Final report

Grazier engagement to increase knowledge, skills and ability to combat pasture dieback

Project code: B.PAS.0511

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Abstract

Pasture dieback causes significant productivity and financial losses over thousands, if not millions, of hectares of highly productive pastures across Queensland. The aim of this project was to provide knowledge to support and develop graziers capability to accurately identify and diagnose pasture dieback, and understand practices that could combat dieback.

This project conducted and delivered three main activities. First, the Pasture Dieback Industry Network (PDIN) was developed to connect graziers, researchers, and industry personnel and keep participants up to date on DAF's activities. Membership of the PDIN is currently 297, which includes graziers in all Queensland regions where pasture dieback occurs. The network was used to promote engagement activities to members, but also, attendees at activities were encouraged to join the PDIN. Workshops, field days, forums, and seminars were conducted and attended by close to 1,000 people who collectively managed more than 1.5 million hectares of grazing land. Feedback surveys from DAF extension activities demonstrate that participants recorded an increase in knowledge and understanding of pasture dieback, how to identify it and how to manage affected areas. Other project activities included the development of fact sheets, newsletters, conference papers and online materials, all of which have had more than 10,000 views or clicks.

Second, six on-farm field research trial sites were initiated, five of which are fully operational and will continue beyond this project. These field sites will generate new knowledge of which management practices will provide effective solutions to combat pasture dieback.

Third, the project team coordinated the development of a new pasture dieback survey application (app) for mobile devices. The app will primarily provide data on the location of pasture dieback and the area affected at that site. This product has been field tested and is publicly available, likely release will be March 2022.

Executive summary

Background

Pasture dieback causes significant productivity and financial losses over thousands, if not millions, of hectares of highly productive pastures across Queensland. Pasture dieback is a complex condition, likely involving multiple biotic and abiotic factors, some of which may be pre-cursive factors. These risk factors associated with the pasture dieback condition are poorly understood, as are the management option solutions to restore productivity. The aim of this project is to provide knowledge, support and development of a grazier's capability to accurately identify and diagnose pasture dieback on their property, and to understand the practices being trialled that could effectively combat dieback. The target audience for this project was graziers affected by pasture dieback in Queensland. A range of other stakeholders have also been involved including industry representatives, the scientific community including university and government agencies, and agronomists/agribusinesses. The outcomes of this project will enhance graziers and industry stakeholders' ability to diagnose pasture dieback as opposed to other pasture conditions and determine the most effective management solution to their specific situation.

Objectives

The objectives of this project are to:

- Improve the knowledge and skills of up to 20 central Queensland graziers in their ability to identify and diagnose pasture dieback, and their knowledge of management solutions.
- Initiate one core trial site and up to six demonstration sites in central Queensland.
- Produce an electronic survey application (app) suitable for use by any grazier or industry personnel to capture where pasture dieback is occurring, and the area impacted.
- Benchmark the production and economic impact that pasture dieback imposes on affected graziers in central Queensland.

All objectives of this project have been met. The knowledge and skills of over 300 graziers and industry personnel in their ability to identify, diagnose and manage dieback have been improved. Six research sites have been initiated and five are fully established and continuing. A pre-production version of the pasture dieback app has been delivered, and field testing has been conducted by the project team and other organisations. The app is now publicly available for iOS and Android devices with the public release scheduled for March 2022. The production and economic impact that dieback imposes on affected graziers in central Queensland have been benchmarked.

Methodology

The key project activities undertaken include:

1. Initiating and coordinating extension events – workshops, forums, field days
2. Producing extension materials – workshop content, fact sheets, newsletter articles etc.
3. Initiating on-farm research field trials
4. Developing the pasture dieback survey app

The main method used to engage with industry stakeholders through the extension events, and the on-farm field trials, was the development of the Pasture Dieback Industry Network (PDIN). The PDIN consists of a group of graziers and industry personnel with a strong interest in learning about pasture dieback. Members of the PDIN, along with other industry stakeholders, were engaged at a range of extension events including workshops, field days and seminars. On-farm research trials were also developed as a method to improve knowledge of effective management solutions and as

focal sites for increased learning and understanding. A new pasture dieback survey app for smart devices was also developed as a method to collect information on the locations and areas impacted by pasture dieback.

Results/key findings

This project delivered three key outcomes. First, the Pasture Dieback Industry Network (PDIN) was developed to deliver learning opportunities to stakeholders through a range of industry engagement activities. The PDIN has been a critical success factor of this project. Graziers knowledge and skills to identify pasture dieback has been significantly improved, as has the understanding the potential casual agents and ability to develop management strategies suitable to their situation. Engagement activities conducted included workshops, field days, forums, seminars and products such as fact sheets, newsletters, and conference papers. Participants of these events collectively manage more than 1.5 million hectares of grazing land. Participants attending workshops indicated their knowledge and skill to manage pasture dieback almost doubled at the end of the workshop (rating of 5.9 out of 7) compared to before the workshop(rating of 3.0 out of 7). Over 87% of participants stated they would be highly likely to adopt practices to address pasture dieback on their property. Overall, close to 1000 graziers and industry personnel had direct involvement with project activities or at events where project staff spoke at. There were almost 10,000 clicks on webpages produced by staff during the project. The membership of the PDIN is currently 297 which includes graziers from all Queensland regions where pasture dieback occurs, industry representatives as well as the scientific community including government agencies.

Second, six on-farm field research trial sites were initiated, five of which are fully operational and will continue beyond this project. These field sites will generate new knowledge of which management practices will provide effective solutions to combat pasture dieback. Third, the project team coordinated the development of a new pasture dieback survey app. The app will primarily provide data on the location of pasture dieback and the pasture affected at that site. This product will be released March 2022.

The key findings of this project include:

- Graziers have increased:
    a. ability to correctly diagnose pasture dieback
    b. knowledge of the range of potential casual agents of pasture dieback, and which ones are more likely
    c. knowledge and skills to decide appropriate and effective management practices applicable to their situation
- The area affected by pasture dieback is dynamic; previously unaffected pastures are being affected, while previously affected pastures are concurrently recovering.
- Pasture dieback will likely be an ongoing condition in the future that graziers will need to consider and manage from time-to-time.
- Grass pastures affected by dieback can eventually recover. What is unknown is how long this will take and what grass species will re-establish. Management practices used during pasture dieback appear to impact the speed of recovery. Which species regenerate will be influenced by the degree of dieback (i.e. how much of the original pasture survives) and the species composition of the soil-seedbank.
- Multiple management options which provide reliable outcomes are available for graziers to restore pasture productivity. While knowledge is still evolving, enough is known that graziers can have confidence in specific management practices.

- Based on current knowledge, graziers will not be able to cost effectively beat pasture dieback on typical commercial sized grazing areas by directly targeting a pathogenic organism(s).
- Solution(s) to this condition will be to manage it by altering pasture management using known practices and techniques. The key recommendations include the use of tolerant pasture species, especially perennial legumes, flexible grazing management strategies, and soil fertility management.
- Economic analysis of the impact pasture dieback can have on a typical central Queensland beef business demonstrates a loss of over $66,000 with moderate level of impact (four years of reduced stocking rate) versus over $181,000 with a severe level of impact (eight years of reduced stocking rate) over a 10-year period. This equates to an economic impact of $7.59 and $20.81/ha/yr of affected area for each scenario.

Benefits to industry

The main benefits of this project to industry include:

- Improved knowledge of how to identify pasture dieback in typical situations, as opposed to other pasture conditions that can produce similar symptoms
- Improved knowledge of potential causal agents, and the ones that are more likely
- Improved knowledge and skills of management practice options, and the ability to choose the most appropriate action for the situation

The combined knowledge of these issues and how to address them provide affected graziers the ability to adopt management strategies to:

- Minimise the possibility of dieback affecting their property initially
- Reduce the impact that dieback has on their carrying capacity and beef production once dieback occurs on their property
- Minimise the longer-term productivity and economic impact, or reduce the potential of dieback re-occurring

Future research and recommendations

Due to the success of the Pasture Dieback Industry Network (PDIN), it is recommended the network is maintained for on-going industry engagement and learning through the dissemination of research outcomes as new insights are generated. The network could also be expanded to include graziers and other stakeholders in New South Wales (NSW) to increase information exchange on pasture dieback.

A range of management options were formulated and extended to project participants. These were combined with management plan templates which enabled graziers to plan and undertake practices to address pasture dieback. To maximise adoption of suitable practices, a follow-on project is recommended to support graziers through group and one-on-one engagement processes to ensure the successful implementation of their management plans. The pasture dieback app can also be utilised during this engagement process to collect location and area impact data. It is also recommended that the existing on-farm field research sites continue so further longer-term learnings and outcomes of effective management solutions can be generated.

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1. Background

Pasture dieback is a complex condition, likely involving multiple biotic and abiotic factors, some of which may be pre-cursor factors. These risk factors associated with the pasture dieback condition are poorly understood. The aim of this project is to provide knowledge, support and development of a grazier's capability to accurately identify and diagnose pasture dieback on their property, and to understand the practices being trialled that could effectively combat dieback. This was achieved by forming a grazier group in central Queensland (QLD), a region severely affected by dieback. Grazier participants were taken through a tailored action learning process where knowledge, skills, attitudes and aspirations are improved to ultimately facilitate informed management practice change on-farm. The outputs of this project include action learning processes and resources, an electronic survey application for smart devices to enable consistent recording of dieback locations, assessments of productivity and economic impacts due to dieback, and the initiation of on-farm demonstrations and trials.

The specific achievement criteria for this report are:
5.1 One page summary outlining key findings, progress and messages to date suitable for a general media/producer audience.

5.2 Results reporting on improved knowledge and skills of graziers involved in the project including their ability to identify and diagnose pasture dieback, knowledge of research into management solutions and aspirations to implement practice change.

5.3 Results and outcomes the from establishment of core trial site and grazier demonstration sites.

5.4 Progress on production of an electronic survey app suitable for use by graziers or industry personnel to capture where dieback occurs and the area impacted. Report feedback from industry groups (e.g. NSW-DPI and AgForce) on app functionality.

2. Objectives

The objectives of this project are:

1. Improve the knowledge and skills of up to 20 central Queensland graziers in their ability to identify and diagnose pasture dieback, and knowledge of research into management solutions.
2. Initiate one core trial site and up to six demonstration sites in central Queensland.
3. Produce an electronic survey suitable for use by any grazier or industry personnel to capture where dieback is occurring, and the area impacted.
4. Benchmark the production and economic impact that dieback imposes on affected graziers in central Queensland.

All objectives of this project have been met.

1. The knowledge and skills of over 300 graziers and industry personnel in their ability to identify, diagnose and manage dieback have been improved.
2. Six research sites have been initiated. Five are fully established and continuing.
3. A pre-production version of the pasture dieback app has been delivered and field testing by the project team and other organisations has occurred. Feedback on improvements have been provided to the app developer. It is anticipated the public release of a final product will be in March 2022.
4. The production and economic impact that dieback imposes on affected graziers in central Queensland have been benchmarked.

3. Methodology

The key project activities undertaken include:

1. Initiating and coordinating extension events – workshops, forums, field days
2. Producing extension materials – workshop content, fact sheets, newsletter articles etc
3. Initiating on-farm research field trials
4. Developing the pasture dieback app

The main method used to engage with industry stakeholders through the extension events, and the on-farm field trials, was by the development of the Pasture Dieback Industry Network (PDIN). The PDIN is a group of graziers and industry personnel with a strong interest in learning about pasture dieback. The network was launched on the 13th August 2020. Members are located across the main areas where pasture dieback occurs in Queensland, i.e. northern, central and southern Queensland.

An action learning package was developed which outlines what and how members will be engaged throughout the project. Therefore the 'package' is a living document that outlines activities, process concepts, and learning objectives (Table 1).

Table 1. The Action Learning Package for the PDIN.

Outcomes	How to achieve	When	Why
Initiate grazier group	Form the PDIN	As soon as possible once project contracted	Platform for industry engagement to facilitate and enhance knowledge and learning opportunities.
Initiate PDIN engagement	Workshop / forum for members	As soon as possible after initiation	Set up group. Benchmark current knowledge. Develop action learning cycle applicable to group (review, plan, act, reflect)
Improve knowledge by experiencing situations inside and outside own district	Bus tour to Dawson/Callide and northern Burnett regions	February-March 2021	Group bonding. Learn from other experiences. Assess and implement appropriate concepts on own property.
Improve knowledge by experiencing situations within own district	Field day at trial site(s) in Dawson/Callide valleys	Planned for Feb/March but dependant on seasonal rainfall, treatment outcome.	Improve knowledge of management practices to address dieback.
On-going PDIN engagement	On-farm consultation	Throughout project duration	Support to understand own situation. Trial site establishment and maintenance.
On-going PDIN and industry engagement, production of legacy products	Newsletter. Social media. Publications.	Once/month. Throughout project. Throughout project.	Keep members and broader industry updated with progress and outcomes.
End of project PDIN engagement	Workshop/forum	May/June 2021	Conclude group. Summarise learnings. End of project knowledge survey.

The first meeting of PDIN members occurred on the 8th September 2020 at Moura in central Queensland. The forum was limited to 25 attendees to allow for maximum interaction and abide by the venue's COVID-19 plan. In total, 25 attendees participated from 22 businesses. The forum had multiple objectives including:

- Outline the new project, initiate the PDIN
- Benchmark current pasture dieback knowledge of participants
- Enable participant sharing and discussion of experiences with pasture dieback
- Outline DAF pasture dieback project(s) including activities, outcomes to date
- Initiate trial sites, provide participants opportunity to get involved and provide input to trial designs/treatments
- Develop group ground rules, and an operational plan for the year

The forum agenda was designed as an action learning event where participants interacted and contributed to discussions including outlining their experiences with pasture dieback, learnt about the research DAF (and others) are undertaking, and actively contributed to facilitated discussion to form multiple on-farm field trial sites. While all participants actively contributed and interacted to develop treatments at each trial site, some stated they were happy for project staff to guide treatments to ensure trials complemented the pasture dieback research being conducted by other organisations. Eleven graziers offered to host trial sites, and a range of treatments were discussed and identified (Table 2). It was determined that project staff would visit each property after the forum to discuss and determine the most suitable sites based on landscape, pasture situation, equipment availability, and accessibility parameters, with the landowner.

Table 2. Graziers and potential treatments identified during the forum at Moura.

Grazier	Location	Potential treatments
Number 1	Goovigen	Up-to project staff
Number 2	Moura	Re-sowing new pasture
Number 3	Taroom	Up-to project staff
Number 4	Bauhinia	Up-to project staff
Number 5	Taroom	Impact of burning
Number 6	Dysart	High density grazing
Number 7	Biloela	Re-establish new pasture
Number 8	Mulgildie	Insecticide application for mealybug control
Number 9	Banana	Re-sow grass in-between Leucaena
Number 10	Middlemount	Re-establish new pasture or forages
Number 11	Moura	High density grazing

To ensure PDIN members are kept up-to date with current knowledge, a monthly newsletter was created. Project staff have also utilised DAF's specialist communication staff (as an in-kind contribution) to advertise the PDIN across multiple internet and social media outlets (e.g. webpage on the FutureBeef website, Facebook, Instagram, Twitter, and LinkedIn) to keep the wider agricultural industry updated with pasture dieback information generated from this project.

4. Results

4.1 One page summary outlining key findings, progress and messages to date suitable for a general media/producer audience.

Graziers affected by pasture dieback are actively seeking information about how to identify pasture dieback, what is causing pasture dieback, and what can be done about pasture dieback. Through this project graziers have increased their ability to correctly diagnose pasture dieback, increased their knowledge of the range of potential casual agents of pasture dieback, and which ones are more likely, and increased knowledge and skills to decide appropriate and effective management practices applicable to their situation.

A diverse range of extension methods is needed to communicate messages to a large and broad range of stakeholders in different geographic locations.

Multiple management options which can provide reliable outcomes are available for graziers to restore pasture productivity. While knowledge is still evolving, enough is known that graziers can have confidence in specific management practices.

The area affected by pasture dieback is dynamic; previously unaffected pastures are being affected, while concurrently, affected pastures are recovering. It is likely pasture dieback will be a permanent condition that graziers will need to consider, and manage from time-to-time, into the future. The area affected by pasture dieback and the level of impact will vary from year to year, and from district to district.

Grass pastures affected by dieback can, and will, recover. What is unknown is how long this will take and which grass species will re-establish. Management practices used during pasture dieback can have significant impacts on the speed of recovery. Which species regenerates will be influenced by the degree of dieback (i.e. how much of the original pasture survives) and the species composition of the soil-seed bank.

Based on current knowledge, graziers will not be able to cost effectively beat pasture dieback on typical commercial sized grazing areas by directly targeting a pathogenic organism(s).

Solution(s) to this condition will be to manage it by altering pasture management using known practices and techniques. The key aspects are the inclusion of tolerant pasture species, especially perennial legumes, flexible grazing management strategies, and soil fertility management.

4.2 Results reporting on improved knowledge and skills of graziers involved in the project including their ability to identify and diagnose pasture dieback, knowledge of research into management solutions and aspirations to implement practice change.

4.2.1 Engagement activities

The project was contracted to deliver specific engagement activities. These included:

- Form one group of up to 20 graziers affected by dieback in the Fitzroy
- Action learning package
- A grazier workshop / forum
- Study tour (bus tour) of research trials at Brian Pastures Beef Research Facility and any other applicable sites

- Up to 6 demonstration and one core on-farm trial sites (to generate knowledge of effective management practices, to be used for field days etc).

All contracted engagement activities have been delivered except for the study tour (bus tour) of research trials at Brian Pastures. The bust tour was planned for March 2021 with the aims of:

- Increasing knowledge of current research, and outcomes to date, in different situations
- Increase knowledge of effective management practices that might be applicable
- Peer-to-peer learning

Due to a lack of summer rainfall at all trial sites resulting in unsuitable pasture conditions to observe outcomes, the project team decided to postpone the bus tour until the week of 17th May 2021. At the time of postponement approximately 25 people had registered. Instead, based on the forecast of reasonable rainfall across central Queensland for March, the project team took the opportunity to initiate and deliver three district based on-farm paddock walks. These were held on properties of PDIN members and occurred late March 2021, just after the forecasted rain.

After postponing the bus tour from March to May, only eight registrations were received. It is believed this was due not only to the dry weather but also the proximity to Beef Australia 2021 (early May). Based on limited registrations and deteriorating pasture conditions to showcase pasture dieback, the project team made the decision to cancel the bus tour. However, to maintain productive engagement with industry through the PDIN and extend research outcomes, the project team developed and delivered a field day (held at Brian Pastures in May 2021) and nine workshops (from north to south Queensland during September and November 2021). The following sections will outline the specific outcomes of these engagement activities.

The project team have actively engaged with all levels of industry using a variety of methods over the life of the project. Key messages communicated at engagement activities include:

- Summary of DAF pasture dieback activities
- Accurate identification and diagnosis of pasture dieback
- Update on diagnostic research into cause(s)
- Management options for affected areas
- Promotion of Pasture Dieback Industry Network

The audience for engagement activities has included graziers with and without dieback, industry advisors and consultants, research scientists, beef industry stakeholder organisations, and other DAF staff. Activities have been strategically planned to engage with interested parties using a variety of methods including workshops and field days, webinars, Beef Australia seminars, and media articles.

The engagement targets have been exceeded for this project. The full breath of extension and engagement activities undertaken by the project team is summarised in Table 3. Some example photos are included in Fig. 1. Note that the project team have not only conducted DAF-hosted events but participated in other industry events which further increased the level of industry engagement achieved by the project.

Table 3. Summary of engagement activities over the life of the project.

Engagement type	Activity name	Location	Date	Audience	Host	Presenter
Science forum	MLA Pasture dieback science forum	ZOOM	17/6/20	~40	MLA	SB, NB
Industry forum	Pasture Dieback Industry Network forum	Moura	08/09/20	22	DAF PD team	SB, NB, MM, KC, KH
Field day (initiated and lead by the project team)	Pasture Dieback paddock walk	Taroom	24/03/21	53	DAF PD team	SB, NB, KH, KT
	Pasture Dieback paddock walk	Arcadia Valley	25/03/21	48	DAF PD team	SB, NB, KH, KT
	Pasture Dieback paddock walk	Anakie	26/03/21	41	DAF PD team	SB, NB, KH, KT, PJ
	Brian Pastures field day	Gayndah	19/05/21	38	DAF PD team	SB, NB, MM, KH, KT
Field day (initiated by others, project team spoke at)	Ametdale grazing systems field day	St Lawrence	10/11/20	15	DAF	SB
	Feedbase field day	Moura	28/5/21	12	CHRRUP	SB
	Deep ripping pasture field day	Rolleston	11/8/21	40	Kurt Mayne	SB
Workshop	Pasture Dieback Management workshop	Nebo	8/09/21	13	DAF PD team	SB, NB, KH
	Pasture Dieback Management workshop	Ingham	10/09/21	14	DAF PD team	SB, NB, KH
	Pasture Dieback Management workshop	Malanda	11/09/21	10	DAF PD team	SB, NB, KH
	Pasture Dieback Management workshop	Gin Gin	09/11/21	9	DAF PD team	SB, NB, KH, KT
	Pasture Dieback Management workshop	Gympie	10/11/21	20	DAF PD team	SB, NB, KH, KT
	Pasture Dieback Management workshop	Esk AM	11/11/21	20	DAF PD team	SB, NB, KH
	Pasture Dieback Management workshop	Esk PM	11/11/21	15	DAF PD team	SB, NB, KH
	Pasture Dieback Management workshop	Boonah	12/11/21	17	DAF PD team	SB, NB, KH
	Pasture Dieback Management workshop	Millmerran	13/11/21	12	DAF PD team	SB, NB, KH

Engagement type	Activity name	Location	Date	Audience	Host	Presenter
Seminar	Latest research findings into pasture dieback across Queensland, Beef Australia seminar	Rockhampton	7/5/21	117	Beef Australia, DAF PD team	SB, NB, MM, KC, DO
	MLA Beef Australia seminar	Rockhampton	3/5/21	240	Beef Australia, MLA	SB, NB
	MLA advisors update	Brisbane	29/11/2021	35	MLA	NB
Meetings	Pasture dieback update to Office of the Great Barrier Reef staff	ZOOM meeting	12/3/21	12	DES	SB
	Pasture dieback update	Grazier group Roma - ZOOM meeting	21/5/21	20	DAF	SB
	Pasture dieback update to Qld Govt state land valuation staff	ZOOM meeting	1/6/21	12	DNRME	SB
Webinar	Pasture dieback update	ASQ Webinar	5/8/20	104	DAF PD team	SB
Conferences	The Resurgence of pasture dieback in northern Australia	Conference paper	Feb 2021	Unknown	Australian Association of Animal Sciences	SB, TB, LL
	Is there a link between dieback in Mitchell grass across central-west Queensland and sown pastures in eastern Queensland?	Conference paper	Aug 2021	Unknown	Australian Rangeland Society	SB, NB, DP
	Targeted industry engagement spot-on for pasture dieback	Conference paper	24/11/21	Abstract submitted	Australian Association of Animal Sciences	KH, SB, NB, KT
Media articles	Pasture dieback update	CQ Beef lift out in Queensland Country Life	13/12/2021	148,893 readers	FutureBeef, DAF PD team	KH, SB
	Pasture dieback engagement project raising awareness	CQ Beef lift out in Queensland Country Life	13/12/2021	148,893 readers	FutureBeef, DAF PD team	KH, SB
Fact sheets	What is pasture dieback	Online factsheet	20/03/21	9,706 clicks	FutureBeef, DAF PD team	SB, NB
	How to identify pasture dieback	Online factsheet	20/03/21		FutureBeef, DAF PD team	SB, NB
	Research into management solutions for pasture dieback	Online factsheet	20/03/21		FutureBeef, DAF PD team	SB, NB

Engagement type	Activity name	Location	Date	Audience	Host	Presenter
	How to manage pasture dieback	Online factsheet	20/03/21		FutureBeef, DAF PD team	SB, NB
Web pages	Pasture dieback pages	FutureBeef website	N/A		FutureBeef, DAF PD team	SB, NB, KH
TV	Pasture dieback	Landline program	July 2020	Unknown	ABC DAF PD team	SB
	Formation of the Pasture Dieback industry Network	DAF – Parkhurst office	Sept 2020	Unknown	WIN news DAF PD team	SB
	Pasture dieback update	Beef Australia	7/3/21	Unknown	WIN news DAF PD team	SB
Ute guide	Pasture Dieback Identification Guide	Distributed to workshop attendees and DAF offices	09/09/2021	480	NSW DPI DAF PD team	SB

* SB = Stuart Buck, NB = Nicholas Brazier, KH = Kylie Hopkins, KT = Katie Thomas, MM = Melina Miles, KC = Kathy Crew, PJ = Paul Jones, DO = Diane Ouwerkerk, TB = Terry Beutel, LL = Lara Landsberg, DP = David Phelps, DR = David Reid

Figure 1. Example photos of face to face extension events. Top to bottom: Paddock walk at Arcadia Valley, shed (left) and newly planted legume paddock (right); Brian Pastures Field Day, drone photo of trial inspection (left) and inspection of mealy bug trial cages (right); and Management workshops at Ingham (left) and Gympie (right).





