (red bars: no change to grazing management, blue bars: 4-hour grazing management, green bars: 2-hour grazing management) for 100ha in Fish Creek (poorly drained soils)

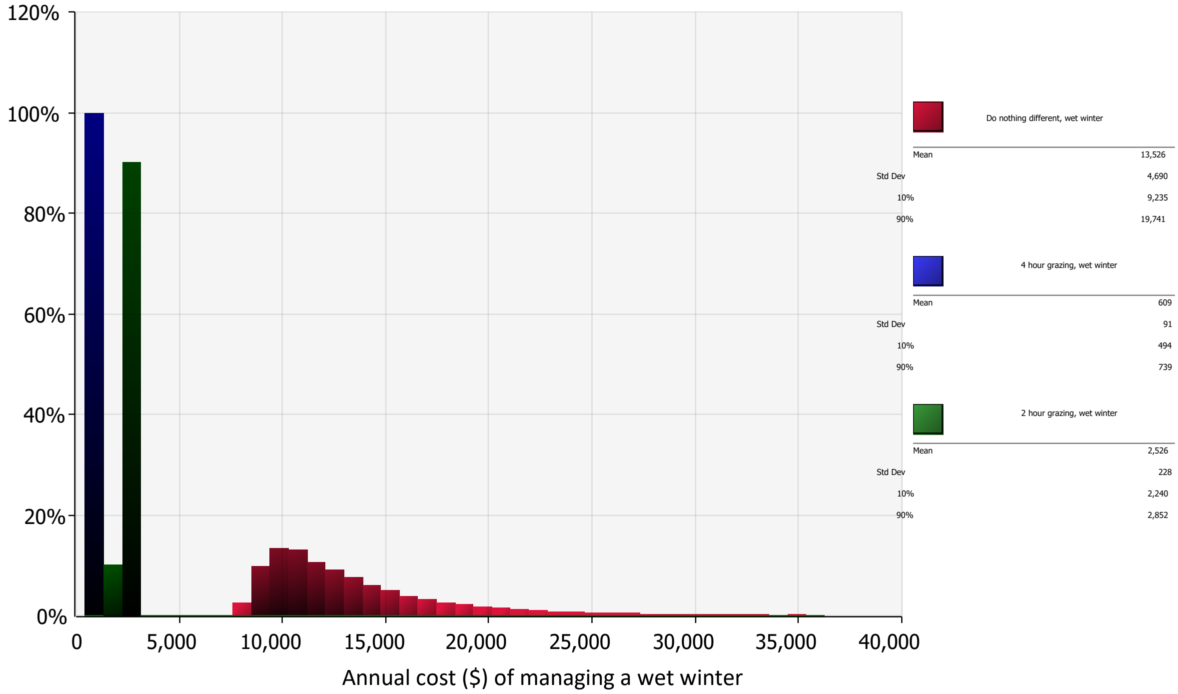

Figure A10. Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred every year (red bars: no change to grazing management, blue bars: 4-hour grazing management, green bars: 2-hour grazing management) for 100ha in Fish Creek (poorly drained soils)