Final Report

Rural R&D for Profit Program – Round Three Forewarned is Forearmed (FWFA) (RnD4Profit-16-03-007)

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Abstract

The Forewarned is Forearmed (FWFA): managing the impacts of extreme climate events project was a long-term collaborative project funded by the Australian Government Department of Agriculture Fisheries and Forestry in the third round of the Rural R&D for Profit program along with contributions from multiple Rural Development Corporations, research institutions and state governments. It is focused on improving the forecasting of extreme events and equipping farmers with the information and tools needed so that they can prepare for and manage the risks associated with extreme climate events on farm.

As a part of project activities, the UoM was responsible for activities primarily delivering to Work Package 3 – Interfacing to Industry Decisions and Work Package and to subcontract to DJPR and BCG to deliver to Work Package 4 – Extension, training communications. These enabled members of the project team and beyond to share research outcomes, tools and services relating to extreme events, and gain an increased understanding of gaps and producer needs in forecasting extreme events and to provide the Bureau of Meteorology (BoM) with feedback during the development of the FWFA forecast tools. Initiatives such as online webinars and CoP provided training to help facilitate the adoption of the new products amongst their networks.

A structured and iterative consultation process involving the Dairy and Southern Red Meat industry reference groups involved a) identifying the extreme events of greatest consequence to their industry, b) identifying appropriate response scenarios to each identified extreme event c) evaluating the products and tools produced by BoM and d) identifying response scenarios to explore the risk mitigation costs. As the Bureau products were released late in the project a variation to the contract incorporated a more focused Extension and Communications Campaign across the final 14 months aiming to deliver more presentations, webinars and legacy products. This Campaign included delivery of over 20 industry talks, five webinars and videos, four farmer focussed case studies and a multiple part eLearning focused around the new FWFA products.

Executive summary

Background

Australian farmers and agribusiness operate in one of the most variable climates of any country in the world, with extreme events and climate variability the largest drivers of fluctuations in annual agricultural production and income.

The project Forewarned is Forearmed (FWFA): equipping farmers and agricultural value chains to proactively manage the impacts of extreme climate events focussed on:

- Identifying areas for improvement in the performance of seasonal climate forecasts.
- Development, trialling, and subsequent operationalisation of new Bureau of Meteorology forecast products for extreme events in the weeks to months ahead.
- Development of risk management packages for extreme events for specific agricultural sectors, and for agriculture more generally; and
- Communicating the progress of the project through a variety of media platforms.
- Building project legacy

Objectives

As a Forewarned is Forearmed (FWFA) Project partner, the University of Melbourne (UoM) delivered against Work Packages 3 and 4 of the total four work packages comprising the FWFA project. A structured and iterative consultation process involving Dairy and southern Red Meat Industry Reference Group (IRG) members:

- Identified the extreme events of greatest consequence to their industry
- Identified appropriate response scenarios to each identified extreme event
- Evaluated the experimental and operational BoM FWFA products and tools.

The identified response scenarios were subject to farm systems expert analysis (biophysical and economic) to explore the risk mitigation costs and then published as scenarios. Risk packages based on identified information were produced and further legacy material was developed as part of work package 4 for extension. These included farmer talks/workshops, webinars and online presentations, case studies and an eLearn package.

Methodology

Work Package 3: Interfacing to Industry Decisions
The structured and iterative consultation process involving the IRG:

- face-to-face workshops,
- scheduled virtual meetings and email,
- scheduled real-time sessions with resources made available on web and facilitation of surveys and web forums

Work Package 4: Extension, training and communications
Promote and explain new extreme event forecasting products through

- webinars
- talks
- case studies
- eLearning
- Social media

Results/key findings

- Dairy and southern red meat producers identified and prioritised the same three most important extreme climate events of most consequence: extended wet seasons (wet winters), extended dry (drought) and heatwaves
- IRG members identified 13 vulnerability areas being pasture, livestock health, livestock condition/productivity, infrastructure, operations, fodder quality/silage, cash flow, crops, social, water supply, soil, environment, biosecurity and social (see next point for latter).
- Social impacts of extreme events were raised but farmers did not volunteer responses. This could be a gap in their expertise that requires further research.
- Improved forecasts of extreme events are required to inform key economic decisions around the timing of selling off stock and buying in feed/water.
- Weather/climate forecast tools are only one of a combination of tools and resources used by farmers in extreme event decision making.

Benefits to industry

- Dairy Australia and Meat & Livestock Australia have expanded detail and information regarding producer's climate extreme events risks and those of most consequence on-farm
- The FWFA BoM new extreme forecast products have been promoted across the Australian agricultural networks beyond those industries involved in the project
- Following on from above,
    - Improved understanding of user's requirements and priorities
    - increased consultation and uptake of the FWFA BoM new extreme forecast products
- Research and experimental prototypes will flow through to other projects backed by industry (e.g. Climate Services for Agriculture)

Future research and recommendations

Improved climate risk management require three things:

1. Better forecasts (models, weather, multiweek, seasonal, climate change))
2. Better understanding of forecasts (climate literacy of users and forecast products)
3. Farm risk management and adoption (strategies, tactics, tools to better manage risks both with and without forecasts)

Table of contents

1. Background

1.1 Rural R&D for Profit programme

The objective of the Rural R&D for Profit programme is to realise productivity and profitability improvements for primary producers, through:

a) generating knowledge, technologies, products, or processes that benefit primary producers.
b) strengthening pathways to extend the results of rural R&D, including understanding the barriers to adoption; and
c) establishing and fostering industry and research collaborations that form the basis for ongoing innovation and growth of Australian agriculture.

1.1.1 The Forewarned is Forearmed (FWFA) Project

Australian farmers and agribusiness operate in one of the most variable climates of any country in the world, with extreme events and climate variability the largest drivers of fluctuations in annual agricultural production and income.

The project **Forewarned is Forearmed (FWFA): equipping farmers and agricultural value chains to proactively manage the impacts of extreme climate events** (2017 - 2022) provided numerous outputs including five new Bureau of Meteorology forecast products for extreme events in the weeks to months ahead, risk packages for target agricultural industries, new research publications and communications material. Funding partners included the Australian Government Department of Agriculture, Fisheries and Forestry as part of its Rural Research and Development (R&D) for Profit Program ($6m), with further cash and in-kind contributions ($8m) from multiple RDCs (GRDC, DA, MLA (project lead), RIRDC, SRA, CRDC, WA, APL), research providers (Bureau of Meteorology, University of Melbourne, University of Southern Queensland, Monash University), state governments (DPJR, SARDI, DAFQLD) and the Birchip Cropping Group (BCG).

The project focussed on:

- Identifying areas for improvement in the performance of seasonal climate forecasts.
- Development, trialling, and subsequent operationalisation of new Bureau of Meteorology forecast products for extreme events in the weeks to months ahead.
- Development of risk management packages for extreme events for specific agricultural sectors, and for agriculture more generally; and
- Communicating the progress of the project through a variety of media platforms.

The main agricultural sectors of focus were red meat, grains, dairy, sugar and wine grapes with support also for the cotton, pork and rice industries.

The University of Melbourne (UOM) worked with Dairy and Southern Red Meat Industry Reference Groups (IRG's) to obtain feedback regarding development of new Bureau of Meteorology forecasting tools and conducted research to deliver an extreme event risk management package for the dairy and southern red-meat industries. A structured process of consultation with the reference groups, identified the extreme event risks of consequence to their industry, identified multiple appropriate response scenarios to each identified extreme event and provided feedback to the Bureau of Meteorology (BoM) during the development of the products. The response scenarios research included whole farm biophysical and economic analysis.

2. Objectives

As a FWFA project partner, the University of Melbourne (hereafter UoM) delivered primarily to work package 3 (WP3) and subcontracted to Agriculture Victoria for delivery to WP4, with contributions to WP2 via the Industry Reference Group feedback mechanisms. Table 1 outlines the UoM contracted objectives and the degree of successful delivery.

Table 1 Forewarned is Forearmed Project - UoM objectives and delivery

+ *indicates additional delivery*

WORK PACKAGE	OBJECTIVE	DELIVERY
2	**1.** Facilitate and provide dairy and southern red meat industry reference group feedback to support the Bureau of Meteorology's (BoM) development of five forecasting products	✓+
3	**2.** Establish Reference groups for southern red-meat and dairy industries	✓
3	**3.** Identify key extreme events of consequence and evaluate associated response scenarios for the dairy and southern red-meat industries	✓+
3	**4.** Develop Industry-specific risk management plans for the dairy and southern red-meat industries	✓+
3	**5.** Deliver extreme event risk management packages and evaluated response scenarios for the dairy and southern red-meat industries and farmers	✓+
4	**6.** Communication of products developed in WP1, 2 and 3 through to targeted industries, using existing extension	✓
4	**7.** Establish a communications and extension campaign in the final 14 months of the project	✓
4	**8.** BoM new forecast product launch webinars	✓
4	**9.** eLearn modules for each new BoM forecast product	✓
4	**10.** Industry talks around FWFA output	✓+
4	**11.** Farmer-focussed case studies for each southern industry: grains, viticulture, dairy, southern red meat	✓
4	**12.** Social media and news via Climate Kelpie	✓
4	**13.** Linkages with advisor and farmer group opportunities, industry communications, new opportunities	✓
4	**14.** Opportunities for articles in RDC and partner communications	✓
4	**15.** Increase awareness in the agricultural industries of the extreme events products, risk management tools and evaluated response scenarios.	✓
4	**16.** Establish project legacy evidence	✓+

3. Methodology

3.1 Interfacing to Industry Decisions

The University of Melbourne (UoM) undertook research to deliver an extreme events risk framework, and associated response scenarios, for the dairy and southern red-meat industries, within the context of the broader 'Forewarned is Forearmed' program. The project established industry reference groups (comprised of farmers and farm advisers) in the dairy and red-meat industries in south-eastern Australia. The reference groups were presented with the science on extreme events, along with the products and tools being developed by the Bureau of Meteorology.

3.1.1 Industry engagement

The project set out industry engagement plans to strategically enhance a direct relationship between the University of Melbourne (UoM) project contribution and the dairy and southern red meat industry bodies for the mutual benefit and confidence of all collaborating project parties. The two industry partners engaging with the UoM with respect to industry reference groups (IRG) and data were Dairy Australia and the Southern Australian Meat Research Council (SAMRC).

Dairy Australia is the national service body for the Australian dairy industry. They invest across the dairy supply chain and identify best opportunities for collective action towards a profitable and sustainable dairy industry. Dairy Australia provided IRG members from their existing Land, Water and Carbon Community of Interest (LWC CoI) group as the project reference group.

SAMRC is an independent Incorporated Association and one of three National Councils set up to provide advice on Research, Development and Adoption (RD&A) within the Australian Red Meat and Livestock Industries. The other two Councils are the Northern Australia Beef Research Council (NABRC) and the West Australian Livestock Research Council (WALRC). Together the three Councils provide advice to the Red Meat Panel and act as a conduit for the flow of information from and to grass roots producers. IRG members were sought from producers across the seven regional committees of SAMRC (each Regional Committee has an appointed Chair, up to six producers (nominated representatives of key investor groups), selected members of the RD&A community and broader red meat industry in each region).

3.1.2 IRG function

The function of the IRG member was to participant and contribute to the FWFA with the aim of representing the views of dairy producers/southern red-meat producers around extreme climate and weather events, identifying likely on farm impacts, prioritising the extreme events risks of most consequence to their industry, contribute to an extreme events risk management framework for their industry as well as provide feedback for the Bureau of Meteorology (BoM) forecasting products on their usefulness and applicability to dairy and southern red meat producers.

3.1.3 Methodology change across project

The initial methodology focusing on the IRG was:

- To convene three face-to-face reference group workshops across the project

- To convene online project and specific reference group sessions (at least 3 but up to 6) - duration 45 minutes each
- To have members evaluate sets of Bureau of Meteorology forecasting products and provide feedback, by providing access to the BoM's research site.
- To request their input and comments on the risk outputs for the project

The onset of the COVID Pandemic and subsequent extended lockdowns meant only one face to face workshop was convened and the methodology shifted to a virtual mechanism, with an increased use of digital technology.

Work Package 3: Interfacing to Industry Decisions
The structured and iterative consultation process involving the IRG:

a) Identify the extreme events of greatest consequence to their industry *(first face-to-face workshop)*,
b) Identify appropriate response scenarios to each identified extreme event *(scheduled virtual meetings and email)*,
c) Evaluate the products and tools produced by BOM *(scheduled real-time sessions, resources made available on web and facilitation of surveys and web forums)* and
d) Identified response scenarios were subject to farm systems expert analysis (biophysical and economic) to explore the risk mitigation costs.