4.2.2 Overall impact of face-to-face extension events

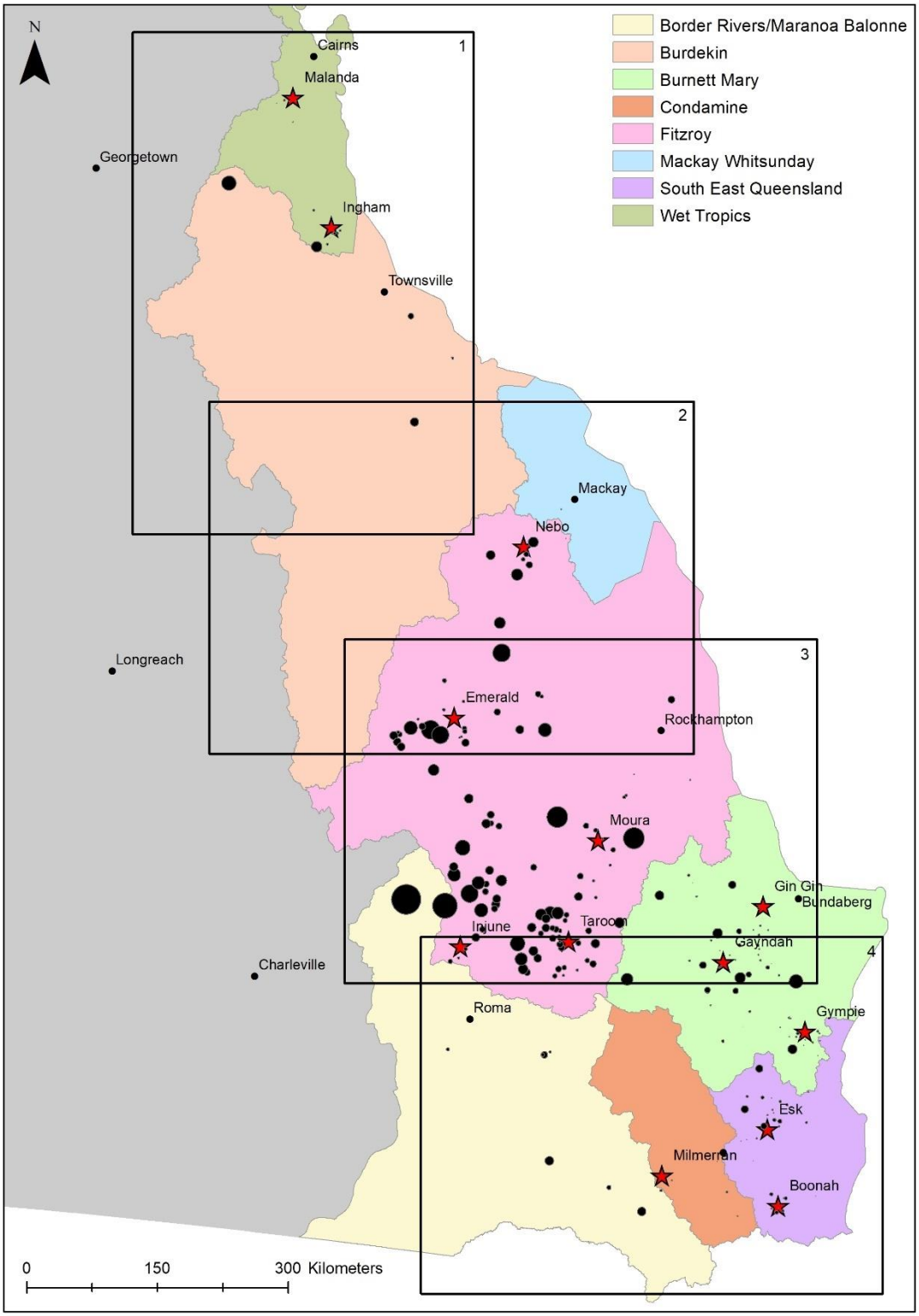
The DAF pasture dieback team have been effectively engaging members (and non-members) of the PDIN through high-impact extension events and other activities. Fourteen events in four formats have been conducted since the commencement of the project, with 332 participants in total. Attendees consisted mostly of beef producers with over 300 graziers managing more than 1.5 million hectares of land (Table 4).

Table 4. Summary of all industry engagement extension events, producer attendees numbers, and hectares managed.

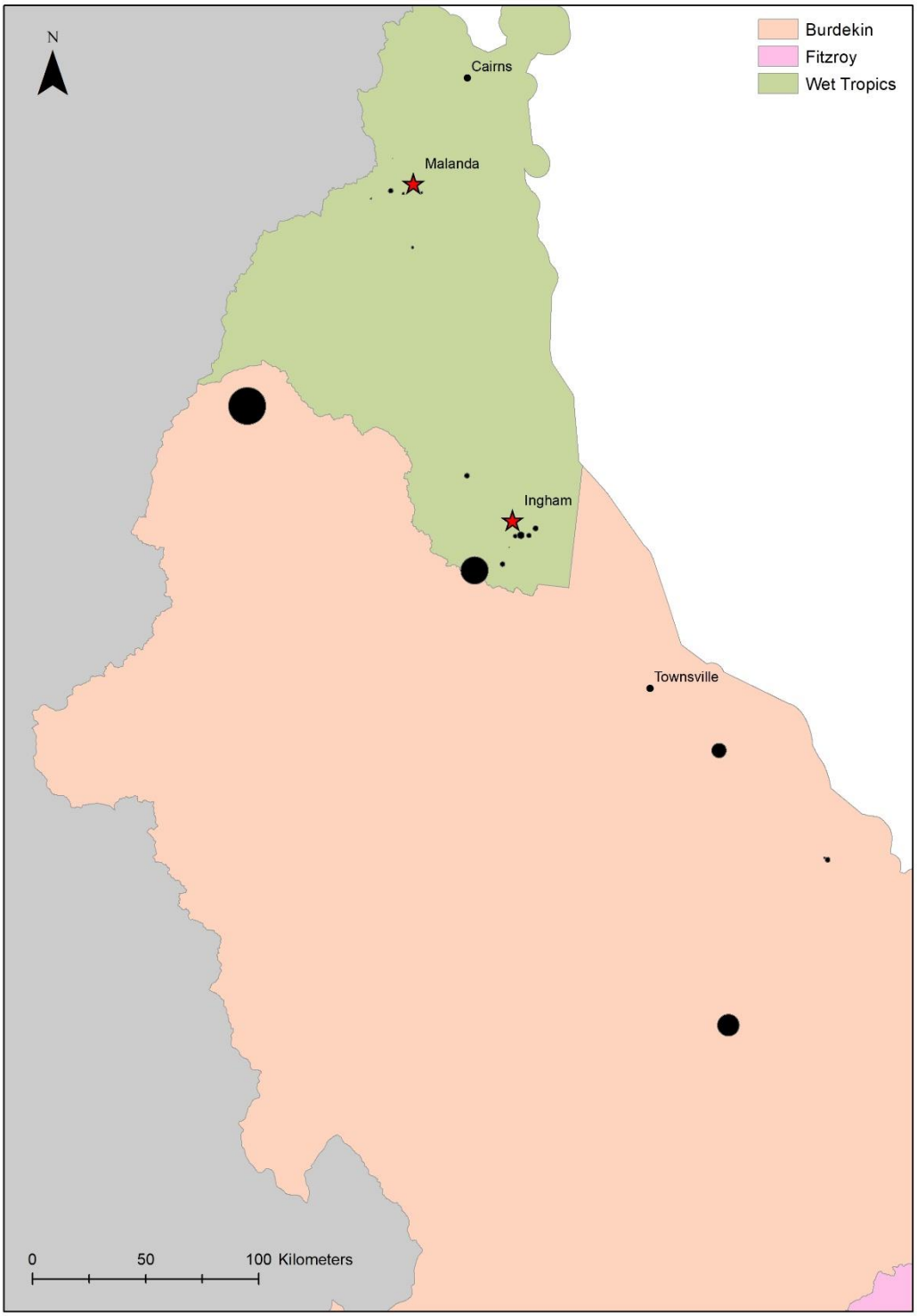
Event	Date	Producers	Hectares managed
Forum, Moura	08/09/2020	22	411,305
Paddock walk, Taroom	24/03/2021	53	244,910
Paddock walk, Arcadia Valley	25/03/2021	48	429, 157
Paddock walk, Anakie	26/03/2021	41	215,316
Brian Pastures field day, Gayndah	19/05/2021	38	98,378
Management workshop, Nebo	08/09/2021	13	50,401
Management workshop, Ingham	10/09/2021	14	16,018
Management workshop, Malanda	11/09/2021	10	28,963
Management workshop, Gin Gin	09/11/2021	8	8,814
Management workshop, Gympie	10/11/2021	19	21,426
Management workshop, Esk AM	11/11/2021	14	15,482
Management workshop, Esk PM	11/11/2021	13	12,231
Management workshop, Boonah	12/11/2021	15	4,644
Management workshop, Millmerran	13/11/2021	9	10,564
Total		**317**	1,567,609

Grazier participants were well dispersed across the Eastern coast of Queensland (Fig. 2).

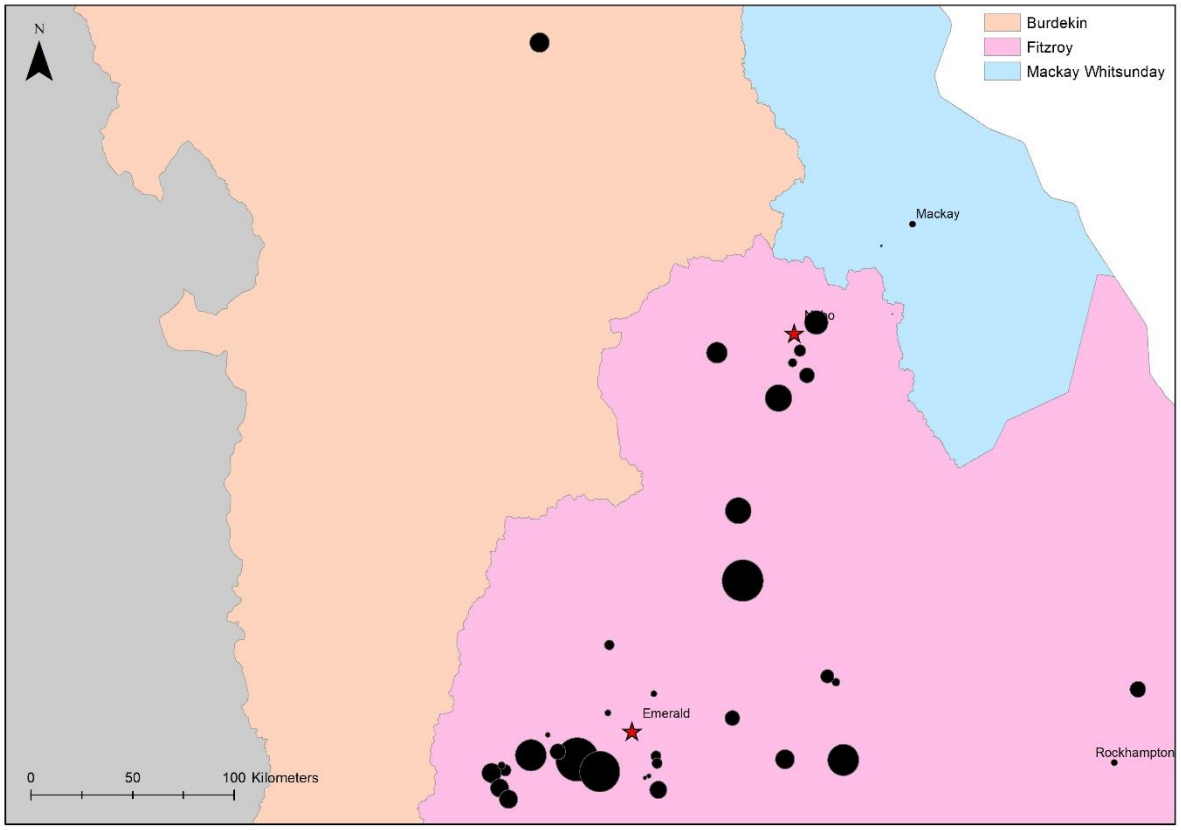
Figure 2. Map displaying the distribution and size of properties associated with attendees of pasture dieback extension events between September 2020 and November 2021. Size of black circles is relative to property size. ★ symbol denotes location of extension events. Coloured areas represent river catchments.



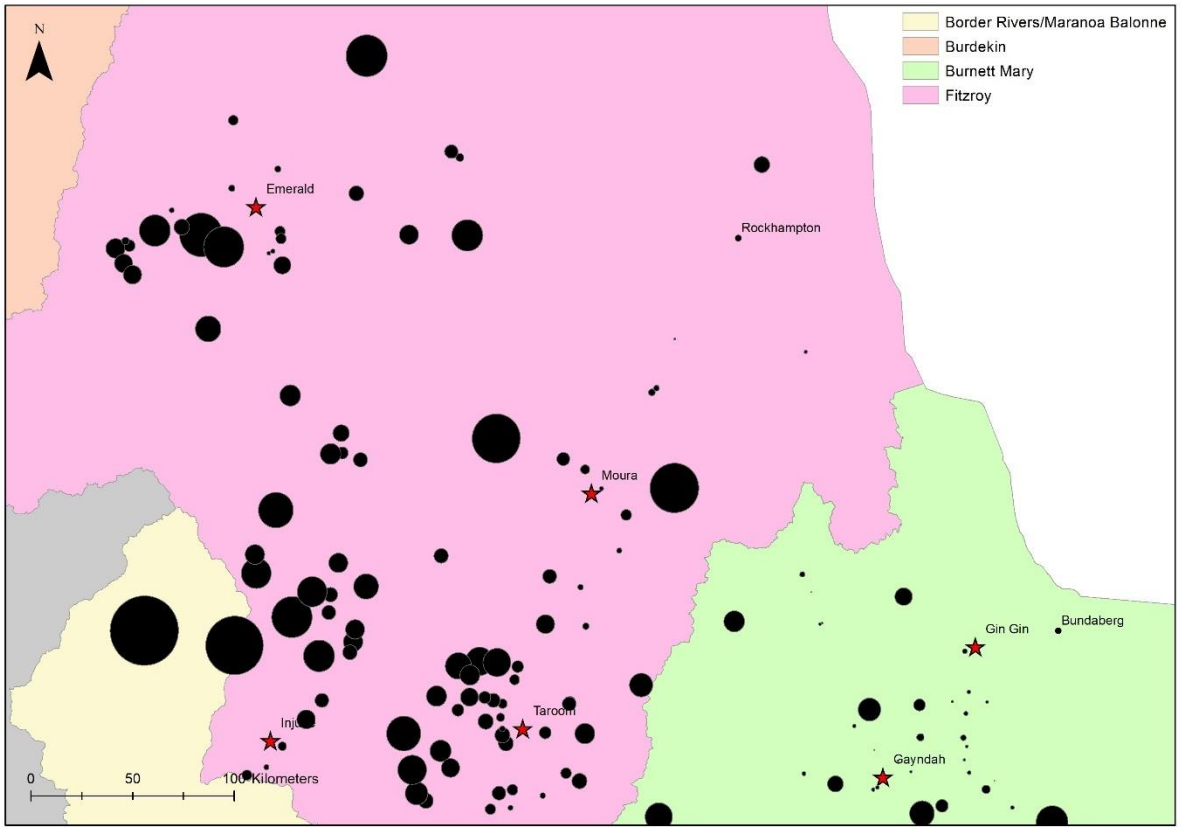
Inset 1, North Queensland.



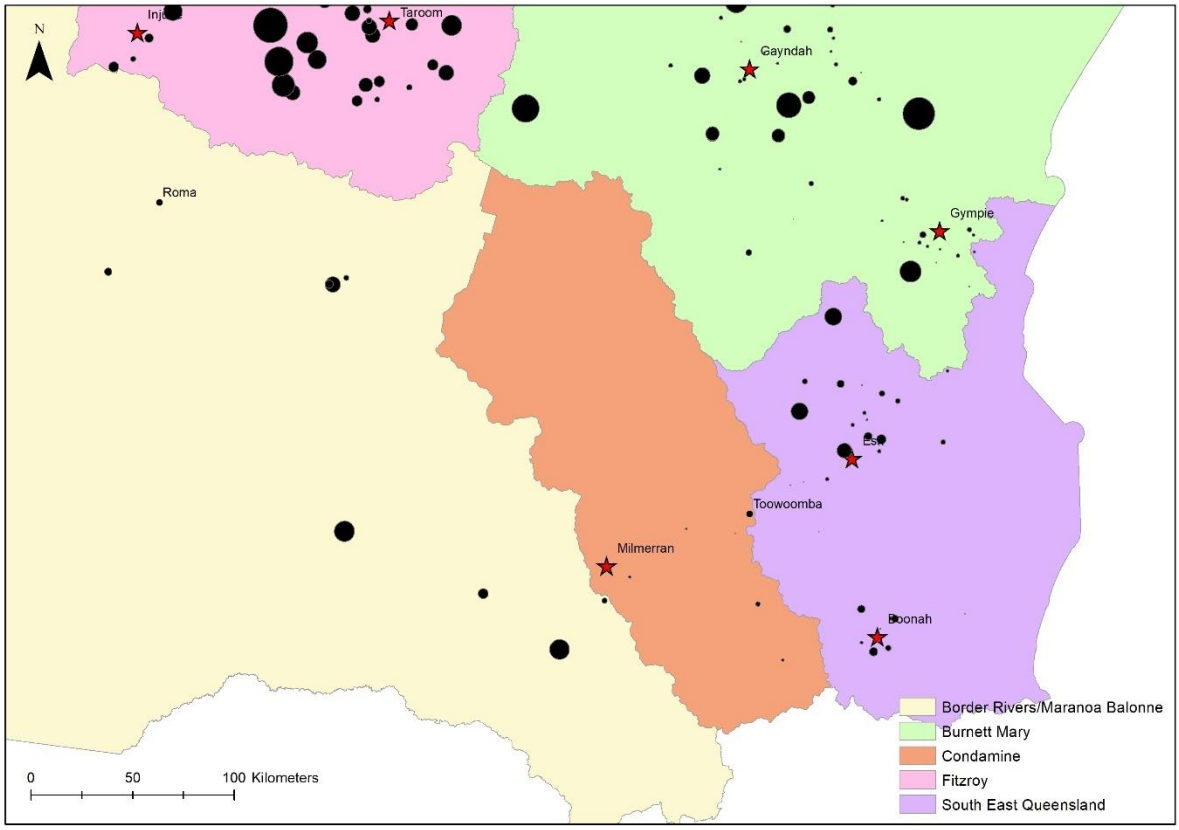
Inset 2, Northern central Queensland.



Inset 3, Central Queensland.



Inset 4, South Queensland



4.2.3 Pasture Dieback management workshops key messages

The final workshops in the project were aimed at assisting producers to develop management plans for dieback affected areas on their property. Workshops were delivered in central-north Queensland (Nebo, Ingham and Malanda) in September 2021 and central-south Queensland (Gin Gin, Gympie, Esk, Boonah and Millmerran) in November. The specific locations were chosen where limited pasture dieback extension had occurred previously. The central-north Queensland workshops delivered best practice management options based on results from DAF field trials. At the conclusion of these workshops, attendee feedback was considered and the workshop content and processes were revised for the central-south workshops.

The central-south workshops contained three major sections:

- How to identify pasture dieback
- What is causing pasture dieback
- Management options.

