Final report

EPDS: Using Drones on-farm to monitor sheep welfare

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Abstract

Are drones all they are cracked up to be? Can they save time and money monitoring sheep welfare? These are the sorts of questions the Boort BestWool/BestLamb (BWBL) group wanted to find out during the three-year 'Using drones on-farm to monitor sheep welfare' demonstration.

Using technology to save time and labour is an increasing area of interest for farmers. As such, the Boort farmers looked to measure the practical uses of a drone and identify if the labour requirements to check ewe welfare at lambing using a drone were more efficient than everyday practice. The usefulness of the drone was also assessed for other tasks at other times in the year.

More than 150 videos were recorded from three different drones across three lambing periods (2019, 2020, 2021) and two summer periods (2019,2020). It was observed that sheep stayed calm when the drone was at a distance, or if approached slowly, it could be flown at lower heights between 10-15 metres. When the drone was travelling at speed at any height, the sheep tended to move away from it. The farmers observed that this was due to the sound of the drone.

The trial identified items to consider when looking to purchase a drone and how best to fly it around sheep, information that was previously not available. Ag tech limitations affected the uptake of drones in this trial. However, the drones were found to undertake some tasks on-farm quickly and effectively, such as water trough checks, and they could be used to check ewe and lamb welfare at lambing if approached slowly.

Executive summary

Background

The use of technology to save time and labour is an increasing area of interest for farmers. With drones being used more frequently in agriculture and advertised as the 'next best tech tool farmers should have', the Boort BWBL farmers wanted to see if a drone could be used to check sheep welfare during lambing whilst saving time. There was little to no information available about using drones to check on livestock, particularly sheep. To fill this knowledge gap, the Boort farmers decided to evaluate drone practicality and usefulness by monitoring sheep welfare at lambing and at other critical times in the year to see if the technology reduced time and labour costs normally associated with these tasks.

There was no proforma to suggest which drone might best suit the needs of the farmers or how to use one around sheep. Drone suppliers and farmer observations during the course of the trial were thus relied upon to identify the most appropriate drone and process for checking/monitoring sheep welfare.

Nine producers from the Boort group were directly involved in the trial. With lambing occurring from autumn through to spring, the drones were moved from one property to the next according to their lambing schedule.

Objectives

The overall objective was to assess the practical use of drones to remotely monitor sheep welfare during lambing and at different times in the year. This was to identify if the technology reduced time and labour costs usually associated with these tasks. In addition, the findings were to be extended amongst the group and to the broader public.

The on-farm demonstration successfully increased the farmers' knowledge, skills and confidence in using the drone and allowed them to identify what jobs it could perform on-farm and its limitations. The trial demonstrated, however, that using a drone (any of the brands used in the trial) did not reduce the time and labour costs associated with checking ewe and lamb welfare during lambing due to the camera, battery and farmer limitations.

The trial achieved significant extension success with local, national and international media and farmer and industry interest, thus providing a platform to inform people about the usefulness of drones on-farm to check sheep welfare at lambing.

Methodology

A GoPro drone, followed by the addition of two DJI drones, a Phantom Pro and Mavic Pro were used during the demonstration. These are all off-the-shelf commercial sub-two-kilogram drones. Particular drone brands were not sought as the drone supplier was relied upon to supply the most appropriate drone, particularly in the first year. In year two, a different drone was sought that allowed a longer flying time and could travel further from the operator.

Host producers were trained in using the drone and asked to monitor ewe and lamb welfare of one flock at lambing and at another critical time of the year as identified by the participant, for example, water trough levels in summer or pasture feed on offer.

Producers recorded the time taken to undertake sheep welfare checks during different periods of the year using a drone and undertaking their normal practice as a comparison.

Videos taken while flying the drone were used to determine the height, speed and how the drone affected the ewe, i.e. whether the sheep stayed calm or reacted to the drone.

Results/key findings

More than 150 videos were recorded from the drones across three lambing periods (2019, 2020, 2021) and two summer periods (2019,2020). Video footage from the drones clearly showed when sheep were standing still or moving in response to the drone and at what height or speed this occurred.

Sheep generally ignored the drone was at a distance or when the drone was more than 30 metres overhead and travelling slowly or hovering. The sheep moved away from the drone when it was travelling at speed at any height, which the farmers believed was due to the sound of the drone. In the final year of the trial, farmers approached ewes and lambs with the drone at a lower height (8-15 meters) to see if they would ignore the drone. The sheep were observed to not move away from the drone if approached very slowly.

Unfortunately, the drone cameras used in this trial could not zoom; hence, the drone needed to be lowered until ground-level items could be clearly seen, which could trigger the sheep's flight response. Newer drones now have cameras that can zoom, which may negate the need to lower the drone and disturb the sheep.

The demonstration also looked at whether drones could enable more frequent sheep welfare checks and offered any labour savings. Newer drones like the DJI drones can travel up to 5 km from the operator, although it is a Civil Aviation Safety Authority (CASA) requirement that the operator must always have 'visual line-of-sight. Due to the large paddock size, some of the Boort lambing paddocks exceeded the visual line-of-sight requirement.

The economic outcomes of an investment in a drone to reduce labour and vehicle costs were assessed using partial discounted cash flow budgets over five years. The results showed that an investment in a drone was less profitable than an alternative investment earning 5% for labour-saving scenarios of 0, 5 and 15 minutes compared to using a car.

At the conclusion of the trial, none of the host or observer farmers adopted drones on-farm. Nevertheless, 100% of core producers improved their knowledge, skills and confidence in using the drone and understood what jobs it can and can not perform on-farm.

Despite the trial results, the project attracted significant local and national media, farmer and industry interest. Extension included two field days, six internal and external presentations, three radio interviews, two podcasts and numerous written articles. The project also attracted international interest, with one article being placed in the UK based Farmers Guardian magazine.

Follow this link to see the drone in action https://connection.vic.gov.au/farmers-add-drone-pilot-to-skill-set

Benefits to industry

The benefits and limitations of drones for checking sheep welfare at lambing were identified. The results from the trial indicate aspects to consider when looking to purchase a drone (i.e. camera – does it zoom?) and how best to fly it around sheep. This information and knowledge did not previously exist, perhaps why it created so much interest in the demonstration. Nevertheless, the drones in their current format may be of great value in hilly regions or in spots that are difficult to access in other ways or be used on farms with smaller paddocks.

Today, drone technology has progressed to a point where some of the limitations identified in the trial would not exist. The technological advances seen in drones today may have been the catalyst for farmers to adopt this technology. For example, drone cameras have zoom capability, enabling the farmer to fly the drone quickly at height and still have a good view of ground-level items. Furthermore, new drones can fly for up to 45 minutes compared to the trials 15 minutes.

Future research and recommendations

Overall the demonstration found that the drones used in this trial can be used to undertake some tasks on-farm quickly and effectively, such as water trough checks. They can be used to check ewe and lamb welfare at lambing, but in this trial, the lack of zoom ability on the camera, limited battery life. Loss of visual line-of-sight in some of the large lambing paddocks also impacted their overall usefulness to perform this task.

With drone advancements in technology, future research should look to support new drone on-farm trials to determine if the newer technology can save farmers labour and time to check sheep welfare at lambing in the same environment or determine if it is better suited to farms with smaller or hilly paddocks.

