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"Eagles Nest" – development and assessment of UAV supported technologies and data capture for extensive beef production across northern Australia

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Abstract

Across the beef and sheep meat sectors the use of improved digital information tools is predicted to provide more than $2.2 Billion in improved productivity. A key challenge in adopting such tools across extensive grazing lands is developing cost effective methods for remote monitoring of livestock, infrastructure and land productivity. The use of autonomous Remotely Piloted Air Systems (RPA) or more commonly called UAVs or drones provides one solution to this challenge.

The ability for RPA to monitor pasture and animals in extensive beef production across northern Australia has been identified in this project. The project has demonstrated that an RPA, with the ability to launch itself, transition into horizontal flight and return to its base for recharging could be used for infrastructure inspections, paddock surveys of pasture biomass and animal counting. However, for successful deployment in the very large properties of northern Australia, any RPA must have the capacity to cover large areas and operate for longer flight times.

Working with Australian RPA manufacturer Carbonix, the Volanti Vertical Take-off and Landing (VTOL) RPA was the choice for autonomous flights up to 2 hours. To achieve longer flights, alternative power sources were required, and the French designed Sunbird hybrid RPA was selected for endurance up to 7.5 hours with solar panels charging the batteries in flight.

Imagery and data collected from the RPA flights were used to improve the assessment of land and pasture condition and animal locations. Based on improvements in stock, pasture and labour management, the two RPA platforms provided a high level of return. B

Current CASA regulations for RPA limit the use of such systems to approved flight controllers or pilots. To enable the industry to capture the benefits for RPA, these restrictions will need to be overcome. With the technology proven to be both technically and economically viable, the next step is to work with the regulatory bodies such as CASA to improve the licencing and permit application process for long distance flights so that the technology is able to be used more extensively by producers.

Executive summary

After extensive consultation with producers, who confirmed that a business case existed and that an autonomous RPA solution would be considered an important asset to operations, the Hitachi Consulting Team consulted RPA operators and manufacturers to understand the current available technology and its capability. It soon became apparent that the initial concept of a completely autonomous solution would require a fixed wing RPA (for range) with vertical take-off capability (for autonomous operation). The project commenced initially using a hand launched fixed wing RPA with a multispectral camera and the ability to determine biomass from the images was soon demonstrated. Beyond Visual Line of Sight (BVLOS) operations were demonstrated in a secure airspace with flight missions up to 30 km delivered.

After further research the development team found a suitable RPA manufacturer in Australia that was developing a vertical take-off, fixed wing system. With this platform, fully autonomous operation was demonstrated on two extensive properties with biomass estimation and fence line imaging. The RPA was pre-programmed for its missions and autonomously deployed, executed the mission and returned to the base station. For safety reasons these operations were conducted under Extended Visual Line of Sight protocols with spotters and pilots monitoring operations.

While the initial concept called for autonomous recharging stations, detailed analysis revealed the productivity of such a system was poor due to battery recharging time, which took up to 2 hours. A new design was developed whereby a mobile recharge station charged spare batteries which were then rapidly exchanged allowing the RPA to redeploy in 15 minutes. This required the RPA to return to base which was acceptable in many cases as the range being achieved was around 180 km prior to recharging. Cognisant of the requirement for longer range applications, the team investigated and trialled the solar powered Sunbird RPA which achieved flight durations of up to 7.5 hours and a range of 350 km. Although hand launched, the Sunbird was seen as a good solution to include in the Eagles Nest system as it would only require launching once or twice a day.

Imagery and data collected from the RPA flights were used to improve assessment of land and pasture condition, infrastructure such as fence lines and animal locations. Machine learning methods were used for identification of individual grass species and calculation of biomass. Leucaena-based pastures were area assessed for the first time to enable improved evaluation for such pastures. This data can be used for improved modelling of animal productivity and pasture management.

Satellite remote sensing methods were also used for general vegetation assessment. Such imagery may be used to prioritise RPA flight missions therefore improving the utilisation and efficiency of using RPA across a property.

Initial capital costs for the RPA systems are between $55,000 to $100,000. However, for the sites studied improvements in stock productivity, pasture and labour management ($105,000) provided a high level of return with benefit to cost ratios of between 3.0 and 4.9 and a return on investment (ROI) of between 185% to 345% over five years. These levels of returns are expected to increase as the cost of RPA and sensors systems decline.

During the delivery of this project the Hitachi Consulting Team had many interactions with the CASA, the Civil Aviation Safety Authority through the RPA operators. Safety has always been at the forefront of Eagles Nest development with design of a ruggedised Control Centre to ensure an efficient and effective base for RPA operations with fixed radios, antennas and computers for communication, flight planning and control. The Eagles Nest RPA was fitted with an ADS-B transponder to ensure that it automatically communicated with all aircraft flying IFR (Instrument Flight Rules) and that radio communications and spotters where deployed to ensure no aircraft flying VFR (Visual Flight Rules) entered the RPA operating area.

Obtaining BVLOS permission from CASA for properties is a challenge and will restrict commercialisation and industry adoption. The current requirement for RPA pilots flying BVLOS to be IREX (Instrument Rated) is also very restrictive. Proposed changes in this regard recently announced by CASA is very encouraging with a more-straight forward Certificate IV in RPA BVLOS being announced, commencing July 2019. A more streamlined approach to BVLOS applications has also been announced which should commence July 2019.