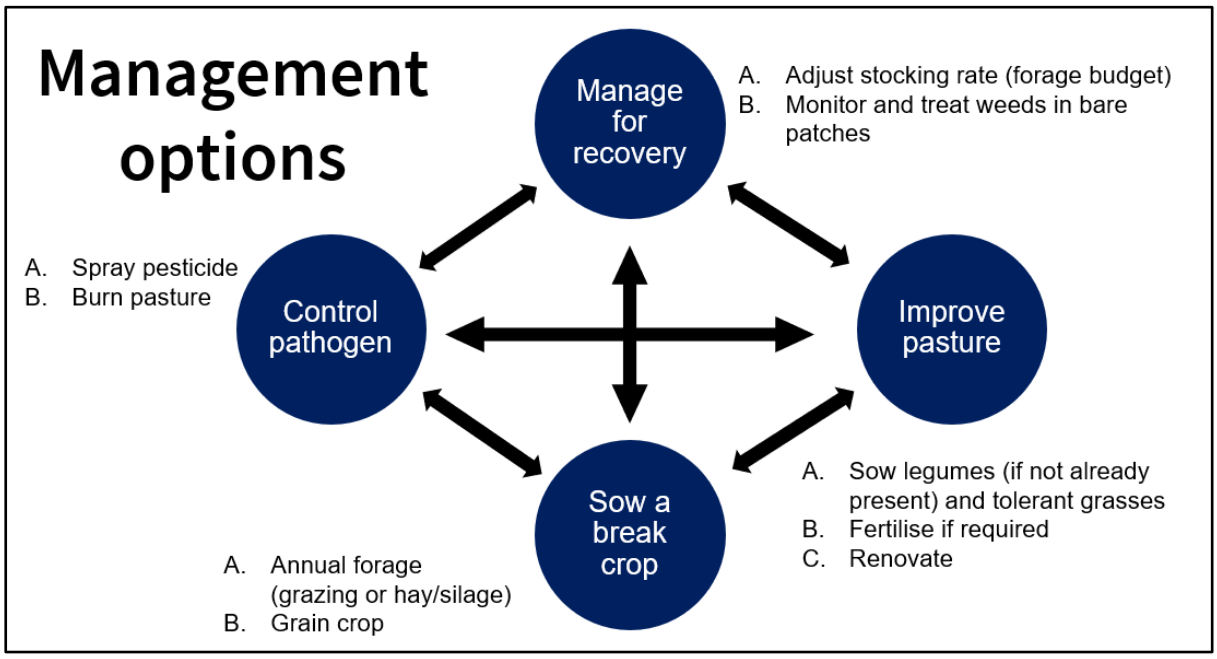
Each workshop commenced with an interactive and energising activity where attendees introduced themselves and expressed what they wanted to learn at the workshop. Most attendees wanted to know how to identify dieback and/or how to manage it. Attendees were also asked to give themself a ranking from zero to ten on how confident they were to manage pasture dieback on their property, at the start of the workshop. At the end of the workshop participants were asked to go back to their score and change it if applicable. Results of this interactive activity are summarised in Table 5. The average confidence rating at the start of the workshop was 3.2 out of 10. This had improved to 6 out of 10 at the end of the workshop, a positive change of 2.8.

Table 5. Average self-assessed confidence rating to manage pasture dieback, at the start and end of pasture dieback management workshops.

Start of workshop	End of workshop	Change
3.2	6	+ 2.8

Management options presented at the central-south workshops were regrouped after the central-north workshops. This was based on participant feedback including the types of questions posed to the presenters. There are four management option groupings: 1. Manage for recovery; 2. Improve pasture; 3. Sow a break crop; 4. Control pathogen (Fig. 3). Within each grouping there are multiple practices that may be used. Every paddock and property situation with pasture dieback is different therefore the pasture and soil type, landscape characteristics, availability of machinery, aims of the property owner etc all need to be considered. Also, multiple practices from various option groupings can be used in combination (hence the multiple arrows). For example, weeds might be sprayed out first, then the paddock renovated and a forage crop sown before re-sowing with a perennial pasture with legumes. More detail of these options is provided in the next section.

Figure 3. Management options for pasture dieback, as presented at the central-south Queensland Pasture Dieback Management workshops.



1. Manage for recovery

In some dieback affected areas, paddocks are recovering where the new pasture re-establishes from the soil-seedbank. The fastest recovery occurs when stock numbers are matched to the available pasture (i.e. using a forage budgeting approach) and where weeds have been controlled. Both practices accelerate recovery by allowing young seedlings to quickly establish without being restricted by grazing or competing for moisture with weeds.

2. Improve pasture

Pasture improvement can be undertaken by sowing legumes and tolerant grasses, fertilising, renovating, or a combination. Renovating the whole pasture through cultivation can break a pathogen cycle and accelerate nutrient cycling to provide a healthier, nutrient-rich environment for new seedlings to thrive. Likewise, fertiliser (after a nutrient soil test is conducted) will supply nutrient(s) to maximise the new pasture's

productivity. Grazier experience and DAF research trials demonstrate legumes are unaffected by pasture dieback. Economic research by DAF also demonstrates legumes significantly improve business profitability. There are legumes suitable for all areas and soil types across Queensland. Suitable pasture and legumes species are included in Section 8 (Appendix).

3. Sow a break crop

A break crop, such as annual grain or forage crop, can be used in suitable country to break a pathogen cycle and generate short-term feed supply. A forage crop could be grazed, baled, or used for silage depending on the need and availability of machinery. The intention is to sow a break crop for one to two years then return the paddock to a perennial pasture with legume.

4. Control pathogen

The last option includes spraying an insecticide or using fire to control a pathogen. Insecticide application has not produced beneficial outcomes in DAF management option research trials; these trials demonstrate the effectiveness of the beneficial (predatory or parasitic) insects – these need to be encouraged and not disadvantaged by applying insecticides. Likewise burning (in spring) has also produced limited benefits in trials however several graziers have anecdotally reported that late wet-season mosaic burns have provided temporary benefits. Based on these outcomes, and uncertainties about the practicalities and effectiveness of insecticide application in commercial situations, most graziers are better off choosing another option. However, if spraying an insecticide is considered necessary for pasture mealybug control, multiple products are available via emergency permits issued by the Australian Pesticides and Veterinary Medicine Authority (APVMA) and included in Section 8 (Appendix). The application requirements on the permit must be strictly adhered to ensure legal use of the product.

Planning templates for the four management options were provided to attendees in a workshop booklet. The management plan is included as Section 8 (Appendix).

To assist graziers determine which management option is suitable for specific situations, a matrix (Table 6) was presented and the options explained. This was well received by producers and discussion demonstrated this was a useful tool to assist their planning to decide which option and practices are applicable.

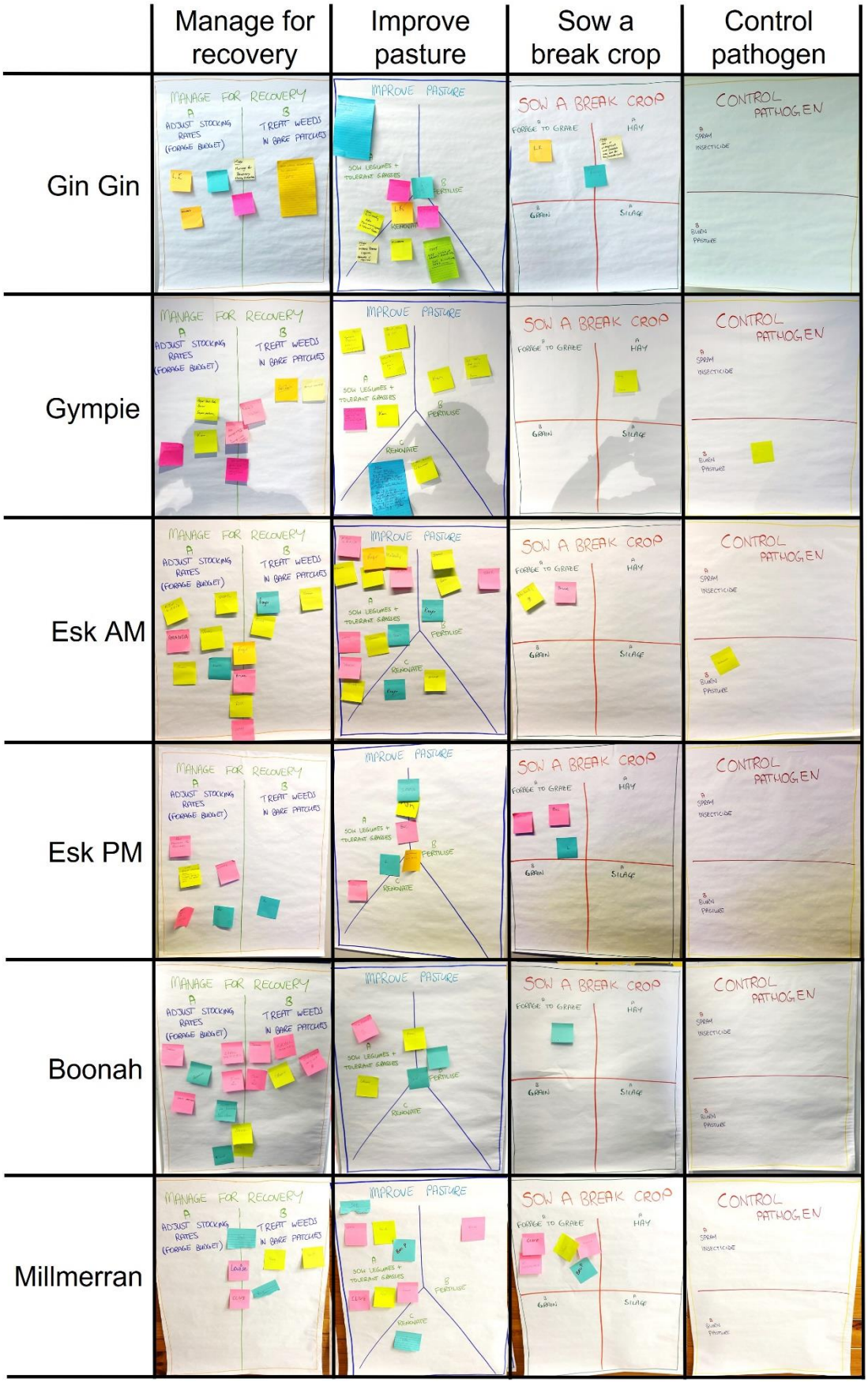
Table 6. Matrix of management options determined by size of dieback affected area and arability of the country.

Management options		Small patch		Widespread	
		Arable country	Forest country	Arable country	Forest country
1. Manage for recovery	Adjust stocking rate (forage budget)	✓	✓	✓	✓
	Monitor & treat weeds in bare patches	✓	?	✓	?
2. Improve pasture	Sow legumes and tolerant grasses	?	?	✓	?
	Fertilise	?	?	✓	?
	Cultivate	?	×	✓	×
3. Sow a break crop	Annual forage (graze or hay/silage)	×	×	✓	×
	Grain crop	×	×	✓	×
4. Control pathogen	Spray pesticide	?	×	×	×
	Burn	?	?	?	?

× = not practical or do not work/not cost effective. ? = might work depending on the situation. ✓ = effective option for consideration.

At the end of the workshop, attendees were asked to consider the most suitable management option(s) for their property. In a final activity, they were asked to put their name on a post-it note(s) and stick it on the wall under the management option(s) they were going to implement on their property after the workshop. Results of this activity are displayed in Fig. 4. Overwhelmingly the most common response at all workshops were *Manage for recovery* and *Improve pasture*. Some participants with arable land chose *Sow a break (forage) crop*. Only two attendees out of 78 chose *Control pathogen*, specifically to burn the pasture.

Figure 4. Management options that workshop participants indicated they would implement on dieback affected areas.



4.2.4 Change in industry knowledge

The project aimed to increase the knowledge and skills of producers and industry representatives in three key areas:

- How to identify pasture dieback
- What is causing pasture dieback
- Management options.

All engagement activities, especially the face-to-face extension events, delivered these messages through a multi-faceted approach that included: sharing grazier experiences both at workshops and in the paddock; communication of research trial results through presentations, fact sheets and viewing trial sites; development of management plans via the use of planning templates, and maintaining connection with industry and offering follow up information through the PDIN, FutureBeef e-communication, industry seminars, and newspaper articles.

Participant feedback was collected at the Paddock Walks in March, Brian Pastures Field Day in May, and Management Workshops in September and November. Feedback from the Paddock Walks and Brian Pastures field day are summarised in Tables 7 and 8 respectively. All events showed a large increase (over 4.4 points) in knowledge on identifying pasture dieback, potential causes of pasture dieback, management of pasture dieback and experiences from other graziers. The majority of respondents indicated that they would implement a change in their business. The overall satisfaction of the Paddock Walks and Brian Pastures Field Day were rated 5.9 and 6 out of 7, respectively.

Table 7. Attendee feedback from the paddock walks held in March 2021 at Taroom, Arcadia Valley and Injune.

Respondents = 83	**Average score**	
How much has today's field day increased your knowledge on the following? • How to identify pasture dieback in the field • Potential casual factors of pasture dieback • Management solutions for your property • Experiences of other graziers	**(1= no increase in knowledge; 7= very large increase in knowledge)** 4.9 4.6 4.8 5.6	
Have you, or will you, be implementing management practices to address pasture dieback?	**Yes** 58	**No** 4
Overall, how do you rate today's workshop?	**(1= poor; 7= excellent)** **5.9**	
Sample comments: *Very well done - right balance of presentation, questions + comments.* *Very informative - good speakers. Learnt quite a bit from other graziers.* *Informative across the whole subject*		

Table 8. Attendee feedback from the Brian Pastures field day in May 2021 at Gayndah.

Respondents = 28	**Average score**	
How much has today's field day increased your knowledge on the following? • How to identify pasture dieback in the field • Potential casual factors of pasture dieback • Management solutions for your property • Experiences of other graziers	**(1= no increase in knowledge; 7= very large increase in knowledge)** 4.7 4.9 4.4 5.1	
Have you, or will you, be implementing management practices to address pasture dieback?	**Yes** 16	**No** 12
Overall, how do you rate today's workshop?	**(1= poor; 7= excellent)** **6**	
Sample comments: *Great to have such an update, every 6 to 12 months would be good.* *Practical information, research presented as it unfolds, opportunity to share experiences amongst other producers and pasture experts/future beef staff, etc.*		

Overall feedback from the management workshops held in central-north and central-south Queensland was very positive with most respondents scoring all elements of the workshop as useful to their businesses (Table 9). The feedback sheets for these workshops were developed to calculate a change in knowledge as a result of the workshop. On average, knowledge across the concepts (Table 9) improved by 2.4. Attendees commented that hearing other graziers' experiences with pasture dieback was a highly valuable part of the workshop and many commented that the presenters were well prepared and could present scientific results in an approachable and relatable manner. One follow-up email from an attendee stated, "*I really enjoyed the morning and I learned so much… the workshop was comprehensive and very well run. You guys are a great team*!"

Table 9. Combined attendee feedback from all Pasture Dieback Management workshops during September and November 2021.

Respondents = 115	**Average score**		
How useful to your business were these aspects of today's workshop? • Hear experiences from other graziers • Understand how to identify pasture dieback • Update on DAF's research program (causes and management options) • Pasture dieback management plan	**1= no use; 7= extremely useful** 5.9 6.1 6.1 6.0		
What was your knowledge and understanding of these concepts before and after today's workshop?	**1 = very poor; 7 = very good**		
	Before	**After**	**Change**
• How dieback is affecting pastures in the local area	3.7	5.7	+ 2.0
• How to identify pasture dieback	3.7	6.0	+ 2.3
• Potential casual factors of pasture dieback	3.3	5.7	+ 2.4
• Whether pastures can recover from dieback	3.4	5.8	+ 2.4
• Successful management solutions	3.0	5.7	+ 2.7

After today's workshop, do you intend to make any changes in your business within the next 12 months?	**Yes** 87	**No** 21
How likely are you to make this change?	**1=will not change; 7=extremely likely to change** 6.0	
Overall, how do you rate today's workshop?	**1= poor; 7= excellent** 6.4	
Sample comments: *Room for group discussion and questions was great, opening with people's experiences from the area acted as a good ice breaker.* *Information was presented very well and easily understood.* *Explanations were easily understood and have a good understanding of the problem.* *Liked relaxed atmosphere and general discussion with participants.* *Highly informative presentation. Excellent "hand out" materials.* *Very informative presentation on a challenging subject.* *Presenters were well prepared. Presentations were interesting and informative.* *Excellent overview with management options. Good presenters, interesting + approachable.* *Good depth - balanced with time in each topic.* *Workshop was facilitated well, good opportunity for engagement and feedback.* *It was very informative. Backed by research.* *Well paced, easy to follow, open to discuss.*		

4.2.5 Pasture Dieback Industry Network

Membership of the Pasture Dieback Industry Network (PDIN) is continuing to grow as many extension event attendees are signing up to the PDIN email list. The PDIN contact list currently has 297 members which includes graziers, public and private service providers, and natural resource management (NRM) officers. Six newsletters (does not include event promotion) have been sent in the life of the project, as summarised in Table 10.

Every effort has been made to ensure that PDIN newsletter updates are not 'spamming' email subscribers and are providing interesting content that keeps members updated on DAF's work. Videos have been created to show field trial sampling and planting and to summarise the north Queensland workshops. Clicking on the links in Table 10 will open each full newsletter content including the videos.

For the six PDIN newsletters delivered there was, on average, a 69.6% open rate and a 20.2% click rate, which is 46.3% and 17.3% higher than the industry average, respectively (Mail Chimp 2019).

Table 10. Statistics for PDIN newsletters updates.

Statistic	November 2020	December 2020	January 2021	April 2021	August 2021	September 2021
Newsletter link	November 2020 PDIN update	December 2020 PDIN update	January 2021 PDIN update	April 2021 PDIN update	August 2021 PDIN update	September 2021 PDIN update
Date	11/11/20	21/12/20	27/01/21	15/04/21	10/08/21	30/09/21
Recipients	67	121	122	206	216	238
Individual opens	50	73	98	132	141	127
Total opens	182	238	323	543	480	316
Individual link clicks	15	19	26	28	50	39
Total link clicks	25	70	66	93	147	116
Link most clicked	40% Pasture Dieback – your questions answered	71% Measuring the impact of pasture dieback	29% Registration for pasture dieback bus tour	14% Darling Downs – Pasture dieback watch!	27% Drone video of Brian Pastures field day	48% Pasture Dieback ID guide
Unsubscribed	0	0	0	0	0	0

4.2.5.1 FutureBeef e-communication

The FutureBeef program has been a highly effective method to communicate with the Northern Australian beef industry. Pasture dieback information has been extended through FutureBeef in a variety of mediums including website, newsletters and social media.

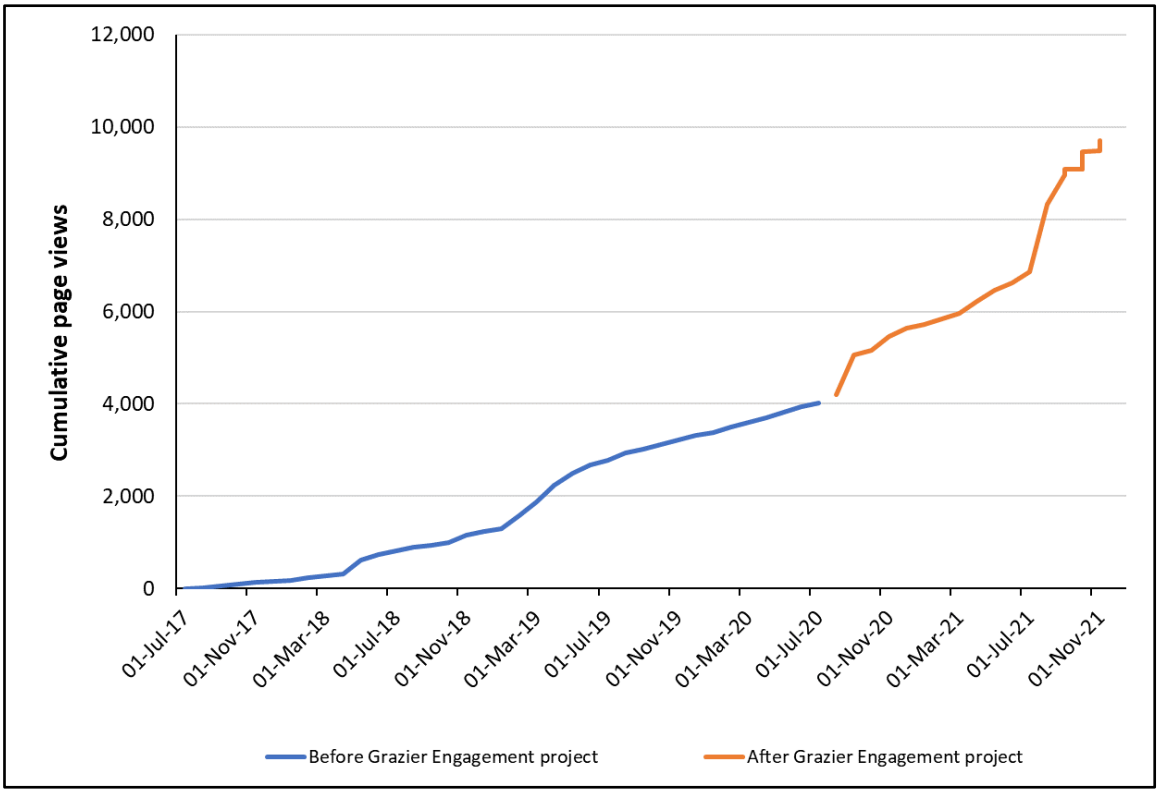
4.2.5.2 Website

The FutureBeef website features several pages on pasture dieback including:

- Pasture dieback landing page
- PDIN sign up
- Information from fact sheets
    - Signs and symptoms
    - Species affected
    - Research into management solutions
    - Management options
- Difference between pasture dieback and pasture rundown
- Event summaries
    - Brian Pastures field day

Website analytics (Fig. 5) demonstrate an upward trend in cumulative page views of all pasture dieback webpages. Since the inception of the PDIN sign up page in August 2021, page views have more than doubled from 4,011 to 9,706, highlighting that the project has had a significant impact on the dispersal of information to the wider industry.

Figure 5. Cumulative sum of views of pasture dieback web pages on the FutureBeef website.



4.2.5.3 Newsletters

The FutureBeef e-bulletins are send out monthly to a mailing list of over 3000 subscribers across Northern Australia. Two articles have been published in the e-bulletin since August 2021, statistics for these are summarised in Table 11.

Table 11. Summary engagement statistics for FutureBeef e-bulletin articles about pasture dieback.

Statistic	Apr-21	Aug-21
Link	Darling Downs pasture dieback watch	Pasture dieback field day a success
Total clicks	104	170
Unique clicks	70	119

4.2.5.4 Social media

FutureBeef has an active social media presence on Facebook, Twitter and LinkedIn. Social media posts are used to generate engagement with the FutureBeef website where all updated information is published. Table 12 summarises the engagement statistics for the pasture dieback social media posts.