PDS key data summary table

Project Aim:
To assess the practical use of drones to remotely monitor sheep welfare during lambing and at other critical times in the year to see if the technology reduces the time and labour costs normally associated with these tasks.

	Comments		Unit
Number of core participants engaged in project	Includes host producers	6	
Number of observer participants engaged in project	Includes other group members (does not include field day attendances)	7	
Total field day attendances **Other presentation attendances** **Group meeting attnedances**		75 141 98	
Core group no. ha		10753	
Observer group no. ha		11105	
Core group no. sheep		12500	hd sheep
Observer group no. sheep		11400	hd sheep
Core group no. cattle		0	hd cattle
Observer group no. cattle		0	hd cattle
% change in knowledge – core		295%	
% change in skill & confidence – core		418%	
% practice change adoption – core		0%	
% practice change adoption – observers		0%	
Key impact data			
Reduction in expenditure Reduction in labour i.e. DSE/FTE,	**There were no savings in the reduction in labour**		
Labour savings from drone use (minutes/day)	0 minutes	5 minutes	15 minutes
Net present value at 5% discount rate	-$3,085	-$2,453	-$1,191

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1 Background

Time is a valuable resource that many farmers lack. Farmers spend many hours on critical, yet time-consuming tasks such as checking sheep welfare during lambing. Summer tasks may include monitoring stockwater levels and quality (via colour) and pasture or crop stubbles feed on offer regularly, if not daily.

Sheep are often run in flocks of 200-300 and spread across many paddocks situated across a farm, sometimes several kilometres apart. As such, welfare checks can consume many hours of a farmer's time. Furthermore, these welfare checks can often occur at times when other farm activities, such as crop sowing or harvesting, are critically time-dependent and often take priority.

Farmers generally monitor and visually assess ewe welfare at lambing once or sometimes twice daily. This visual assessment can disturb lambing ewes and cause mismothering, particularly if the ewes associate a ute with being fed. In summer, sheep welfare may only be observed once a week depending on their age, pregnancy status and the paddock in which they are grazing.

The use of technology to save time and labour is an increasing area of interest for the Boort BWBL group.

Several of the farmers have purchased time-saving devices such as auto-drafts and electronic identification equipment (to record weights for example) to reduce the time and labour costs associated with sheep handling and the collection of data used to make better on-farm decisions.

Drones are being used more frequently in agriculture, mainly for monitoring crops and pastures and the Boort farmers were keen to see if a drone could be used to check sheep welfare during lambing. As there was little to no available information about using drones to check on livestock, in particular sheep, the Boort farmers looked at evaluating their practicality and usefulness by monitoring sheep welfare at lambing and at other critical times in the year to see if the technology reduced time and labour costs normally associated with these tasks.

2 Objectives

The original objectives of the demonstration and outcomes are outlined in Table 1.

Table 1. Demonstration objectives and overall outcomes.

Objectives	Achieved
Demonstration trials across five sites will have measured the practical uses of a drone and identified if the labour requirements to check ewe welfare at lambing using a drone is more efficient vs normal practice by • checking sheep welfare at lambing • identify the level of disturbance to the lambing ewe using a drone vs normal practice	Overall, eight trial sites were established over the three-year trial period. More than 150 videos were recorded checking sheep welfare at lambing and used to determine how the sheep reacted to a drone. All the results are outlined in section 4
80% of core producers and 40% of observer producers will have adopted (or intend to adopt) the drone to check either sheep welfare or be used for another farm practice e.g. check	None of the core or observer farmers adopted a drone at the conclusion of the trial. This is mostly due to the limitations of the drone outlined in section 4

water levels/colour in troughs/dams during summer.	
100% of core producers and 80% of observer producers will have improved their knowledge, skills and confidence in using the drone and understand what jobs it can perform on-farm that is more efficient than normal practice	100% of core producers and 80% of observer producers increased their knowledge and skill in using a drone on-farm. Three observers in the first year trialled the drones in years 2 and 3.
The results of the EPDS will be widely disseminated with targeted extension and adoption activities such as a farmer field day, distribution of social media via BestwoolBestlamb, Ag Vic facebook, online webinar to interested farmers and external providers and internal colleagues.	The demonstration attracted significant media, farmer and industry interest, and some international interest. The results were widely extended to farmers via a field day, online webinars and social media. Refer to section 4.6 and Appendix 1 for a comprehensive list of extension activities.

3 Demonstration Site Design

3.1 Methodology

3.1.1 Producer involvement (Year 1-3)

Host farmer involvement was decided at a Bestwool Bestlamb meeting. Six farmers volunteered to trial the drone in the first year, with a further three farmers trialling the drone in years two and three.

Host producers were asked to monitor sheep welfare of one flock per participant at lambing and at another critical time of the year as identified by the participant, for example, water trough levels in summer or pasture feed on offer. Table 2 outlines the movement of the drone during lambing and summer between farmers.

Producers recorded the time taken to undertake sheep welfare checks during different periods of the year using a drone and when undertaking normal practice. Results were recorded manually and compared to the drone video.

Table 2. Drone movement amongst the group Years 1-3.

The coloured boxes represent the drone's movement during the autumn, winter and spring lambing period and during the summer period from December to March.

	Farm1 Year 1,2,3	F2 Year 1,2,3	F3 Year 1,2,3	F4 Year 1,2,3	F5 Year 1,2,3	F6 Year2	F7 Year2	F8 Year 3
April	Autumn lamb							Autumn lamb
May		A/W lamb						
June			Winter lamb			Winter lamb		
July				W/S				

				lamb				
Aug					Spring lamb		Spring lamb	
Sep								
Dec								
Jan								
Feb								
Mar								

3.1.2 Drone selection and Sheep welfare analysis

There was no proforma on what drone or supplier to approach to best suit the needs of the trial. As such, several drone suppliers were approached and relied upon to supply the most appropriate drone for checking/monitoring sheep welfare during lambing for a competitive rate. In Year 1, the group shared a Go-Pro drone; in Years 2 and 3, two DJI drones, a Phantom and Mavic, were trialled. Refer to Fig. 1 for pictures of each drone.

Figure 1 Pictures of the drones used in the EPDS

Sheep were to be inducted to the drone prior to lambing to limit their flight response. Once some data had been collected and analysed, practises that limited flight response were identified and put in place to trial during the following lambing seasons.

Drone data was captured via video and viewed on a program specific to the drone, on the group coordinator's PC only (Figs. 2 and 3). The video and information on flight times/paths data from the drone were collated and recorded in excel.

The video was used to assess and record the positive and negative aspects of the drone on sheep during welfare checks.

The flight times/paths were used to benchmark and compare the time taken (and economic cost) to undertake sheep welfare checks during different periods of the year (both normal practice and using a drone).

Figures 2 and 3 show the Go Pro and DJI drone dashboards and tools used to determine speed,

height and distance. The key of symbols follow.

Figure 2 Go Pro dashboard

Figure 3 DJI dashboard used to view videos from the Mavic and Phantom drone

Key

1. GPS path: Shows the route taken and the position of the drone as you move along the path
2. Speedometer: This shows how fast the drone is going and includes a compass to show what direction the drone is heading
3. Information: This shows an overview of real-time stats as you watch the drone video
   - Distance: How far the drone travelled
   - Height: how high or low the drone is to ground level
   - Elevation gain: How high the drone is from its starting altitude
   - Date & time: The date & time the drone footage was captured
4. Speed Tracker: This shows the change in the speed of the drone over time. The upwards spike in the graph indicates the drone is accelerating while the down spike is deacceleration. A flat line is hovering

3.2 Economic analysis

The economic effects of an investment in a drone to reduce labour and vehicle costs were assessed using partial discounted cash flow budgets over five years.