RPA platforms will become key solutions on most farms in the future. Long range autonomous RPA platforms will be a key part of managing extensive beef production operations in northern Australia. As more of these systems are deployed it will be essential that the airspace is managed safely. This will happen through the deployment of UTM’s (Unmanned Aircraft System Traffic Management) systems as well as the education of pilots operating helicopters and light aircraft at low altitude under VFR to be aware of RPA operations and to take note of communications and Notice to Airmen (NOTAM’s).

Future research opportunities include the integration of new pasture identification and biomass analysis methods to further improve land and animal management systems. Biomass data by species could be improved by developing new imagery analysis methods for assessing pasture quality as well as biomass. Such techniques will allow for improved stocking rate management allowing greater turnoff rates and overall productivity.

Project Eagles Nest has proven that RPA solutions are technically capable of supporting extensive beef production operations across northern Australia and can provide business value by providing significant data in the areas of pasture management and infrastructure management for improved decision making. While the technology has been proven, there are still barriers to adoption, many due to current regulations.

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1 Background

In partnership with the MLA Donor Company, Hitachi Consulting initiated a series of projects enabling Digital Agribusiness Transformation using Hitachi Process Intelligence (HPI). This approach utilises previous learnings and platforms from other industries and aims to capture all processes along the value chain to identify opportunities for improvement and operating procedures that will improve the production and delivery of red meat to the retail sector.

One significant challenge to the HPI approach is generating sufficient and consistent data that captures both off and on farm activities. On farm activities and the environment are the most challenging in the value chain. Data capture needs to be autonomous, seamless and temporal to provide operational trends and an indication of seasonal patterns. The functionality of infrastructure, particularly fences and water points, is also of significant interest to on farm operations and currently relies on staff to service and report faults.

Remotely Piloted Air Systems (RPA), commonly known as a UAV or drone, is an aircraft without a human pilot aboard and their application to the agriculture industry is substantial. The distances required to cover extensive beef production operations with often little infrastructure is beyond the capability of existing smaller low-cost drone technologies. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator, or fully or intermittently autonomously, by on-board computers. The application of on-board cameras can be achieved with one or more technologies to provide visual assessment of the landscape and livestock for extensive beef production systems.

An initial MLA supported project P.PSH.0815 "Assessing value chain improvements in processes, practices and technologies using optimised data capture and analytics", saw Hitachi Consulting (HCC) in partnership with the Australian Country Choice/Australian Cattle and Beef Holdings (ACC/ACBH) develop a digital transformation pilot project to capture data and generate management systems to assess improvements in processes, practices and technologies for a backgrounding property. A range of sensor devices were deployed on the property covering watering points and weather data. The use of drone imagery was also used to identify changes in paddock Brigalow regrowth biomass estimations. A key outcome from the project was the development of a central control centre that enabled property managers to see data captured across the property in real time. One of the findings from this project was the need for assessing new drone or RPA technologies that had improved capabilities for use in extensive livestock industries.

To improve the benefits offered by the use of RPA technologies, the project would also assess new imagery capture and data analysis methods to improve pasture, animal and property infrastructure management. This would target for the first-time techniques for specific pasture identification and new approaches to biomass modelling which would enable property managers to improve land and stock management.

2 Project objectives

1. Detail data capture and management opportunities for RPA platforms on farm for integration into a red meat value chain using existing technologies developed by Hitachi.

2. Identify gaps in existing capabilities of RPA platforms on farm through assessment of best practice and sensor combinations that optimise capture of qualitative and quantitative data.

3. Evaluate individual or sensor/camera combinations that optimise data collection for livestock, infrastructure and/or pasture resource assessment and determine the outcomes of the on-farm autonomous system across the value chain.

4. Deploy and assess existing autonomous RPA systems to test deployment range and use of recharging systems in an extensive beef production system.

5. Third party independent review of the technical feasibility, cost benefit and business case associated with adoption of autonomous RPA platforms for the extensive beef industry and value to supply chain.

3 Methodology

3.1 Prioritisation for data management targets

Extensive discussions with property owners and managers where conducted as part of the previous project P.PSH.0815 “Assessing value chain improvements in processes, practices and technologies using optimised data capture and analytics” to identify primary management objectives within extensive grazing systems. The targeted areas included:

- *Pasture and vegetative biomass;*
- *Animal identification;*
- *Infrastructure assessment including:*
    - *Equipment location;*
    - *Fence line surveys;*
    - *Water supply - dam levels; and*
    - *Road conditions.*

A range of Remotely Piloted Air System platforms, sensor types and satellite imagery were used to evaluate the best methods for collecting such data. Machine learning approaches were used to allow accurate assessment of imagery data and to allow a combination of data sets to be use. These methods are explained for each of the targeted area.

3.2 RPA platforms assessed

To assess the capacity for Remotely Piloted Air System platforms to operate across extensive grazing lands, four (4) aircraft types and service providers were used.

These systems were assessed for their capacity to carry a range of sensors, flight time and distance or area covered.