Table 12. Summary statistics of pasture dieback posts on FutureBeef Facebook, Twitter and LinkedIn.

Platform	**Facebook**			
Date	13/11/2020 06:00 PM	23/04/2021 10:20 AM	30/04/2021 09:30 AM	20/08/2021 10:37 AM
Content	Refresh your memory of all the signs and symptoms of pasture dieback and register for the PDIN.	April eBulletin is out now! Pasture dieback on the Darling Downs	Queensland Agriculture has recently verified reports of pasture dieback on the Darling Downs.	Pasture dieback management workshops are coming to Nebo, Ingham and Malanda.
Reach	838	1214	1076	1180
Engaged users	24	38	28	11
Clicks	20	17	10	4
Link clicks	12	8	5	3
Photo views	4	9	5	1
Video play	0	0	0	0
Other clicks	4	14	9	2
Platform	**Twitter**			
Date	13/05/2021 09:29 AM	14/08/2021 10:02 AM	19/08/2021 07:02 AM	
Content	Pasture Dieback Field Day, 19 May at Brian Pastures Research Station, Gayndah.	A recent field day held at Brian Pastures Research Station, Gayndah, provided an update on the latest results from @DAFQld pasture dieback research.	Pasture dieback management workshops are coming to Nebo, Ingham and Malanda.	
Likes	1	1	3	
Retweets	1	0	1	
Engagement	2	1	4	
Platform	**LinkedIn**			
Date	13/05/2021 9:32 AM	6/08/2021 6:55 AM	13/08/2021 9:35 AM	
Content	Pasture Dieback Field Day, 19 May at Brian Pastures Research Station, Gayndah.	In the August eBulletin: * The latest pasture dieback research and more!	A recent field day held at Brian Pastures Research Station, Gayndah, provided an update on the latest results from the Department of Agriculture and Fisheries (Queensland)'s pasture dieback research.	
Impressions	201	419	250	
Clicks	4	64	6	
Likes	0	2	2	
Shares	1	0	0	
Comments	0	0	2	
Engagement	5	66	10	

4.3 Results and outcomes from the establishment of core trial site and grazier demonstration sites

As previously outlined, 11 graziers offered to host trial sites at the PDIN forum in September 2020. A range of treatments were discussed and identified. It was determined that project staff would visit each property after the forum to discuss and determine the most suitable sites based on landscape, pasture situation, equipment availability, and accessibility parameters, with the landowner. Once the property visit inspections were completed, the number of trials sites was reduced to five (Table 13). This was based on one grazier re-considering his commitment to hosting a site and others either not having a large enough area of dieback suitable for a trial, not having confirmed dieback, pasture regenerating after dieback, a lack of machinery capability, or combination of these.

Another trial site was developed at a property near Habana (Mackay district in north Queensland) in late 2020 after Mackay based DAF staff inspected a property affected by pasture dieback. This site was included due to the different geographic location and pasture type compared to the other sites in central Queensland.

Table 13. Details of the pasture dieback trial sites established.

Number	Location	Treatments	When established
1	Mulgildie (discontinued)	Insecticide application for mealybug control	End of 2020
2	Middlemount	Multiple: new pasture, burning, insecticide, cultivation	End of 2020
3	Banana	Multiple grasses sown in-between Leucaena rows	End of 2020
4	Moura	Multiple grass-legume mixes	End of 2020
5	Biloela	Multiple: new pasture (grass only, grass-legume, forage), cultivation.	End of 2020
6	Habana	Pasture improvement practices including re-sowing	End of 2020

On-farm research trials have been developed in different situations to maximise the learning opportunities for graziers and researchers. The aims (and treatments incorporated) at each site were specific to each situation. These include:

1. Mulgildie. Treat the pasture with insecticide to assess impacts on pasture mealybug numbers and pasture growth/yield.
2. Middlemount. Multiple treatments are applied, some will treat the existing pasture with various practices whereas other treatments will remove the existing pasture and allow pasture regeneration to occur, or re-sow grass/legume mix, or a forage.
3. Banana. Replace the existing grass-pasture with eight single grass species, one grass/legume mix, and a cultivate-only option.

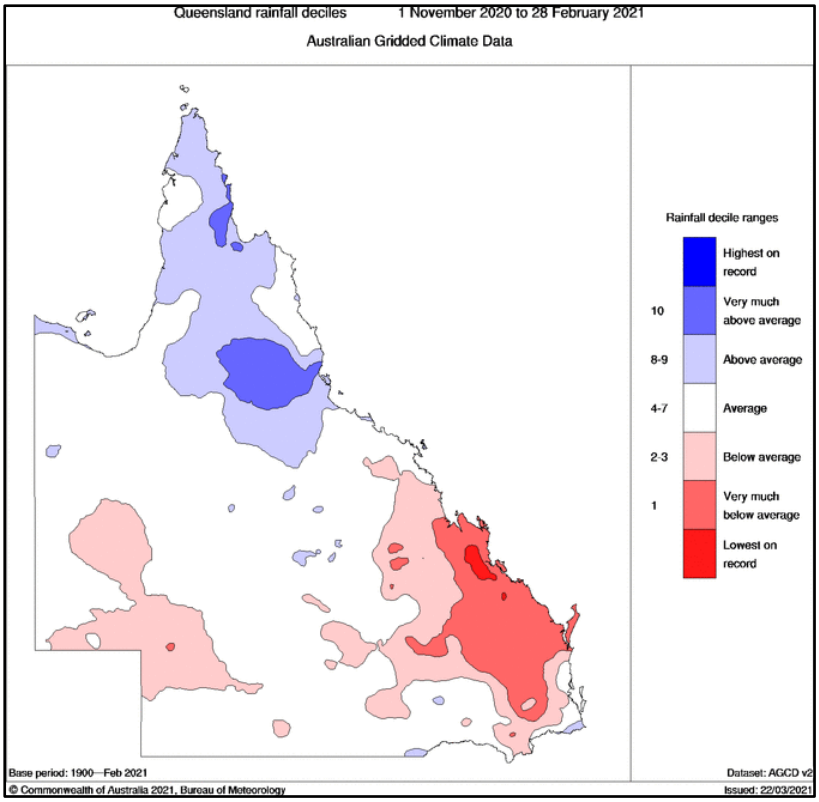
4. Moura. Replace the existing pasture with multiple grass species in combination with legumes. These are sown together as grass/legume mixtures, with grass species being the main treatment, legume species are sub-treatments.
5. Biloela. Replace the existing severely affected pasture with very high weed population with: grass only; grass and legume mixture; one forage; and a cultivate-only option.
6. Habana. Multiple treatments, one will renovate the existing pasture and the other will remove the existing pasture and re-sow grass-legume mix with fertiliser.

Due to the complexity of pasture dieback and the need to obtain reliable and repeatable data, the project team decided all trials will be conducted using scientific protocols and so can be classified as 'core sites'. The protocols include:

- The positioning of site within the paddock and site design (treatment and replicate layout) overseen and developed by a biometrician in consultation with project team
- Multiple treatments (numbering between 3 – 12)
- Replication of treatments (at least 3 times)
- Randomisation of treatments within trial area
- Detailed site characterisation (soil, existing pasture condition etc)
- Statistical analysis of all data collected

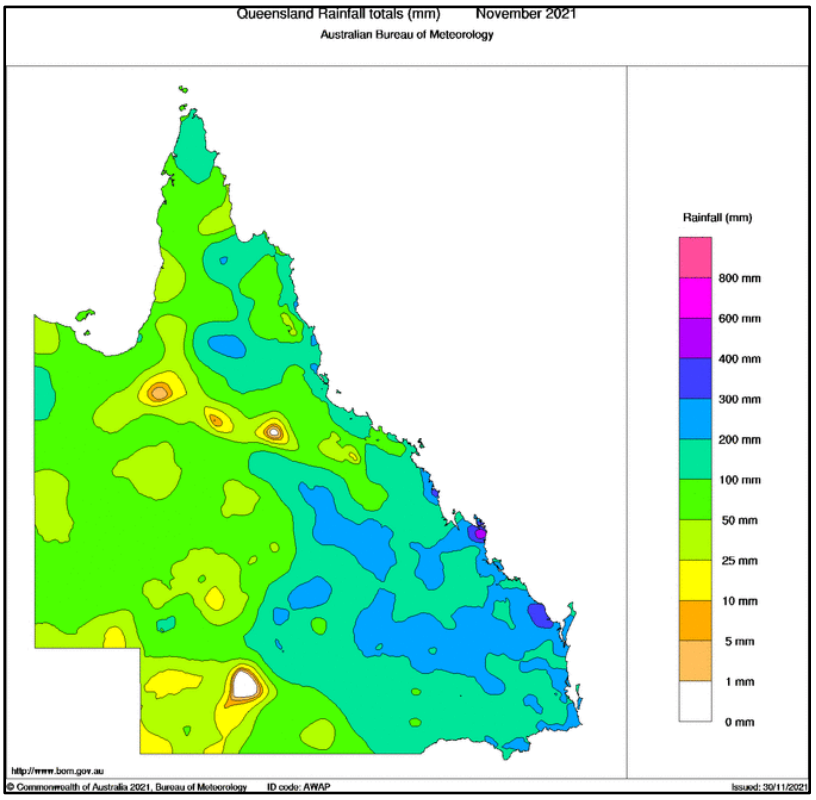
While a total of six on-farm trial sites were initiated only five have continued through to the end of the project. After the sites were established late 2020, all trials received below average summer and autumn rainfall conditions during 2020/21 (Fig. 6). This restricted the growth and response of pastures in trial plots and also provided challenging conditions for the establishment of new pasture in other trial plots.

Figure 6. Queensland rainfall deciles November 2020 – February 2021. Source: www.bom.gov.au



Winter and early spring rainfall conditions did not improve across all trials. In November 2021, all sites received significantly above average rainfall (Fig. 7). This has provided ideal conditions for the pastures to respond and grow very well.

Figure 7. Rainfall totals during November across Queensland. Source: www.bom.gov.au



4.3.1 Mulgildie site

The Mulgildie site was initiated in November 2020 and investigated the impact of insecticide (Movento®) on pasture mealybug population and pasture growth. A suitable pasture mealybug population for a trial purpose was initially detected at the site however due to the very dry conditions late spring and into summer, no pasture growth (Fig. 8) or mealybugs were subsequently recorded. The Mulgildie site was eventually discontinued due to on-going dry weather through 2020/21 summer which resulted in unfavourable conditions to achieve the aims of the trial. Efforts were then directed at undertaking pasture mealybug research at the Brian Pastures Beef Research Facility where the site could be watered to overcome any rainfall deficiencies and ensure continual pasture growth.

Figure 8: Mulgildie site late January 2021.

4.3.2 Middlemount site

The Middlemount site contains 10 treatments (randomised and replicated three times) investigating the impacts of either treating the existing pasture or removing the existing pasture and re-sowing to a new pasture. The details of each treatment are outlined in Table 14.

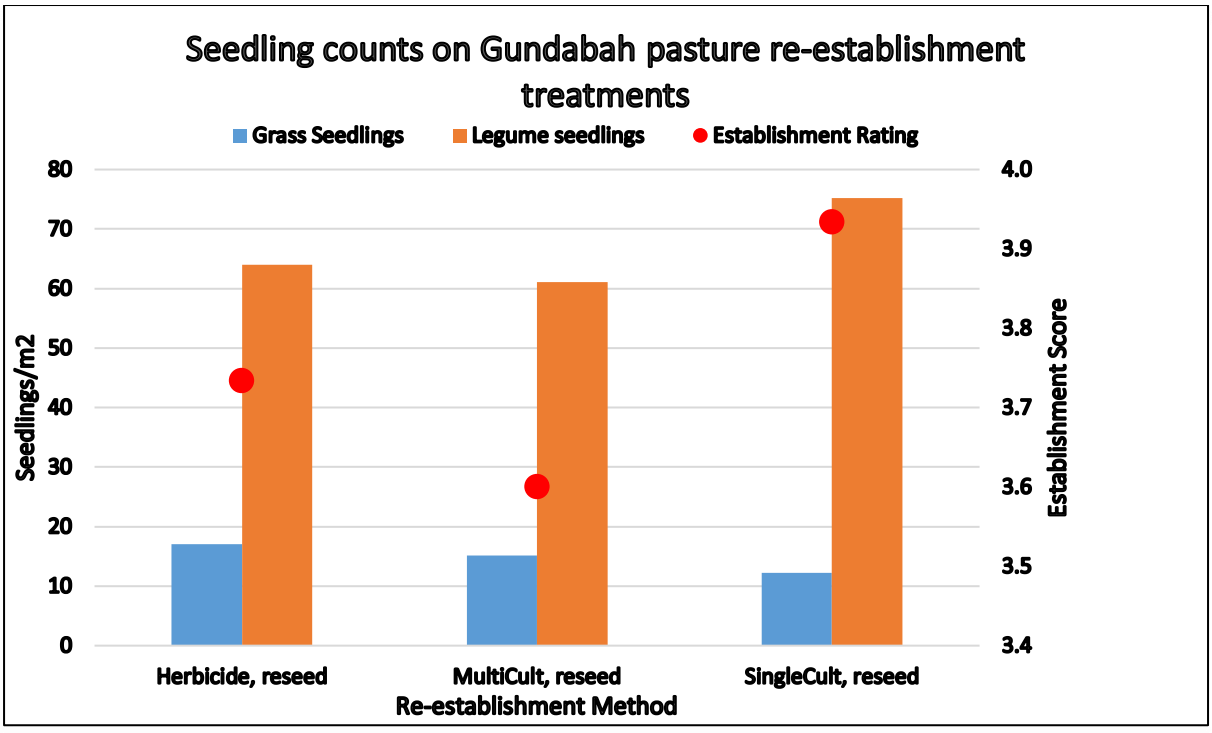
Table 14. Treatments applied at the Middlemount site.

Treatment number	Treatment details
1	Control (existing untouched pasture)
2	Cultivate once, regenerate
3	Spray herbicide twice, re-seed with grass/legume mix
4	Fungicide – Propiconazole
5	Cultivate twice, sow forage (oats)
6	Insecticide – Spirotetramat (Movento)
7	Cultivate once, re-seed with grass/legume mix
8	Fungicide – Azoxystrobin
9	Fertiliser – N,P,K, S mix (50:50 mix CK88 and urea at 370kg/ha)
10	Cultivate twice, re-seed with grass/legume mix
Legume mix:	*Grass mix*:
Caatinga stylo	Purple pigeon
Progardes	Gayndah buffel
Desmanthus	Epica Rhodes
	Gatton panic
	Bisset creeping blue
	Premier digit

The treatments applied to the existing pasture (4, 6, 8, 9) were implemented during the summer of 2020/21. Both fungicides and the insecticide were applied twice, the fertiliser was applied once.

Treatment numbers 3, 7 and 10 were sown to a grass/legume mix on the 11th March 2021. All treatments established very well despite low rainfall over the summer/autumn 2021 period (Fig. 9).

Figure 9. Graphical display of the seedling numbers at the Middlemount site in April 2021.



The '*Cultivate twice, sow forage'* treatment was planted to oats in July 2021. This is considered very late for a winter forage crop and was due to a lack of sufficient rain in the preferred late-autumn and early-winter

time of the year. The crop establishment was very good and overall (Fig. 10), no plant health issues related to pasture dieback were observed.

Figure 10. Well established oats forage crop at 7 weeks post sowing (8th September 2021)

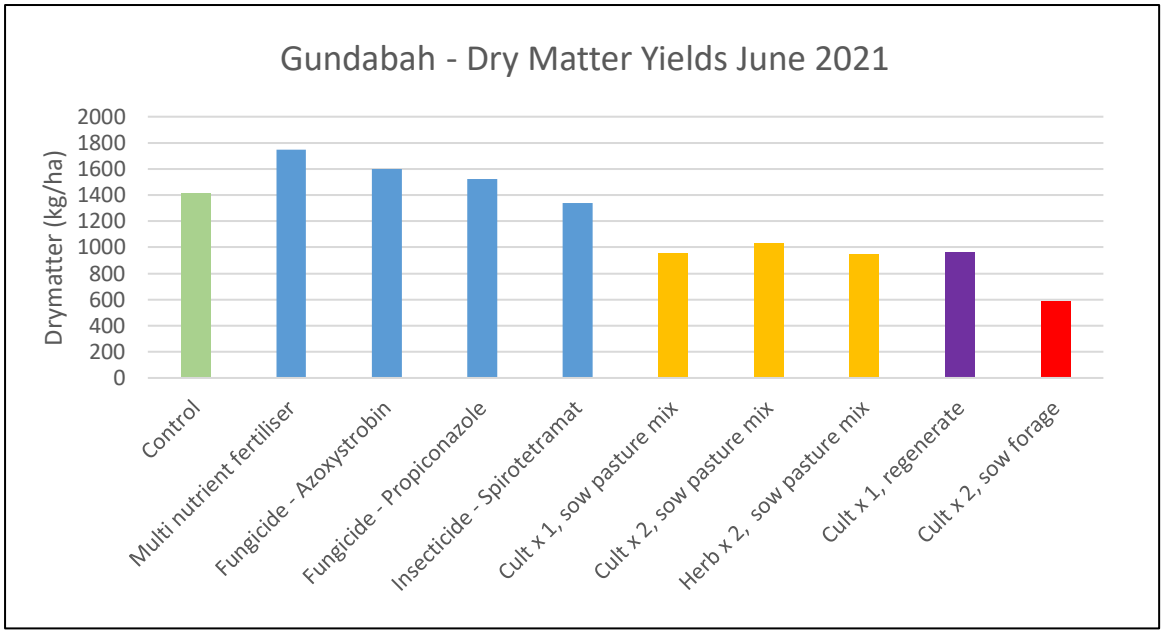
Dry matter yields from all other treatments were measured in June 2021 (Table 15; Fig. 11). Overall dry matter yields are generally low (<2000kg/ha) due to the prominence of Indian couch across the trial area (data not shown), the below average rainfall during summer 2020/21, and slashing prior to treatment implementation to provide an even pasture-yield starting point. The treatments that were significantly higher yielding than the control included *Broadcast Fertiliser* and *Fungicide - Azoxystrobin*. The other fungicide treatment (Propiconazole) produced the same yield as the control. The insecticide treatment (Movento) was significantly lower yielding than the control, as was all cultivate/herbicide treatments where the existing pasture was removed regardless of whether re-sown or not. The result from the cultivate/herbicide treatments is not unexpected due to the late sowing time (March 2021) and the low rainfall received before measurement was taken (June 2021). Also, all treatments where the pasture was retained had similar ground cover, whereas the cultivate/herbicide/re-sow treatments recorded the lowest. The site was not grazed during this time.

Table 15. Biomass yields and statistical analysis of each treatment at the Middlemount site June 2021.

	Biomass (kg/ha)		Organic Cover (%)	
Treatment	P<0.001		P<0.001	
1. Control	1455	c	90.6	a
2. Fungicide (Propiconazole)	1501	bc	90.2	a
3. Fungicide (Azoxystrobin)	1618	ab	91.8	a
4. Cult x 1, regenerate	978	e	35.9	d
5. Cult x 1, pasture seed mix	1037	e	44.4	cd
6. Cult x 2, pasture seed mix	957	e	46.6	c
7. Cult x 2, forage	556	f	13.3	e
8. Herb x 2, pasture seed mix	933	e	80.3	b
9. Insecticide (Movento)	1311	d	87.0	ab
10. Broadcast fertiliser	1740	a	94.0	a
ave. s.e.d.	67		4.4	
ave. l.s.d. (P=0.05)	162		9.3	

Means not followed by a common letter are significantly different (P=0.05).

Figure 11. Graphical display of the dry matter yields at the Middlemount site in June 2021.



The dry matter yield of the forage oats was measured in November 2021. The yield was consistently low across all plots (Table 16) due to the late planting time, poor in-crop rainfall, and the warm-hot temperatures in spring which severely supressed yield potential. From here these plots will be fallowed to replenish soil-moisture levels and sown to a new perennial grass-legume pasture in summer 2021/22.

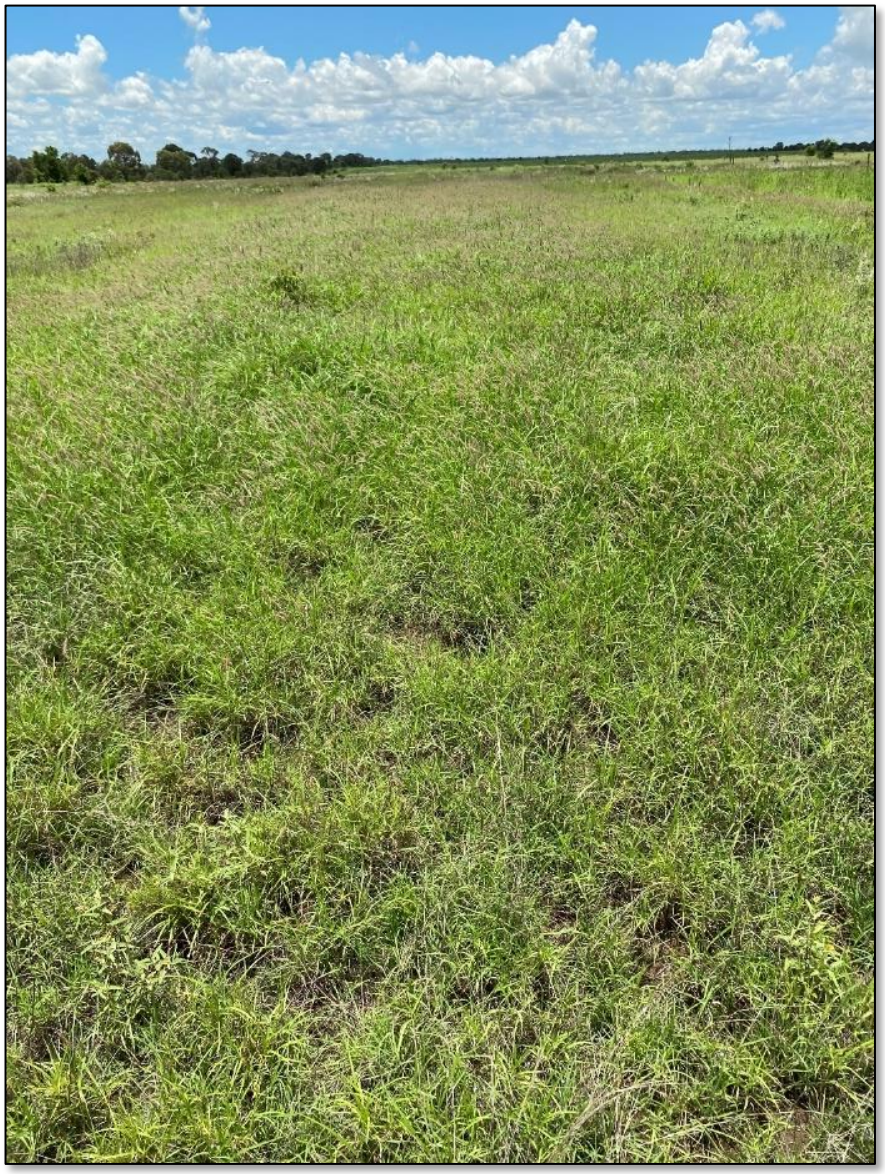
Table 16. Dry matter biomass yield of oats at the Middlemount site November 2021.