3.3 Extension and communication

Yearly:

- Two social media posts (on AgVic's and MLA's Facebook and/or Twitter)
- One media article based on annual outcomes
- One field day or major engagement event open to the public
- Group meeting to review the demonstration and discuss how the project is performing, results and levels of adoption by the group, and any modifications for next year's methodology.

After the EPDS (over the next 12 months):

- Four presentations (face-to-face, phone seminar or webinar)
- Two case studies (print or video)
- One Fact sheet
- One Final report

3.4 Monitoring and evaluation

Monitoring and evaluation were undertaken according to the MER plan (Table 3).

Pre and Post PDS Surveys were filled out by the original core producers.

Field day participants were also surveyed with a standard evaluation form.

Table 3. MER plan

	Performance metrics	M&E process
Engagement	Pre and post Knowledge, skills and confidence Number producers directly and indirectly engaged (+ demographics) Practice change – intended and actual	Pre-project, Mid-point and Post-project verbal and survey of core and observer participants
Productivity	Labour efficiency	Cost-benefit analysis using excel spreadsheet
Profitability	Increased welfare of ewes/lambs due to less disturbance at lambing time Identify the role that drones can undertake on-farm	Video footage was analysed to estimate the effect on welfare Verbal feedback of participants and video footage to identify the role that drones can undertake on-farm

4 Results

4.1 Demonstration site results

4.1.1 Year 1

The first year of the drone demonstration focused on farmers learning to use the technology. Figure 4 shows farmers at their first session learning how to fly the drone in April 2019

Figure 4 Go Pro Drone training April 2019

Lambing period

Five host farmers used the drone from April through to September 2019, with the drone being flown over 50 times collectively. With no proforma on how to fly the drone around sheep, the farmers used trial and error. Sharing one drone meant there was not enough lead time for producers to accustom or induct ewes to the drone adequately prior to lambing, and there was concern that the ewes would scatter, adversely affecting lambing.

The sheep were found to run away from the drone without prior induction; consequently, it was not used again for fear of adversely impacting lambing. This was an unfortunate setback for the project; however, each producer tried and tested the drone and became familiar with it by using it to undertake other farming activities over the lambing period. By doing this, the farmers were able to identify the benefits and weaknesses of the drone for checking ewe welfare over lambing.

Qualitative data was collected in place of quantitative data (e.g. flight times) due to the ewes' inadequate induction period prior to lambing.

The main outcomes at the end of the 2019 lambing period included:

- One farmer found that if the drone hovered rather than travelling quickly, the ewes were less likely to move away from the noise.
- The battery life and range of the drone limited its effectiveness to check ewe welfare across large lambing paddocks.

  Adam, for example, had four lambing paddocks situated together (Fig. 5) of approximately 190Ha

  Ideally, Adam wanted to park in one location (X on the map in Fig 5) and use the drone to fly over all four paddocks without the need to relocate. However, the drone could only be flown a distance of 1km before it reached the edge of its range to communicate with the indicator. To adequately cover all four paddocks without the need for the operator to move, the drone needed to be able to fly 1.6km. This, it was unable to do.

Figure 5 Lambing paddocks are inside the red lines on the given map

- The distance the drone could travel from the indicator operating the drone meant that, in some cases, the drone could not complete a circuit of a large paddock as it reached the limit of its range from the operator. When on the edge of the range of operation, the camera could not be viewed as it became fuzzy

- The drone camera was inadequate to clearly view items at ground level unless lowered to within two metres above ground level.
- Cold mornings experienced during winter lambing (<6 degrees Celsius) impacted the drone's battery, limiting its operation.
- Windy conditions were found to shorten battery life, reducing flying time.

Summer 2019/20

Four of the five farmers used the drone during the summer period due to the drone being out of action from 1 January 2020 until late February 2020 with a software issue.

Twenty-four videos were recorded over the summer period. The drone was mainly used to: check the water level and colour in troughs and dams, irrigation channels and water movement in an irrigated paddock. Some footage was obtained of sheep being trail fed and sheep movement through the sheep yards. As the drone was flown at several different heights during each task, the sheep's response to the drone was recorded.

Summary of results

Farmer observations and video analysis indicated that the sheep remained calm when the drone was at a distance from the flock and/or above 30m and travelling slowly or hovering above them. In contrast, the sheep moved away from the drone when it was lower and/or was travelling at speed at any height (less than 30m).

The Go Pro drone was not well suited to checking ewe welfare during lambing as the camera view at height (high enough to keep the ewes calm) was not very clear.

There was an obvious need for more drone training to make the most of the technology before use.

4.1.2 Year 2

Two new DJI drones – Phantom and Mavic –were trialled from July 2020. The drones utilised the same software, had longer battery life, and travelled further from the indicator compared to the Go Pro. A new drone instruction manual was developed and one-on-one training undertaken with the farmers (Fig. 6).

Figure 6 One-on-one drone training with the farmers

Two new host farmers participated in the trial due to the arrival of the new drones and first-year results (increasing the number of core participants to eight).

Two drones were crashed during the year, resulting in a few weeks of repair time before they could be used again.

It was identified that video subtitles needed to be enabled in the camera settings of the DJI Go App. to capture flight information for analysis. This occurred a few weeks after farmers had received the drones, and as such, some videos could not be analysed as height, speed and other details were missing.

More drone flights occurred than videos recorded. It was assumed that the button to record a video was probably pressed, yet it did not always engage and as the video icon was small it may not have been noticed.

Lambing period

Three farmers used the Go Pro, two farmers had the Phantom and one farmer used the Mavic

Twenty-one videos in total were recorded from the drones

Similar observations and results to the 2019 lambing period were found. Due to the lack of videos that could be analysed (due to no flight data), qualitative data was collected. This is presented in section 4.7.2.

The data collected across the 2020 lambing period revealed that the height and speed that a drone travels at affects the flight response of the sheep. The data from this period is comparable to the summer 2020 and lambing 2019 data.

Summer 2020/21

Six farmers used a drone and twenty videos were recorded undertaking a task.

Informal feedback from the farmers revealed that time constraints limited how often they tested the drone, with many finding it quicker to jump into their car/bike to perform sheep welfare checks.

Tasks performed included paddock pasture/weed checks, water trough and dam checks and ewe and lamb checks.

Summary of results

More drone footage was captured as the farmers became more familiar with the drone controls.
The camera capability from height was still limited, even on the newer and smarter drones; hence the drone needed to be lowered to see ground-level items clearly.
The drone was used less frequently when the farmers were busy, as they found it easier to jump into their car/bike to perform sheep welfare checks than take the drone with them.

4.1.3 Year 3

One new host farmer participated in trialling the drone in Year 3, increasing the number of core participants to nine.
Thirty-nine videos were recorded across six different farms. Two drone runs were pre-programmed autonomous flights to test if it was easier than manual flying.

New dashboard software was purchased to view the flight data from the DJI drones.

Lambing period

Thirty-nine videos across five different farms were recorded.

The drone was flown slowly at a much lower height (8-15m above ground) across a number of different farms to assess how the sheep responded. In general, the sheep were not spooked by the drone when it was flown in this way.