Work Package 4: Extension, training and communications

This project subcontracted the Climate Specialist team, led by Graeme Anderson, in the Department of Jobs, Precincts and Regions (DJPR), to utilise their extensive experience and existing networks (including the "The Break" newsletter with over 3000 subscribers, over 100 forums and webinars conducted each year by the team, plus the PICCC newsletter with over 400 subscribers).

As the Bureau products were released late in the project a variation to the contract incorporated a more focused Extension and Communications Campaign across the final 14 months aiming to deliver more presentations, webinars and legacy products. The DJPR subcontract was extended along with a new subcontract with Birchip Cropping Group to deliver detailed aspects of this campaign.

4. Results

4.1 Project Outcomes

4.1.1 Project level achievements

According to the UoM team (including AgVic and BCG) the project has successfully achieved its objectives Table 2 itemises the project activities against the achievements and activities.

Table 2 Forewarned is Forearmed Project – outputs, activities and achievements against UoM objectives

Objective	**Activities**	**Achievements and outputs**
1. Industry feedback re development FWFA BoM forecasting products	i. access and tour of BoM research site and feedback spreadsheet ii. real-time online explanation and discussion sessions with BoM and IRG iii. provision of recording of ii. Above, plus slide packs and questions in forum and survey on webpages	IRG aware of and able to access and use the experimental site and all feedback mechanisms
2. Reference groups for southern red-meat and dairy industries	Consultation with Dairy Australia, MLA and SAMRC to nominate potential IRG members	Built IRG groups from these consultations
3. Identify key extreme events of consequence and associated response scenarios	i. two face-to-face workshops (one per industry pre COVID) ii. correspondence and online discussion regarding scenarios ii. distribution of draft scenarios for comment	Identified scenarios: - Pastures and heatwaves - Drought and stocking - Pastures and wet winters
4. Develop Industry-specific risk packages	i. Risk matrix developed from IRG workshops, document and risk matrix distributed to IRG members for refinement, comment and feedback ii. multiple meetings with industry investors (MLA and DA) iii. online risk discussion and paper to clarify iv. detailed risk document	i. See Milestone Report 3 Appendices 1 and 2 ii. & iii. Reworking and prototyping to deliver to Risk outputs see Objective 5.

5. Deliver extreme event risk packages and response scenarios	Continuing from 4 above: i. risk documents for each industry (perused by IRF) ii. building of protype risk pages for discussion and consideration iii. Response scenarios – engaged expert analysis and worked with team to deliver	**i. Risk Packages**: final documents delivered to MLA and DA May 2022 **ii. Web prototypes** Risk Framework introduction https://piccc.org.au/research/project/FWFA_RiskFrameworkV3.html Rapid Climate Decision Analysis introduction https://piccc.org.au/research/project/FWFA_RCDA.html RCDA application example – nitrogen https://piccc.org.au/research/project/FWFA_RCDA_applicationV2.html Extreme heat page for SRM https://piccc.org.au/research/project/FWFA_SRM_Heatwaves.html **iii. Response Scenarios:** Pastures & heatwaves: The potential of deep-rooted species to mitigate the impacts of heatwaves and declining rainfall on pastures in southeast Australia Crop and Pasture Science Drought and stocking rates – Darriman Case Study Drought Stocking Management Wet-winter grazing management: Managing wet soils economically – Accepted Australian Farm Business Management Journal 2023 – full in Appendix 8.1
6. Communication of products developed using existing extension	i. prior to public release of operational products AgVic used selected experimental products in extension activities ii. once operational products promoted in workshops, webinars, updates and newsletters ii. presentations to BCG CoP meetings	See extensive listing in Appendix 8.2
7. Comms & extension campaign final year of project	i. liaison with MLA, AgVic and BCG to draw up proposal for contracting	Contract executed March 2022

8. BoM new forecast product launch webinars	i. work with presenters and BoM comms to establish dates ii. build registration site and promote event ii. hosting, recording and post-production editing of event iv. releasing edited recording to the public and promoting link	**Products 1 & 2** https://www.youtube.com/watch?v=IhHmZS9h2LI **Products 3, 4 & 5** https://youtu.be/RL0JrRY61NU **BoM Media promo** https://www.youtube.com/watch?v=uv6c6Vh5Zr4
9. eLearn modules for each new BoM forecast product	i. AgVic (DJPR) subcontracted to produce the eLearn ii. review and proofing of drafting product iii. testing and deliver to online platforms	eLearn regarding the FWFA products https://agriculture.vic.gov.au/support-and-resources/elearning/climate-and-weather-courses
10. Industry talks around FWFA output	For FWFA South: Numerous face-to-face presentations and online presentations to farmers and advisors by AgVic and UoM	See section 4.3
11. Farmer-focussed case studies for each southern industry: grains, viticulture, dairy, southern red meat	Subcontracted to BCG i. selection of farmers/case study properties from IRGs ii. drafting and review of web document ii. distribute and promote case studies	See final three of four Case Studies below – these will be housed and accessible from the Climate Kelpie and PICCC websites in 2023 FWFA Barry Mudge Final.pdf Wayne Clarke Case Study FWFA final.pc FWFA Jenny OSullivan Final.pdf
12. Social media and news via Climate Kelpie	Subcontracted to BCG: i. Twitter, Facebook and website blogging ii. Climate Kelpie Newsletter articles	Facebook, Twitter, Website, Climate Kelpie News See Appendix 8.3 for stats.
13. Linkages with advisor and farmer group opportunities, industry communications	i. media release and information/material to all FWFA industry comms teams ii. working with specific requests for media and comms opportunities iii. call out to relevant FWFA partners for specific media/comms opportunities	Articles across, sugar, grains, wine and cotton, for example Sugar Wine Grains Red Meat Cotton Numerous local media take up at launches (see previous Milestone reports)

14. Opportunities for articles in RDC and partner comms	Working re-working and review of relevant articles and material	As above
15. Increase awareness of the BoM products, risk packages and response scenarios.	i. series of FWFA webinars ii. product launch webinars & videos iii. AgVic: use and referral of FWFA information in activities iv. Use and referral of FWFA material and information in Carbon Neutral Training for advisors and farmers v. case studies vi. video case studies: input and liaison with National Coordinator regarding process, talent and proofing of four professional case study videos	i. Webinars 1. Products and forecasting - The Australian Bureau of Meteorology 2. Overview of the Managing Climate Variability R&D Program and Extreme Events Forecasting (CRSPI/FWFA) 3. Past rainfall changes over Australia and implications for agriculture (CRSPI/FWFA) 4. Climate risk in the grains and wine grape industry – frameworks to support the discussion between climate science and growers? 5. Understanding forecasts and on-farm management of climate and variability. (CRSPI/FWFA) 6. Managing extreme events in the southern Australian grazing industries. 7. Forewarned is forearmed: Project update, CoP, extension and partner panel. 8. The Australian Bureau of Meteorology's climate forecasts discovery tour 9. "An agricultural scientist's view on FWFA products to help manage a La Niña summer" 10. New extremes outlooks for agriculture 11. How are new climate extreme outlooks helping sugarcane farmers and the agricultural industry? 12. New climate forecasting products developed for the wine industry as part of the FWFA Project ii. See 8 iii. See 6 v. See 11 vi. Series of

16. Establish project legacy evidence	i. online architecture to point to FWFA outputs ii. writing and delivery of case studies iii. recording, editing and uploading of webinars iv. eLearn accessibility for all	i. BoM FWFA Forecast Products: https://piccc.org.au/research/project/FWFA_Forecast_products.html FWFA Research publications: https://piccc.org.au/resources/research-publications/FWFA_publications.html FWFA videos and recordings: https://piccc.org.au/resources/videos-webinars/ https://piccc.org.au/research/project/FWFA.html ii. See 11 iii. See 15 and i. above iv. See 9

4.1.1 Contribution to program objectives

The FWFA Project contributed to the program objectives by:

1. providing unique forecasts of extreme climate and weather events for multiple agricultural industries delivered to farmers.
2. directly linking research groups with industry-specific reference groups to
   2.1. provide input to the products they will use.
   2.2. identify response scenarios for evaluation.
   2.3. facilitate the development of risk management strategies, and
   2.4. strengthen pathways to extend the results of the R&D.
3. establishing industry and research collaborations with high likelihood for ongoing innovation and growth of Australian agriculture.
4. developing legacy material to continue to contribute beyond the projects funding period.

The project successfully established collaborations between significant government, university, agribusiness and industry bodies and produced extreme events forecasting awareness and tools, risk management scenarios and packages, along with numerous peer reviewed publications, example industry case studies and video material, all of which will serve as valuable legacy material for Australian agricultural producers and industries.

4.2 Collaboration

Table 3 Forewarned is Forearmed Project – collaborative relationships and organisations

Organisation	Innovation	Will continue
DJPR Agriculture Victoria (Partner)	Subcontracted to them as part of FWFA. UoM has a strong record and relationship of collaboration with the Ag Vic Team. The general sharing and learning in climate variability and the FWFA output is especially important for future consistency and progress in innovation.	Highly likely e.g. Drought Hubs
BCG (Partner)	Subcontracted to them as part of FWFA. As with the Ag Vic Team, UoM has a strong record and relationship of collaboration with the Birchip Cropping Group.	Highly likely
SARDI (Partner)	Focused collaboration with SARDI (specifically Peter Hayman) on the development of the FWFA generic risk management product. This has been a great learning curve with progressive discussions and work which will flow through to the way producers' approach and make decisions about climate risks.	Likely
Dairy Australia (DA) (Partner)	UoM (PICCC) has an established history collaborating with DA. In this project the collaborative continuity was challenged due to multiple DA personnel and structural changes	Highly likely
MLA (Partner)	A lead organisation on this project MLA oversaw all reporting and as a rep for the Southern Red Meat Industry UoM could run a variety of risks prototypes and discussions by Doug McNicholl until his departure.	Highly likely

BoM (Partner)	This is the first project where UoM (PICCC) has worked directly with staff from the BoM and arguably builds a new strategic alliance to develop further projects.	Likely
USQ (Partner)	Less collaboration and involvement with northern partners during this project.	Possible
DAFQ (Partner)	Less collaboration and involvement with northern partners during this project.	Possible
Industry reference groups members – farmers (VIC, NSW, WA)	The collaboration with individual producers has been amazing throughout the FWFA Project. Enabling the option for end users to access and give feedback on experimental and operational forecast products including collaborating with the BoM has been very valuable and is likely to be taken up as a model for future product development. The risk work with the IRG members meant we were getting first-hand, robust information to feed into frameworks and response scenarios.	Likely through other projects
Fonterra, Parmalat & NORCo (External)	Access to 17 years of milk record data for specific heat stress periods which was then collated into a database for analysis of financial impacts on farm and costing of specific heat stress management options. Increase inter-industry collaboration: while corporate confidentiality of the data from each of these collaborators exists, these collaborations enable an element of external collaboration and agreement (between essentially competitors). Enabling these interactions benefits all parties.	Possible through other projects
Sheep CRC (External)	UoM initiated collaboration with the Sheep CRC, specifically with respect to their Ag360 (ASKBILL) tool (with a view to look at whether the tool may extend to the dairy and beef industries and used as a risk management tool for the FWFA project).	Early in project, sporadic
AGBU UNE (External)	Breeding stakeholders' discussion and presentation. This has opened an opportunity for UoM (PICCC) to be part of the breeder network discussions.	Likely
National Australia Bank (External)	Ongoing discussions and interest in this project to explore risk management frameworks for agriculture. Likely this will contribute to future financial development in the climate risk on farm in these organisations.	Highly likely
Rabobank (External)	Ongoing discussions and interest in this project to explore risk management frameworks for agriculture. Likely this will contribute to future financial development in the climate risk on farm in these organisations.	Highly likely

4.3 Extension and adoption activities

Extension and measurable impacts of extension occurs over significant time and with focused strategies and investment. At this point in time (the life of the FWFA project), a measure of the degree to which both southern and northern agricultural industry stakeholders and farmers have (through FWFA), increased understanding and capability to use forecasting tools and via the extension expertise. Work Package 4 was to deliver FWFA extension and training which as it turns out, within the timeframe was not an insignificant challenge given the first two BoM products were operational just over a year before project end (November 2021) and the final three only six months (July 2022) before the end of the project. In addition, the risk work which involved considering the new tools was delivered also in the final year.