Plot	Kg/Ha
5	1290
18	1090
22	1026
Average	1135

The pasture across the site responded very well after receiving around 200mm of rain during November 2021 (Fig. 12). During a site visit in early December 2021, the standout treatment visually was Broadcast fertiliser. These plots were prominent from the other treatments by a darker green colour, higher biomass, and prolific buffel grass seed-heads (Fig. 13).

Figure 12. Drone image of the Middlemount trial early December 2021.

Figure. 13. Broadcast fertiliser treatment. December 2021.



4.3.3 Banana site

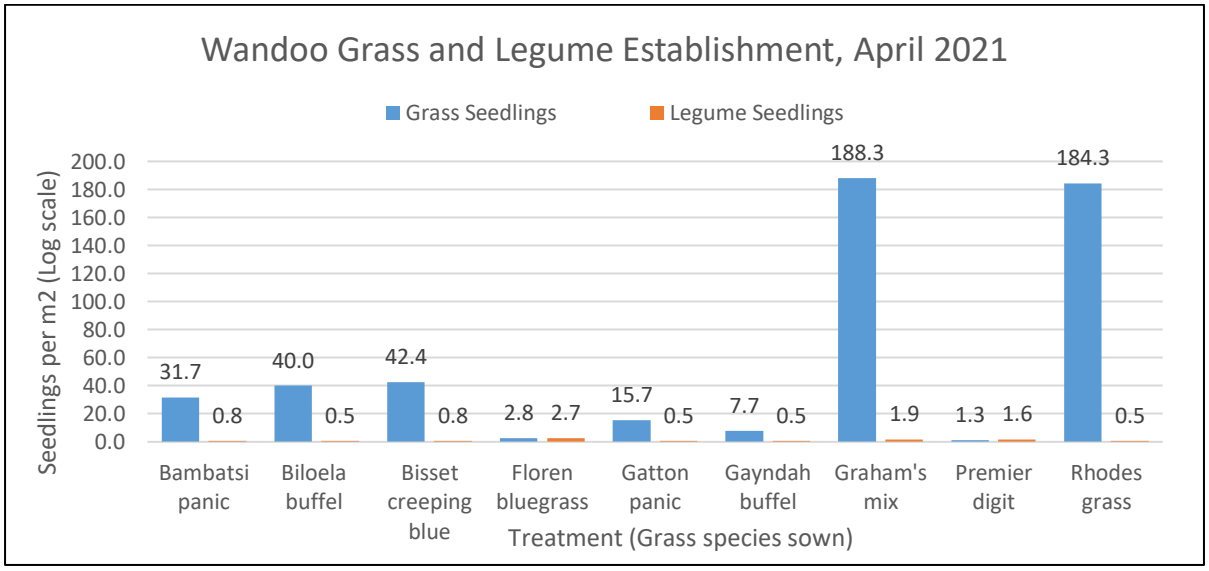
The Banana site contains 12 treatments (randomised and replicated three times) investigating the impacts of a single cultivation only or sowing various single species of grasses or a grass legume mixture. The details of each treatment are outlined in Table 17.

Table 17. Treatments implements at the Banana site.

Treatment number	Treatment details
1	Control (existing untouched pasture)
2	Cultivate once only
3	Bisset creeping bluegrass
4	Biloela buffel
5	Gayndah buffel
6	Floren bluegrass
7	Premier Digit
8	Bambatsi panic
9	Gatton panic
10	Rhodes grass
11	Grass/legume mix
12	Forage (oats)
Legumes:	*Grass mix*:
Butterfly pea	Biloela buffel
Ray desmanthus	Bambatsi panic
Burgundy bean	Gatton panic
	Premier digit
	Bisset creeping blue

The grass and grass-legume mixture treatments at the Banana site established well due to good rainfall received in late March 2021after the trial was planted. This is despite a lack of follow up rainfall for over a month after the initial germination rain event. The plant population achieved is very high, especially the plant numbers in the Rhodes grass treatment (Fig. 16), and due to the Rhodes grass component in Grahams Mix treatment (Fig. 14). However the establishment of some treatments (Floren bluegrass (Fig. 15) and Premier Digit) was very low due to poor seed quality. This is despite the project team undertaking germination tests prior to sowing and applying suitable rates of seed (aimed to apply 1.5kg/ha of pure live seed) to compensate.

Figure 14. Grass and legume establishment counts April 2021.



Observations during August 2021 indicate the soil water competition of the existing leucaena, combined with the lack of rainfall over winter, was having a significant impact on the survival of the new pasture. Low

rainfall conditions continued into early-spring until approximately 150mm fell in multiple falls over the month of November. No measurements were collected over the winter and spring periods, however the project team conducted pasture establishment and health assessments (specifically recording any pasture dieback symptoms), and spraying of weeds in December2021.

Figure 15. Poor/no establishment of Floren bluegrass (plot mainly contains broadleaf weeds). December 2021.

Figure 16. Good establishment and growth of Rhodes grass (very few broadleaf weeds). December 2021.

4.3.4 Moura site

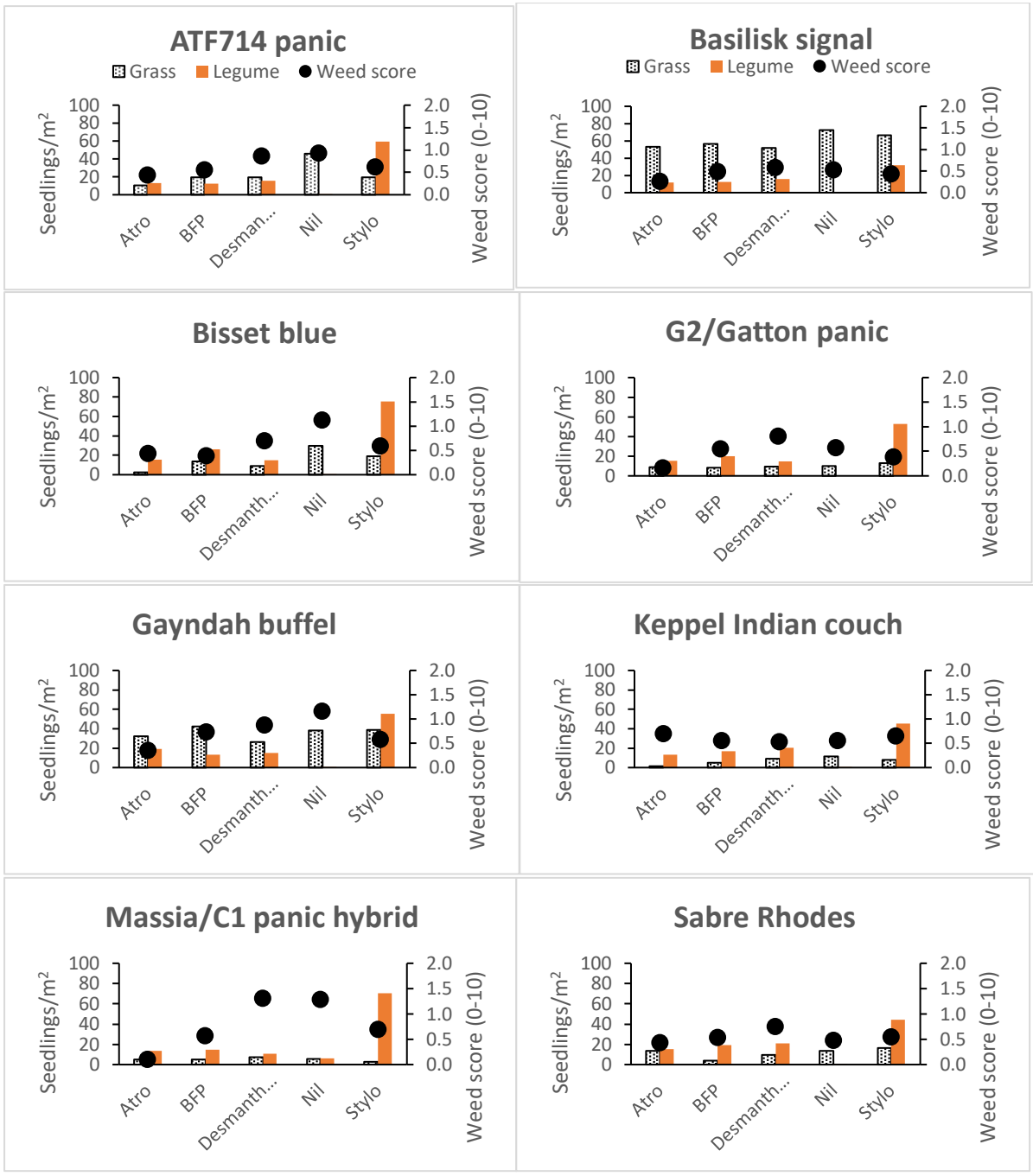
The Moura site contains 10 grass treatments and five legume sub-treatments (randomised and replicated three times) to investigate the comparative performance in a paddock with pasture dieback. The details of each treatment are outlined in Table 18.

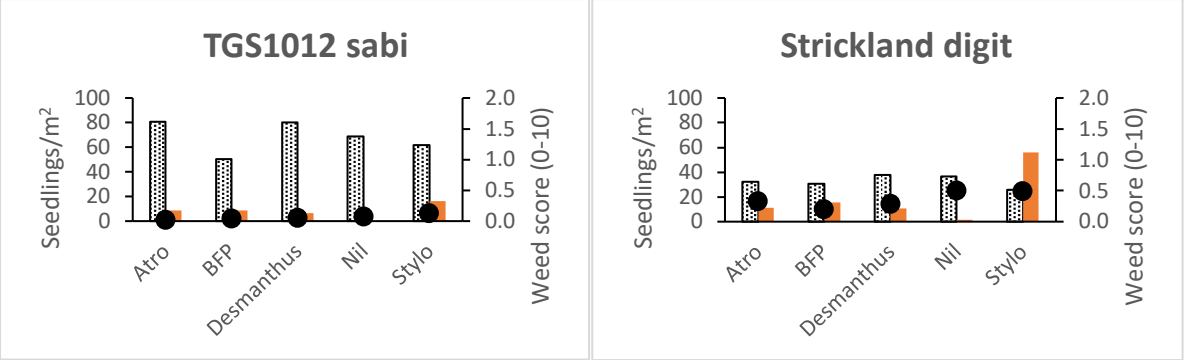
Table 18. Treatments implemented at the Moura trial site.

Grass treatment number	Treatment details
1	Bisset creeping bluegrass
2	Medway Indian couch
3	Basilisk signal grass
4	Gayndah buffel
5	Sabre Rhodes grass
6	Strickland finger grass
7	AFT714 (*P. coloratum)*
8	Massai panic
9	G2 panic
10	TGS 1012 (*U. mosambicensis*)
Legume treatment number	
1	Butterfly pea
2	*Desmanthus sp.* x 3
3	*Stylosanthes sp.* x 3
4	*Macropitilium sp*. x 2
5	None

The overall establishment of the treatments (recorded April 2021) has been very good (Fig. 17). The two standout grasses to date are TGS1012 sabi grass and Basilisk signal grass. Both have produced very high population with high ground cover. Gayndah buffel grass and Strickland digit grass are also high performers. The standout legume to date is the stylo treatment; this is not surprising due to the suitability of this legume species to the soil type at this site (sandy-loam). Overall weed pressure (as measured by observation score) across the trial is low, the highest score is about 1.5 on scale of 0 (no weeds) to 10 (100% coverage). This provides an ideal opportunity for the new pasture to establish as quickly as possible.

Figure 17. Seedling establishment for each grass and legume combination at the Moura site.





No measurements have been collected since April 2021 however the project team conducted pasture health assessments (specifically recording any pasture dieback symptoms) prior to the end of 2021. This site also received high rainfall over the month of November 2021 (244mm was measured) which has significantly boosted pasture growth (Figs. 18 and 19).

Figure 18. Drone photo of the trial site December 2021.

Figure 19. Photo looking across the trial from the ground. December 2021.

4.3.5 Biloela site

The Biloela site contains five treatments (randomised and replicated three times) to investigate the success of sowing buffel grass only, a grass-only mixture, a grass-legume mixture, and one pass cultivation without re-seeding. The details of each treatment are outlined in Table 19.

Table 19. Treatments implemented at the Biloela trial site

Treatment number	Treatment details
1	Control (cultivated once)
2	Buffel grass only
3	Grass mix only
4	Grass and legume mix
5	Forage crop (season dependant)
Legumes:	*Grass mix*:
Caatinga stylo	Purple pigeon
Progardes	Gayndah buffel
Desmanthus	Epica Rhodes
	Gatton panic
	Bisset creeping blue
	Premier digit

The trial was planted 10th March 2021 and overall, the pasture establishment was very poor. The site was visually assessed four weeks after planting and very few grass or legume plants had established at that time (Fig. 20). The reasons for this include poor stored soil-moisture prior to sowing due to below average rainfall over the 2020/21 summer. Then once the site was planted, good germinating rains fell soon after however sporadic follow-up rainfall occurred. Unfortunately, fast growing weeds (including pigweed and tarvine) swamped the young pasture seedlings and despite herbicide application, the pasture establishment was

poor. The project team decided at this stage the best way forward was to re-seed the site therefore only site maintenance was undertaken over winter/spring 2021.

Figure 20. Buffel grass-only plot full of pigweed and very little pasture. April 2021.

In mid-November 2021, herbicide was applied after good rain was received late October-early November 2021 to control broadleaf weeds. Another visit early December indicated a significant amount of grass pasture has established, especially Rhodes and buffel grass (Fig. 21, 22). However very few legumes were observed at that time. Buffel grass was also slowly regenerating in the control plots (Fig. 23). The control plots were cultivated once only (this occurred across the whole trial area prior to the trial starting) and have not been touched since i.e. buffel grass is regenerating from the soil seedbank. The project team has decided to continue with the pasture across all treatments due to the satisfactory pasture establishment achieved by the end of 2021.

Figure 21. Legume and grass mix plot. December 2021.

Figure 22. Grass mix only. December 2021.

Figure 23. Control plot. December 2021.

4.3.6 Habana site

The Habana site contains three treatments (randomised and replicated three times) to investigate the effect of practical management practices on a pasture with severe dieback in a high rainfall situation in north Queensland. The trial paddock had been monitored for around 18 months by local DAF staff to gain insights into the progression of dieback. A trial was initiated in November 2020 as the pasture had almost completely died out due to dieback. The paddock was predominately (99%) pangola grass, with the odd green panic plant throughout the pasture. The land type is coastal tea tree plains (typical of the region), which is sandy loam over clay soil. Treatments were devised through consultation with the property owner and DAF staff (Table 20).

Table 20. Treatments implemented at the Habana trial site.

Treatment number	Treatment name	Details
1	Control	Untouched pasture
2	Harrow and fertilise (no added seed)	The dead thatch/drymatter was removed by harrowing then fertilised
3	Cultivate, fertilise, apply new pasture seed	These plots were cultivated with an offset cultivator twice, harrowed, fertilised, and seeded to a grass and legume mixture

The pasture mix sown in Treatment Three included Callide Rhodes grass, Jarrah digit grass, and V8 stylo. Each plot is 20m X 10m with 5m inter-plot spacing. The fertiliser added to Treatments Two and Three was applied at a rate of 225kg/ha. The fertiliser contained 15% Nitrogen, 4% phosphorus, 11% potassium and 14% sulphur (i.e. 15-4-11-14) and was applied by hand, as was the pasture seed mix. No pesticide sprays have been applied to the trial. The whole site was fenced off to allow for control of stock grazing.

The pasture biomass yield across the site prior to the trial starting (November 2020) was measured at 289kg/ha. This low yield reflects the severe impact pasture dieback was having on the pasture at that time. After the site was pegged and treatments implemented, all treatments grew very well during the establishment phase. Biomass yields were high (Fig. 24) and greater than 10,000kg/ha at the April 2021 recording date (Table 21). Since the pasture assessment in April 2021 the site has been heavily grazed by cattle. Observations during a visit to the trial during September 2021 indicated pasture health had deteriorated (minor yellowing and reddening of leaves) since April. It was unknown whether this was pasture dieback coming back, typical end of dry season senescence, or another stressor e.g., lack of soil fertility. The next pasture assessment was made on the 25th October 2021 (Fig. 25) to determine biomass yield, ground cover, species composition, and pasture health.

Figure 24. Trial plots at the Habana site. April 2021.

The pasture yield at the October 2021 recording date averaged around 1100kg/ha (Table 21), which is about 10th of the yield measured in April 2021. Ground cover was also slightly lower at the October 2021 recording date. Stress rating, which is a visual assessment of leaf colouration and plant health, indicated less plant stress in the *Cultivate, fertilise, sow pasture* treatment. Pasture species composition data (Table 22) indicates the original pasture species (pangola) has remained present across all treatments but is the lowest in the *Cultivate, fertilise, sow pasture* treatment. The legume mix sown in the *Cultivate, fertilise, sow pasture* is contributing a significant (36%) proportion of the pasture composition.

Table 21. Pasture ground cover and dry matter yield at the Habana pasture dieback trial.

	October 2021			April 2021	
Treatment	Stress rating*	Average ground cover %	Average drymatter pasture yield (Kg/ha)	Average ground cover %	Average drymatter pasture yield (Kg/ha)
Control	8.9	94	1362	99	13,994
Harrow and fertilise	8.5	96	1072	100	13,019
Cultivate, fertilise, sow pasture	6.1	91	1103	99	10,398

* 0 – 11 scale. 0 = healthy. 11 = dead

Table 22. Pasture species composition across treatments October 2021 (average proportion (%) when present in quadrat).

	Pasture species				
Treatment	Pangola grass	Rhodes grass	Green panic	Jarrah grass	V8 Stylo legume mix
Control	62.5	69.5	78.4	0	0
Harrow and fertilise	70.1	67.7	45.8	0	0
Cultivate, fertilise, sow pasture	43.5	52.6	47.6	41.1	36.2

Another outcome of this trial has been the large increase in the number of plant species present across the trial area (Table 23). Before the trial was initiated, only two plant species were present across the trial (pangola and green panic). This changed to over 20 species present (both pasture and undesirable types) across the trial area at the April 2021 recording date. Obviously two treatments received new pasture seed, but this mix only contained three pastures (two grasses and a legume). All the other plants present have grown from seed already present in the soil at this site.

Table 23. Plant species present at the Habana trial site at two recording dates. Species in bold were sown, other species were either existing or grew from background seedbank populations.

November 2020		April 2021	
Pasture species	Undesirable species	Pasture species	Undesirable species
Pangola	None	Pangola	Sida urena
Green panic		Green panic	Sedge
		Jarrah grass	Urena burr
		Callide Rhodes	Gambia pea
		V8 Stylo	Common sensitive weed
		Summer grass	Northern Cane grass
		Kazungula Seteria	Purple scented top
		Crows foot grass	
		American joint vetch	
		Wynn cassia	
		Seca stylo	
		Verano stylo	
		Signal grass	
		Indian couch	
		Tully grass	
		Hymenachne	

The site will continue over the 2021/22 summer and another pasture measurement will be undertaken before winter 2022.

Figure. 25. Photo looking across the trial October 2021.

4.4 Progress on production of an electronic survey APP suitable for use by graziers or industry personnel to capture where dieback occurs and the area impacted. Report feedback from industry groups (e.g. NSW-DPI and AgForce) on APP functionality.

The project team facilitated the development of a pasture dieback application (app) for smart devices. The app is essentially an electronic survey where graziers and other interested people can quickly and easily report the location and area impacted by suspected pasture dieback. Current pasture characteristics are collected in a consistent manner across all these sites. The data is collated and stored for analysis and interpretation. The project team have contracted a professional app developer, Viewdale IT Pty Ltd, to undertake the development and production of the app. Viewdale are highly experienced in application development and have successfully delivered the Stocktake GLM app. After substantial internal DAF contracting processes, a contract was fully executed on 3rd of September 2021. Work commenced within the following week and the estimated timeframe for delivery of a testable product was approximately six weeks. This has been achieved by Viewdale.

The app has been developed to deliver on the following requirements:

- To geo-reference and record the area impacted by pasture dieback at that location
- Record the characteristics of the pasture and dieback stage at that time and location in a consistent manner
- Ability to capture a photo(s) of the situation at that time and location

- Be simple enough for anyone with basic pasture knowledge to correctly fill out
- Be short enough to take no longer than 5 minutes to fill out

The project team composed a selected set of survey questions and other information including an opening statement, description of pasture dieback including photos, questions to gauge the user's knowledge of pasture dieback and hence the reliability of the information recorded, process to log a GPS point. The survey questions were originally sourced from the questions contained in DAF's comprehensive paired site survey built on Survey123. This was to provide consistency of questions across programs to potentially allow the ability to combine data sets into the future for a more comprehensive analysis of the pasture dieback situation across Queensland (and NSW).

The overall framework and survey questions were circulated amongst the MLA coordinated Pasture Dieback Research Committee members for feedback. Positive feedback was obtained along with suggestions for additions and improvements. These included:

- Collect respondent contact details once only. This information to be saved and attached to the responses uploaded by the user.
- Include clear statements that is it *optional* for the user to supply contact details, and the purpose of collecting this information is to only make contact in relation to their survey responses.
- The app needs to have the ability to save responses to be submitted later if there is no internet connection at the time of survey completion.
- An 'admin' panel is required to download responses.
- Questions to be asked include:
    - Respondents' role in the grazing industry
    - Confidence in identifying pasture dieback
    - If the respondent has read the factsheets on MLA, DAF, or NSW DPI webpages
    - Location of dieback through GPS location on the mobile device
    - Estimation of affected area within a 60m radius
    - Date pasture dieback was first observed at that location
    - The main affected species at that location (one only)
    - Current symptom expression
    - Ability to upload photos (up to 5) for each site, linked to the individual survey responses

A pre-release version of the app was made available to the project team on 15th October 2021. This draft version was made available to the project team while app creation and publishing access to the MLA app stores was being negotiated. The project team reviewed this pre-production version and discovered some minor issues that needed to be addressed. These included some missing questions, and improvements to the flow of data collection (such as prompting the user about providing their contact details the first time the survey is completed). While the app saves responses when no internet connection is available, the uploading of these responses needs to be manually initiated. While this manual upload is likely to remain, some design changes are being made to remind the user if there are pending responses that need uploading, as well as making the process to achieve this more intuitive. These changes were made for the next iteration of the testing process and were incorporated prior to the app being made available for testing to a wider audience.