Summary of results

The sheep mostly remained calm and did not move away from the drone when it was flown slowly at a low height. This was particularly important the first time sheep were exposed to a drone. Anecdotally if the drone is flown over the sheep often, they can become trained to not respond to the drone noise. This was not trialled as the farmers lacked time to undertake the task along with enough battery power to ensure enough flyovers.

The DJI drone battery life was around 15 minutes and at the given slow flight speed, it took longer and more batteries to review the whole flock.

4.2 Engagement

Six farmers trialled the drone in the first year and three further farmers trialled the drone in Years 2 and 3.

The drone on-farm demonstration has attracted significant media and farmer and industry interest. It also attracted international interest with an article placed in the UK based Farmers Guardian magazine. Extension and communication metrics are outlined in detail in section 4.6.

4.3 Drone flights and analysis

Overall, more than 150 videos were recorded from the drones across three lambing periods (2019, 2020, 2021) and two summer periods (2019, 2020). The drone was flown more than this, but pictures and videos were not always recorded at the time[1]. Table 4 summarises all the data recorded and shows drone heights and speeds at which sheep stayed calm or moved away from the drones, accompanied with pictures.

All of the drones tended to elicit the same response in the sheep, i.e. no drone brand created a different behaviour response.

Table 4. Summary of drone activity and height (m) above ground level at which the sheep remain calm or move away from the drone.

Drone activity	Figure	Height at which the sheep remained still and calm	Height at which the sheep moved away from drone
Ewe & lamb welfare check Farm 1		13m (Fig. 7)	13m (Fig. 8)

[1] The drone records all flight details on a hard drive within the drone and this shows that the drone had been flown more than the number of pictures or videos recorded on the sim card. Farmers may have simply forgotten to record a video or were practising how to fly and did not turn the video on.

		The sheep still moved, albeit slowly	When the drone was moved at speed (41km/h)
Ewe & lamb welfare check Farm 4		30m (Fig. 9) The ewe is focused on the lamb	30m (Fig. 10) When the drone was moved at speed (45km/h)
Trail feeding sheep in containment Farm 3	Fig. 11	22m The sheep are further away from the drone and are focused on the feed	21m The drone is deaccelerating & is now at 9km/hr
Sheep being worked in yards Farm 3	Fig. 12	16m	The sheep are looking at the drone but not moving
Ewes and lambs walking along a channel bank Farm 5	Fig. 13	9m The drone is moving under 2km/hr	NA
Ewes and lambs in lambing paddock Farm 5	Fig. 14	12m The drone is hovering	NA

Figure 7 Drone just hovering. The sheep are aware of the drone but are moving away slowly. The drone is 13m above ground level.

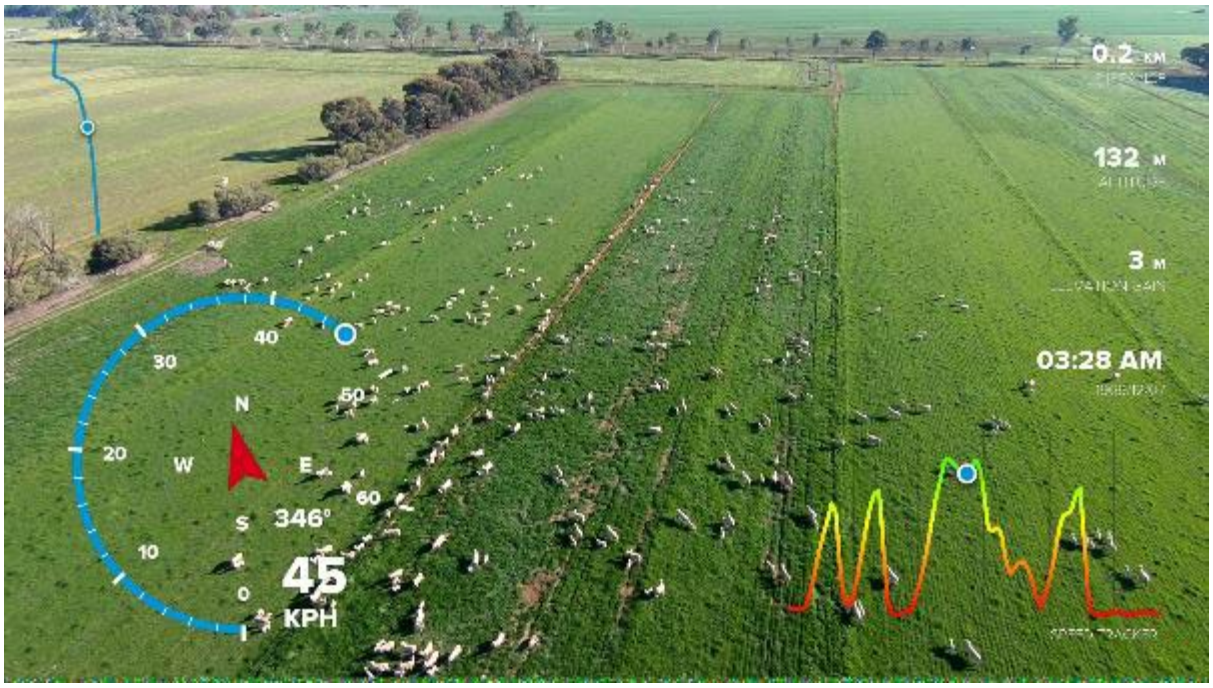
Figure 8 Drone moving at speed (41km/hr)

The drone moving at a speed of 41km/hr has made the sheep run. The drone is 13m above ground level (Fig. 8)

Figure 9 Drone moving at 3km/hr.

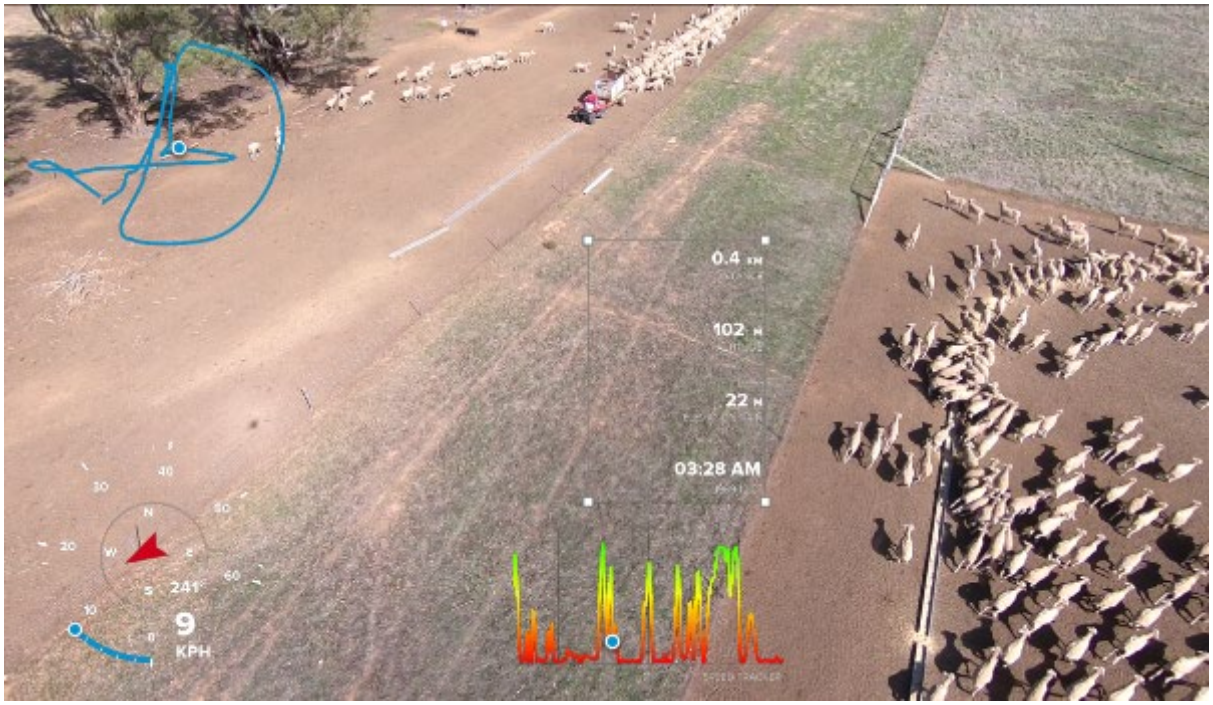
In figure 9 the drone is moving at 3km/hr. The ewe is focused on her lamb and not looking at the drone. The drone is 30m above ground level.

