Local Land Services

Case study

Use of drones for pasture monitoring in Western NSW

The Western region of New South Wales has the potential to benefit significantly from the effective implementation of drone technology and there is considerable interest in using drones for various applications. However, those who have invested in the technology have had limited success with using it regularly as a tool to improve their management.

The limited success is due to a range of factors including, technology rapidly changing, limitations of drones, confusion regarding rules and regulations, additional software requirements, cost, lack of knowledge and lack of specific technologies designed for extensive agriculture.

One of the potential applications for landholders in the region is using drones to make pasture management decisions. Using additional software, drones can collect information and images that can be stitched together to create maps and models. These maps capture large amounts of useful data not attainable with the naked eye and more efficiently than through on ground measurement.

Western Local Land Services received funding from the Australian Government's Smart Farms small grant program to demonstrate the use of this technology to improve monitoring of pastures and increase landholder adoption in the Western Local Land Services region through capacity building and demonstration of drone technology in extensive paddocks.

The project aimed to assess if affordable and commercially available drone technologies are currently suitable for adoption in Western NSW and to assist landholders in implementing the technology.

Monitoring pastures using drones demonstration

To assess if drones are useful for monitoring pastures and making grazing decisions in rangelands, available drone technology was tested in varying conditions across Western NSW. Drones and software were used to complete seasonal maps from June 2021 until June 2023. The results were compared to on ground monitoring to assess capabilities, practicality and potential uses.

The demonstration was designed to test a method of using drones for monitoring pasture that was practical, affordable and commercially available to landholders.

The sites

The seasonal monitoring was completed at 6 sites that differed in vegetation, grazing management and landscape type. The variation was chosen to observe the drone's performance and capability in different landscapes and pasture systems.

As it is currently impractical to map an entire paddock in extensive systems using drones, the demonstration sampled small representative areas to monitor the larger area as you would for on ground monitoring sites. The sample area was chosen as it was representative of the extensive pasture in the paddock or because it was of specific interest to the landholder.

Drone maps

The maps were collected via an autonomous drone flight that was planned using Drone Deploy. 8 maps were collected across the 2 years to capture varying seasonal conditions and pasture types. The timing of the maps was chosen to observe common seasonal pasture change.

Each map was 10 hectares in size as this was the area that could be mapped using one battery and to the desired specifications. The maps were flown at 60 m high and 1.6 cm pixel size.

The demonstration used one battery per map to test a method practical for landholders to implement. Using one battery per map allowed monitoring to be completed across multiple sites in a day and would be less cost and time prohibitive.

Ground truthing

To compare and assess this technique on ground, monitoring was completed in line with the assessment techniques outlined in the publication The Glovebox Guide to Tactical Grazing Management for the Semi-Arid Woodlands. The techniques included step point collection of ground cover, landscape function assessment and species diversity quadrats.

The ground truth area was a 100 m square representative and chosen within the 10 ha drone map area. A transect was walked every 10 m (9 total) along this square measuring ground cover step points and species composition via quadrat every 20 steps. Landscape function was collected along the sides of the square (0 m and 100 m).

The drone

The project used a Mavic 2 Pro drone. This drone was chosen as it had the capability to connect to the software and is commonly owned by landholders in the area, is affordable, had a reputation for being reliable and fits into the "very small" weight class (<2 kg). Landholders do not require a remote pilot's license to operate these drones. The maps were collected using the red, green and blue (RGB) sensor within the camera that is built into the drone. This RGB sensor is used to deliver colored images by capturing light in red, green and blue wavelengths.

The software

Currently, there is no drone software specifically designed for monitoring extensive pastures. Hence, the software program, Drone Deploy was tested for its adaptability for use in monitoring rangelands pastures.

Drone Deploy was chosen for its simplicity of use, commercial availability, repeatability of maps, ability to be used without phone reception, built in photogrammetry and ability to collect plant health data.

The software includes features to view vegetation layers and elevation, measure volumes, length, GPS points and other cropping and surveying specific features.