Screen shots of the pre-release version of the app are shown in Figs. 26 to 28. Some minor changes will be made to the final version however the overall appearance and functionality these screenshots display will be maintained.

Figure 26. The splash/welcome screen and the main menu

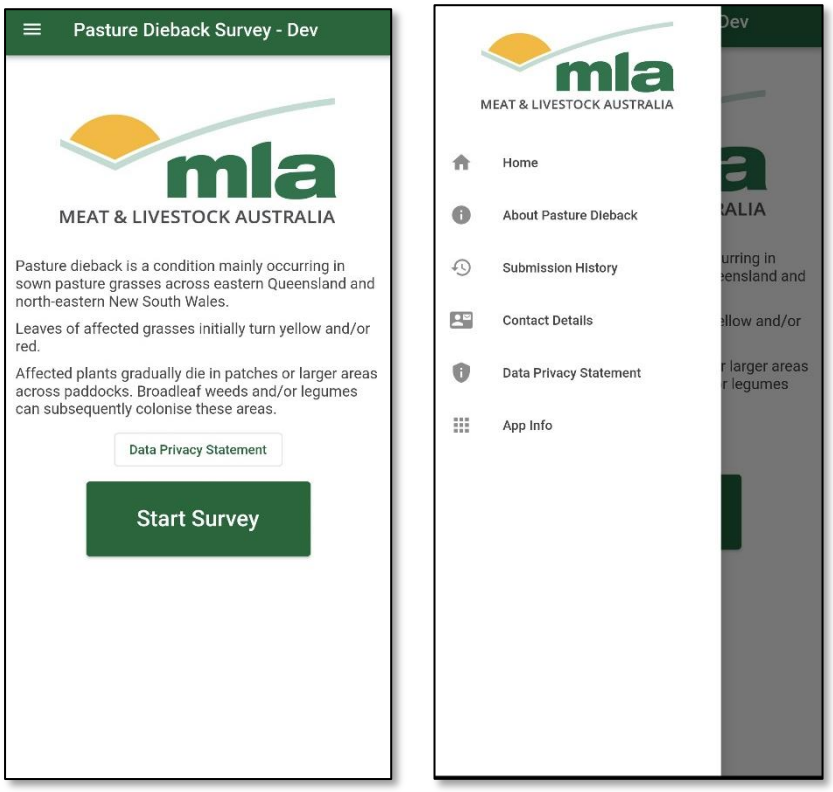


Figure 27. The survey screen

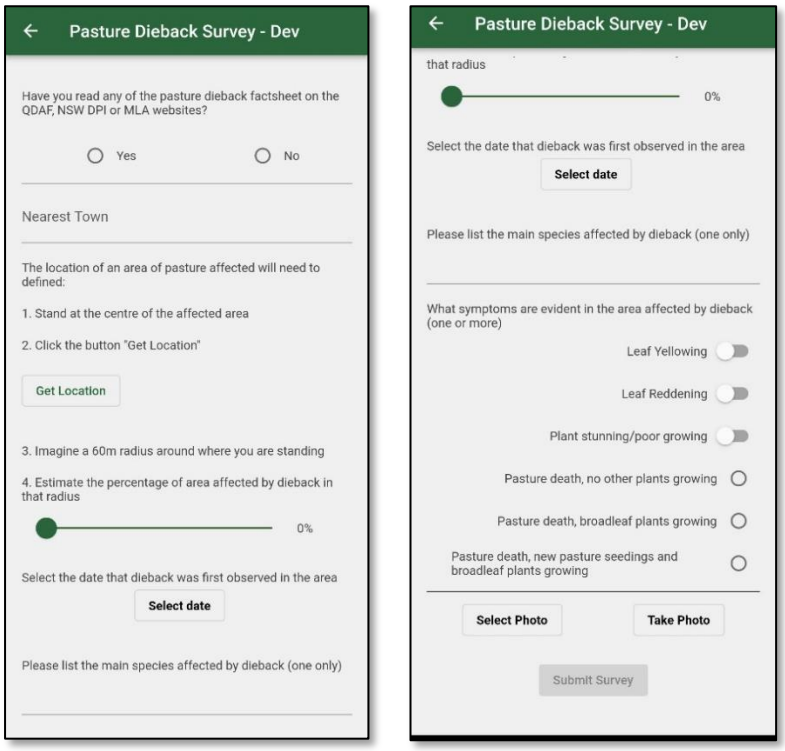
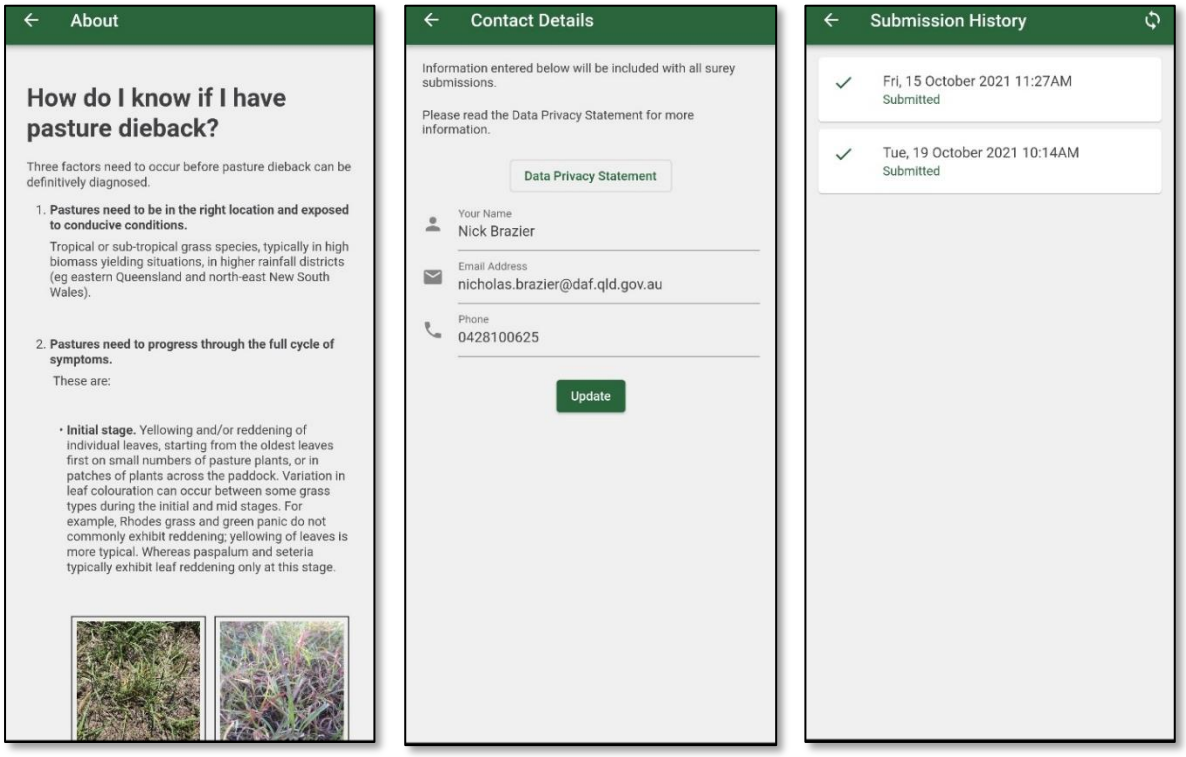


Figure 28. The "About Pasture Dieback" ID guide (with zoomable high quality photos), user contact details page, and submission history



During November and December 2021, the project team coordinated two rounds of user testing. The first round of testing was conducted by the project team. After changes from the first round were implemented by the developer, test links were circulated to DAF staff with extension and research backgrounds and other organisations conducting research into Pasture Dieback including AgForce, university researchers, and NSW DPI. Feedback and suggestions from this second round have been collated and summarised in Table 24. A total of 10 feedback responses were received with some of these responses tested on multiple devices. Six respondents used iOS devices (5 iPhones of various ages and 2 iPads), the remaining four used Android devices (Samsung S7, Samsung S9, Samsung S20, and Google Pixel 5). The overall look, feel, and ease of use of the app were all rated very positively.

Table 24 – Summary of Dieback Survey App feedback questions and the common responses

Feedback Question	Options (scoring value)	Common Responses
How was the overall look/feel of the app?	Terrible (1) OK (2) Good (3) Excellent (4)	Average response: 3.3 Median response: 3 (Good)
How was the overall ease of use of the app?	Terrible (1) - Fantastic (7)	Average response: 6.1 Median response: 6
What works well?	Free text	- Good offline functionality - Strength is ability to respond offline
What needs to be improved?	Free text	- Limited by having to be where dieback is, and not collecting affected area - Longer text field for additional comments - Could make drop down boxes clearer by highlighting them
Any issues opening and/or navigating through the app?	Free text	- Long download/install times on some android devices - Didn't save half completed response when the phone went to sleep, had to refill
Any issues collecting a GPS point?	Free text	- Had to manually allow permissions for GPS (not automatically prompted)
Any issues uploading photos?	Free text	- Had to manually allow permissions for photos (not automatically prompted), and could only select one photo at a time
Any issues with off-line survey collection (simulated with airplane mode if needed)?	Free text	- Worked well - Easy
Was the wording of the questions clear & understandable?	Free text	- Minor typos
Was the size of the text OK?	Free text	- Could be increased for users of poor vision
Any suggested changes?	Free text	- Feedback on mandatory questions that haven't been answered when trying to submit a survey - Additional options for symptoms (e.g. dieback killed existing pasture, different undesirable pasture now colonising affected area).
Overall impressions?	Free text	- Good - Minor bugs/typos

While some feedback suggested increasing the font size, it is likely users requiring a larger font will already have increased font size as part of their phone accessibility settings. The app respects these settings and adjusts the font size accordingly.

The most common piece of feedback was users being unable to 'submit' their survey. One-on-one discussions identified this was because mandatory questions had not been answered, but this wasn't made

clear to the user. Feedback on what mandatory fields have not yet been filled will be a key improvement in the next version of the app.

All required documentation for the publishing of the App (Privacy Policy and Terms of Service) has now been completed and published online by MLA. Terms of Service are available at https://www.mla.com.au/general/terms-and-conditions---mla-pasture-dieback-app/, and Privacy Policy available at https://www.mla.com.au/general/privacy-policy-mla-pasture-dieback-app/.

The final version of the app is now publicly available for either iOS or Android devices. The project team will be undertaking advertising and media for a public release in March 2021. This is anticipated to be through a range of media (traditional and social) and email newsletters including the Pasture Dieback Industry Network, along with newsletters managed by other research partners such as MLA and the NSW DPI.

4.5 Productivity and economic impact of pasture dieback on a beef business in central Queensland

An economic analysis was conducted to examine the economic implications of pasture dieback, as well as selected short-term treatment options, to a representative grazing business in the Fitzroy region of Central Queensland. The representative business used was the case study model developed by Bowen & Chudleigh (2018) for use in the Drought and Climate Adapation Program (DCAP). The case study model was developed using the Breedcow and Dynama programs based on median herd data for the region from relevant industry surveys and research. Further information about the case study model can be found in the report 'Fitzroy beef production systems: Preparing for, responding to, and recovering from drought'. Alternatively, the model is available online at Breedcow & Dynama (breedcowdynama.com.au). Whilst all details pertaining to the base scenario can be viewed in the DCAP report, some key parameters for ease of reading are noted:

- The case study property is 8,700ha with an assumed carrying capacity of 1490 adult equivalents (AE).
- Self-replacing breeding herd with steers grown out for the feed-on market by their third year.

The Dynama and Investan programs were used to model the difference in profitability (revenue - costs less interest) from the representative case study business, or the 'base scenario', and the same business after implementing the effects and treatment of pasture dieback, or a 'change scenario'. The analysis period comparing the economic impact was over a 10 year period. Two different scenarios of varying pasture dieback severity were modelled along with three different treatment options. Expert opinion of experienced DAF staff and preliminary survey data was used to determine parameters of the study. Survey data collected has shown the average property was required to reduce their stocking rate by 13% due to pasture dieback. This impact was the primary impact assessed in the scenarios. Details of the different severity scenarios are outlined below:

- The moderate impact scenario examined a stocking rate loss of 6.5% (half of 13%) of the herd in the 1st year, followed by the full stocking rate loss of 13% in the 2nd year. The following year the herd begins to recover through natural increase and by the 4th year the herd is back to the full stocking rate.
- The severe impact scenario examined a 50% stocking rate loss of 6.5% (half of 13%) of the herd in the first year, followed by 5 years of the full stocking rate loss to 13%. In the 7th year the herd begins to recover through natural increase and by the 8th year the herd is back to the full stocking rate.

Two separate short-term treatment options, insecticide treatment scenarios and a prescribed burning treatment scenario, were modelled and compared against both the moderate and severe impact scenarios. Details of the treatment scenarios are outlined below:

- The first insecticide scenario modelled a generic insecticide costing $52/ha plus an application cost of $12/ha, totalling $64/ha. The total affected area of the case study business is 1,131ha (13%) which costs the treatment at $72,384, applied in the first year. This scenario had a stocking rate loss of 6.5%

in the first year, but it is assumed the treatment has an immediate effect and therefore the 2nd year is in recovery and returns to the full stocking rate in the 3rd year.

- The second insecticide scenario modelled the more expensive Movento® insecticide, costing $105.10/ha plus an application cost of $12/ha, totalling $117.1/ha. Spread over 1,131ha, this costs the treatment at $132,440, applied in the first year. This scenario had the same herd stocking rate as the first insecticide scenario.
- For the prescribed burning treatment scenario, 13% of the herd was agisted for 6 months (24 weeks) at the beginning of the wet season to allow the pasture to recover after being burnt. Assuming 194 AE are agisted over 24 weeks at $5 per AE, that costs the treatment at $23,280, applied in the first year. This scenario had no stocking rate loss due to the agistment. It should be noted that fire as a treatment for pasture dieback requires further validation.

The assumptions regarding the modelling are noted below:

- There is a key assumption regarding the treatments options that a response occurs only if pasture rehabilitation occurs, and/or any pathogenic organisms (insects, fungi, viruses etc.) present within or on the pasture plant at the time are fully affected by the treatment option.
- Two year old steers were destocked to reach the required AE carried rather than selling any breeders which would have a major impact on herd dynamics. This was done for two reasons. The first was that producers generally sell male cattle in periods of destocking and secondly, there were enough steers to destock to satisfy the required numbers.
- A 13% impact to herd stocking rates equates to 13% of land impacted.
- The pasture in other paddocks of the property is in good enough condition to withstand additional grazing pressure for 14 days in the insecticide treatment options, to account for the grazing withholding period.
- A discount rate of 5% was applied over the 10 year analysis period to represent the opportunity cost of funds to the business.

4.5.1 Economic impact of pasture dieback on the base scenario

The results from the two scenarios are summarised in Table 25. The net present value (NPV) results approximate the change of profit from the case study business and the peak deficit is the maximum accumulated difference in cash flow over the 10-year analysis period. A negative NPV does not necessarily indicate that the alternative scenario is unprofitable, only that it is less profitable then the base scenario. The $/ha/yr columns indicate the cost per hectare per year to the business spread over both the affected dieback area (1,131ha) and also spread across the total property area (8,700ha).

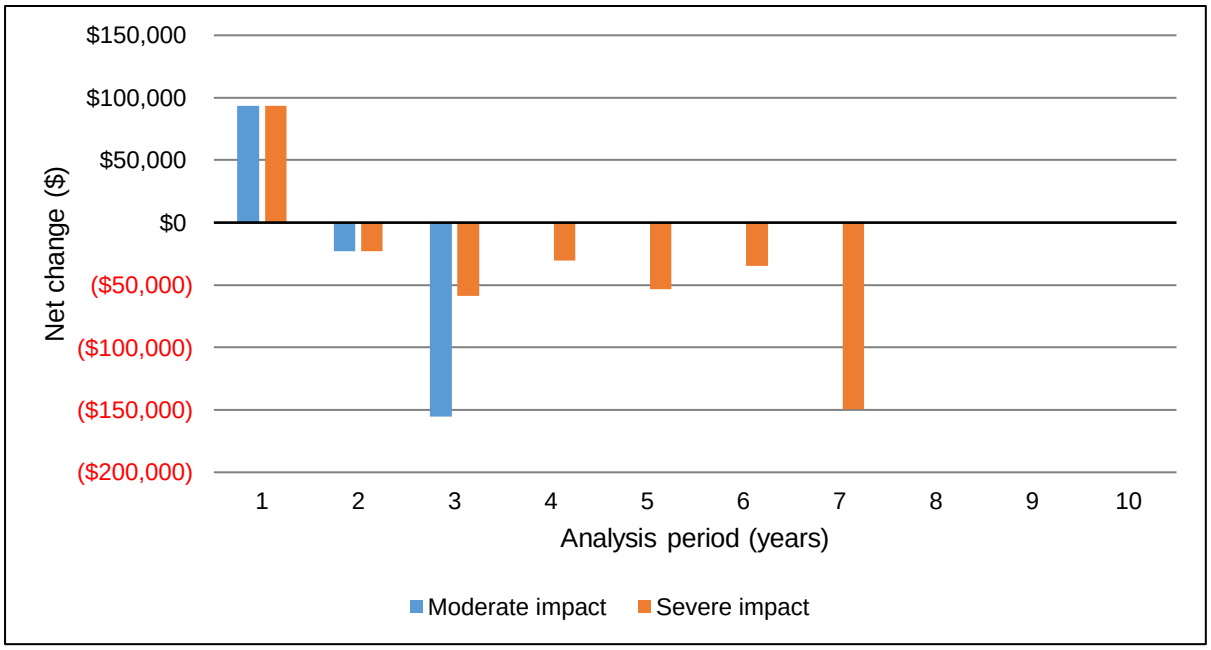
Table 25. Economic impact of dieback on the representative grazing business

Scenario	NPV of change	Peak deficit	$/ha/yr of affected area	$/ha/yr of total property
Moderate impact	-$66,320	-$108,029	$7.59	$0.99
Severe impact	-$181,701	-$295,972	$20.81	$2.70

Fig. 29 presents the net change in wealth from the base scenario for the moderate and severely impacted scenarios with the solid line at $0 representing the base scenario. As can be seen, there is an initial cashflow

benefit from destocking however this declines due to lack of sales as stocking rate declines in subsequent years. To note, year 3 (moderate scenario) and year 7 (severe scenario) suffers a large cashflow deficit compared to earlier years as it is the year that the herd recovers and forgoes more sales to do so. Another compounding factor is that selling the 2yr old steers does not achieve revenue as high as the 3yr old steers in this model.

Figure 29. Net wealth change from base scenario.



4.5.2 Economic impact of short-term treatment options on pasture dieback affected scenarios

The results of the treatment scenarios are summarised in Table 26.

Table 26. Economic impact of pasture dieback treatment options

Scenario	NPV of change	Peak deficit	Year of peak deficit	Payback period (years)
Moderate impact pasture dieback treated with generic insecticide	-$33,590	-$185,021	2	n/a
Severe impact pasture dieback treated with generic insecticide	$81,791	-$185,021	2	6
Moderate impact pasture dieback treated with Movento®	-$90,786	-$248,080	2	n/a
Severe impact pasture dieback treated with Movento®	$24,594	-$248,080	2	6
Moderate impact pasture dieback treated with prescribed burning	$44,149	-$116,606	1	2
Severe impact pasture dieback treated with prescribed burning	$159,530	-$116,606	1	4

The negative NPV for treating moderately impacted dieback with either insecticide treatments indicate that if the stocking rate loss is low and recovery rate is quick, it would not be worth investing the capital in treatment costs. The severely impacted scenarios have a positive NPV as the missed cashflow is greater due to a longer time impacted by dieback. As a result, being able to restore the stocking rates quicker via treatment options results in a larger, positive NPV.

Figure 30 presents the total AE's carried for each scenario (note the prescribed burning treatment had the same stocking rate as the base scenario).

Figure 31 and Figure 32 present the net change of the treatment scenarios for both the moderate and severe impacted pasture dieback scenarios.

Figure 30. Total AE's carried for each dieback scenario

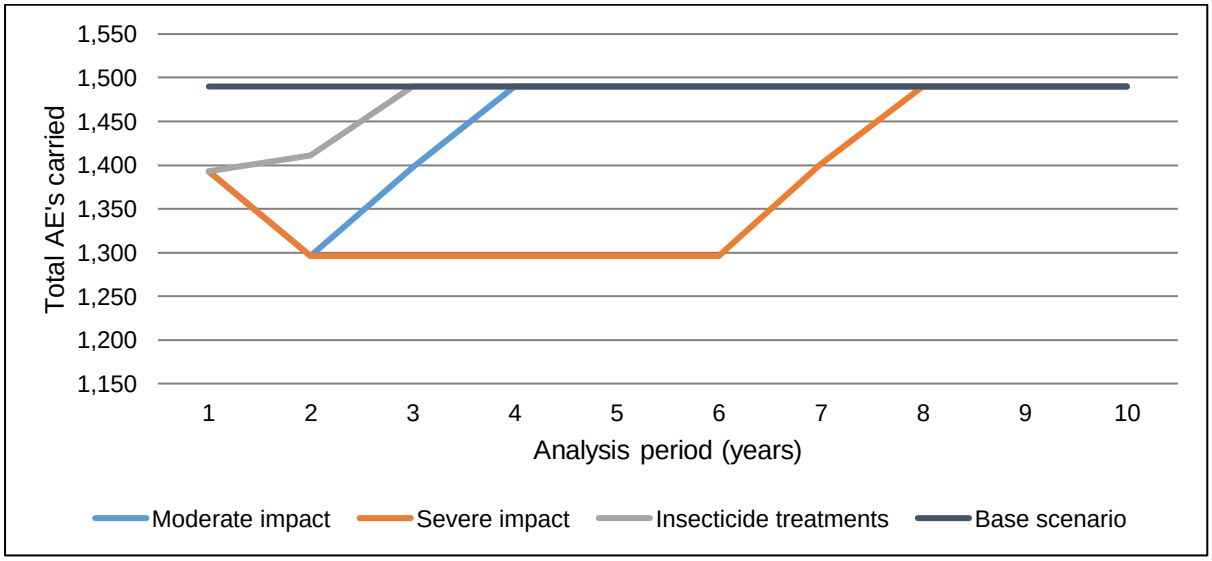


Figure 31. Net change of treatment scenarios from the moderate impact scenario.