Figure 10 Drone moving at speed (45km/hr) has made the sheep run.



The drone is moving at speed (45km/hr) has made the sheep run. The drone is 30m above ground level (Fig. 10)

Figure 11 The drone is 20m above the sheep in containment



The drone is 20m above the sheep in containment. The sheep are focused on feeding in the left-hand side of the picture. To the right, the sheep feeding at the trough are moving away from the drone. The drone speed is deaccelerating (Fig. 11).

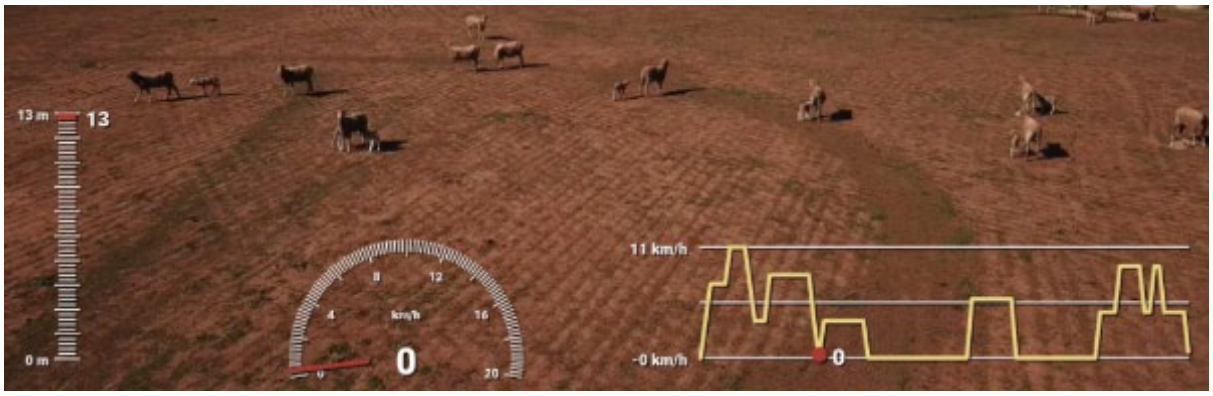
Figure 12 Drone hovering above sheep in yards

The drone is only 17m above the sheep(Fig. 12). They are looking at the drone – noted by blue arrows – however they do not seem agitated by the drone, possibly because they are contained in a small area. The drone has been hovering.

Figure 13 Drone over ewes and lambs walking a channel bank

Ewes and lambs walking along a channel bank. The drone is at 9m and moving at under 2km/hr (Fig.13). None of the ewes or lambs are looking at the drone.

Figure 14 Drone hoevering over ewes and lambs at 13m



The drone is at 13m and is hovering over Ewes and lambs. The ewes or lambs are looking at the drone and aware of its presence but are not moving (Fig 14). The ewe looking at the drone is feeding two lambs.

Productivity metrics to measure labour efficiency are detailed in section 4.5. In summary, the drone was not cost-effective compared to standard practice, nor did it increase labour efficiency. This was essentially due to the slow speed at which it needed to be flown across lambing ewes (to limit disturbance) and its CASA requirement to be in visual line of sight.

4.4 Other drone uses and observations

The usefulness of a drone to undertake other activities during different times of the year was also trialled. The drone was useful for undertaking some jobs that were not easily viewed from the car. Two examples are shown below. In Fig.15 the ewes were placed in an oat crop for lambing. The sheep were invisible when viewed from the car but could be seen easily from the drone.

Figure 15 A cast pregnant ewe in an oat crop

A cast pregnant ewe in an oat crop. Viewed from the car (bottom right picture) and the drone at 30m and 5m above ground level (Fig 15).

The drone was used to check on the welfare of ewes and lambs in Fig 16. after a rain event. The paddock was wet, but much wetter than the farmer expected with sheets of water still visibly present on the ground. Subsequently, the ewes and lambs were moved onto a drier paddock.

Figure 16 Drone view of wet lambing paddock

During summer, the drone was used to check summer pasture, water troughs, dams, fences, irrigation channels and sheep (Fig. 17 and 18). One farmer found the drone very useful for checking irrigation channels and looking at how far the irrigation water had moved through a paddock. These activities were mostly undertaken quickly and effectively using the drone. Another farmer used it to muster sheep which he found easier to do than using his dog as he had more control over the drone. He thought this was a beneficial use of the drone, particularly when the paddock was too wet to drive on.

Figure 17 Water trough checks

Figure 18 Pasture and sheep checks

In summary

The farmers said

- The drone can do the job for you - it is just a matter of what and how you prefer to do these jobs.
- Checking in person is probably more accurate
- Long term – I would get used to using the drone but ideally would like better programs to assist with flying and analysis of images. Down the track I think the drone will become more effective.
- Checked water troughs ok

Issues that restricted drone use

- The battery life of the Go Pro was between 8-10 mins which restricted this drone's flight time. Whereas the battery life of the DJI drones was greater and allowed up to 15 minutes of flying time.
- The distance the Go Pro drone could travel from the operator meant that in some cases the drone could not complete a circuit of large paddocks as it reached the limit of its range from the indicator. When on the edge of the range of operation, the camera could not be viewed as it became fuzzy.
- Farmers still need to drive to paddocks to undertake tasks, particularly if there were roads in-between paddocks or the paddocks were very large.

Coordinator learnings

The technology to fly the drones was relatively straightforward, with plenty of online manuals and videos. The DJI app. also included a flight simulator that could be used to learn how to fly the drone without actually flying the drone.

The technology to analyse the information from the drone flights was more challenging to identify and effectively use. It took time to identify the most effective desktop tool to use and apply the correct sequence of events to ensure the videos could be analysed.

4.5 Economic analysis

The cost-benefit was analysed over four adjoining lambing paddocks totalling 168 hectares, indicated by a yellow outline(Fig 19). This included paddocks labelled drain, irrigated, dead sheep and failure. This scenario ensured drones were not flown over any roads as per CASA rules.