As per Section 3.1.3 the UoM subcontracted to the Agriculture Victoria Team in DJPR to deliver to Work Package 4 using their extensive experience and existing networks. Given the release times of the BoM products, a variation to the UoM contract incorporated a more focused Extension and Communications Campaign across the final 14 months: DJPR's subcontract was extended and a new subcontract with Birchip Cropping Group was negotiated to deliver focused aspects including further webinars, farmer talks, FWFA eLearn online, case studies, increased social media and online material and legacy products.

Earlier milestone Reports listed details for the DJPR events including workshops, talks, seasonal updates etc. During the early stages of the project, FWFA information was introduced across events by sharing access and discussing products under development including: quintile products, 3-month outlooks plus discussion around prediction of extreme events and the comparison of above and below median maps. As the products developed, the AgVic brought them directly into their presentations/discussion. By December 2022 Graeme Anderson and Dale Grey had spoken with over 3,441 farmers and 4,350 advisors across 160 events to southern producers (note these numbers will be underestimated as not all counts were recorded). In addition the AgVic team has developed an eLearn which is housed on the DJPR site and will grow in promotion and distribution in 2023.

These numbers do not include the attendees and viewers of webinar/video and recording products. From the Excel listing in Appendix 8.2 over 21,300 viewers have either attended live (791) or viewed recordings (20,590) regarding the FWFA products and research. Note around 85% of online views are attributed to the BoM product launch video in 2022 and the latest Climate and Water Outlooks video (29/12/2022) using the new FWFA Tools. This relates to 59 online recordings and includes Project specific webinars, Community of Practice meetings and some industry webinars. Again, this will be undercounted as the northern activities and other industry activities in the south have not been reported/captured.

An example for the audience mix in webinars is represented by the aggregate list in Table 4 of those who attended the launch webinar for the FWFA BoM Products 1 and 2 (November 2021). Of those who attended, 28 completed a post webinar survey provided in full in Milestone 11 Report Appendix II. Figure 1 is a snippet from the respective survey results and it indicates a successful and informative webinar in addition to providing excellent feedback from BoM FWFA product users.

BCG supported a further two Community of Practice meetings in early 2022 and then focussed on supporting the social media promotion across the Climate Kelpie Facebook, Twitter and website. In addition the FWFA project and outputs featured highly across editions of Climate Kelpie News (in 2022 alone with over 6000 opens) with 16 focussed articles published on the Climate Kelpie Website blog. Please refer to Appendix 8.3 for further details.

BCG has produced four farmer-focused case studies based on the FWFA Project products. These will be disseminated in early 2023 and accessible via the Climate Kelpie and UoM PICCC websites. To date, beyond 2022 the Climate Kelpie website will no longer be maintained as it has not been taken on by another organisation.

Table 4 Example demographics listing from FWFA BoM Products Webinar November 2021

Area	Registered	Attended
Climate/ Weather	6	4
Extension	7	5
Beef/sheep	10	7
Agronomy	11	7
Research	15	11
Government	37	13
Sugar	2	0
Consult/ Advisor	20	12
Dairy	22	14
Crop/ grains	10	4
Ag Business	5	0
Horticulture	5	4
Finance	14	7
Other	20	14
Unspecified	17	0
Total	201	102

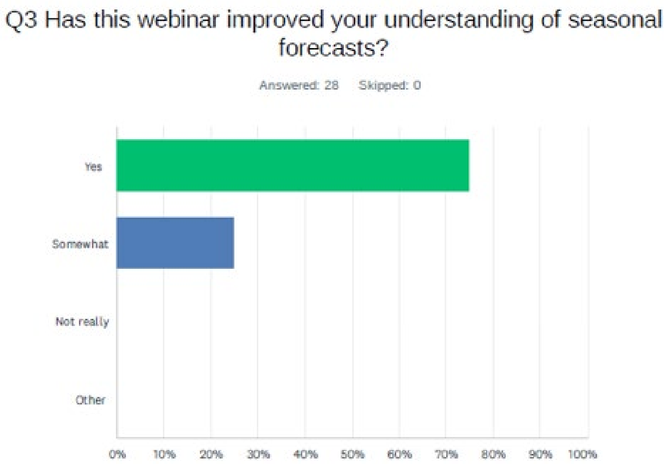

Figure 1 Survey response from FWFA BoM Products webinar November 2021

Recommendation for Extension and Adoption
For longer term use and application of forecasts there needs to be growth in the investment, capability and extension being delivered within agricultural industry networks and farmer groups (trusted pathways). If the Bureau of Meteorology only are tasked with doing this (that is in the absence of this wider agricultural community) capability growth would be a retrograde step.

4.4 Lessons learnt

Please refer to the Lessons Learnt Synthesis paper to be submitted by SARDI (Peter Hayman) to which UoM contributed. The following are supplementary notes to that report.

4.4.1 Overarching - what worked well

- Co-creation of products with farmers
- Considered historical project/program outcomes, identified gaps in forecast tools and aimed to address those gaps

- Collaboration between diverse groups
- Establishing a project community accessible to networks

4.4.2 Some Challenges

- **Engagement:** Reference group members
  IRG were provided Terms of Reference for participation and onboarding to the BoM research site for product site was explicit: provided guidance and mechanism for exploring the experimental site and how to submit feedback.
  Flaw on FWFA side: we assumed IRG members would explore products and give feedback in their own time.
  Flaw on IRG side: many expected they would be getting insider knowledge on the forecast rather than it being extra characterisation of the forecast.
- **Platforms for engagement.**
  Pre-COVID we had planned **face-to-face workshops** and those that were held prior to the pandemic restrictions were successful and achieved objectives
  We tried these ways:
    - Work independently and provide feedback
    - Online real time sessions with BoM there to answer questions (usually provided 3 sessions at times to cater for variety of attendance). Overall the attendance was poor (across all IRGs) although those who attended provided valuable discussion and feedback.
    - Provided a web page containing a short video recording exploring the product plus the slide pack accompanied by forums with guidance questions. This was essentially virtual hand -holding but by products 4 and 5 the response rate was minimal to none. So overall this did not work (again, people had to go there in their own time and do it – not really any incentive)

  Online sessions were hit and miss. Some worked well and others not. Overall it was difficult to predict attendance. The degree to which 'online fatigue' played as the pandemic progressed is not clear. Overall, the focus group is better off with face to face.
  COVID restrictions limited our real time face to face engagement and therefore had an impact. However despite the pandemic challenges, with a project this long, it would have been beneficial to design how we could engage our reference members for the duration e.g.
    - careful, clear onboarding to set up and manage expectations from outset.
    - a strategy for retention and maintaining momentum for the duration.
    - use of different platforms/appropriate platforms.
    - understanding the different elements of project fatigue – online attention span is shorter than face-to-face time. Whilst COVID did impact this area, additionally a string of extreme climate events impacted the most engaged UoM IRG members which made their busy schedules even busier (and diminished the prioritisation of time for the FWFA project).
- **Incentivise participation:** for example working with these farmers to show any relationship between the forecast and their decision making. This was done to a degree in online sessions with Barry and Peter – but perhaps it required more personalisation for the farmers?
- **Small working groups:** Relying on the same farmers for feedback repeatedly (and generally the same ones who already have a decent understanding of the climate and forecast information) is tricky to navigate because, whilst you want to work with people who are engaged and will provide good feedback, working with others having different levels of understanding and a different lens would be beneficial. Plus it would promote new tools etc. to a different group of users.

- **Communications**
  The five new FWFA Products became publicly available late in the project which left a short amount of time to ensure extension and sharing to increase public awareness – this task will need to be embedded into the future projects and ensure BoM (CSA) and AIA (Agri-Outlooks) play a role to promote the FWFA products amidst the new project outreach.
  Research side of FWFA: did we undersell the research? Peer reviewed publications output from the project are impressive. Is there a way we could have enhanced communications around this work? For example, to encourage the flow through to broader community through output translation to more common vernacular. An article in The Conversation Sept 2019 is a lay translation of work from the FWFA project published by the BoM in Nature October 2019. The popular article has had almost 1M accesses compared with the ~4K of the scientific article. Could we have set up a project architecture where the research could be communicated more widely by requiring the related delivery of a popular article translating that research?
  Communicating the products: notwithstanding the acknowledgement that extension of the products will take a considerable while to move through the community of users: and therefore it would currently not be a 'good measure' of communication about the products, the question remains is did the project do enough to communicate these products? In November 2021 and July 2022, media releases and Ministerial announcements were made, webinars coincided with the public launch, online publications picked up and wrote about the releases, information was sent out to large networks and more recently online information sessions have been convened. The BoM has communication KPIs and stats to indicate the circulation of this information. However anecdotal evidence appears to indicate that some people who should be aware of the products are not (Andrew Watkins pers comm).
  Communications and extension strategy for FWFA: In hindsight as the project had a late-stage delivery of the major products it would have been valuable to have funded, planned and built in a later stage or second phase project focussing on communications and extension to the project design.

5 Conclusion

5.1 Key findings

General

- Cross collaboration of research partners, industry and end users to realise the objectives of FWFA Project was effective
- The extension through DJPR's Agriculture Victoria presentations, workshops and BCG CoP's along with UoM hosted online sessions, were key to promoting the extreme forecast products in both the experimental and operational phases
- We had expected the Dairy and Southern Red Meat Industry Reference Groups to focus on animal impacts (e.g. heat stress), but they clearly focused on pasture impacts, stating that "animals can be moved to shade and shelter, but the pasture cannot".
- Dairy and southern red meat producers identified and prioritised the same three most important extreme climate events of most consequence: extended wet seasons (wet winters), extended dry (drought) and heatwaves

- IRG members identified 13 vulnerability areas being pasture, livestock health, livestock condition/productivity, infrastructure, operations, fodder quality/silage, cash flow, crops, social, water supply, soil, environment, biosecurity and social (see next point for latter).
- Social impacts of extreme events were raised but farmers did not volunteer responses. This could be a gap in their expertise that requires further research.
- Improved forecasts of extreme events are required to inform key economic decisions around the timing of selling off stock and buying in feed/water.
- Weather/climate forecast tools are only one of a combination of tools and resources used by farmers in extreme event decision making.
- Some generally useful tools are limited in range and require extension e.g. Ag360 is set up for temperate based farming systems and not that effective for rangelands, graziers alert should be extended for other parameters, BoM shorter term forecasts are not as reliable / easy to read as 10-day Norwegian forecast. The SGS, GrassGro and AusFarm models are too complex for use by farmers.

Research

Wet-winter grazing management: Managing wet soils economically *Sinnett et al. 2023*

It was found that if the representative farm businesses:

- did not change grazing management during a wet winter this would result in extra costs between $11,000 to $44,000 (depending on the likelihood of a wet winter).
- had a stand-off area and practiced on-off grazing then the annual cost of this grazing strategy would be between $520 to $2,600.

The maximum amount the representative farm business could invest in a stand-off area and be no worse off than doing nothing differently to manage wet soils, was found to be from $65,000 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.

The representative farmer may be better able to manage the risk of a wet winter through active grazing management, essentially 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.

A cost framework was developed that other farm businesses could use to consider the costs of different wet winter management strategies for their businesses.

The Potential of Deep Roots to Mitigate Impacts of Heatwaves and Declining Rainfall on Pastures in Southeast Australia *Meyer et al. 2021*

It was shown

- that pasture production from deep-rooted species is not always substantially greater. This study in southern Australia demonstrated that deeper-rooted species could be a good adaptation response, assisting in maintaining farm profitability, for farmers in higher rainfall areas where soil moisture was available for the deep-rooted species to access. However, soil moisture limited the adaptation benefit for farmers in the lower rainfall areas.
- that pasture persistence is important to the profit of climate adaptation responses. Persistence pays and should be incorporated when modelling climate impacts. Management options that focus on summer dormancy and improve pasture persistence during hot, dry

periods would likely provide more benefit for dry areas than a focus on deep-rooted species, and the potential for such options in a future climate warrants further investigation.

Managing livestock in an extended drought – case study. *Climate Kelpie 2020*

A response scenario comparing the sell and maintain options on an actual farm in Gippsland over two failed seasons. The 1,500-hectare property at Darriman has an average annual rainfall of 570 mm. The case study follows the property through a severe drought period from spring 2017 to spring 2019. The enterprise consists of Merino wool, prime lambs, beef cattle on improved grass/legume pasture and a small area of irrigated pastures and hay. The Darriman drought case study illustrated that a return to profitability was more rapid when animals were retained, however this is a feasible strategy only with availability and accessibility of alternative feed sources for the duration of the drought. If this was not available, then this strategy could result in severe overgrazing of the pastures.