V-TOL Seeker multi-rotor

Figure. 1 V-TOL Seeker is a multi-rotor which was used by Hitachi for LiDAR survey at ACBH Croydon and Australian Country Choice (ACC) Brisbane Valley Feedlot

The V-TOL Seeker multi-rotor RPA was capable of a flight time of 30 minutes. The multi-rotor can be equipped with high resolution Red, Green and Blue (RGB), Light Detection and Ranging (LiDAR) and Infra-Red (IR) cameras. This airframe was able to complete:

- Optical Infrastructure surveys (RGB Camera).
- Multispectral surveys for biomass estimation.
- LiDAR Surveys for biomass estimation.
- Infrared Survey for cattle location assessment and counting.

Specifications:
Dimensions & Weights

Diameter	1000 mm
Height	600 mm
Weight Empty	5.0 kg
MTOW	25.0 kg

Performance

Max Level Speed	20 Kts
Max Wind Speed	20 Kts
Operational Height	5000 ft AMSL
Mission Radius	3 km (BVLOS/Night ready)
Endurance	18 – 30 minutes (Subject to weather and payload)

V-TOL Goshawk

Figure. 2 Goshawk Airframe is a fixed wing RPA used by Hitachi for the initial flight tests

The V-TOL Goshawk RPA was used in initial flight tests, BVLOS operations, fence line and optical infrastructure surveys. It can be equipped with RGB and Multispectral cameras. Like the V-TOL Seeker platform the Goshawk was used to complete:

- Optical Infrastructure surveys (RGB Camera).
- Multispectral surveys for biomass estimation.
- Infrared Survey for cattle location assessment and counting.

Specifications:

Dimensions & Weights

Wingspan	1900 mm
Length Overall	1300 mm
Weight Empty	2.8 kg
MTOW	5.0 kg

Performance

Max Level Speed	45 Kts
Cruising Speed	36 Kts
Operational Height	5000 ft AMSL
Mission Radius	10 km
Endurance	120 – 150 minutes (Subject to weather)

Carbonix Volanti

Figure. 3 The Volanti Airframe used at Croydon Station and Calliope Stations (Carbonix ®)

The Carbonix Volanti, a medium sized hybrid (V-TOL and Fixed Wing), 2.85 m x 2 m carbon frame with a maximum payload of 1.5 kg and 2 hour endurance. This airframe was able to complete:

- Optical Infrastructure surveys of fence line and water points (RGB camera).
- Multispectral surveys for biomass estimation.

Specifications:

Dimensions & Weights

● Wingspan 3,611 mm
● Length 2,250 mm
● Maximum take-off weight (MTOW) 13 kg
● Weight (airframe only) 4 kg
● Packaging dimensions Box 1: 1,580 x 973 mm (@ 30 kg)
● Box 2: 1,090 x 930 mm (@ 25 kg)
●

Performance

● Flight time Up to 2 hour (all electric)
● Vertical take-off / landing (VOTL)
● Full VTOL capability
● Alternate between hover and cruise
● Optimum speed 70 km/h optimal airspeed
● Stall speed 50 km/h
● Max speed 120 km/h

- Operating temperatures (Celsius) -2 - 45 degrees (Tested. More extreme temperatures possible with testing)
- Water resistance Light drizzle
- Optimum turn radius 40 m
- Minimum turn radius 30 m
- Wind resistance 35 km/h (Tested. Withstanding more extreme wind conditions expected with testing)
- Altitude Up to 8,000 ft

Sunbird

Figure. 4 The fourth airframe used at Calliope Station for Hi-Res imaging (Sunbirds ®) with solar panels on its wings to recharge its battery pack for enhanced flight endurance

The Sunbird, a solar powered RPA with an extended battery life of up to 7 hours 18 mins tested, was used at Calliope Station. This airframe can carry a 300-g payload being an RGB camera or Multispectral. This airframe was able to complete:

- Optical Infrastructure surveys of fence line and water points (RGB camera).
- Multispectral surveys for biomass estimation.

Specifications

Weight 1.7 kg
Wingspan 3200 mmChord length 2.7 m
Material Carbon fibre Foam
Solar Power 100 Wc

3.3 Sensor systems and their use

A range for sensors were used across the four RPA platforms. These sensors and their applications are described;

Sony a6000 Optical Camera (RGB)

The optical payload planned for the RPA platform was a Sony a6000 camera 24 MP optical camera, capable of shooting 11fps @ 1920x1080/60p and designed for high resolution still pictures. It has the ability to shoot in true 1080 HD providing clarity at operational altitudes up to 55 metres. At 35 metres altitude this camera is excellent for infrastructure observation having a sensitivity of 3 cm per pixel and can provide images of infrastructure such as fence lines, water reservoirs and roads. This was used to detect water levels, wire breaks and other damage which would normally require staff to physically inspect.

Figure. 5 Sony a6000 24MP optical Camera

MicaSense Red Edge Multispectral Camera

The multispectral camera, had a 3.2 MP pixel count and was used for the RPA payload. Pixel size is 8 cm at a height of 120 m. This payload offered the flexibility of imaging the widest array of light spectrum of all the different sensor options.

- blue (475 nm centre, 20 nm bandwidth);
- green (560 nm centre, 20 nm bandwidth)
- red (668 nm centre, 10 nm bandwidth);
- red edge (717 nm centre, 10 nm bandwidth);
- near-IR (840 nm centre, 40 nm bandwidth).