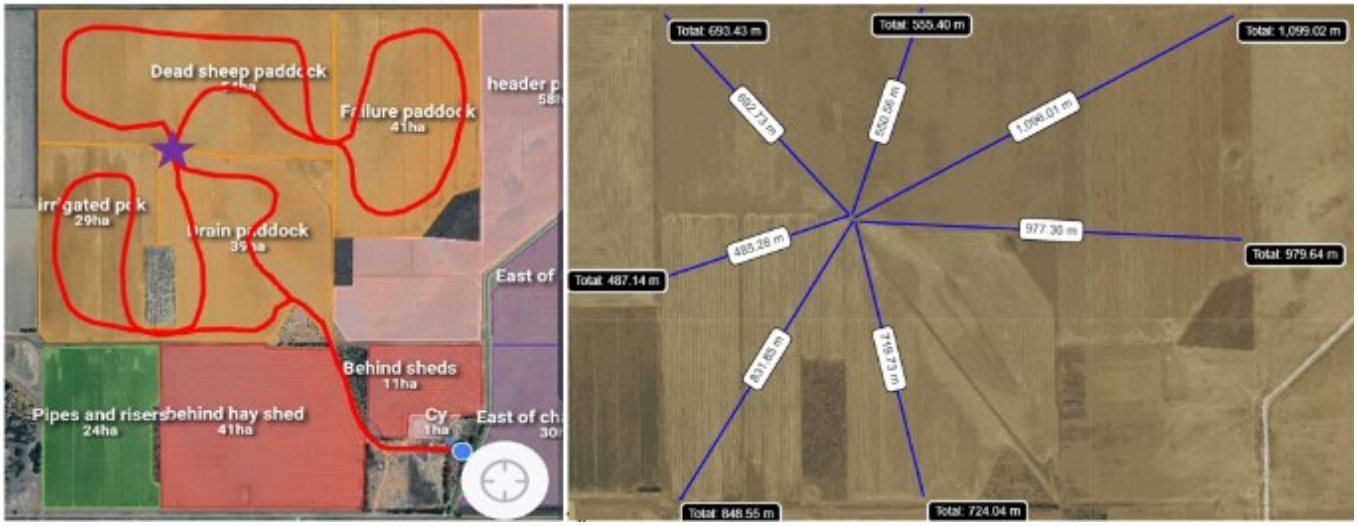
Ewe welfare checks were undertaken daily during lambing for approximately five weeks.

Figure 19 (left side) shows the general drive route (red line), a 10 km return trip from the house (bottom left-hand side of figure) which took 30 minutes without stopping. While the right side shows the drone route across the same paddocks. The star in the left side picture represents the location the drone was flown from.

The approximate time to undertake the task does not alter much for each scenario, assuming that the drone's return trip for each line will be approximately five minutes.

However, if a ewe needs help, more time will be needed to assess the situation both in the car or with the drone.

Figure 19 Lambing paddocks overlaid with drive route (left) and drone route (right)



The economic effects of an investment in a drone to reduce labour and vehicle costs was assessed using partial discounted cash flow budgets over five years. The approach is standard farm management economics, as described in Malcolm et al. (2005).

Avoided costs

When a change is made to a farm system, it is the marginal changes that matter. This analysis focuses on the marginal change to costs associated with lambing ewe surveillance from using a drone, compared to using a farm vehicle (standard practice). On the case study farm, it was estimated that using a drone would result in a vehicle saving of seven kilometres per day and zero daily labour saving compared to standard practice. All daily savings were applied for an annual lambing period of 35 days. It was assumed the cost of owning and operating a farming vehicle was

$0.72 per kilometre, and the labour rate for the driver of the vehicle and the pilot of the drone was $50 per hour.

Investment cost

It was assumed that the drone was purchased for $3,899 (complete package with extra batteries) in the first year of the analysis and had a salvage value of $0 at the end of the analysis. An annual CASA license cost of $40 was incurred from year 2 to year 5.

Key performance measures

The economic performance of using a drone for lambing ewe surveillance was compared with the standard practice. The key measure of profitability and economic performance was net present value. Net present value (NPV) reflects the net benefits over the life of the investment adjusted to present value by discounting using the opportunity cost of the capital invested. For this analysis, a 5% (real) discount rate was used to compare the NPV of the project to alternative investments.

Sensitivity testing

The sensitivity to annual labour saving was examined using a discrete scenario. Three labour saving scenarios for the lambing period were tested: 0 minutes per day (min/day), 5 min/day, 15 min/day.

Results

Profitability is indicated by the stream of annual net benefits having a positive NPV at the required rate of return of 5% real p.a. An investment in a drone is less profitable than an alternative investment earning 5% for all labour-saving scenarios (Table 5).

Table 5. The effect of labour-saving on the net present value of an investment in a drone over a 5-year period.

Labour savings from drone use (minutes/day)	0	5	15
Net present value at 5% discount rate	-$3,085	-$2,453	-$1,191

4.6 Extension and communication

The extension and communication activities (Table 6) involved group and public meetings, social media articles, publications and two podcasts to increase awareness of using drones around livestock. COVID-19 lockdowns implemented in Victoria during 2020-2021 impacted the ability to meet and conduct group activities in person.

Table 6. Extension and communication activities 2019 until 2022

Extension and communication	**Published**	**Number people/view/hits**
Group meetings and fieldwork	Meetings Fieldwork visits	23 in total from 2019
Social media posts (on AgVic's Facebook and Twitter)	The Victorian Connection/ Ag Vic Facebook https://connection.vic.gov.au/farmers-add-drone-pilot-to-skill-set DJPR Twitter DJPR LinkedIn	877 views 3227 impressions 3878 impressions (2021 data)

Spin-off from Social media posts placed into other newsletters/papers	Australia wide 2020 International including the UK based Farmers Guardian magazine	Approx. 11 articles
Media article based on annual outcomes	Group profiles in BWBLNewsflash 2020 & 2022	2 (1969 recipients)
Media article	Ag Vic AgTech byte article 2022 The do and do not of using a drone	
Social media radio interviews	Country Today/Ace Radio 2020 – Libby Price Victorian Country Hour 2020 – Warick Long Rural ABC – Annie Brown – played on Victorian Country hour and Goulburn Murray ABC 2022	3
Field day event open to the public	Boort April 2022 – 30 people Mitta Valley June 2022 – 20 people	2 Approx 50 people face to face
Presentations	Internal presentation 2020 – 20 people Stock handling & Ag tech day 2021 – 73 people DISA (Digital Innovation and Smart Agriculture Festival) 2021 – video only Bendigo TAFE students 2022 – 8 people Bestwool Bestlamb coordinators conference 2022 – 25 people Ag Vic Healthy soils service provider discussion group session 2022 – 15 people	6 presentations Approx 150 people engagements
Podcast	AWI 2021 (not published) Agriculture Victoria 2022	2
Newspaper article	National machinery and agtech journalist - Melody Labinsky 2022 Published in the Stock and land, Farmonline, Farm weekly	
Videos	4 Short videos for social media and internal presentations Ag Vic AgTech hack 2022 with a short video about using a drone	

Appendix 1 provides a comprehensive list of presentations, publications, social media, and associated links.

4.7 Monitoring and evaluation

4.7.1 Pre and Post KASA

At the start of the trial, the farmers rated themselves poorly on their knowledge (average 2.2/10), skills (average 1.6/10) and level of adoption (average 1/10) but indicated a more positive attitude (average 5.8/10) and reasonably high motivation (average 7.4/10) towards the innovation.