Heat stress impacts and responses in livestock production *Meyer et al. 2018*

The cost of heat stress is significant across the livestock industries, with impacts on production, fertility, feed intake and nutritional requirements, welfare, risks of illness, and mortality. As the climate warms, the risk of heat stress and high cumulative heat loads increases, resulting in more expensive mitigation options becoming cost effective. Decisions regarding available options to minimise the impacts of heat stress must incorporate a clear understanding of

- the cost of implementation,
- the effectiveness of the option, and
- the value of the avoided losses that include the risk of heat stress on an operation.

For breed selection, valuing the benefits of increased heat tolerance includes accounting for the sensitivity of available breeds to heat stress, productivity of the breeds in thermoneutral conditions, and the likelihood of exceeding heat stress thresholds. Strategic decisions addressing heat stress should be addressed at whole-farm and supply chain level and integrate logistical feasibility and long-term economic sustainability.

Using milk tanker pickup and weather station data to quantify the impacts of heat stress on milk production in Australia *Meyer et al. 2021*

The average milk solids response reported in this analysis, suggests a loss of 49 kg, 84 kg, 98 kg of milk solids per average farm with a 10-unit increase in the relevant THI metric occurring over seven days for the southeast Queensland – northeast New South Wales, Murray, and Gippsland regions, respectively (e.g., 1.4*10*7 = 98 in the case of the Gippsland region). Over a region the size of Gippsland this equates to a reduction of approximately 83,200 kg of milk solids (based on the 849 farms included in this analysis) and a financial loss of $499,200 to the region's dairy industry, assuming the 2015-2020 average Victorian milk price of $6/kg milk solids. Such estimates assist with cost benefit analysis, necessary to inform decisions regarding investments in farm infrastructure that can alleviate impacts.

Without action, these impacts are expected to worsen as the duration and frequency of heatwaves increase with climate change. This analysis implies that although milk production in the subtropical north may be affected by heat for much of the year, cows in the cooler climate in Gippsland are more impacted by individual heat waves. Improved performance of THI metrics over longer time frames demonstrates the importance of cumulative impacts and lag effects on milk production.

Better performance of averages and minimum THI metrics over maximums, imply that cool nights can offset the impacts of high day-time temperatures. These findings are important for both productivity and animal welfare considerations.

5.2 Benefits to industry

- The FWFA Project has been a successful model of cross industry research and development work which involved the end users from the beginning stages, a key success that could be applied to other industry initiatives
- As per Section 4.2 the collaboration of partners, end users and investors in the FWFA Project has established relationships, networks and connections that will likely continue or pick up again to support other opportunities, R & D work and projects
- Dairy Australia and Meat and Livestock Australia have expanded detail and information regarding producer's climate extreme events risks and those of most consequence on-farm
- The FWFA BoM new extreme forecast products have been promoted across the Australian agricultural networks beyond those industries involved in the project
- Following on from above,
    - improved understanding of user's requirements and priorities
    - increased consultation and uptake of the FWFA BoM new extreme forecast products
- Research and experimental prototypes will flow through to other projects backed by industry (e.g. Climate Services for Agriculture)

6 Future research and recommendations

- **Explicitly address uncertainty**. Ensemble modelling along with the broad dimensions of the climate system result in considerable uncertainty in the forecasting/predictability. It is essential that these uncertainties are acknowledged and transparent and if possible attempted to be addressed in projects like this one. Uncertainty in forecasts deserves stand-alone attention in these projects rather than a by-product. Doing such in future will openly address the issues with forecast accuracy/skill.
- **Address and improve skill.** Following from above, although the FWFA products visually show the level of skill/accuracy to the user, the project work has not included improving the accuracy of the forecast. As the skill varies with products and end-users have explicitly clarified they will not consider, and do not have confidence in, forecasts of low skill it is strongly recommended that in future work skill is addressed and as a general practice, forecasts of low skill are not issued publicly.
- **Communicate scientific research output in broader vernacular.** Future research projects producing journal articles may benefit from having a parallel delivery on their subject published in popular publications (e.g. The Conversation) to extend circulation of information and results.
- **Strategically manage end users in the project.**
    - **Include and increase interaction with end users from project initiation stages** and continue throughout the life. IRGs were set up following the commencement of the project and after the project design. The consultation and discussion began only in the face-to-face workshops and following (pandemic induced) online sessions including CoP and BoM monthly meetings. Key information from producers about how they are currently using seasonal climate forecasting/ managing for extreme events and importantly the critical information gaps would greatly enhance the focus and delivery

outputs. It is strongly recommended that any future projects have early and continuing focused engagement with end users.

- **Continually manage IRG member expectations from outset and duration.**
    - careful clear onboarding to set up and manage expectations from outset
    - a strategy for retention and maintaining momentum for the duration
    - use of different platforms/appropriate platforms
    - understand and cater for project fatigue (e.g. online vs face-to-face time).
- **Incentivise end user engagement carefully** – for example working with these farmers to show any relationship between the forecast and their decision making –more personalisation for the producers.

- **Include first users experience in extension**. The Ag Vic team began promoting awareness of, and using, the developing experimental products in their extension activities as early as 2019. This was an effective segue to the eventual release of products and once launched those producers involved in the Ag Vic activities had an idea of the products use and application. It is recommended that where appropriate early user experiences are used in extension and training activities.
- **Ride the FWFA coattails.**
    - This project has shown a growth in users understanding probabilities, continued extension and communication in this area will strengthen this broader understanding.
    - Make use of and do not underestimate, the growing language and concepts of climate science in the broader community narrative and adopt ways/deliveries to continue promoting/pushing this information in future projects.

Over the life of the FWFA project – how much has the agriculture industry stakeholders taken on more forecasting capability and extension expertise to reach farmers via trusted agri-networks? This is an important question. For longer term use and application of forecasts there needs to be growth in the investment, capability and extension being delivered within agricultural industry networks & farmer groups (trusted pathways). Focus on only the Bureau doing more without this wider agricultural community capability growth would be a retrograde step.

As FWFA and the MCV era ends, it’s critical that across the agriculture/climate community the three core elements for improved climate risk management in Australia are recognised.
Improved climate risk management require three things:

1. Better forecasts (models, weather, multiweek, seasonal, climate change)
2. Better understanding of forecasts (climate literacy of users & forecast products)
3. Farm risk management & adoption (strategies, tactics, tools to better manage risks both with and without forecasts)

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THE CLIMATE KELPIE BLOG: 'You got to know when to hold 'em' – managing livestock in extended drought. Posted by BCG on 27th July 2020 [*http://www.climatekelpie.com.au/index.php/2020/07/27/you-got-to-know-when-to-hold-em-managing-livestock-in-extended-drought/*](http://www.climatekelpie.com.au/index.php/2020/07/27/you-got-to-know-when-to-hold-em-managing-livestock-in-extended-drought/)

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We are grateful to all of those with whom we have had the pleasure and honour to work and collaborate as part of this project and look forward to what may eventuate in the future.

9 Appendix

9.1 Wet-winter grazing management

Wet-winter grazing management: managing wet soils economically

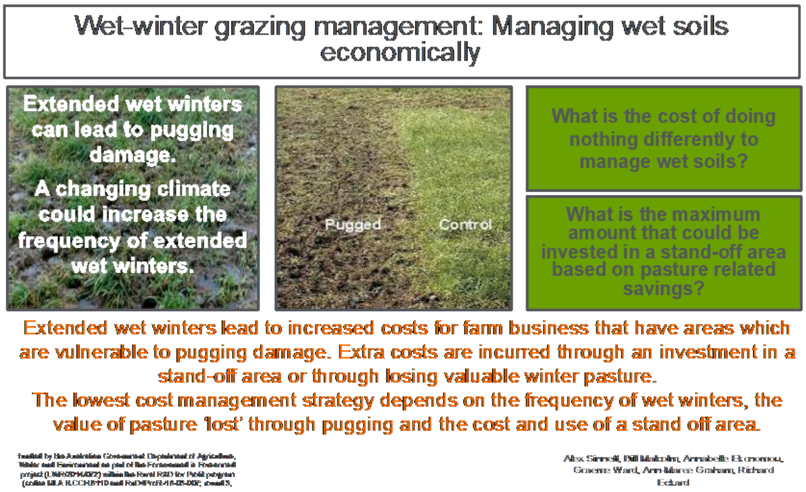
Alex Sinnett, Bill Malcolm, Annabelle Ekonomou, Graeme Ward, Ann-Maree Graham, Richard Eckard
School of Agriculture & Food, University of Melbourne Australian Farm Business Management Journal 2023

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 estimated, for two representative farm businesses with 100 hectares affected by a wet winter: (i) the cost of doing nothing differently to grazing management to manage a wet winter; (ii) the cost of actively managing a wet winter through 'on-off' grazing (assuming 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 winter management. To do this analysis both biophysical modelling and economic analysis was used. It was found that if the representative farm businesses did nothing differently to grazing management during a wet winter this would result in extra costs between $11,000 to $44,000 (depending on the likelihood of a wet winter). Whereas, if they had a stand-off area and practiced on-off grazing then the annual cost of this grazing strategy would be between $520 to $2,600. The maximum amount the representative farm business could invest in a stand-off area and be no worse off than doing nothing differently to manage wet soils, was found to be from $65,000 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, essentially 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. Lastly, a cost framework was developed that other farm businesses could use to consider the costs of different wet winter management strategies for their businesses.

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

Graphical abstract –



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 (CSIRO 2020). These extreme events will mean more waterlogged pastures, for longer times.

On dairy, beef and sheep farms in the higher rainfall regions of south-eastern Australia, when waterlogging of soils occurs during the winter and early spring, pastures can be damaged and profits reduced (Ward 2002). Waterlogging of pasture also has longer term adverse effects on soils when pastures on wet soils are grazed. Grazing waterlogged pasture causes crushing, bruising and burial of herbage in mud, making it difficult to eat and unpalatable to stock -reducing pasture utilisation by up to 50% (Ward 2002). Cow intake of pasture is reduced at the time of grazing, and the quality of the feed offered to cows in subsequent grazings is also reduced while ungrazed clumps also reduces subsequent pasture grazed. Grazing and the associated pugging of a wet pasture also causes serious long-term damage to the density of and botanical composition of that pasture. Wet soils are at risk of structural damage and a decline in soil physical health by either 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 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 density. Taken together the effect is that the growth potential of the pasture is severely restricted. Pugging occurs at high soil water content when pressure from the animal's hoof is greater than the bearing strength of the soil which has been weakened by waterlogged conditions. The resulting deformation and remoulding of the soil causes an undulation of the soil surface. This process is self-perpetuating because of the soil compaction at the bottom of the pug marks restricting downward percolation of water and causing ponding of water and reduced root penetration. Further, 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 are reduced for the remainder of the growing season (mid spring-early summer) for the pugged pasture, compared to the 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. Essentially, the pasture is growing in a more hostile soil environment with a loss of macro-porosity (reduced air-filled porosity at Field Capacity) poorer structure with zones of compaction. Further, 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 spring-early summer pasture DM yield reductions of 40-42% following late winter-early spring pugging events (for more information on effect of pugging in damaging the pasture sward see Ward et al 2003, and Nie et al 2001). Pasture damage from wet soil pugging can necessitate the resowing of the pasture or some other form of pasture renovation.

Waterlogging and soil pugging also have wider effects on the natural environmental. Waterlogging increases denitrification of plant available nitrogen in the soil, increasing emissions of nitrous oxide, a powerful greenhouse gas (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 are contaminated (Eckard *et al.* 2004). Increased soil erosion from land with siltation of drains and waterways also occurs.

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. 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, and more expensive application methods (e.g. by air) are necessary. There is increased risk to animal welfare and health with increased stress, lameness, 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). These include:

- Spreading the stock over the whole farm to reduce grazing pressure and set stocking 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 & hollow' or 'ridge and furrow' sub-surface drainage) are costly options, often not viable for grazing activities. The 'on-off' grazing strategy is widely used on dairy farms in the higher rainfall areas of southern Australia and in New Zealand.

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

An on-off grazing strategy means cows are provided access to graze the wet pasture for a restricted time, usually 2-6 hours, 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.
- 'Sacrifice paddocks', usually on 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 (e.g bringing focus on social licence to farm animals).
- Purpose-built containment areas such loafing, standoff or feed pads that can hold all the herd for extended periods. This method involves significant initial capital costs and the use of these structures involve running and maintenance costs such as the labour and equipment to feed cows and remove manure.