Analysis of the results

Due to the uncertainty of the drone and software capabilities, the ground truthing data was collected with attempts made to extract the same information from the drone maps. Additionally, the capabilities and functions of the software were investigated and observed to determine their usefulness in making pasture decisions.

The plant health layer feature built into Drone Deploy was the main avenue of analysis for the pasture. A standard RGB camera was used to provide a plant health layer measuring "greenness" rather than Normalised Difference Vegetation Index (NDVI), which would require a red edge or near infra-red sensor. The values were extracted by adjusting what was highlighted "green" to include desired components to quantify. A percentage based on green area (ha) relative to the total area was then calculated.

Results

The drone was capable, reliable and practical to use for collecting pasture data. The main advantages of using the drone were its ability to collect a larger sample area more efficiently, reduce time out in the paddock and potentially improved accuracy due to reducing human error. See table 1.

Table 1. Comparison between on-ground monitoring and drone imagery for area, time, process and outputs of results.

	On-ground monitoring	Drone imagery
Area assessed	**100 m^2**	**10 ha**
Time to collect data	Total = 2 hr 10 minutes Ground cover step points (9x100 m) -30 minutes 36 quadrats–40 minutes Landscape organisation-1 hour	Total = 35 minutes 10 min Prep time 25 min Map collection
Time to process/analyse	Total = 30 min-1 hour Counting step points Calculations	Total= 15-30 minutes in front of the computer Plus: Upload time (depends on internet speed) Processing-1-2 hours wait time (can be doing stuff elsewhere)
Results/output	Ground cover % Landscape organisation value Species composition %	10 ha interactive map Ground cover % Visual comparison to past maps Zoom into 1.6 cm pixel Landscape organisation value Green map-green quantity Elevation map Built in measurement tools