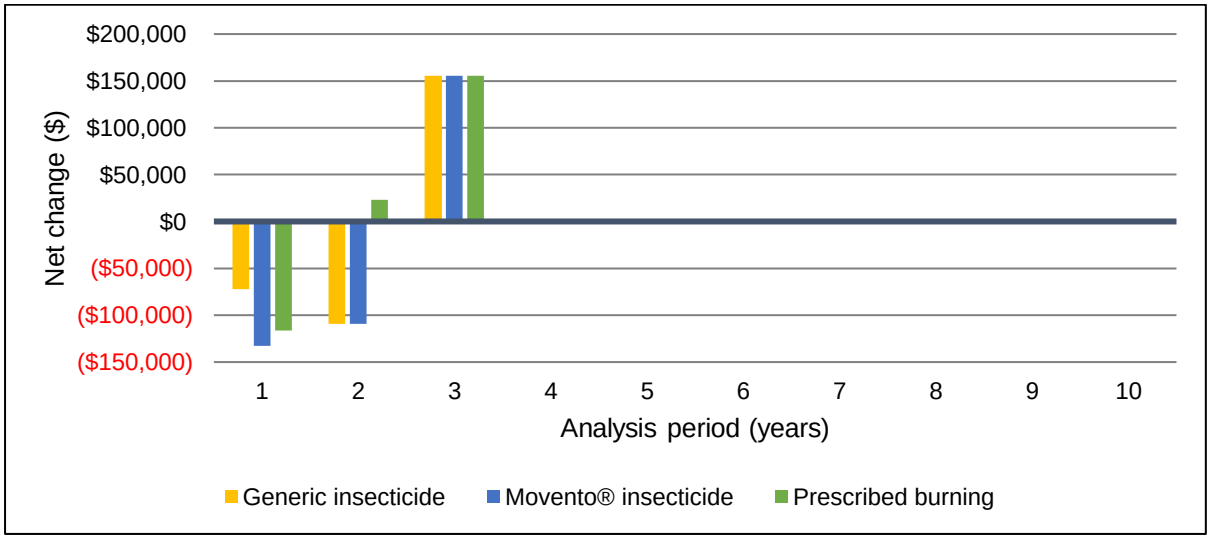
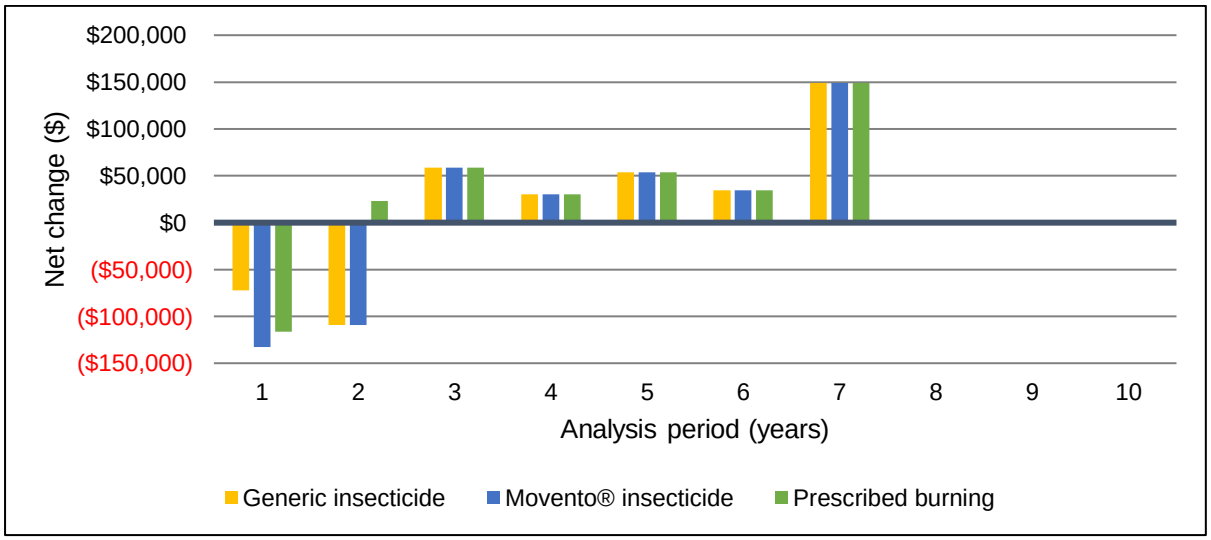


Figure 32. Net change of treatment scenarios from the severe impact scenario.



The economic cost of pasture dieback reported here may change significantly depending on the individual circumstance and management response. For example, if the scale of impacted pasture was larger than modelled here, this would result in a higher stocking rate loss and therefore the missed cashflow and treatment costs would increase. Similarly, if different classes of stock were destocked (e.g. breeders) the impact to the herd structure could incur greater economic costs in the recovery period. Furthermore, one treatment of insecticide may not be 100% effective, necessitating a second application that could result in a doubling of costs and a likelihood of perverse economic outcomes. Due to the range of variables that impact on the outcome of the analysis, it is recommended that a producer seek individual expert advice regarding which treatment options, if any, are best suited to their circumstance.

Whilst pasture dieback does incur economic costs it also presents an opportunity to introduce improved pastures and/or cropping. Pastures impacted with dieback potentially need to be destocked, as is the case of establishing improved pastures. As a result, if a producer were to establish improved pastures whilst destocked from pasture dieback then the opportunity cost is lessened. Recent economic analysis from the DCAP report (Bowen & Chudleigh, 2018) and analysis done for high-quality forages (Bowen & Chudleigh,

2019) show the profitability of establishing and grazing different pastures and crops in Central Queensland. The analyses show perennial legumes as the most profitable option, particularly Leucaena where it is suitable to grow.

Once more treatment response and effectiveness data from the pasture dieback trials has been obtained, the information presented in this preliminary analysis can be confirmed. Further economic analysis can then be conducted on the various treatment options including a longer-term approach to the analysis.

5. Conclusion

Based on the level of engagement achieved with both graziers and beef industry representatives, this project has exceeded milestone targets. In 16 months, the project team have been involved in 43 engagement activities including: 27 live events, 8 written pieces, 4 fact sheets, 1 identification guide and 3 TV interviews. Fourteen targeted extension events were developed and delivered by the project team. A total of 333 participants attended these events (workshops and field days), of which 317 were graziers who manage more than 1.57 million hectares of grazing land. An industry network has been established and maintained, comprising of 297 graziers and industry representatives. Furthermore, six producer-host trial sites have been established and can be used into the future for long-term monitoring of pasture dieback management options. Finally, a smart-device app has been developed and released to report pasture dieback occurrence.

Economic analysis of the impact pasture dieback can have on a typical central Queensland beef business demonstrates a loss of over $66,000 with moderate level of impact (four years of reduced stocking rate) versus over $181,000 with a severe level of impact (eight years of reduced stocking rate) over a 10 year period. This equates to an economic impact of $7.59 and $20.81/ha/yr of affected area for each scenario.

Overall, feedback from targeted extension events indicates a substantial increase in participants' ability to identify pasture dieback and develop management strategies for affected areas, thereby achieving the aims of this project.

5.1 Key findings

The key findings of this project include:

- Graziers affected by pasture dieback are actively seeking information about:
    a. how to identify pasture dieback
    b. what is causing pasture dieback
    c. what can be done about pasture dieback.
- Through this project:
    a. graziers have increased their ability to correctly diagnose pasture dieback
    b. graziers have increased knowledge of the range of potential casual agents of pasture dieback are, and which ones are more likely
    c. graziers have increased knowledge and skills to decide appropriate and effective management practices applicable to their situation.
- A diverse range of extension methods is needed to communicate messages to a large and broad range of stakeholders in different geographic locations.
- Multiple management options which can provide reliable outcomes are available for graziers to restore pasture productivity. While knowledge is still evolving, enough is known for graziers to have confidence in specific management practices.

- The area affected by pasture dieback is dynamic; previously unaffected pastures are being affected while affected pastures are recovering.
- It is likely that pasture dieback will be a permanent condition into the future that graziers will need to consider and manage from time-to-time.
- It is apparent the area affected by pasture dieback and the level of impact will vary from year to year, and from district to district.
- Grass pastures affected by dieback can eventually recover. What is unknown is how long recovery will take and what grass species will re-establish. Management practices used during pasture dieback may impact the speed of recovery. Which species regenerates will be influenced by the degree of dieback (i.e. how much of the original pasture survives) and the species composition of the soil-seedbank.
- Based on current knowledge, graziers will not be able to cost effectively beat pasture dieback on typical commercial sized grazing areas by directly targeting a pathogenic organism(s).
- Solution(s) to manage this condition will be altering pasture management using known practices and techniques. The key aspects involve the inclusion of tolerant pasture species, especially perennial legumes, flexible grazing management strategies, and soil fertility management.

5.2 Benefits to industry

The main benefits of this project to industry include:

- Improved knowledge of how to identify pasture dieback in typical situations, as opposed to other pasture conditions that can produce similar symptoms
- Improved knowledge of potential causal agents, and the ones that are more likely
- Improved knowledge and skills of management practices, and the ability to choose the most appropriate option for the situation.

The combined knowledge of these issues and how to address them provide affected graziers the ability to adopt management strategies to:

- Minimise the chance of dieback affecting their property initially
- Reduce the impact that dieback has on their carrying capacity and beef production once dieback occurs on their property
- Minimise the longer-term productivity and economic impact or reduce the potential of dieback re-occurring.

This project has directly and indirectly engaged with many beef industry stakeholders over the short 18 months duration. While pasture dieback is primarily a condition affecting tropical pastures in Queensland, dieback is now reported to be in north-eastern New South Wales. Learnings from research, development and extension activities in Queensland are being utilised to support inter-state graziers affected by this condition. An example is the joint development of the Pasture dieback identification guide developed by NSW DPI and the DAF pasture dieback team.

6. Future research and recommendations

1. The project has successfully implemented multiple industry engagement events and other extension techniques to disseminate results and findings of research to the beef industry. The main method for information dissemination has been the formation of the Pasture Dieback Industry Network (PDIN). It is recommended that this highly valued network is maintained for on-going industry engagement and learning

through the dissemination of research outcomes as new insights are generated. There may be a possibility of extending the network into New South Wales to increase information exchange and learning for a larger number of graziers and industry stakeholders.

2. Feedback from extension event participants demonstrates the value of how the management option information was packaged together into easy-to-understand units. Participants also valued the associated management plan templates highly, especially the planning and operational checklists of what practice to do when. To maximise practice change and adoption of suitable practices, it is recommended that graziers are supported through group and one-on-one engagement processes to ensure the implementation of their management plans into the future. The pasture dieback app can also be utilised during this engagement process to collect location and area impact data.

3. Further to point two, suitability qualified pasture agronomists with high level knowledge of the management of tropical pastures in Queensland are required to effectively undertake the one-on-one engagement needed to achieve practice change. Pasture agronomists also need to be supported by suitably qualified agricultural economists to provide guidance on ensuring the practices espoused for adoption improve business profitability, not just productivity.

4. The short duration of this project has meant insufficient time to generate conclusions from the research field sites. It is recommended future projects have a longer time frame so field trials can generate meaningful outcomes for the industry. While this point was acknowledged and accepted during project development and contracting, it has caused some concern of site co-operators that funding might stop before the trials on their properties generate any meaningful results.

5. It is recommended that any future plans of developing a smart device application (i.e. app) needs to be well considered, planned, and executed. Issues that have arisen when producing this pasture dieback app are related to DAF being the organisation contracted to develop the product while MLA is the holder of the product's IP.

7. References

Bowen, M. K., & Chudleigh, F. (2019). Productivity and profitability of alternative steer growth paths resulting from accessing high-quality forage systems in the subtropics of northern Australia: a modelling approach. Animal Production Science, 1739-1751.

Bowen, M., & Chudleigh, F. (2018). Fitzroy beef production systems: Preparing for, responding to, and recovering from drought. State of Queensland.

Mail Chimp (2019) *Average email marketing campaign stats of Mailchimp customers by industry*. https://mailchimp.com/resources/email-marketing-benchmarks/

8. Appendix

Pasture dieback management workshop

presented by the

Queensland Department of Agriculture and Fisheries

9 November - Gin Gin 10 November - Gympie 11 November - Esk

12 November – Boonah 13 November - Millmerran

DAF's pasture dieback diagnostic research and grazier engagement activities are co-funded by Meat and Livestock Australia and the Queensland Government.

MEAT & LIVESTOCK AUSTRALIA

Queensland Government

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Links for more information

DAF's pasture dieback information:

https://futurebeef.com.au/knowledge-centre/pasture-dieback/

MLA's pasture dieback information:

https://www.mla.com.au/research-and-development/Grazing-pasture-management/pasture-dieback/

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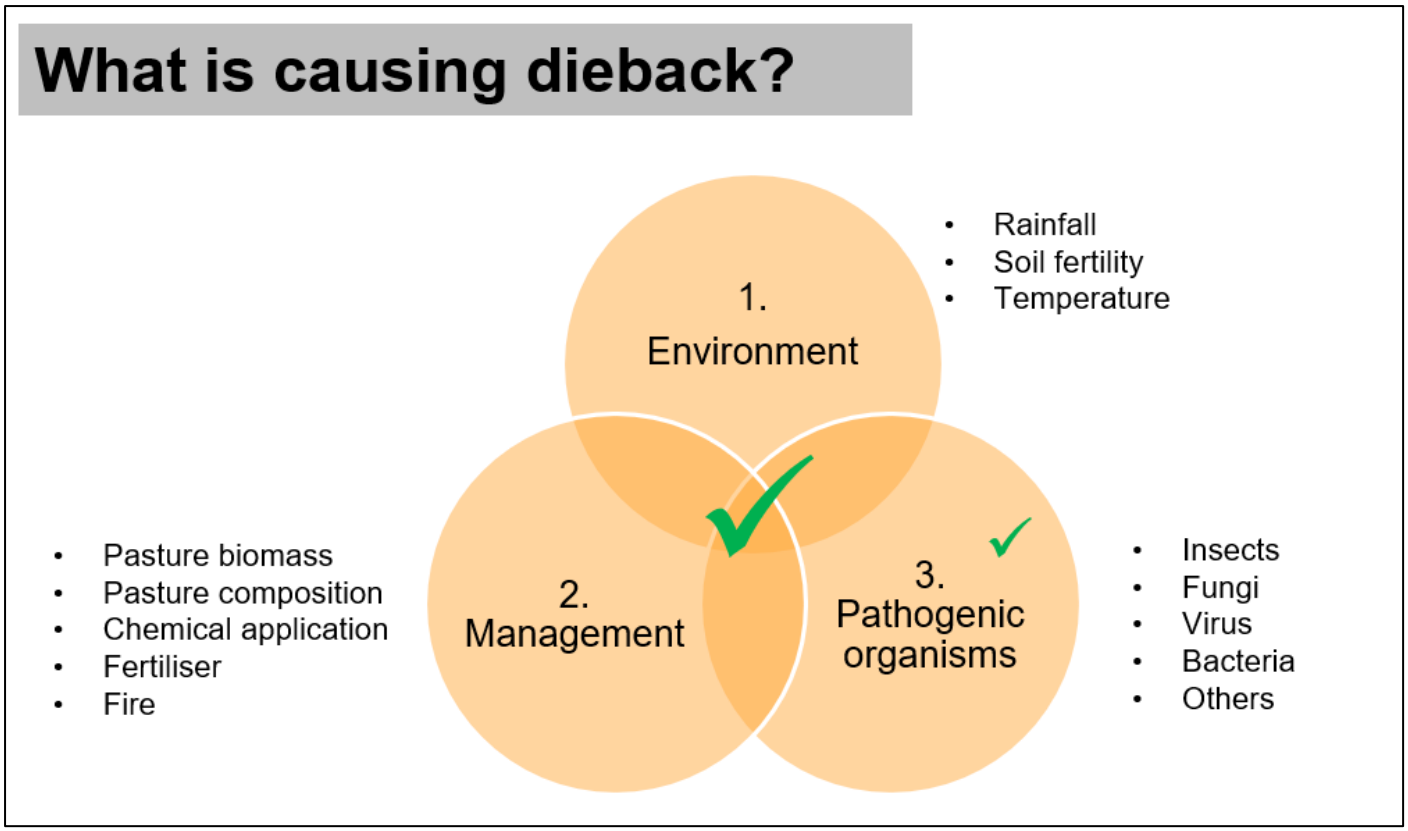
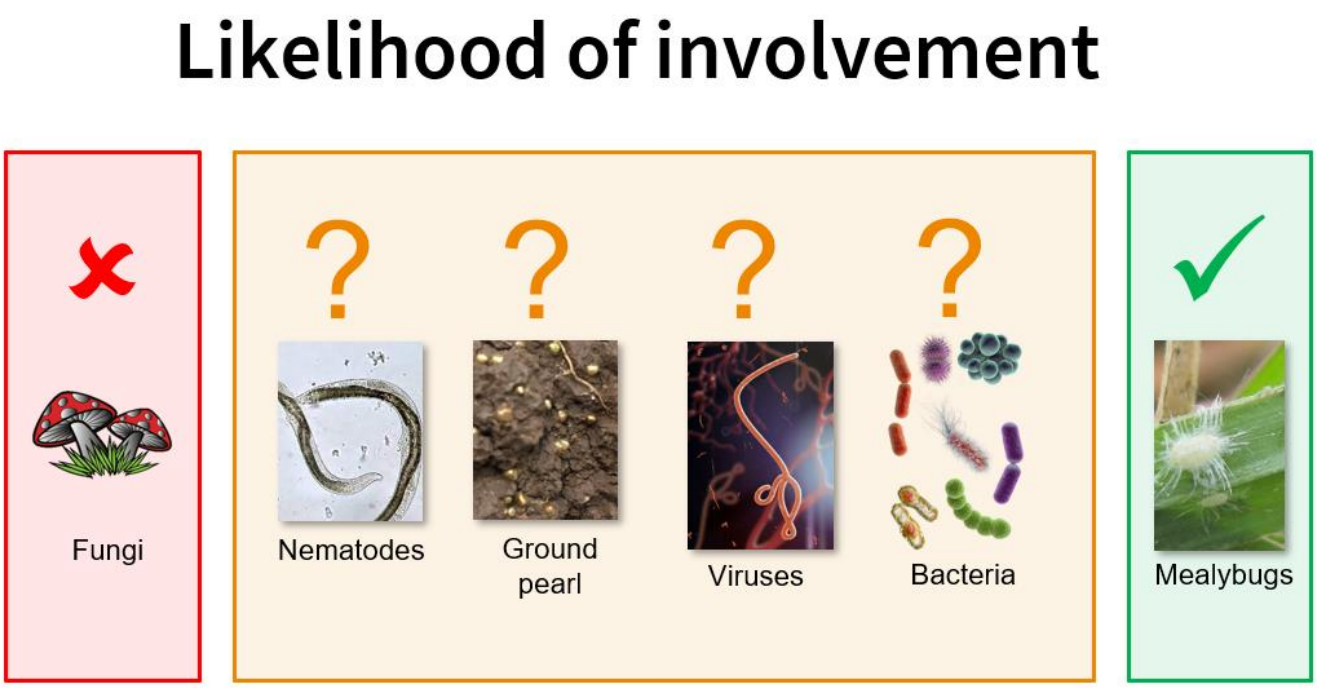
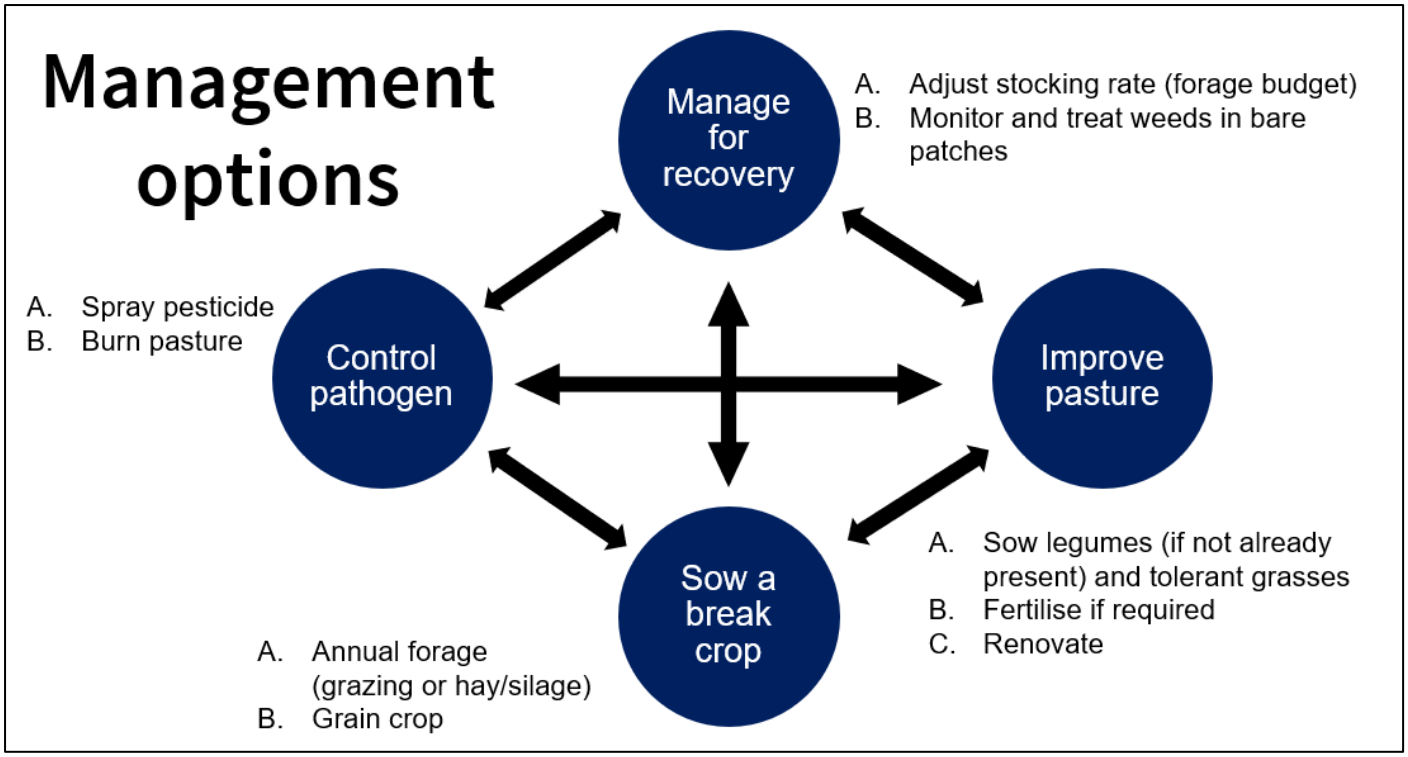

What is causing dieback?
1. Environment
• Rainfall
• Soil fertility
• Temperature
2. Management
• Pasture biomass
• Pasture composition
• Chemical application
• Fertiliser
• Fire
3. Pathogenic organisms
• Insects
• Fungi
• Virus
• Bacteria
• Others


Likelihood of involvement
Fungi
Nematodes
Ground pearl
Viruses
Bacteria
Mealybugs


Management options
Manage for recovery
A. Adjust stocking rate (forage budget)
B. Monitor and treat weeds in bare patches
Control pathogen
A. Spray pesticide
B. Burn pasture
Improve pasture
A. Sow legumes (if not already present) and tolerant grasses
B. Fertilise if required
C. Renovate
Sow a break crop
A. Annual forage (grazing or hay/silage)
B. Grain crop

Management option 1 – Manage for recovery

If managing the pasture to naturally recover is your preferred option, there are two practices that can assist the new pasture to recover as quickly as possible:

A. Adjust stock numbers to match pasture growth with the Forage Budget process
B. Control unwanted weeds to encourage a new pasture to quickly establish without moisture and nutrient competition from weeds

A. Adjust stocking rate (forage budget)

A forage budget is a tool to determine how long a paddock of grass will sustain a number of cattle for a certain time. It assists in planning cattle movements between paddocks and aids in record keeping of pasture condition. There are 5 main steps in forage budgeting:

1. **Make a plan**
   Determine what the plan for the paddock is. How big is it? How long will the grazing period be? How many head in the mob and what weight are they?
2. **Assess pasture supply**
   Pasture photo standards are the best way to do this. Pasture photo standards can be downloaded for free and printed from the following two sources:
   - FutureBeef website: https://futurebeef.com.au/knowledge-centre/pasture-photo-standards/
   - FBA website: https://www.fba.org.au/fba-releases-pasture-budgeting-in-central-queensland-book/
3. **Determine cattle demand**
   Convert cattle weights to Adult Equivalent ratings based on their weight and status.
4. **Calculate results**
   Determine whether the grass will be in excess or deficit, how many AEs the paddock can run in the chosen time frame, or how many days the paddock will sustain the mob.
5. **Reassess**
   Before the end of the graze period, check the feed supply in the paddock to check the accuracy of the forage budget.