Figure.6 MicaSense Rededge Multispectral Camera

Near Infra-Red sensors can be used for gathering data on vegetation, pasture condition, groves, orchards and crops. Still images are put through post processing and can produce what is called the Normalized Difference Vegetation Index (NDVI). The normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used assess whether the target being observed contains live green vegetation or not, as well as:

- Plant health.
- Variance in soil water availability.
- Yield potential.

When combined with red and green band widths, it can produce a Colour Infrared Composite (CIR) image which is used for mapping:

- Water bodies.
- Soil moisture.
- Soil composition such as variance between clay and sand.

Red Edge wave lengths were best suited for detection of chlorophyll and nitrogen and produce mapping of:

- Normalized Difference Red Edge (NDRE) which provides a better indication of plant health than NDVI.
- Relative leaf chlorophyll content indicating plant stress.
- Vegetation nutrient demand, nitrogen uptake and chlorophyll mapping.
- Crops with low chlorophyll levels.
- Estimate chlorophyll levels and estimation of Nitrogen content.

Thermal or Infrared camera

Thermal imaging was used to differentiate animals from the ground and was best utilised in the early morning when the temperature differential between the ground and the animal is at its greatest . Thermal imaging was used for detection and determining stock numbers.

LiDAR

Light detection and ranging (LiDAR) cameras were used to measure distances between the RPA and the ground. These cameras allowed accurate measurement and averaging of pasture dry matter by calculating the height of the grass for the calculation of volumetric biomass (kg DM/ha).

3.4 Trial sites

The properties selected represented a cross section of the industry, from a large corporate operation to a medium sized operation. The three properties were:

- **ACBH Croydon Station**
  Latitude 22°27’50.28”S
  Longitude 149°10’1.16”E
- **Calliope Cattle Company**
  Latitude 24°1’31.12”S
  Longitude 150°58’4.35”E
- **Marburg**
  Latitude 27°34’0.00”S
  Longitude 152°34’60.00”E

Figure 7. The location of the 3 properties that the RPA surveys were conducted in Queensland

3.4.1 Properties descriptions

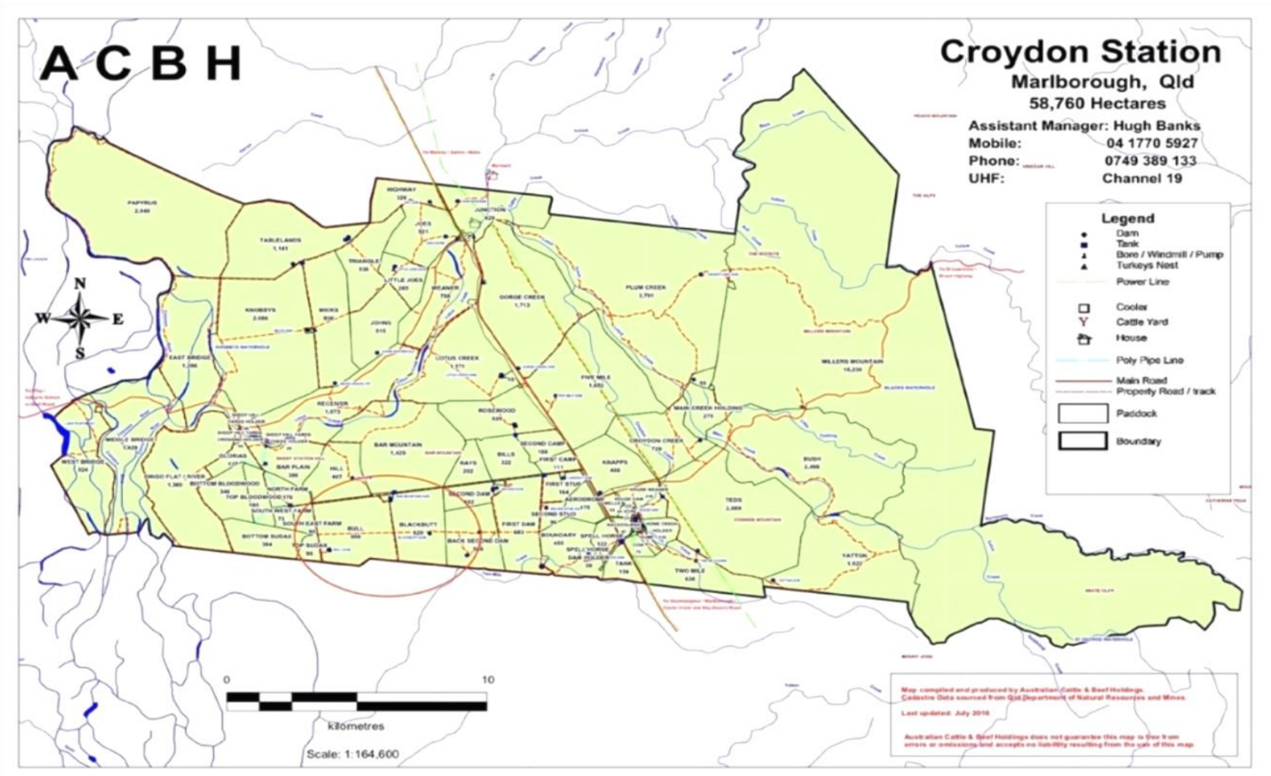
Marburg Site

The airspace over Marburg was controlled by the Royal Australian Airforce. Special permission for BVLOS was granted by the RAAF and CASA prior to operations