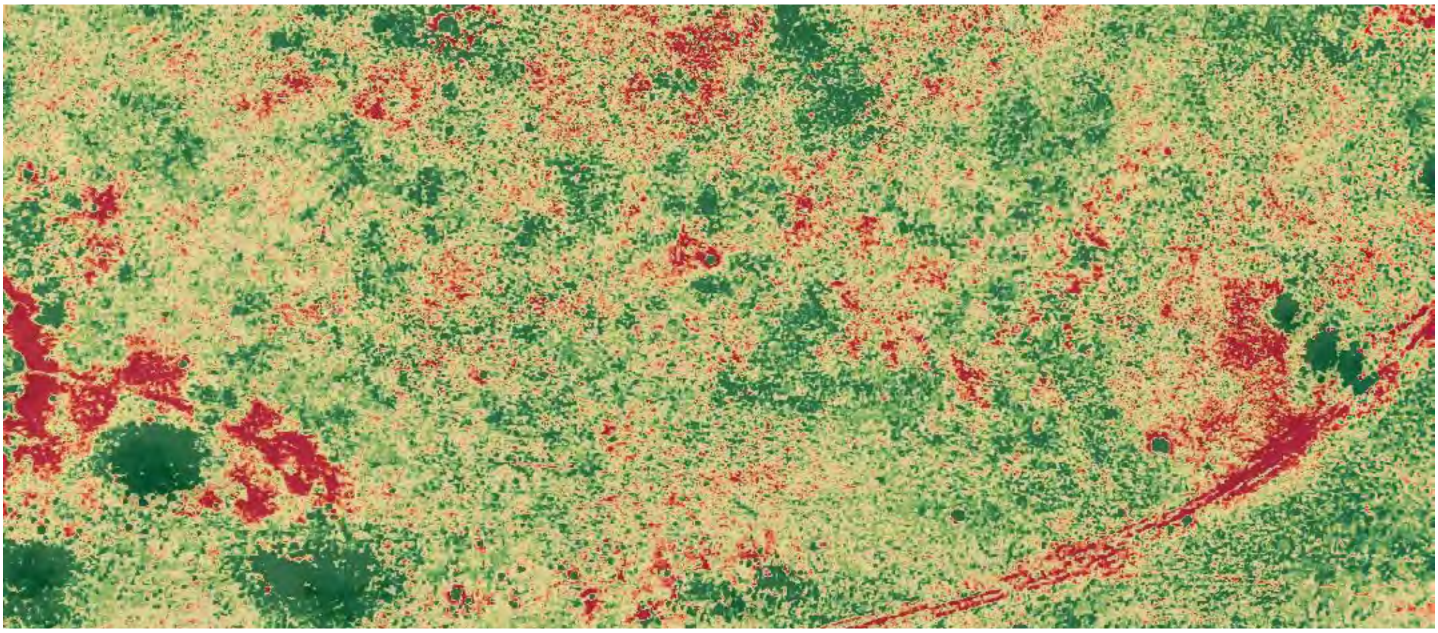


Figure 1. Example of the "plant health" drone map for the 1 ha ground truth area. The map was collected on 19 December 2022 in a spear grass and annual pasture vegetation paddock.

It is possible to fly as large an area as desired if enough batteries are available. However, it would take an impractical amount of time to do so. A single battery flight time is around 27 minutes which at 120 m high (max) could map approximately 35 hecares. Therefore, it is unlikely to get a return on the time spent collecting more than one battery worth of maps representing the same area if a good representative site is chosen.

It is possible to fly the maps at 120 m rather than the 60 m used in the demonstration to increase the area mapped per battery with minimal impacts on the results. However, when flying at higher levels, weather conditions (such as wind) were more of a problem and impacted how timely, accurate and battery efficient the maps are.

The downfall of using this technology is the software. The operations that the software is designed for function well and are user friendly but using it to extract the desired pasture measurements is currently limited. The built in measurement feature allowed landscape organisation to be completed from the mapping which saved time spent in the paddock and was more consistent as a straight line was used on the map rather than a tape measure.

The 'plant health' layer was useful to create and explore visual representations of differences in the pasture and quantify some aspects. This demonstrated that the drone did collect the information that could differentiate between components of the pasture, but it was not currently capable of quantifying each component.

An example of this is being able to create a map such as shown in Figure 1, but not being able to extract percentages of each category of ground cover.

Green is showing the greenest pasture in paddock, yellow the drier material and red bare ground. Even though the drone was able to collect information to visually separate vegetation colour, we could not quantify each percentage of ground cover type.

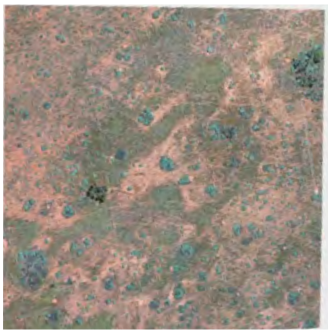
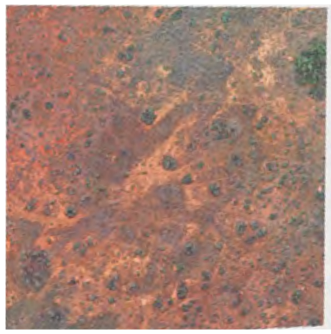
As groundcover is on the 'greener' end of the plant health values it was possible to adjust the scale to show all groundcover as green and calculate a percentage based on the area shaded. This made it possible to calculate a ground cover estimate and green percentage. The drone groundcover estimates were on average within ± 4.24% of the result collected on ground. However, this was improved by ± 2.3 in later maps once practiced and using the ground truthing results to assist.

The on-ground results reduced the human qualitative error of the need to judge if all the ground cover was being counted as green and allowed the plant health layer to be adjusted to a numerical value that could then be used on the entire 10 ha map. This allows a better and more informed estimate of ground cover for the total area without requiring collection of 10ha of on ground results.

As the 'greenness' was measured by the camera it did not require on ground measurement to improve the result and can differentiate between shades of green with more refinement than the human eye.

See table 2 and 3. Therefore we were able to create maps emphasising the green and growing feed vs. less green and haying off plants through comparing the variation of their colour relative across the year and quantify it as a percentage.