FORAGE BUDGET

Property: **Paddock name:** **Date:**

			Units	Eg.	Your paddock	Explanation/ Manual calculation steps
Your plan	A	**Paddock size**	ha	500		Paddock size in hectares (1 hectare = 2.47 acres)
	B	**Date cattle go in**	date	1/04/2020		Date when cattle enter paddock
	C	**Date cattle go out**	date	30/06/2020		Date when cattle exit paddock
	E	**Length of grazing period**	days	90		**= C - B**
	F	**Number of head**	Number	300		Number of cattle you wish to graze
	G	**Cattle weight at entry**	kg	575		Cattle liveweight when they enter the paddock
	H	**Cattle weight at exit**	kg	625		Cattle liveweight when they exit the paddock
	I	**Average cattle weight for grazing period**	kg	600		**= (G + H) ÷ 2**
Pasture supply	J	**Pasture yield at the start**	kg/ha	2700		Estimate of current pasture bulk based on pasture photo standards or cutting and weighing samples
	K	**Percent leaf drop**	%	15%		Estimate the amount of leaf drop/ litter. Generally 15% in extensively grazed systems; may be more where annual plants dominate or under high density grazing.
	L	**Leaf drop**	kg/ha	405		**= J x K**
	M	**Percent unpalatable pasture**	%	10%		Estimate of unpalatable pasture ie. Wiregrass, Giant Rats Tail grass and/or old dead material.
	N	**Unpalatable pasture**	kg/ha	270		**= J x M**
	O	**Desired residual after grazing**	kg/ha	1000		How much grass do you want to retain in the paddock after grazing to ensure there is sufficient pasture to respond quickly to rainfall? 1000 kg/ha is recommended as a conservative residual.
	P	**Total useful available pasture**	kg/ha	1025		**= J -L - N - O**
Cattle demand	Q	**Adult equivalent rating**	Number	1.24		Use Adult equivalent table over page
	R	**Number of Adult equivalents (AE)**	Number	372		**= F x Q**
	S	**Percentage of liveweight cattle will eat over the grazing period**	%	2.2		Cattle eat a percentage of their liveweight every day. On highly digestiable diets (peak of wet season) they can eat 3% of their liveweight, but on poorly digestible diets (worst of the dry season)they can eat as low as 1.5% of their liveweight. If you are unsure of the digestibility of the diet, you can use a conservative average figure of 2.2% for a whole year.
	T	**Daily intake per AE**	kg	10		**= 450 x S**
	U	**Total mob intake/day**	kg	3720		**= T x R**
	V	**Total pasture demand/ha over grazing period**	kg/ha	670		**= U x E ÷ A**
Results		**Excess or deficit of pasture**	+/- kg/ha	355		**= P - V**
		Number of AEs paddock will carry to end date	Number	569		**= P x A ÷ E ÷ T**
		Days feed will last with current AE	Number	138		**= P x A ÷ U**

OBSERVATIONS

Pasture dominated by: _____

Ground cover %: _____ **Grazing/spelling history:** _____

Rainfall: _____ **From:** _____ **To:** _____

Notes:

Adult equivalents

Adult equivalents (AE) are the common unit used to describe the intake of all classes of cattle, relative to a standard weight.

1 AE = 450 kg dry animal

		Example	
Average liveweight (kg) for grazing period	AE rating	Class of animal	Number in a paddock that can carry 50 AE
100	0.32		
150	0.44		
200	0.54	Weaner	50 ÷ 0.54 = 92
250	0.64		
300	0.74		
350	0.83		
400	0.92	Steer	50 ÷ 0.92 = 54
450	1.00		
500	1.08	Lactating cow	50 ÷ 1.38 = 36
550	1.16		
600	1.24	Bullock	50 ÷ 1.24 = 40
650	1.32		
700	1.39		
750	1.47		
800	1.54		
850	1.61		
900	1.68	Bull	50 ÷ 1.68 = 29

For breeding females of any weight, always add 0.3 AE to their AE rating to account for the increase in intake needed for gestation and lactation.

B. Monitor and treat weeds in bare patches

Broadleaf weeds commonly colonise areas where the pasture has died out. Where practical, controlling these weeds can accelerate the recovery of a new pasture. The range of weeds that might be seen are usually what's commonly found in your district, and so can vary from one district to the next.

Components	Details	Cost
Weed pressure (circle)	HIGH MEDIUM LOW	
Weed species present	Primary weed: Secondary weed: Tertiary weed:	
Chemical to use (ensure product(s) are registered first)	Primary weed: Secondary weed: Tertiary weed:	
Chemical rate (L/ha; g/ha)	Primary weed: Secondary weed: Tertiary weed:	
Wetter (if any)	Primary weed: Secondary weed: Tertiary weed:	
Grazing withholding / exclusion period(s) (days, weeks)	Primary weed: Secondary weed: Tertiary weed:	
Machinery required		
Timing of application	Month: Time of day:	

LPA record keeping templates can be found here, including chemical register and recording of chemicals used on crops and livestock feed:

https://www.integritysystems.com.au/on-farm-assurance/record-keeping/

Management option 2 – Improve pasture

A. Sow legumes and tolerant grasses

Grazier experience and research conducted to date indicate sowing resistant plants (e.g. legumes) are one of the most effective ways to restore paddock productivity, both for the short and long term. Adding tolerant grasses should also be considered.

Susceptibility of grasses to pasture dieback

Legume suitability to soil and climate types

Well adapted	Adapted	Not adapted

Climate	Legume	Very Heavy Clay (Puggy)	Heavy clay	Clay	Clay-loam	Sandy Loam	Sand
Tropical	Desmanthus						
	Caatinga stylo						
	Butterfly pea						
	Leucaena						
	Shrubby stylo						
	Caribbean stylo						
	Fine-stem stylo						
	Round-leaf cassia (Wynn)						
	Siratro						
	Lotononis						
	Glycine						
Temperate	Woolly-pod vetch						
	Lucerne						
	Medics						
	Serradella (yellow)						
	White clover						

Pasture establishment			
Stage	**Components**	**Practice**	**Cost**
Planning	Which paddock	Paddock name: Area: Soil type: Phosphorus: Sulfur: Potassium: Zinc: Other:	
	Which type and species (legume & grass)	Species & variety:	
	What method (whole paddock/strips)	Method:	
Fallow	Starting time	Month:	
	Cultivation	Machinery required: Number of passes:	
	Spray	Machinery required: Number of passes:	
	Fertiliser	Product: Rate: Total fertiliser required: Machinery required:	

Stage	Components	Practice	Cost
Sowing	Sowing time	Month:	
	Seeding rate	Rate: Total seed required:	
	Rhizobium	Strain: Formulation: Application method: Total inoculant required:	
	Insect control		
	Sowing method (Broadcast/drill)		
	Machinery required		
Early growth	Weed control		
	Grazing timing		
	Insects		
Survival and thickening	Grazing management		
	Control weeds if present		
Long term production	Grazing management		
	Fertiliser		

B. Fertilise

Conducting a soil test and then fertilising accordingly will ensure no soil nutrients are limiting for pasture recovery.

Fertiliser only		
Components	**Details**	**Cost**
Soil nutrient status	High Adequate Low Unsure	
Nutrient(s) required	Nutrient 1: Nutrient 2: If unsure, where to get soil test done:	
Fertiliser product(s)	Product 1: Product 2:	
Fertiliser rate (kg/ha)	Product 1: Product 2:	
Machinery required		
Timing of application	Month:	

C. Renovate

Pasture renovation through cultivation accelerates nutrient cycling.

Renovate only		
Components	**Details**	**Cost**
Whole or part paddock (Circle)	Whole Part	
Area (ha/acres)		
Where will cattle be moved to during and after the renovation?		
Timing	Month:	
Cultivation	Machinery and implement required:	

Management option 3 – Sow a break crop

Sowing a break crop, such as annual forage for grazing or hay, or grain crop, could be beneficial to fill a short-term feed-gap or to create cash flow. Sowing these could also break the pathogen cycle and improve the health and performance of a subsequent perennial pasture.

Crop establishment			
Stage	**Components**	**Practice**	**Cost**
Planning	Which paddock	Paddock name: Area: Soil type: Phosphorus: Sulfur: Potassium: Zinc: Other:	
	Which type and species	Species & variety:	
	What method (whole paddock/strips)	Method:	
Fallow	Starting time	Month:	
	Cultivation	Machinery required: Number of passes:	
	Spray	Machinery required: Number of passes:	
	Fertiliser	Product: Rate:	

		Total fertiliser required: Machinery required:	

Stage	Components	Practice	Cost
Sowing	Sowing time	Month:	
	Seeding rate	Rate: Total seed required:	
	Rhizobium (if needed)	Strain: Formulation: Application method: Total inoculant required:	
	Insect control		
	Sowing method (Broadcast/drill)		
	Machinery required		

A. Graze for fodder

Graze for fodder	
Components	**Details**
Area (ha/acres)	
Yield assessment	
Start of grazing	Date:
End of grazing	Date:
Number of head	
Expected weight gain	

A. Hay or silage production

Hay/silage production			
Stage	**Components**	**Practice**	**Cost**
Early growth	Weed control		
	Insects		
Cut	Cut timing		
	Machinery required		
Rake	Rake timing		
	Machinery required		
Bale	Bale timing		
	Machinery required		

B. Grain crop

Grain production			
Stage	**Components**	**Practice**	**Cost**
Early growth	Weed control		
	Insects		
Harvest	Harvest timing		
	Machinery required		

Management option 4 – Control pathogen(s)

Treating the pasture with pesticides or burning to control pathogenic organisms, could assist the pasture to recover. Several insecticides are available via AVPMA emergency permits for pasture mealybug control and so can be legally used.

A. Spray pesticide

Pesticide application		
Components	**Details**	**Cost**
Any pathogens present (list)	Insects on plants: Insects in the soil: Fungi:	
Chemical to use (ensure product(s) are registered first)	Insects on plants: Insects in the soil: Fungi:	
Chemical rate (L/ha; g/ha)	Insects on plants: Insects in the soil: Fungi:	
Wetter (if any)	Insects on plants: Insects in the soil: Fungi:	
Grazing withholding / exclusion period(s) (days, weeks)	Insects on plants: Insects in the soil: Fungi:	
Machinery required (list)		
Timing of application	Month: Time of day:	

Pasture mealybug control in pastures

Summary of permits issued by Australian Pesticides and Veterinary Medicines Authority (APVMA).

The permits summarised are:

PER87423, PER88428, PER90238, PER90239 and PER90263.

Document created 15th of March, 2021.

Queensland Government

This publication has been compiled by Stuart Buck and Katie Thomas of Agri-Science/Animal Science, Department of Agriculture and Fisheries.

Permit #	Holder	Insecticide	Pasture situation	Grazing management prior to/at spraying	Mealybug situation	Application requirements	Grazing withholding period (WHP)	Export slaughter interval (ESI)	Who can use the product under the permit	Approx. cost/ha (GST excl)
PER87423	MLA (c/o Agaware consulting)	**Imidacloprid** 200g/L; 350g/L; 700g/kg formulations. Trade names: Confidor; Kohinor; Senator. Rates: 2.5L/ha; 1.4L/ha; 700g/ha.	Do not treat grass pastures containing dicots. Do not spray if grasses are flowering, or if bees present. Ensure plants and crowns actively growing.	Graze to reduce foliage and expose crown, if needed.	Apply when juveniles first observed. Do not spray if mealybug predators have been released.	Ground application only. Do not treat grass pastures greater than 5 ha. Do not apply more than one application per treatment area. Use 100-150L/ha spray volume depending on pasture density. Apply spray to near point of runoff to ensure thorough coverage of plant surfaces and crown. Apply non-ionic surfactant according to label rates.	Treated area must be fenced for 24 weeks. Do not graze or cut for stock food for 24 weeks after application.	None specified.	Persons generally, NSW and QLD only.	$259 for 10L $25.90/L Cost/ha $64.75 *Costing for 200g/L formulation

Permit #	Holder	Insecticide	Pasture situation	Grazing management prior to/at spraying	Mealybug situation	Application requirements	Grazing withholding period (WHP)	Export slaughter interval (ESI)	Who can use the product under the permit	Approx. cost/ha (GST excl)
PER88482	MLA (c/o Agaware consulting)	**Spirotetramat** 240g/L formulation Trade names: Movento 240 SC Rate: 400mL/ha Plus 1L/ha Hasten spray adjuvant A spray drift minimisation strategy should be employed at all times when applying spray near sensitive areas. Comply with spray drift restraints and record keeping requirements on the product label. When applying near non-target pastures, livestock or land producing feed for livestock, comply with mandatory no-spray zones on the product label. Follow the insecticide resistance warning and restraints on the product label.	Do not spray if grasses are flowering, or if bees present. The sensitivity of some species to be treated under this permit has not been fully evaluated. It is advisable to only treat a small area of plants to ascertain this reaction before treating the whole pasture.	If grazing is required to reduce dead foliage cover prior to spraying, allow sufficient regrowth of foliage prior to application as Movento requires green tissue for uptake. If grazing is not required prior to spraying, ensure plants are actively growing and sufficient foliage is present for Movento uptake.	Monitor pest populations and apply when juveniles (crawlers) are fist observed. Do not spray when pest species are well established. Applications should be made when pest numbers are building rather than when pests are well established. Best results will be obtained when applied to low to moderate pest populations. Do not spray if mealybug predators have been released in the pasture.	Ground application only. DO NOT apply more than 2 applications (foliar spray) per crop. Apply by boom spray with a minimum retreatment interval of 14 days. Apply in total spray volume of 150-300L/ha. Adjust spray volume based on pasture foliage density. Apply spray mixture to near point of run-off to ensure thorough coverage of all plant surfaces and crown of plant.	**DO NOT** graze or cut for stock food for 14 days after application.	3 days. Livestock that have been grazed on or fed treated crops should be placed on clean feed for 3 days prior to slaughter.	Persons generally. NSW and QLD only.	Movento: $731.98 for 3L $244/L Hasten: $150.00 for 20L $7.50/L Cost/ha $105.10

Permit #	Holder	Insecticide	Pasture situation	Mealybug situation	Application requirements	Grazing withholding period (WHP)	Livestock producing milk for human consumption	Export slaughter interval (ESI)	Who can use the product under the permit	Approx. cost/ha (GST excl)
PER90238	NSW DPI	**1. Chlorpyrifos** 500g/L; formulations **2. Chlorpyrifos /Lambda-Cyhalothrin** 300g/L; 15.4g/L formulations Trade names: 1. Lorsban; 2. Cobalt. Rates 1. 900mL/ha; 2. 700mL/ha. Follow insecticide resistance warning and restraints as per label.	The impact of these insecticides on beneficial insects should also be considered prior to use.	Apply when mealybugs are visible in pasture.	Apply by boom spray. Use spray volume of 100L/ha for good coverage. Spray total area affected by mealybug, with a barrier zone of approximately 50m beyond the affected area.	Adhere to WHP as per label. Observe grazing WHP's as specified on label prior to grazing treated pastures or fodder crops/cutting for stockfeed. If over spraying of grazing livestock is unavoidable and occurs, withhold stock from slaughter until export grazing interval (EGI) is met.	Observe the grazing or cutting for stockfeed withholding period specified on the registered product label before grazing lactating dairy stock on treated pastures or fodder crops, or before cutting treated crops as feed for lactating dairy stock.	If cut for stockfeed, do not sell stock that have been fed cut material for export slaughter until ESI has been observed.	Persons generally, NSW and QLD only.	1. $145.46 for 5L $29.01/L Cost/ha $26.19 2. N/A

Chemical	Export Animal Feed Interval (EAFI)	Export Slaughter Interval (ESI)	Export Grazing Interval (EGI)
Chlopyrifos (EC)	Not required	**56 days**	**56 days**
Lambda-cyhalothrin	N/A	**42 days**	**56 days**

Permit #	Holder	Insecticide	Pasture situation	Mealybug situation	Application requirements	Grazing withholding period (WHP)	Livestock producing milk for human consumption	Export slaughter interval (ESI)	Who can use the product under the permit	Approx. cost/ha (GST excl)
PER90239	NSW DPI	**1. Carbaryl** 500g/L formulations **2. Diazinon** 800g/L formulations **3. Malathion** 1150g/L formulations **4. Methomyl** 225g/L formulations Trade names: 1. Kendon; 2. Barmac; 3. Hy-mal; 4. Lannate-L. Rates 1. 2.2L/ha; 2. 1L/ha; 3. 950mL/100; 4. 2L/ha Follow insecticide resistance warning and restraints as per label.	The impact of these insecticides on beneficial insects should also be considered prior to use.	Apply when mealybugs are visible in pasture.	Apply by boom spray. Spray total area affected by mealybug, with a barrier zone of approximately 50m beyond the affected area.	Adhere to WHP as per label. Observe grazing WHP's as specified on label prior to grazing treated pastures or fodder crops/cutting for stockfeed. If over spraying of grazing livestock is unavoidable and occurs, withhold stock from slaughter until export grazing interval (EGI) is met.	Observe the grazing or cutting for stockfeed withholding period specified on the registered product label before grazing lactating dairy stock on treated pastures or fodder crops, or before cutting treated crops as feed for lactating dairy stock.	If cut for stockfeed, do not sell stock that have been fed cut material for export slaughter until ESI has been observed. The label withholding period for grazing only applies to stock slaughtered for the domestic market. Some export markets apply different standards. To meet these ensure ESI and EGI is observed before stock are sold for slaughter.	Persons generally, NSW and QLD only.	1. $427.28 for 20L $21.36/L Cost/ha $46.99 2. N/A 3. $45.10 for 500mL $90.20/L Cost/ha $85.69 4. $145.46 for 5L. $29.10/L Cost/ha $58.20

Chemical	Export Animal Feed Interval (EAFI)	Export Slaughter Interval (ESI)	Export Grazing Interval (EGI)
Diazinon	**14 days**	**14 days**	**28 days**
Carbaryl	**7 days**	**EGI applies**	**7 days**
Malathion (Maldison)	Label WHP applies	Label WHP applies	Label WHP applies
Methomyl	N/A	N/A	N/A

Permit #	Holder	Insecticide	Pasture situation	Grazing management prior to/at spraying	Mealybug situation	Application requirements	Grazing withholding period (WHP)	Export slaughter interval (ESI)	Who can use the product under the permit	Approx. cost/ha (GST excl)
PER90263	NSW DPI	285g/L Potassium salts of fatty acids Trade names: Hitman Soap Insecticide Rate: 1.5 – 3.0L in 100L of water. Comply with spray drift restraints and record keeping requirements on the product label. Comply with all instructions outlined on the product label.	Product may not be suitable for plants under stress. *To avoid crop damage* The sensitivity of some species to be treated under this permit has not been fully evaluated. It is advisable to only treat a small area of plants to ascertain their reaction before treating the whole pasture.	None specified.	Apply only when mealybugs are visible in or on pasture.	Apply as per label instructions. High water volume (at least 100L/ha) are required to give good contact with mealybugs. Use the lower rate in IPM programs. Re-apply 5 to 7 days later or as necessary. Always add a vegetable oil-based spreader/sticker at the recommended rate. DO NOT mix with other chemicals including fertilizers unless a trial mix was conducted. DO NOT use during the hot part of the day. Observe safety instructions as per label. PROTECTION OF WILDLIFE, FISH, CRUSTACEANS AND ENVIRONMENT Very toxic to aquatic life. DO NOT contaminate wetlands or watercourses with this product or used containers.	None specified.	None specified.	Persons generally.	Hitman Soap Insecticide: $111.76 for 20L $5.56/L Certified Allowed Input: ACO Cert. No. 11155

B. Burn pasture

The benefits of fire to address pasture dieback have been mixed, use needs to be carefully evaluated.

Fire		
Components	**Details**	**Cost**
Whole or part paddock (Circle)	Whole Part	
Area (ha/acres)		
Where will cattle be moved to during and after the fire?		
Timing	Month:	

Notes