By the end of the trial the farmers rated their knowledge of drones very highly (8.3/10) as well as their skills to fly a drone (7.8/10). However, as the limitations of the drone became apparent the farmers motivation (5/10) and attitude (4.9/10) towards the drone to check sheep welfare at lambing were far less positive. Table 7 lists the results from the pre and post surveys along with the % change in scores. Knowledge and skills increased while the motivation and attitude towards

drones decreased. Figures 20 and 21 visually show the changes in the farmers' knowledge and skills during the demonstration.

Table 7. Pre and Post KASA results

Objective	# of Responses	Knowledge	Attitude	Skills	Motivation	Adoption (current)
		(Score/10)	(Score/10)	(Score/10)	(Score/10)	(Score/10)
PRE Technical skill and knowledge in using and flying a drone on-farm	6	2.6	6.6	2.0	9.2	1.0
POST	6	9.3	NA	7.7	NA	1.0
PRE Generate accurate records of time	6	1.5	5.0	NA	6.7	NA
POST	6	7.5	5.0	NA	NA	NA
PRE Use of a drone on-farm to: Demonstrate and measure the practicla use of drones	6	2.5	5.7	1.2	6.4	1.0
POST		8.2	4.8	7.8	5.0	1.0
AVERAGE PRE		2.2	5.8	1.6	7.4	1.0
AVERAGE POST		8.3	4.9	7.8	5	1.0
% CHANGE		295	-39	418	-74	0

Figure 20 Pre and post knowledge of drones

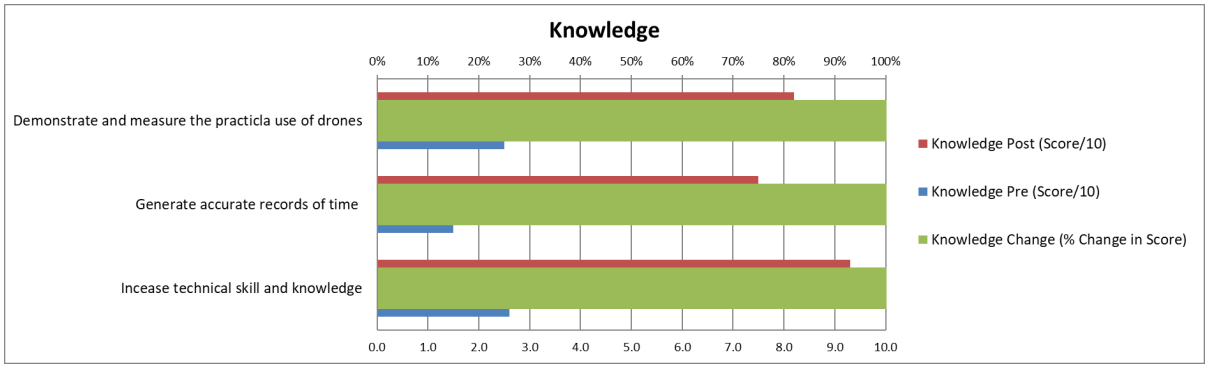
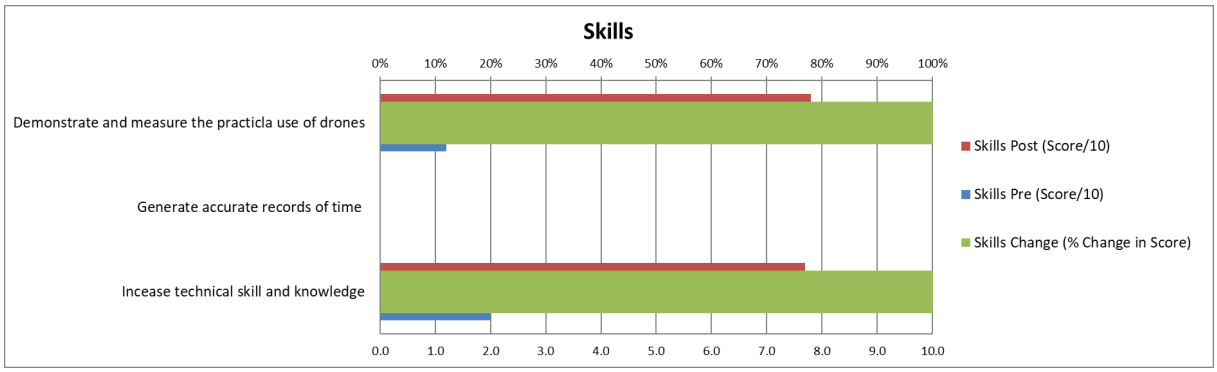


Figure 21 Pre and post skills of farmers to use the drones



Qualitative information was collected at the trial's completion to identify the drone's usefulness and practicality on-farm from the farmers' perspective. The results show that the motivation to use the drone waned once some of the limitations of the drone became apparent (see Table 8).

Table 8. Qualitative results from the post-trial survey

Qualitative question	Comments
Did you gain the knowledge, skills and confidence to use the drones?	Yes x6 Identified heights and speeds that you could approach the sheep at Gained more information from drone than what I thought Could see benefits – fitting time in to use needed a culture change to use the drone more
What activities on farms do you think drones are most useful for	Finding sheep in the long grass as you cannot see them at ground level from the car Could see how far irrigation water had moved down the paddock Can't access the paddock due to being too wet Water trough, check germination, look for insect damage, check fence lines. From above it gives a different perspective that may not see from the ground Check troughs, other aspects like weeds and insects, if using infrared looking for weeds. Looking at setting up a facebook page about what we do – promoting us using drone footage In a lupin crop saw response to different fertiliser rates in the number of flowers on the crop Birds eye perspective of items An interesting addition to your management – but for me its like a toy Provides different perspectives of your farm Very useful over irrigation bay to see where the water has moved to. Check livestock around troughs

	Overall picture of a crop from above
Have you changed practice throughout this demonstration or do you intend to?	I changed during the trial but do not intend to continue using a drone at this stage No – however Very worthwhile project that gave the exposure and hands-on experience without the investment. Understand more about the time taken to check water troughs etc Understand Where I can go to in the paddock to use a drone to make checking sheep quicker Have people in now using drones (paid work) for filming for a project we are involved with Checking sheep a lot more Not against the drone, it's a matter of finding the time to fit it in No. However it has highlighted that we need to go around the sheep more often and we just need to put the time into going around the sheep. It's a labour cost you need to wear for welfare and survalibity of lambs Drones still have a place - the sheep and myself would get more used to it the more I use it
Under what conditions would you change practices	Zoom on the camera and better battery life Be more over the technically advanced myself as well as the drone being more advanced than what we used. Would prefer to trial a 'drone in a box' (ie drone is automous flight on a set path) The drone would need to be ready to go when ever you needed to go as by the time you set it up you can already drive a fair distance The drones need to be more autonomous Improved cameras on the drone, improved battery life More autonomous
What is stopping you from using a drone now?	X2 The cost of purchasing a drone X2 Battery life of the drone X2 The hassle of setting it up X3 Takes nearly as long or longer than a vehicle X1 I need to see for myself (I'd prefer to use a vehicle) X2 The view is not accurate enough (I might miss something) **Other comments:** 5-10 min unpack and set up and fly Didn't trust it so I needed to check the sheep anyhow Didn't use it as much as I thought I would – it took longer than expected to use

	Very worthwhile in doing the trial – not a positive result but we still got a result Not into gadgets so much The cost of the drone was not the issue or barrier to my adoption. Because of the drone project we are now considering placing stationary cameras near the water trough to check what is going on. We can use a phone connected to the stationary camera to view any issues. Whereas you need to get the drone out of box, start it up do what you need to do then if need to travel over roads bring the drone back get in the car and move to the next location A bit of everything above – also concern about whether it will be used enough – timing of labour for critical events led to the drone being put aside All of the above really Takes a little bit of time to set it up before you fly

4.7.2 Practise change / adoption

At the conclusion of the trial, none of the host or observer farmers had adopted drones on-farm. Nevertheless, 100% of core producers improved their knowledge, skills and confidence in using the drone and understood what jobs it could perform on-farm.