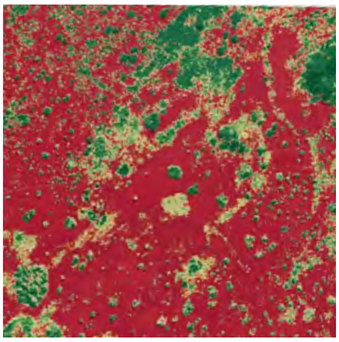
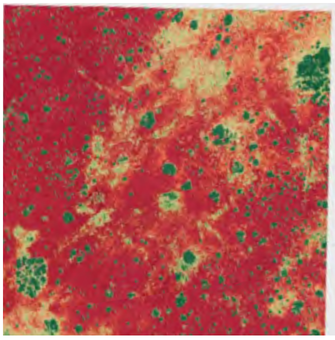
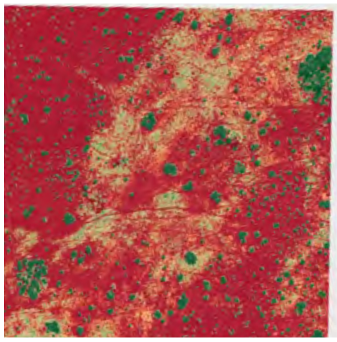
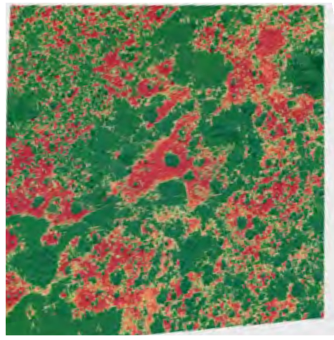
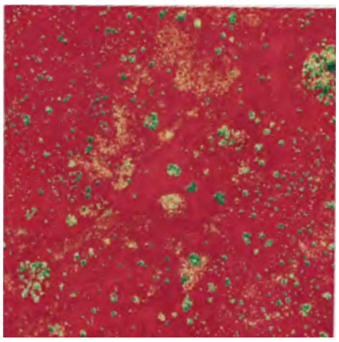
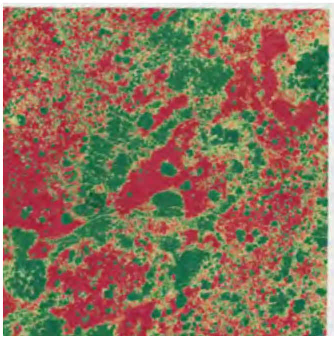
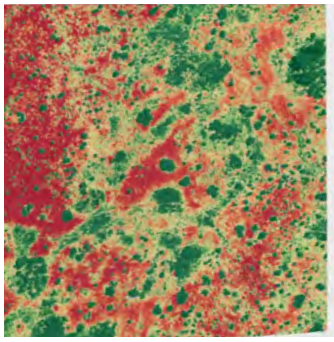
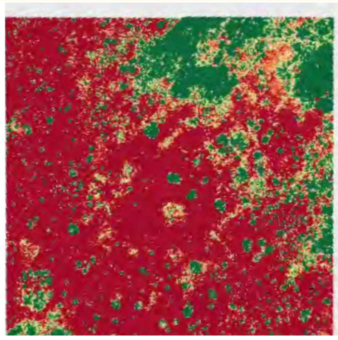
Table 2. This imagery shows the visual changes in the pasture at the site across different seasons. Note: The Autumn seasonal mapping for 2022 was delayed due to wet weather.

Winter: 3 August 2021	Spring: 10 December 2021	Summer: 18 March 2022	Autumn: 16 June 2022
65% ground cover	52% ground cover	48% ground cover	62% ground cover
			
Winter: 6 September 2022	**Spring: 19 December 2022**	**Summer: 13 February 2023**	**Autumn: 31 May 2023**
53% ground cover	73% ground cover	80% ground cover	77% ground cover
			

To the human eye the aerial photos in table 2 would have estimated and highlighted a larger area as being green. Less green is shown in the table 3 as drone deploy can compare the relative greenness of the pasture across time and highlight the "most green" and therefore highest quality feed across the year. This is useful as it can indicate when a pasture is beginning to hay off or changing growth phases more accurately than the human eye.