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. A purpose-built stand-off area was the wet-soil management option considered because other stand-off options such as using laneways and sacrifice paddocks were not considered viable long-term solutions. The research questions were:

I. What is the cost to a grazing farm business if management does not actively manage for a wet winter (i.e. 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 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 whether the stand-off facility is used or the pastures are grazed in their usual manner during the winter, regardless? It follows, that if an effective stand-off area can be established for less than this break-even sum, 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 livestock operation located in Allansford (Western District in Victoria) and Fish Creek (South Gippsland in Victoria). These 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 dry matter 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 was a proxy for the cost of wet winters 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 this cost 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 dry matter (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)

Kilograms of dry matter consumed

The amount of pasture that would be grown on the case study farms during a La Niña year 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, based on a single paddock of 1 ha in a theoretical grazing rotation, with 25 steers, grazing a pure perennial ryegrass pasture with no nitrogen limitation. The simulation was run with two soil types, for a La Niña year[1]. Grazing management was based on 25 steers rotationally grazing a perennial ryegrass pasture, commencing grazing when there was 2.5 t DM/ha in the grazing area, grazing to leave a residual pasture of 1 t DM/ha. Two soil types were selected at each location: poorly drained duplex soil (Table 1) and a loam sand (Table 2) representing a more freely drained soil type.

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

Horizon	Surface	A	B1	B2
Depth (cm)	2cm	0-20 cm	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	13	13	13	13

[1] 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.

VolSWC(%)

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

Horizon	Surface	A	B1	B2
Depth (cm)	2cm	0-20 cm	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 dry matter (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 (table 3 and 4) were inputs into the economic analysis. It was assumed that 70% of modelled pasture growth was utilised.

Table 3. Allansford pasture growth during June to December[2] 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 the June to December[3] in a LaNina 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

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 (e.g. "on-off" grazing), is likely to cause:

- A 35% reduction in herbage accumulation (growth) over the wet soil period (June to September)

[2] Selected because these are the months that damage from pugging and post pugging is expected to occur
[3] Selected because these are the months that damage from pugging and post pugging is expected to occur

- A 28% 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 Greenword 2002). The DairyMod simulations would not account for the physical damage from grazing under these waterlogged conditions. Therefore, 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.

The economic analysis also involved estimating the cost of 'on-off' grazing; involving restricting grazing to either 2 hours or to 4 hours per day. Reducing grazing time can still cause pastures to be damaged, due to under-grazing and subsequent senescence (Chapman & Lemaire 1993). Cows typically consume 70% of their daily pasture intake in the first 2 hours of grazing, and up to 88% 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% of pasture was 'lost' due to under-grazing
- If a wet winter is managed through restricting grazing to 2 hours[4] of grazing each day, then 30% of pasture was 'lost' because of 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 energy, using competitive animal feed markets as a guide (see Meyer *et al* 2021). The value of extra ME produced and used on a farm lies between the market value of ME from sources 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 (see 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 is given a maximum value equal to its replacement value (barley). During times when there is surplus of pasture on the farm relative to animal demand for it, pasture available on the farm and used is given a minimum value equal to its salvage value (standing hay or agistment value). Thus winter pasture grown and used on the farm has a maximum value 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 because 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).

[4] Note: in practice 2 hour on-off grazing is not applied, but it was modelled to represent the costs of undergrazing from applying this management practice

Table 5. Assumptions for the value of pasture during the year

	Probability distribution of the value of pasture ($/kgDM)		
	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

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

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 it experienced pugging or undergrazing. The life of the pasture, with pugging damage of varying degrees, ranged between 4-6 years (*Graeme Ward pers.com*) 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), then 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, then 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% p.a. interest cost) for the life of the pasture (as outlined above). 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 pers.com. Reeves 2020).

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, however, there was no suitable existing stand-off area, then the maximum sum that could be invested to set up a stand-off area, and be just as well (or badly) off as operating under the business-as-usual management approach, was estimated, by:

a. calculating the difference in the annual cost incurred by using the no change to grazing management method and the annual cost of using an active grazing management method - before including a cost for setting up and running a stand-off area. This difference in annual cost between the two management methods before including a cost of a stand-off area is the dollar sum available every year to meet the maximum annual cost of a stand-off area (the interest and depreciation costs) and be equally as well of economically with either system.
b. an annuity of the difference in annual costs of the two systems was represented then as the maximum cost of investing in a stand-off area (present value of the annuity). To estimate this cost it was assumed the life of the stand-off area was 10 years and the opportunity interest cost of investing capital in this use was 10% p.a..

$$\text{Maximum cost of stand-off area} =$$

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

This is the maximum cost a farm business could invest in a stand-off area for wet winter management and be no worse off than under the business-as-usual management regime. If a farm business invested in a stand-off area at this capital cost, which gives the calculated annuity, then the cost of doing nothing differently and the cost of active grazing management would be equal (if the stand-off area had a life of 10 years and an opportunity interest cost of 10%p.a.).

If the actual annual capital (depreciation and interest) and operating cost of investing in a stand-off area was to be less than this maximum annual cost represented by this breakeven annuity sum, then 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 aims comes into it, then more could be invested in a stand-off area to reap these other benefits as well.

A summary of each option is presented in the diagram below and the assumptions behind each scenario is summarised in Table 6.

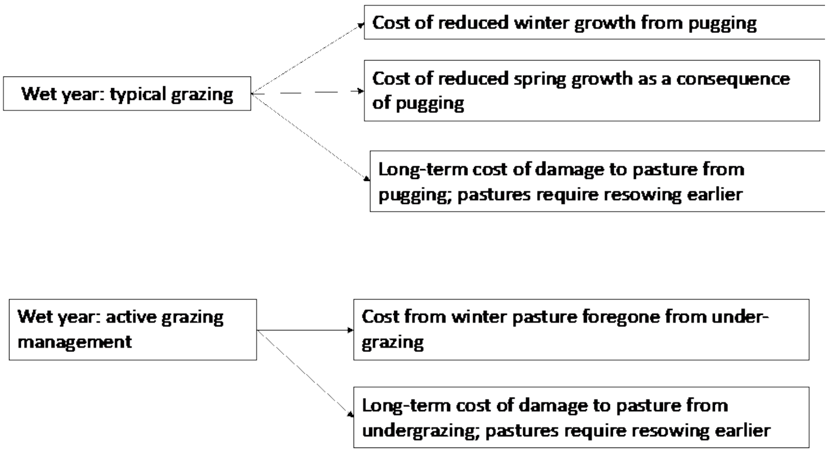


Figure 1. Costs of two strategies to manage a wet winter: doing nothing differently and active grazing management

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 undergrazing	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

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 opportunity cost of capital invested in the pasture and the stand-off area was considered at 6 per cent p.a. and at 10 per cent p.a..

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 2020), 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 Figure 2)[5].

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

	Stylised	Example
What area is vulunerable to damage with grazing because the area is wet?	AA	100
kg DM expected to be consumed from vulnerable paddock over winter (June/July/August)	A	88,970
kg DM expected to be consumed from vulnerable paddock early spring (September and early Oct)	B	157,290
kg DM expected to be consumed from vulnerable paddock over late spring to early summer (second half of Oct/Nov/Dec)	C	241,360
Expected life of the pasture without damage from pugging	D	7
Expected life of the pasture with damage from pugging	E	4
Cost of pasture renovation $/ha	F	430
Interest cost	G	10%
How many years in 10 likely to experience loss in pasture consumed due to wet winter	H	2
Percent of supplement wasted	I	30% (in paddock) 5% (in stand-off area)
Value of pasture 'lost' in winter (c/kg DM)	J	0.25
Value of pasture 'lost' in spring (c/kg DM)	K	0.1

If grazing management is unchanged, expect 35% of usual pasture consumed in the winter to be lost through pugging damage	L = A*35%	31,140
If grazing management is unchanged, expect 35% of usual pasture consumed in early spring to be lost through pugging damage	M = B*35%	55,052
if grazing management is unchanged, expect 28% of usual pasture consumed in late spring early Dec to be lost through pugging damage	N = C* 28%	67,581
Extra feed required due to wastage of supplementary feed in winter	O = I*L	9,342
Extra feed required due to wastage of supplementary feed in spring	P =(M + N)*L	36,790
Cost of pasture 'lost' because of pugging damage	Q=((L+O)*J)+((M+N+P)*K)	31,431
Annuity if life of pasture is 7 years	R=E*(F*((1+F)^C))/(((1+F)^C)-1)	8,832
Annuity if life of pasture is 4 years	S=E*(F*((1+F)^C))/(((1+F)^C)-1)	24,776
Extra depreciation cost	T = S - R	15,944
Annual cost of this management strategy if wet winter event every year	U= Q + T	47,375
Expected value of the cost of this management strategy if wet winter occurs in x years in 10	V = U * (H/10)	9,475

If grazing is restricted to 4hrs/day, expect 12% of usual pasture consumed in the winter to be lost through pugging damage	L = A*12%	10,676
If grazing is restricted to 4hrs/day, expect 0% of usual pasture consumed in early spring to be lost through pugging damage	M = B*12%	-
If grazing is restricted to 4hrs/day, expect 0% of usual pasture consumed in late spring early Dec to be lost through pugging damage	N = C* 0%	-
Extra feed required due to wastage of supplementary feed in winter	O = I*L	534
Extra feed required due to wastage of supplementary feed in spring	P =(M + N)*L	-
Cost of pasture 'lost' because of pugging damage	Q=((L+O)*J)+((M+N+P)*K)	2,803
Annuity if life of pasture is 7 years	R=E*(F*((1+F)^C))/(((1+F)^C)-1)	8,832
Annuity if life of pasture is 7 years	S=E*(F*((1+F)^C))/(((1+F)^C)-1)	8,832
Extra depreciation cost	T = S - R	-
Annual cost of this management strategy if wet winter event occurs every year	U= Q + T	2,803
Expected value of the cost of this management strategy if wet winter event occurs in x years in 10	V = U * (H/10)	561

Figure 2.Cost framework for evaluating the cost of doing nothing differently to manage a wet winter and the cost of doing something different to manage a wet winter (restricting grazing to four hours). (Note: for two hour grazing, the amount of pasture lost for the calculation of 'L' was 30% and the life of the pasture was reduced to five years).

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 four hour on-off grazing strategy was likely to be a lower cost option than a two 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 of the farm business) then the cost of doing nothing differently to manage a wet winter would be even higher (see table 7 and 8)

Table 7 Probabilistic expected value of the cost of each management strategy for a farm business with well drained soils and 100ha of grazing land affected by a wet winter in Allansford and Fish Creek (in brackets assuming different likelihoods of a wet winter occurring in brackets).

	Do nothing different	4 hour active grazing	2 hour active grazing
Allansford Well Drained (2 in 10 years)	11,220	638	2,478
Allansford Well Drained (4 in 10 years)	17,955	1,276	4,955
Allansford Well Drained (every year)	38,321	3,191	12,388
Fish Creek Well Drained (2 in 10 years)	12,266	526	2,131
Fish Creek Well Drained (4 in 10 years)	20,047	1,052	4,262
Fish Creek Well Drained (every year)	43,551	2,631	12,877

Table 8 Probabilistic 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)	11,186	521	2,114
Allansford poorly Drained (4 in 10 years)	17,887	1,041	4,228
Allansford poorly Drained (every year)	38,151	2,604	10,569
Fish Creek poorly Drained (2 in 10 years)	9,005	304	1,444
Fish Creek poorly Drained (4 in 10 years)	13,526	609	3,777
Fish Creek poorly Drained (every year)	27,247	1,521	9,442

The cost of doing nothing differently to manage a wet soil delivered more volatile annual costs than a strategy that actively managed a wet soil using on-off grazing. Of the three strategies to manage a wet winter, the cost of four hour on-off grazing was the least volatile in terms of annual costs (see fig 2 and 3).