Figure 8. RPA Launch during Marburg Flight Tests. The Goshawk airframe required a hand launch for flight operations

Croydon Station - Australian Cattle and Beef Holdings (ACBH) Pty Ltd

Croydon station is a medium sized commercial farm which is part of the ACBH group. It has a fully integrated supply chain business supplying beef to the Australian domestic market. Croydon is a 58,760-ha property running breeding and background operations for up to 14000 cattle. Through ACBH, the project team also had access to other ACBH and ACC



properties for additional testing, verification and calibration of sensor data.

Figure 9. Croydon Station Map

In both Blackbutt and Bull paddocks the main soil type was Vertosol with some of the area made up of Sodosols (Figure 10).

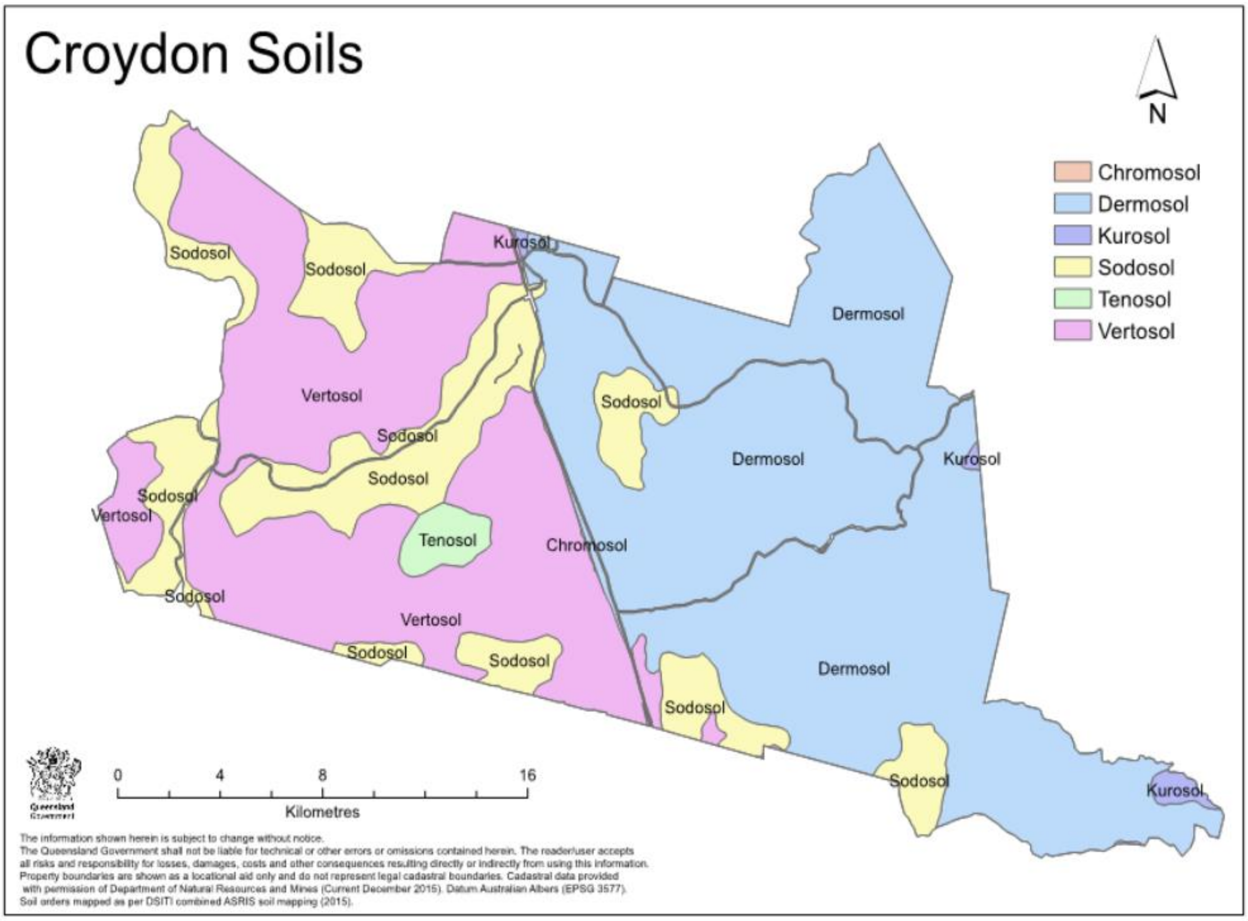


Figure 10. ACBH Croydon Station soil map .

Vertosols are common soils in Queensland and are characterised by:

- brown, grey or black soils which crack open when dry.
- commonly form hummocky relief called gilgai.
- very high-soil fertility.
- large water-holding capacity.

Sodosols are texture-contrast soils with impermeable subsoils due to the concentration of sodium. These soils occupy a large area of inland Queensland. Sodosols have a low-nutrient status and are vulnerable to erosion and dryland salinity when vegetation is removed.