The seasonal maps in table 3 show 0% quantity of green feed whilst the visual map in table 2 has some green highlighted areas. This shows the greenest parts of the pasture. This does not show if pasture is actively growing of higher quality relative to the other seasons.

Table 3. Changes in green feed across two years for the same site. Note: The Autumn seasonal mapping for 2022 was delayed due to wet weather.

Winter: 3 August 2021	Spring: 10 December 2021	Summer: 18 March 2022	Autumn: 16 June 2022
Green - 10%	Green - 0%	Green - 0%	Green - 45%
			
Winter: 6 September 2022	**Spring: 19 December 2022**	**Summer: 13 February 2023**	**Autumn: 31 May 2023**
Green - 0%	Green - 18%	Green - 10%	Green - 0%
			

Species composition could not be extracted from the maps, but for the use of managing pasture the plant health layer and changes in green feed comparison was made to allow the user to make assumptions and observe changes in species, growth phase, pasture quality and quantity of green feed. It is also possible to zoom in to 1.6 cm pixel size within the maps which is close enough to identify the plant type and species if those present have been confirmed with ground truthing.

Uses for the current drone pasture maps

Although values were able to be extracted from the drone maps, it was not a simple process and is not what the software is designed for. In the future, specifically designed software may become available and will make this process simpler and more suitable for purchase, adoption and implementation as a pasture measurement tool.

Currently drones can provide value for managing pastures by being a visual tool to improve current on ground monitoring techniques and records. Due to minimal testing and the features requiring adaptation to suit the purpose, it is important to validate results with on ground data. Combining these techniques will improve results in relation to the time spent collecting and analysing information.

A simple solution would be to use a drone to take aerial photos as part of regular monitoring protocols. Aerial photographs allow a larger area to be observed from different angles that can more effectively show pasture changes compared to photos taken at ground level. See comparison figure 2 and 3.

Figure 2. Comparison of on ground photo with same area on the same day from the air.

Figure 3. Comparison of on ground photo with same area on the same day from the air.

The main advantages of using software over aerial images alone is that it allows higher level of detailed information to be collected efficiently across a larger area and this data can be displayed in an interactive map. The software creates the maps by taking a series of photos whilst flying transects across the chosen area and can then connect the series of images and embed additional information such as spatial data and plant health. These flights are repeatable and displayed in a platform that makes comparing maps and observing changes in the landscape across time easier and more useful compared to records using a ground level photos and ground truthing sheets alone.

This is because when using a drone to take aerial photos it is most practical to take a limited series of individual images that emphasise changes in the pasture and makes managing files and keeping records simple. Each of these photos limits the area shown and value of field view observation within the height limitation of 120 m. However, with the drone mapping software, the entire area can be collected in detail and managed easily by interacting with the data. For example, in the demonstration 10 hectares of map was collected which equates to 500-600 individual photos that took 20 minutes to collect using the repeatable flight plan. This quantity of photos and data would take a lot more time and effort to collect manually, manage and get value from without the software.

In this form it is possible to better encompass trends within the landscape in visual records that may have been missed in a smaller representative sample. An example of this is monitoring site data not showing a lot of change, but the broader landscape may have creeks or flood outs that could have big changes not being measured. The plant health layer assists with visualising these patterns and changes through measuring 'greenness' within the maps to highlight differences in vegetation and groundcover. It is then possible to zoom in on a potential area of interest to 1.6 cm pixel size to observe specific features and easily find that point in the paddock if further observation is required. This zoom allows types of plants and some species to be identified.

These features make it possible to retrieve information about pastures efficiently when needed to make timely decisions. The quality of this information relies on ground truthing data to improve its accuracy and explain changes observed in the drone map. However, it could be used opportunistically on its own when required as the data set of maps for that pasture is repeated. Once there is multiple maps of the same pasture ground-truthed it is easier to adjust the settings within the software to show how the pasture condition compares to a previous map or season.