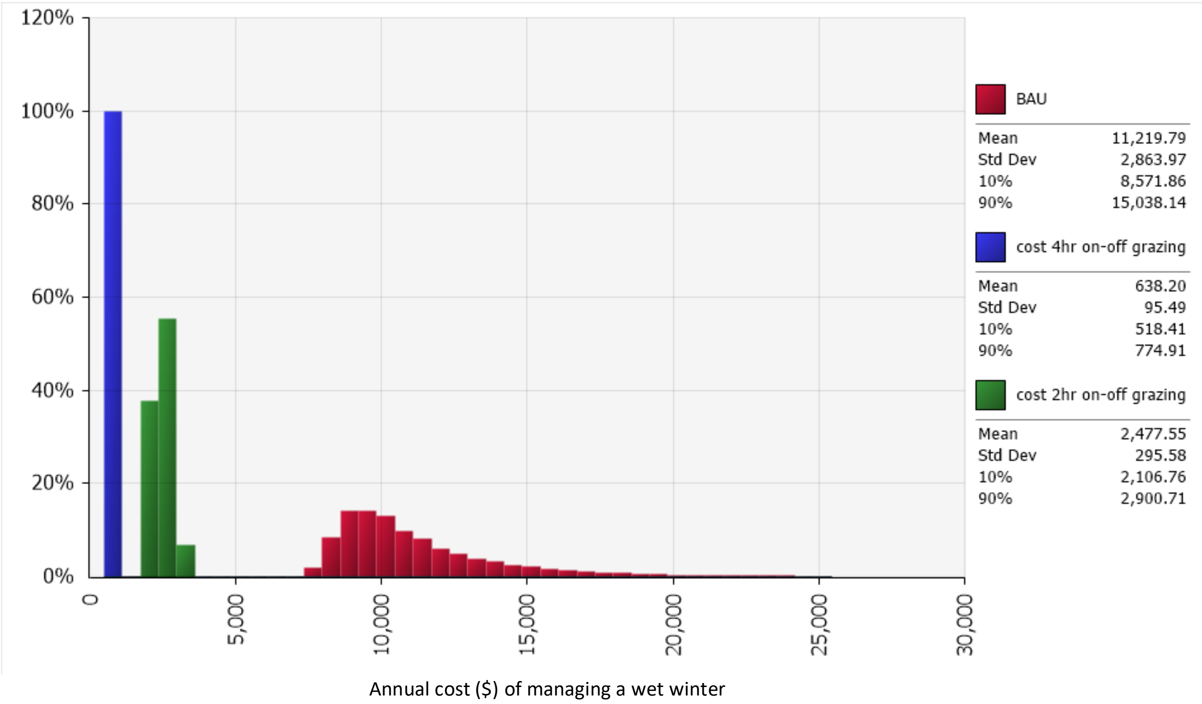


Figure 2 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 2 years in 10 (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Allansford assuming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

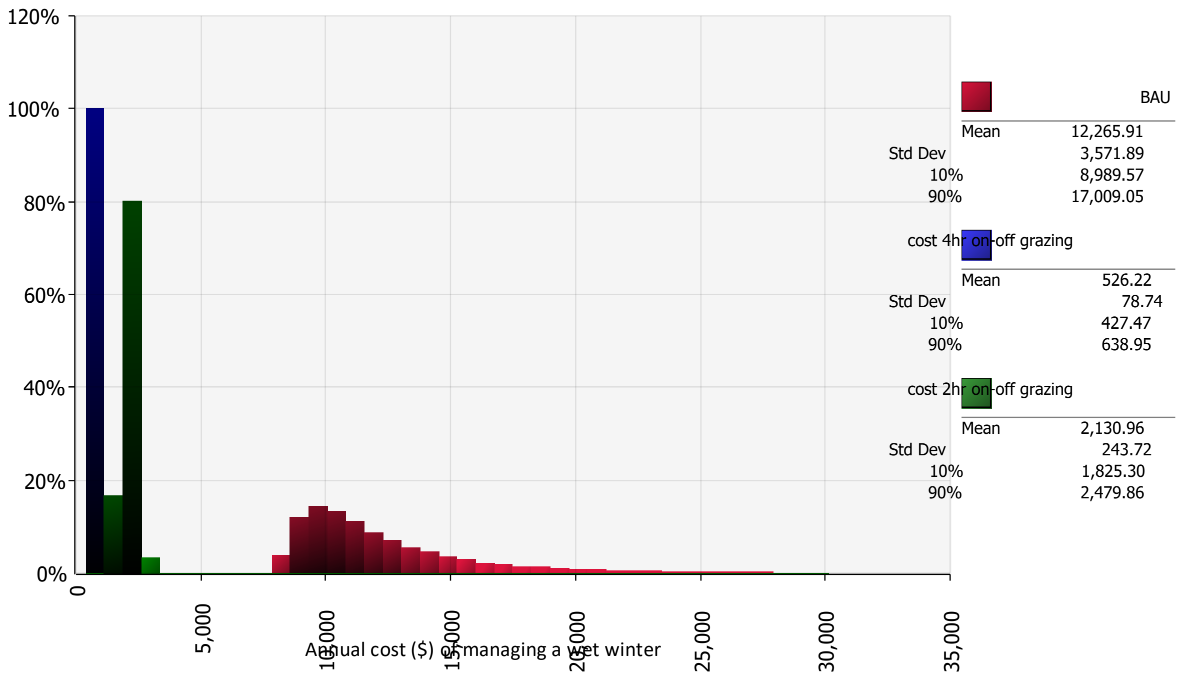


Figure 3 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 2 years in 10 (red bars: no change to grazing management, blue bars: 4 hour grazing

management, green bars: 2 hour grazing management) for 100ha in Fish Creek assuming business has a standoff area (well drained soils)

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

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, then a maximum capital investment of approximately $65,000 could be invested in a stand-off area. This is counting avoided pasture-damage related costs only as the total benefit of the stand-off area. Investing $65,000 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. Note: this is for the situation where a wet winter occurs in 2 years in 10 and the farmer wanted 10% 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 $65,000, 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 table 9 and 10) and a more expensive stand-off area would be justified.

Table 9. 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 such that the management strategy of doing nothing differently and doing something differently equal (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	65,000	54,000
Allansford Well Drained 4 in 10 years	100,000	80,000
Allansford Well Drained every year	215,000	159,000
Fish Creek Well Drained 2 in 10 years	72,000	62,000
Fish Creek Well Drained 4 in 10 years	116,000	97,000
Fish Creek Well Drained every year	251,000	188,000

Table 10. 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 such that the management strategy of doing nothing differently and doing something differently equal (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	66,000	56,000
Allansford poorly Drained 4 in 10 years	104,000	84,000
Allansford poorly Drained every year	218,000	169,000
Fish Creek poorly Drained 2 in 10 years	53,000	46,000
Fish Creek poorly Drained 4 in 10 years	79,000	60,000

Fish Creek poorly Drained every year	158,000	109,000

Concluding Discussion

The aim of this study was to evaluate the cost of two strategies to manage wet soils, being (i) the cost of doing nothing differently in extra wet conditions and (ii) the cost of doing something different through restricting grazing time and using a stand-off area. Past research has shown that actively managing a wet soil 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 afore-mentioned strategies was likely to be the lowest cost -and most profitable - strategy.

It was found that the least cost option for the case study farm businesses that already had a stand-off area was to actively manage a wet winter through restricting grazing time The probabilistic 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 $520 to $2,600 (depending on the likelihood of a wet winter). This was substantially less than the cost of doing nothing differently. The probabilistic expected value of the cost to the farm business that did not actively manage a wet winter on average ranged between $11,200 to $44,000 (depending on the likelihood of a wet winter). 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. Although it is not known for sure and more work is required, it is likely that extreme rainfall events over South East Australia will increase in 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 period (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 longer than 4 grazing 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 a wet winter, and thus 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 different to manage a wet winter results in 'losing' valuable winter feed. In this research, 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, 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 dollar 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, then the representative farmer would be better off to set up a stand-off area and practice on-off grazing than incurring the costs of grazing their wet area pastures in excessively wet winters. Capital needed to establish stand-off areas vary 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[6] (Scott McDonald *pers com*m 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 com*m 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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[6] This is the cost of gravel, earthworks, land forming, drainage works, troughs, fencing, cabling along feed face.

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Appendix: Results for each of the other scenarios

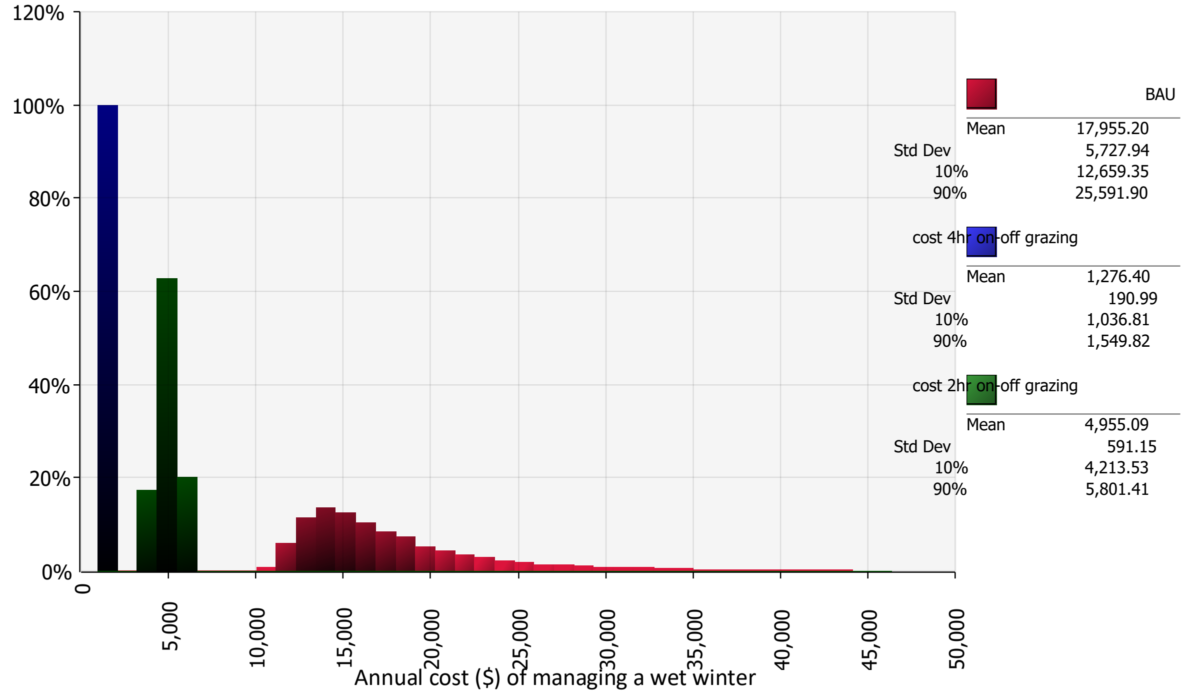

Figure 3 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 4 years in 10 (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Allansford (well drained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

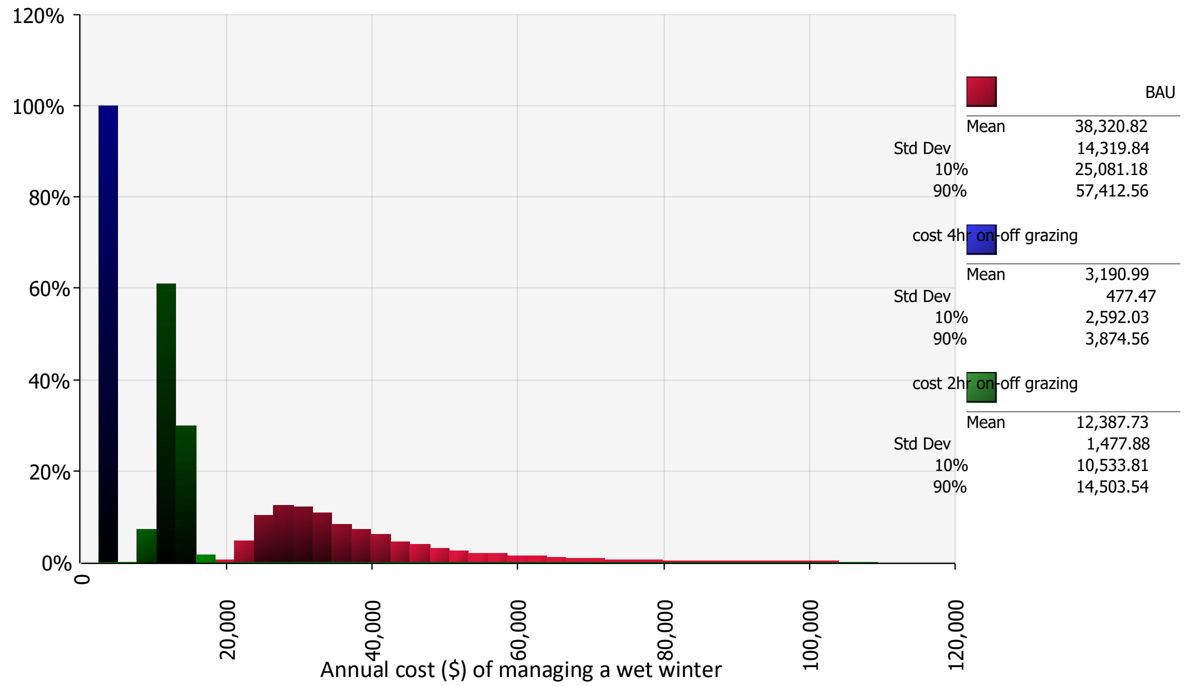

Figure 4 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred every year (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Allansford (well drained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