Calliope Station

Calliope is a property which has a carrying capacity of approximately 17,000 head of cattle across 48,000 ha in central Queensland.

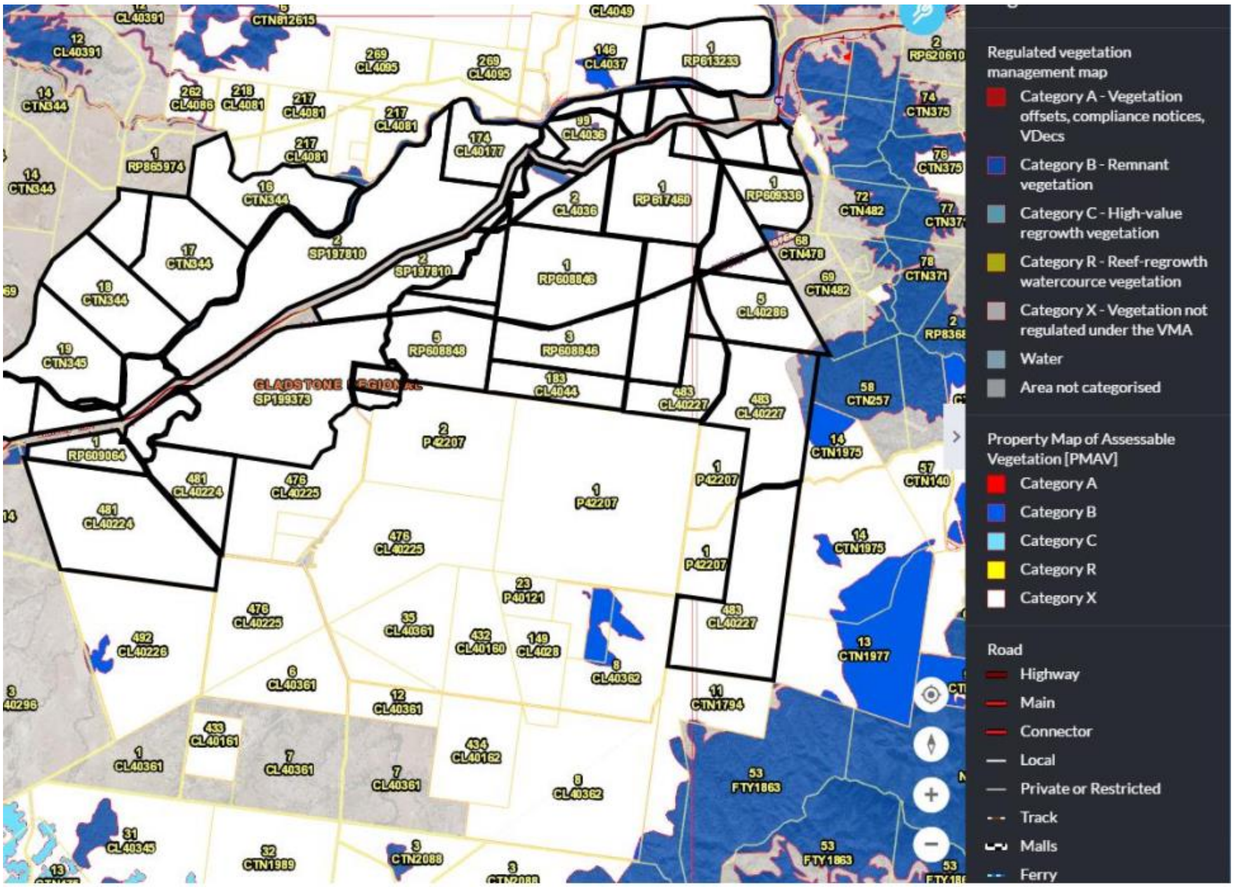


Figure 11. Calliope Station map with vegetation and infrastructure

3.5 Operating Flight Protocols and Flight Preparations

Appendix 7.3 details operating flight protocols as required by Civil Aviation Safety Authority (CASA)

Flight Planning

Prior to site arrival, mission planning was created using Google Earth and Carbonix's autopilot software. This was achieved by identifying key sites suitable for operation within the flight permissions and mapping out the basic flight paths and survey area on Google Earth (Figure 12):

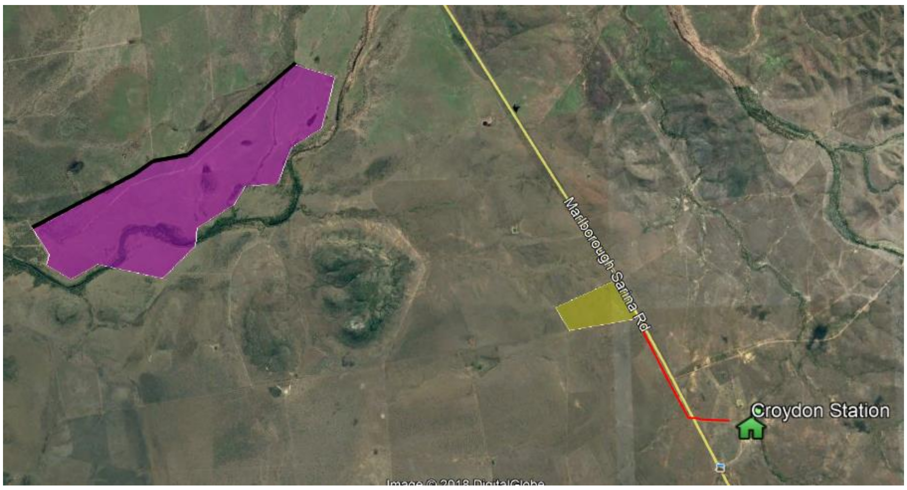


Figure 12. ACBH Croydon Flight plans. The Red and black lines represent fence line surveys. Purple and yellow areas represent multispectral paddock surveys.