Using these observed differences and known data such as rainfall, species composition and time of year it is possible to make assumptions about the trajectory of the pasture and how to manage it accordingly.

Although the maps cannot easily extract many desirable pasture measurements, the ability to measure and display green feed is valuable and could be a substitute for some on ground measurements. As seen in the demonstration, collecting quadrats for species composition can be time consuming and although important to monitor, does not necessarily indicate pasture quality and potential animal performance at that point in time. A change in the quantity or proportion of green and actively growing pasture could be attributed to changes in species, growth phase, rainfall, grazing pressure or other factors that the drone maps could emphasise and allow to manage accordingly.

For landholders wanting specific pasture measurements, drones and software are not currently the best investment, but with some improvements, may be an option in the future. If improving monitoring and creating a visual record of interactive maps of pasture is desired, drones in their current form can achieve this and assist with making pasture management decisions.

Other uses and implementation of drones in Western NSW

In addition to the demonstration, a series of workshops were held across the region to increase participant capacity to effectively use drones and allow them to contribute to discussions focused on the implementation of the technology.

These events identified that drones are of interest to assist with labour shortages, safety concerns, access to difficult terrain, reducing costs, increasing efficiency, monitoring and reducing wear and tear on vehicles. Specific applications of interest include:

- Mustering
- Pasture monitoring and measurement
- Checking infrastructure eg. water and fences
- Monitoring animal health
- Weed spraying – blanket and precision
- Managing pest animals- spotting, infrared, measuring impact eg. warrens, digging
- Plant health and precision management in orchards
- Planning and mapping infrastructure and earthworks
- Observing land management changes
- Recording GPS locations
- Counting and measuring eg. number of cactus, approximate length of fence.

A drone workshop hosted at Dijoe Station.

Experiences using the drone

Overall, experiences using the drone and software were positive. Attendees of the workshops found the technology user friendly and would be more confident using it with practice. Attendees brought along their own drones to the workshops and asked the trainer questions. A variety of drones and potential software programs were discussed along with education on safety practices, drone legislation and checklists.

The technology performed well in flying conditions and under technology limitations common to Western NSW. The maps were collected in areas with no phone reception, limited internet speeds, hot and cold weather, overcast conditions, harsh sunlight, wind and unexpected light rain. Any problems incurred were due to operator error rather than the drone itself.

All the discussed applications are within the scope of drone technology. There are a lot of options available and continually emerging in the space, however their implementation on properties is limited by the cost: benefit, lack of knowledge around usage and current limitations of drones and software.

Consumer drones

Consumer drones (affordable and available) like the one used in the project have battery life of 25-30 minutes. This limits the time it can save an operator and benefit their business. A common complaint is that the flight time is not long enough to muster large areas, check waters or other extensive tasks. However, CASA regulations also limit this as it is illegal to fly a drone outside your line of sight without additional approval or licensing (Sexton-McGrath, 2023).

When purchasing a consumer drone, it is important to check its compatibility with any software that you intend to use as some of the latest models are not compatible yet.

Professional drones

Professional drones are available with longer flight times, as high as 55 minutes for a multi rotor and multiple hours for fixed wings. To utilise these longer flight times by flying out of sight requires either having an additional person as a spotter or an additional license to the REPL (Remote Pilots License) to fly via instruments. These drones are also heavier and if they weigh over 25 kg require a REPL even if flying on private land.

Larger drones for spraying and carrying

Not all larger drones have longer flight times. Bigger drones are available for the purpose of carrying larger quantities for uses such as spraying and fertilising paddocks. Distributing anything via a drone also requires an additional aerial application approval. These drones have a short battery flight time of under 15 minutes. The batteries however charge very quickly, and the drone returns to the same spot to be refilled and battery replaced when needed. As such, they are not the best option for large areas that can be accessed by vehicles, but very useful for hard to access areas such as scrub, hills or wet, inaccessible orchards.