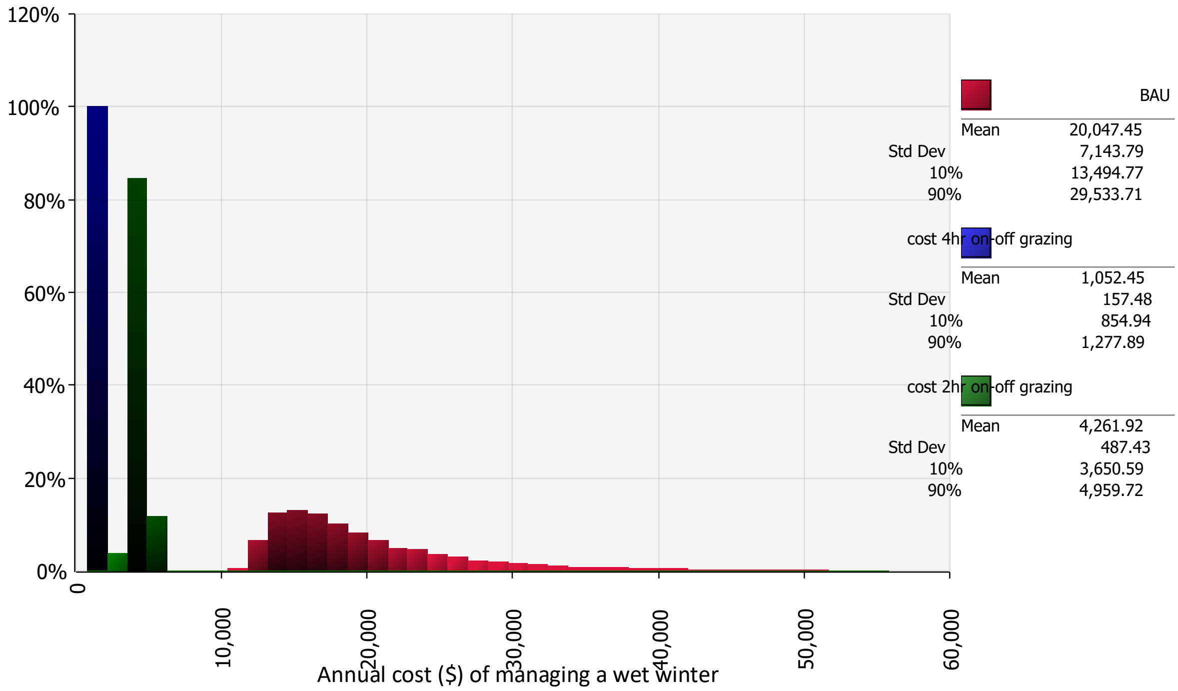

Figure 5 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 4 years in 10 (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Fish Creek (well drained soils)

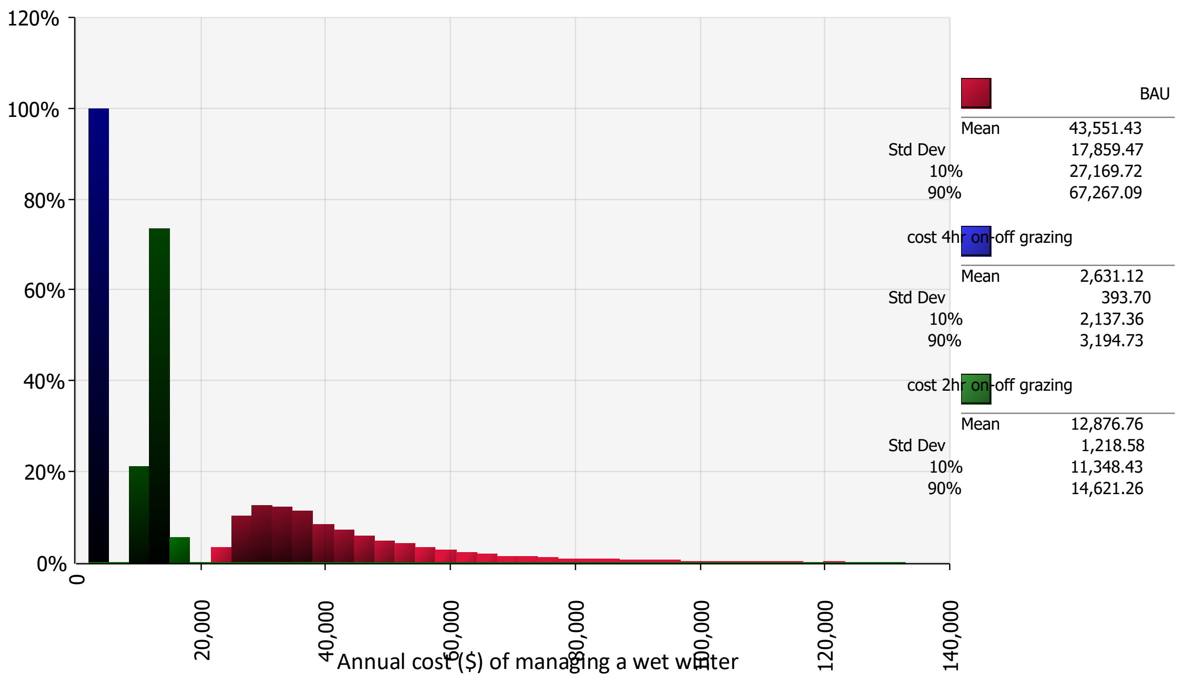

Figure 6 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred every year (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Fish Creek (well drained soils)

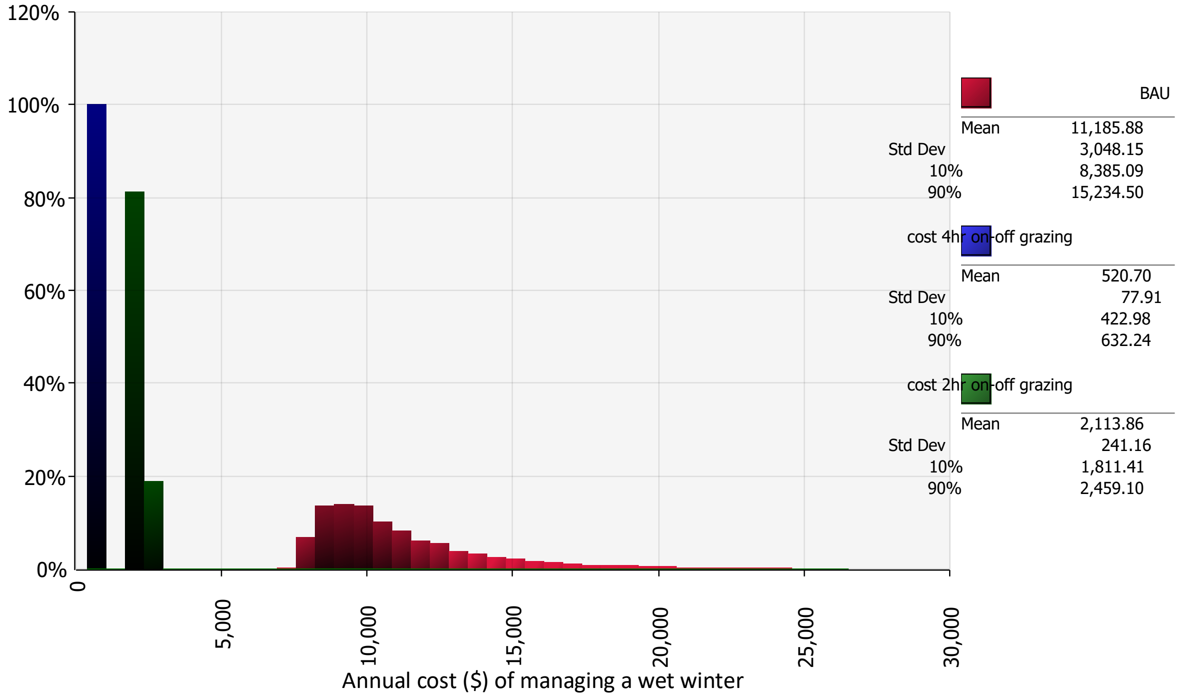

Figure 7 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 2 years in 10 (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Allansford (poorly drained soils)

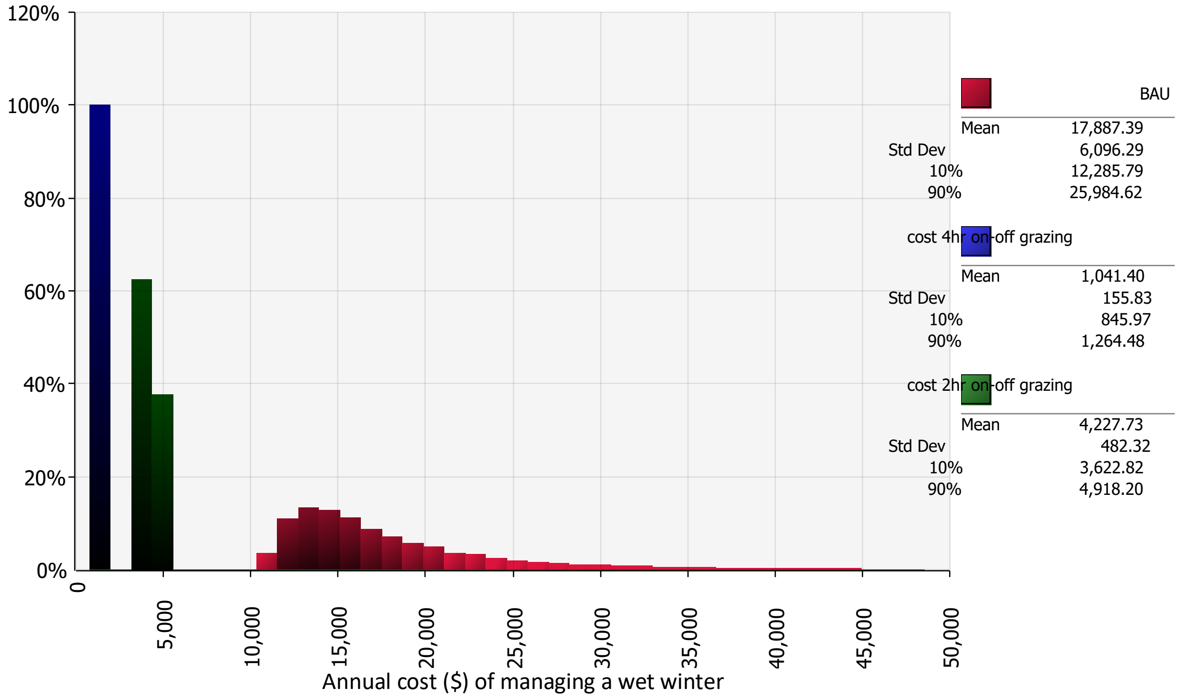

Figure 8 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 4 years in 10 (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Allansford (poorly drained soils)

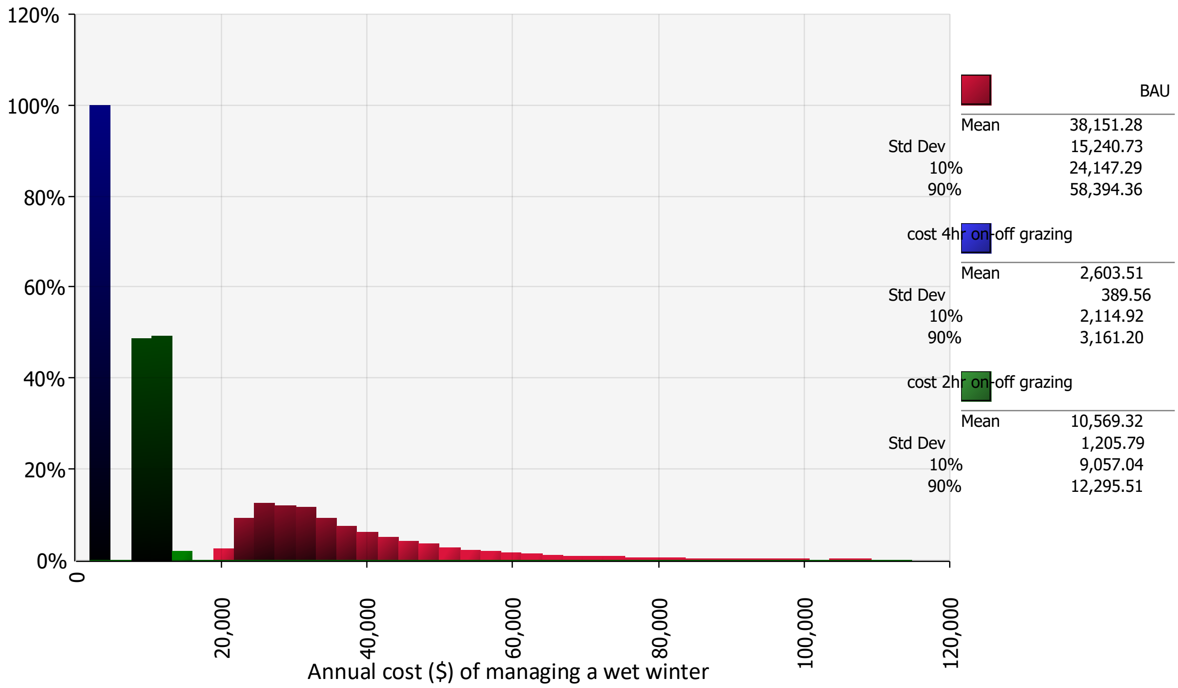

Figure 9 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred every year (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Allansford (poorly drained soils)