The drones were not adopted for several reasons, such as time constraints (the farmers consistently said they lacked the time), not being practical for checking ewe welfare during lambing, worried the sheep, battery life which limited flying time and limited camera zoom capability on the drone. Further issues that impacted adoption are listed in section 4.1.

Despite the overall lack of adoption, the farmers listed many benefits and learnings from being involved in the trial. Table 9 outlines how the participants viewed the drones 12 months into the trial and at the end of the trial.

Table 9. Host comments 12 months and three years after using the drone.

Question	**May 2020 (12 months of using drone)**	**May 2022 (3 years of using drone)**
What are the benefits of being involved in the demonstration?	Get exposure to the technology. Good chance to use to see what it is like	Being able to try the drone out without purchasing one. To see what it was capable of doing and how practical it was on-farm

	before committing to using especially when your not sure that it will work for you in your setting as a drone is not something that you use everyday or can easily try Getting to try out the drone myself, in my own time and not needing to rush	Understanding what a drone is capable of doing and not doing and learning was it worth investing in one and found its not Getting to use the drones, ES to explain the good and bad of the drones Tech is improving and getting a good background of the functions and how to use them To have the opportunity to use a drone to see how it worked for us on our farm Exploring the drone as a option. Animal welfare primary object and wanted to see if drones could raise the level of animal welfare Being able to stand in one spot without needing to move through paddocks to view sheep
What is working well on the demo?	Moving sheep Bird eye view of the farm which provides a different perspective than normal.	Using the drone to find sheep in tall feed such as a oat crop Be able to fly the drone easily and not much training was needed Moved a mob a sheep without the dog Good vision from above Having the coordinator being present. Made sure that people had the access to the drone Opportunity to talk about the drone and heard what others were doing. To try different drones without purchasing one Really good to be involved and have the opportunity to fly drones. Guided by PDS coordinator, who provided the confidence to play with new tech and discover what it could do. Had some time to play with it. It worked well to explore how it could fit into the system Being able to use a drone without purchase of one
How could we improve the demo? Is there anything you'd like to see more of or less of? Anything you'd change?	Good to try different drones to see if any are better than the other Having for a bit longer before lambing and after lambing would be ideal	Having it for longer prior to lambing to get used to it. Farmer also then needed the motivation use it as it still wasn't used prior to lambing Nothing really - needed to wait for the drone – lack of our own discipline to fly the drone resulted in it being not used much

		In hindsight if we have had it longer, we might have used it more and been more educated about it and used it more often A labour unit dedicated to the drone to test what it could do Would've been good to use different drones (*only used one drone as became a host farmer in the 3rd year of the trial)
Is there anything you are doing or might do differently because of your involvement in the demo? And having seen the early results?	Spend more time learning how to fly the drone. Not yet, not sold on using the drone yet.	Weather impacted on the number of times the drone was used which led to not using the drone as often as it could have been Investigate other camera options for measuring and looking at items on-farm Better understand the flight response of sheep – learnt that they are more sensitive than we thought to noise. Great to have hands on use of the drone Great to have hands-on use of the drone Could compare the practicality of a stationary camera to the drone Highlighted a greater need for surveillance during lambing. It was good to be involved with the demo and have the opportunity to try out new technology

4.7.3 Field day evaluation results

Two field days were held in April and June 2022 to present the trial's final results.

The Mitta Landcare group requested the second field day after hearing about the Boort drone and AgTech field day held in April 2022.

The evaluations from both days were very positive and many people who attended saw value in using the drones on-farm and a number indicated that they would purchase a drone in the future. Table 10 summarises the evaluation from both days.

Table 10. Field day evaluations of drone knowledge pre and post field days.

Location	Avg. knowledge before /10	Avg. knowledge after event /10	Change in knowledge /10
Boort 30 people present	3.8	7.3	3.5
Eskdale 20 people present	4.7	7.4	2.9
Comments	• drone application for water trough monitoring & sheep handling		

Description of PRACTICE CHANGE	• remote viewing of stock & troughs • drone to assist with remote farming • drones have a farm use future • monitoring troughs & containment yards • drones are more adaptable for farmers than just livestock mustering • buy a drone for landscape assessment • will be looking at drone users on-farm more closely - will buy a drone in near future

5 Conclusion

The demonstration looked at whether drones could enable more frequent sheep welfare checks and offered any labour savings. The outcomes identified aspects to consider when purchasing a drone, including whether the camera zooms, battery life, how best to fly it around sheep and the impact of CASA rules, information previously unknown to producers. The cost-benefit analysis for this trial found that an investment in a drone was less profitable than an alternative investment earning 5% for all labour-saving scenarios of 0, 5 and 15 minutes compared to using a vehicle. Essentially this was due to the slow speed at which the drone needed to fly across lambing ewes (to limit disturbance) and its requirement to be in a visual line-of-sight at all times.

Whilst the results highlighted some limitations to the drones' ability to undertake some tasks on-farm, the demonstration still attracted significant local and national media, farmer and industry interest, providing a platform to build peoples' knowledge about the usefulness of drones on-farm.

While none of the host or observer farmers adopted drones on-farm, all core producers improved their knowledge, skills and confidence in using the drone and documented what jobs it can perform. The farmers also had the opportunity to trial different drones on their property to see what they could do and how practical they were performing various tasks.

Today some of the limitations identified throughout the trial might be null and void due to the advances in drone technology.

6 Key Findings

- The benefits and limitations of the drones to check sheep welfare at lambing and to undertake other activities on-farm were identified and documented. Many summer activities were undertaken quickly and effectively.
- New knowledge and information that previously did not exist, identify aspects to consider when looking to purchase a drone for farm-use, including whether the camera zooms, battery life, how best to fly it around sheep and the impact of CASA rules.
- The trial allowed farmers to test a new sort of available ag-tech and gain skills and experience in using drones. One farmer said 'It was a good chance to use a drone to see what it is like before committing to buying one, especially when you are not sure that it will work for you in your setting, and a drone is not something that you use every day or can easily try'.

7 Benefits to industry

Today drone technology advances have progressed to a point whereby some of the limitations identified in the trial would be absent and subsequently may make drones a valuable tool to check sheep welfare at lambing. For example, drone cameras now zoom and battery life can provide up to 45 minutes of flight time. The CASA visual line of sight rules may also be negated in a different environment where paddocks are smallller.

Future research should look to support new drone on-farm trials as the advancements in technology may actually find that this tool saves farmers labour and time to check sheep welfare at lambing.

8 References

Malcolm B, Makeham J, Wright V (2005) 'The farming game – agricultural management and marketing.' (Cambridge University Press: Melbourne, Vic.)