RPA flight imagery data was then saved as a .KMZ file and imported into autopilot software which created planned flight paths. A scout map was created, (Figure 13) for the RPA. This map was created from satellite multispectral imagery and displayed the variance in vegetation within the paddock. The markers placed on the map were located at different vegetation types to achieve a diverse and comprehensive sample.

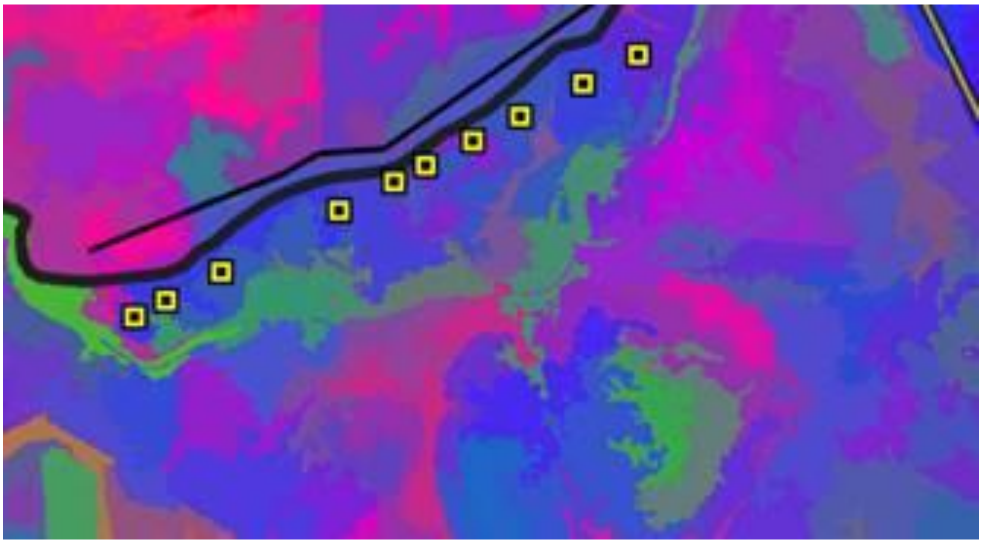


Figure 13. Sentinel satellite photo that shows flight path for Volanti RPA over receiver paddock ACBH Croydon. The yellow squares denote the location of pasture sampling.

The area surveyed was reduced to allow the test area (receiver paddock) to be sample surveyed in one flight making the survey of larger paddocks viable. Figure 14 shows the actual area, which was surveyed across Receiver paddock, Croydon in November 2018.

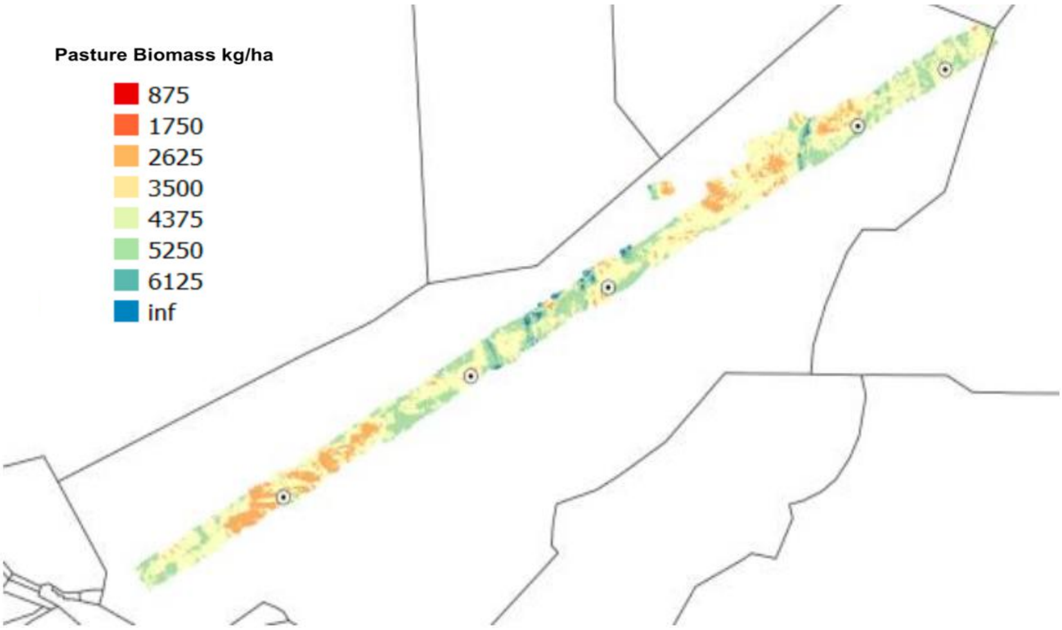


Figure 14. Receiver Paddock Survey Sample as identified by the Sentinel Satellite image and imaged by the RPA Multispectral camera.