Batteries

Consumer drone batteries charge quickly and can be charged on the go using a vehicle's 12-volt power outlet or power bank. This adds to their practicality and extends their capabilities beyond 27 minutes. The standard drone comes with one battery but "fly more" combinations when purchasing are a common extra which may include additional batteries. When collecting the seasonal maps, the first battery had recharged before the other two were empty. This is especially useful when mapping using software, as a map can be collected across multiple batteries and therefore any size.

Additional technology

Additionally, drones can be improved and have added benefit to a business when accompanied by software and sensors. As found in the Western LLS project and similarly by others who have used drones, the current software and sensors are very specialised, not necessarily adapted to farm management applications and require higher investment and knowledge to use effectively. Examples of these include infra-red sensors, multispectral cameras, photogrammetry software, machine learning software and more advanced drones.

Drone Deploy software was used to collect the seasonal maps, but there are others available. As the software is rapidly developing it is recommended to do your own research to find a package suitable for use and drone type. When purchasing software with the intention of mapping, it is important to find one or multiple options that will allow you to plan and fly an autonomous flight, connect the photos and interact with the data. Some software will only connect the photos into a larger photo which can be of interest to create a map but will not provide pasture information or measure.

Research

Researchers have had success extracting accurate pasture measurements and vegetation information (Ramp et al. 2019). However, they have been using multiple software packages that require more knowledge to use as there is currently no purpose-built option for extensive landholders. Although we were able to collect information using a standard drone, the methodology used would not be refined or validated enough to be used in research (Gillan, 2019). Additionally, for research quality results a red-edge or multispectral camera may be required (Akumu, 2021;).

Drone contract services in agriculture

The number of contractors using drones in agriculture is increasing. There are commercially available software options for horticulture and cropping, including Drone Deploy (used in the demonstration). This has created an opportunity for agronomists to provide crop mapping services that integrate with landholders' variable rate and other technologies on farm. Drone services are also available to spray weeds and apply fertiliser and seed aerially which can be a cost-effective solution for hard-to-reach areas and for minimal disturbance. There are currently no extensive pasture specific options.

Mustering

Mustering is an application of interest for the region that can currently be implemented, although the battery life and regulations limit distance and time the drone can be flown (Sexton-McGrath, 2023). With practice this can be maximised and reduce the cost of labour, time and aerial support while mustering (Chaplain, 2022; Embid et al, 2020; Jeffery, 2021; Yinka-Banjo, 2019).

Improvements include having multiple batteries, charge them on the go, planning the muster for areas suited to drones and practice using the drone and features.

As seen in the MLA goat landholder trial (MLA, 2022) using Skykelpie, the landscape will also influence effectiveness. The drone will encourage livestock to move and act as an, eye in the sky, but is unlikely to replace a helicopter when pushing stock out of scrub areas for example. Western NSW landholders commented that it is likely that contractors will adopt drones for this purpose in the future.

Conclusions

Although drones and the associated software can collect pasture information not attainable with the human eye, the lack of purpose-specific software and methodology makes the use of drones as a pasture monitoring and decision-making tool difficult to adopt and implement at present.

Despite the limitations and current regulations of drones, they can currently provide value to a farm business by saving time, labour costs, wear and tear on vehicles and access to hard-to-reach areas. Consumer drones that are readily available are an affordable option to achieve this and performance can be maximised through practice and experience of the user.

Pairing drones with appropriate software improve capabilities and potential usage. In their current forms however, these extra investments have limited on-farm applications that would benefit the business enough to justify the purchase cost.

It can also be time consuming for landholders to develop the necessary skills and knowledge to use the technology effectively if it is not being used often. This creates opportunities for contractors to benefit from investing in the technology and skills in using it. Considering the capabilities, the technology has reasonable establishment costs for those looking to provide additional services and value to clients.

Overall, the drone technology was reliable, practical and useful for collecting information and completing tasks that are difficult or time-consuming on-ground. With further development specific to extensive pasture systems, drones could become a valuable tool for improving management in Western NSW.

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