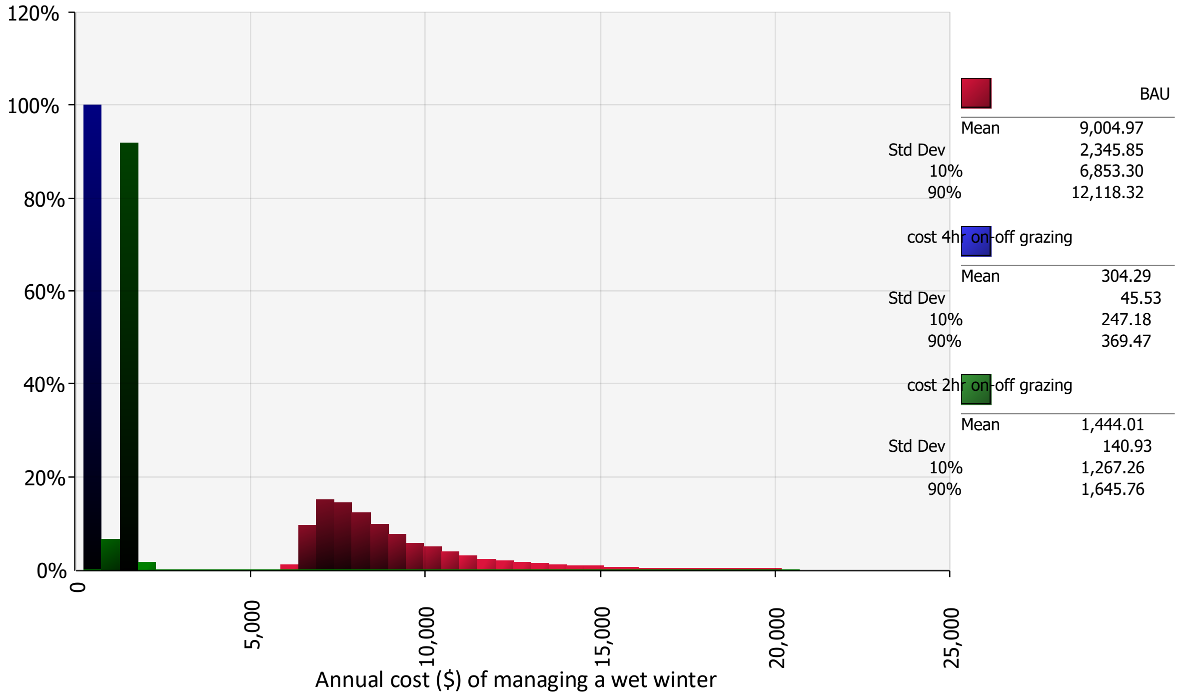

Figure 10 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 2 years in 10 (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Fish Creek (poorly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

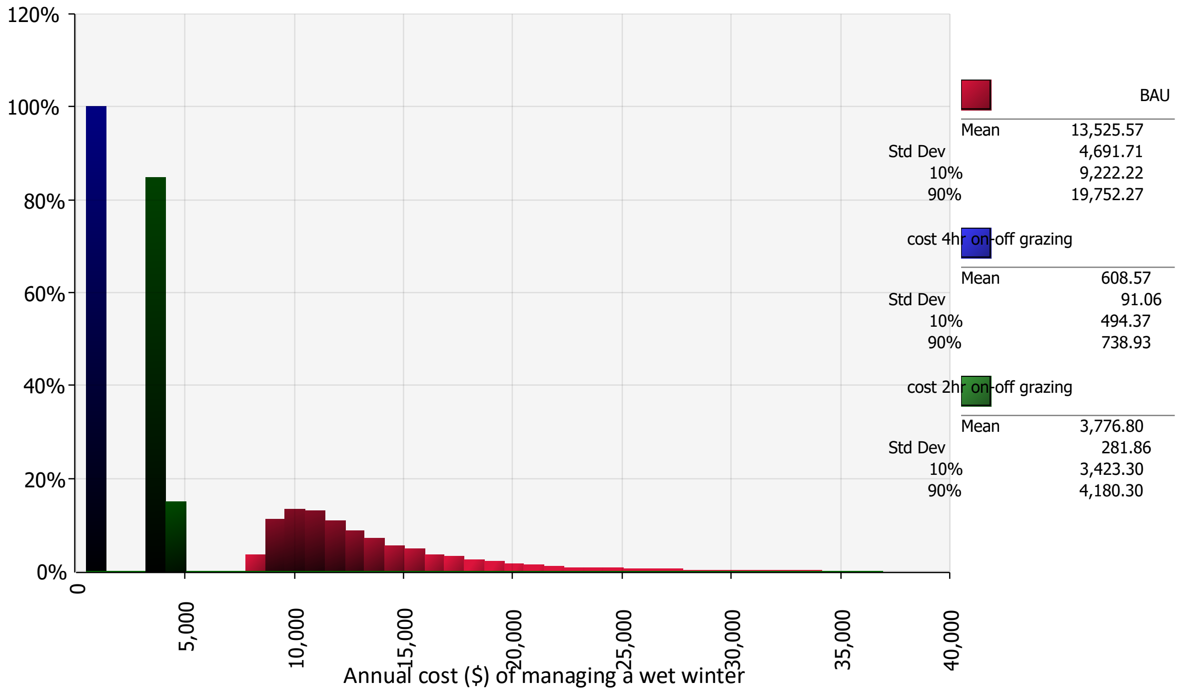

Figure 11 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred 4 years in 10 (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Fish Creek (poorly drained soils)

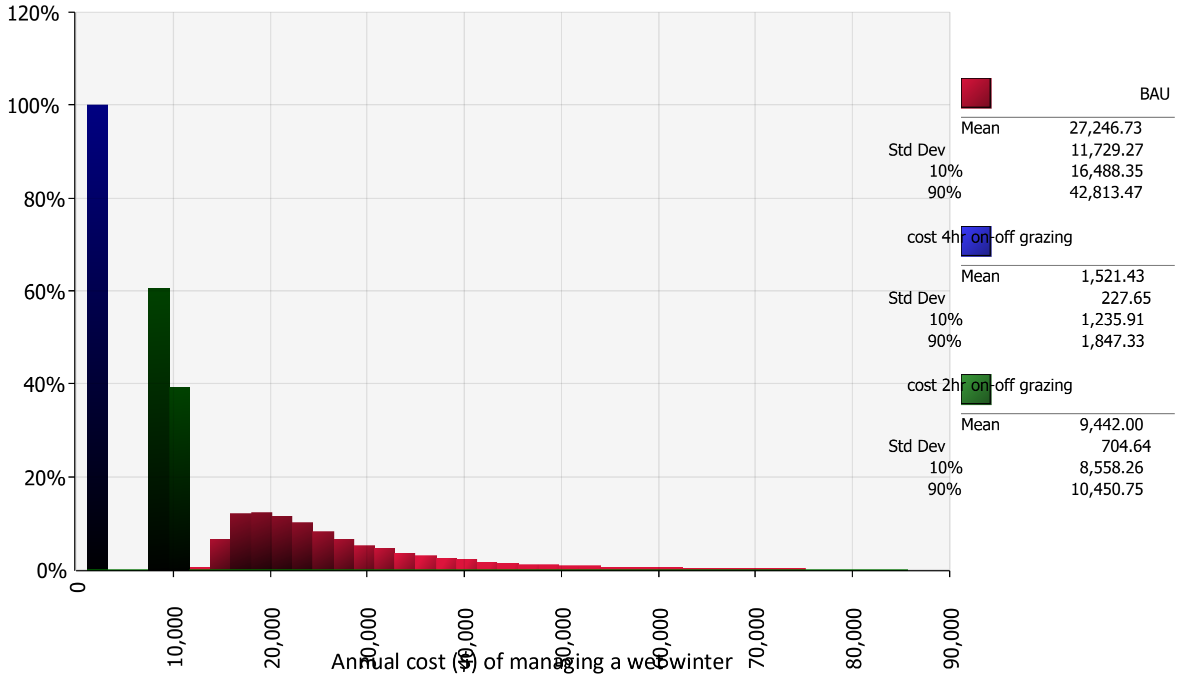

Figure 10 Likely range of the expected value of the cost of three different wet winter management strategies if a wet winter occurred every year (red bars: no change to grazing management, blue bars: 4 hour grazing management, green bars: 2 hour grazing management) for 100ha in Fish Creek (poorly drained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

9.2 FWFA Project Outputs and Legacy Listing

This embedded excel workbook contains an itemised filterable listing of FWFA Project Outputs and Legacy items. It is not exhaustive but captures a majority of the major significant FWFA products.

M12_FWFA_Outputs_and_ Legacy_listin

9.3 BCG FWFA Activity Summary for 2022

Social Media – Climate Kelpie

FACEBOOK*	
Reach	279
Daily users	44
Impressions	686
Page Likes	159
Posts	18

TWITTER*	
Followers	915
Impressions	10913
Clicks	100
Likes	49
Retweets	24
Tweets	20

* For the period 1st January 2022 to 18th November 2022

- In addition to posting about the CKN articles any webinar/information relating to the 5 new Bureau FWFA products was shared.
- 5 further posts are scheduled for December (one for each article in the last CKN edition and one promoting the release of the last CKN publication).

Website – Climate Kelpie

Unique visitors	11375
Returning visitors	1271
Pageviews	23970

* For the period 1st January 2022 to 18th November 2022

Climate Kelpie News - 4 editions published in 2022

CKN	**Average***
Unique clicks	480
Unique opens	6045
Open rate	30.54%

* Averaged across the 3 editions (March, June, September)

Each edition contains 4 articles which are published on the Climate Kelpie website (as blog posts) and can be viewed here: http://www.climatekelpie.com.au/index.php/blog/

FWFA CoP

The regular BoM Catch Ups occurred every month from January to October 2022.

The November Catch Up is scheduled for 2nd December 2022 and the last one is scheduled for the 23rd of December 2022.

The average attendance at these meetings has been 16 (across January to October 2022) with 119 members on the email list.

These meetings occurred via Zoom with recordings housed on a private Slack group where only members have access. Beyond 2022 the Slack account will remain open for members to access but will no longer be actively maintained.

The other CoP meetings wrapped up in 2021, past recordings can be accessed here: https://youtube.com/playlist?list=PLcpKexUUAsQa4ZPQxAJ8Ecgle2oT9uhzL

Two meetings did however occur in 2022:

- February
  - Topics = Consensus seasonal forecasting project results - Dr. Steven Crimp (ANU) and AgScore farm case study results - Dr. Donald Gaydon, (CSIRO)
  - 12 views on YouTube
  - 27 attendees at the meeting
- April
  - Topics = Qualitative market research in using seasonal forecasts - Geoff Kuehne (Meaningful Social Research) & Climate Services for Agriculture (CSA) Update - David McIver (BoM)
  - 4 views on YouTube
  - 16 attendees at the meeting

Case Studies

4x case studies will have been produced for the following industries – grains, southern red meat, dairy and wine.

These will be housed on the CK website and circulated around to project partners to share through their networks.

FWFA Webinars

A public webinar series for the FWFA project occurred in 2020. These were promoted through the CK social media channels (@ClimateKelpie) and the recordings upload to the CK website.

The most recent FWFA Workshop recording was also uploaded to the CK website.

BCG FWFA Activity Summary pre-2022

See BCG's final milestone report to MLA