Mission Planning Software

Automated mission planning was prepared in auto-pilot planning software ARDUPilot (http://ardupilot.org/) and OpenPilot. This software allowed the user to set waypoints on an actual geographical map from Google Earth. Variable parameters including height and velocity were considered to determine which camera to use.

3.6 Flight details for each trial site

3.6.1 Summary of flights by RPA platform and sensors

RPA Type	Sensor type and location for use			
	LiDAR	Digital and RGB	Multi-spectral	IR (Thermal)
Volanti		Site Croydon: Date: 17-18/4/2018 Location: First Camp Paddock	Site: Croydon Date: 17-18 /4/2018 Survey First Camp and receiver paddocks Site: Calliope Date: 19-20 /4/2018 Location: Back of Lockerbie and Berwick Paddocks	

Goshawk		Site: Marburg Date: 22/08/2017	Site: Marburg Date: 22/08/2017	
Sunbird		Site: Calliope Date 25-26/09/2018		
V-TOL	Site Croydon Date: 11-13 Dec 2017 Location: First Camp, Bull, Blackbutt and Receiver paddocks			Site: Brisbane Valley Feedlot Date: 17/11/2017

Table 1. Summary of Imagery and RPA type used across the various assessment properties

3.6.2 Croydon

Operations at ACBH Croydon commenced on 16th of April 2018 and ceased on the 18th of April 2018. Planned objectives were:

- Gather pasture samples with calibration and data verification;
- Survey of two fence lines, taking a path:
  - Along the highway from First Camp to the end of Second Camp paddock then across the road to survey part of the laneway (shown as red in Figure 15)
  - A cleared section of fence at the back of Receiver paddock (shown black on Figure 15)
  - Two multi spectral surveys on First Camp (yellow in Figure 15) and Receiver paddock (purple in Figure 15)

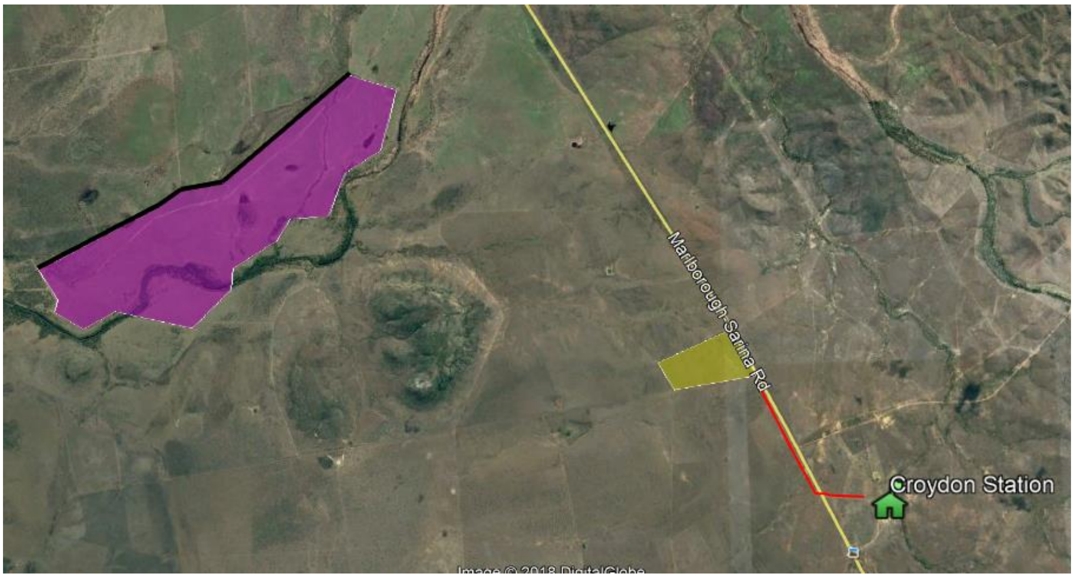


Figure 15. Flight plans for ACBH Croydon for pasture biomass and infrastructure assessments (Fence lines)

During the operational time at ACBH Croydon, all planned missions were successfully completed. Whilst performing fence line surveys, it was noted that the initial flight altitude at 60 m did not produce appropriate results for accurate pasture and detection for fence lines. Flight plans were reconfigured for secondary flights at a lower altitude of 45 m.

LiDAR Survey

Two paddocks were selected for LiDAR survey at ACBH Croydon, First Camp and Receiver paddocks. The two paddocks were selected because First Camp had only recently had cattle taken off (low biomass) whereas Receiver had been rested for an extended period (high biomass).

For this mission a multi rotor RPA was used combined with a VLP-16 Lite LiDAR sensor. Having these two sets of data allowed for the monitoring of vegetation growth on First Camp and Receiver paddocks. A data sample size of 100 ha was surveyed for each paddock. The aim of this was to extrapolate the sample into an estimation of the whole paddock which could be compared to the validation data. The validation data was gathered using a modified Botanal (Tothill, et al., 1992)

Four sets of data were collected from Bull and Blackbutt paddocks (Figure 16).

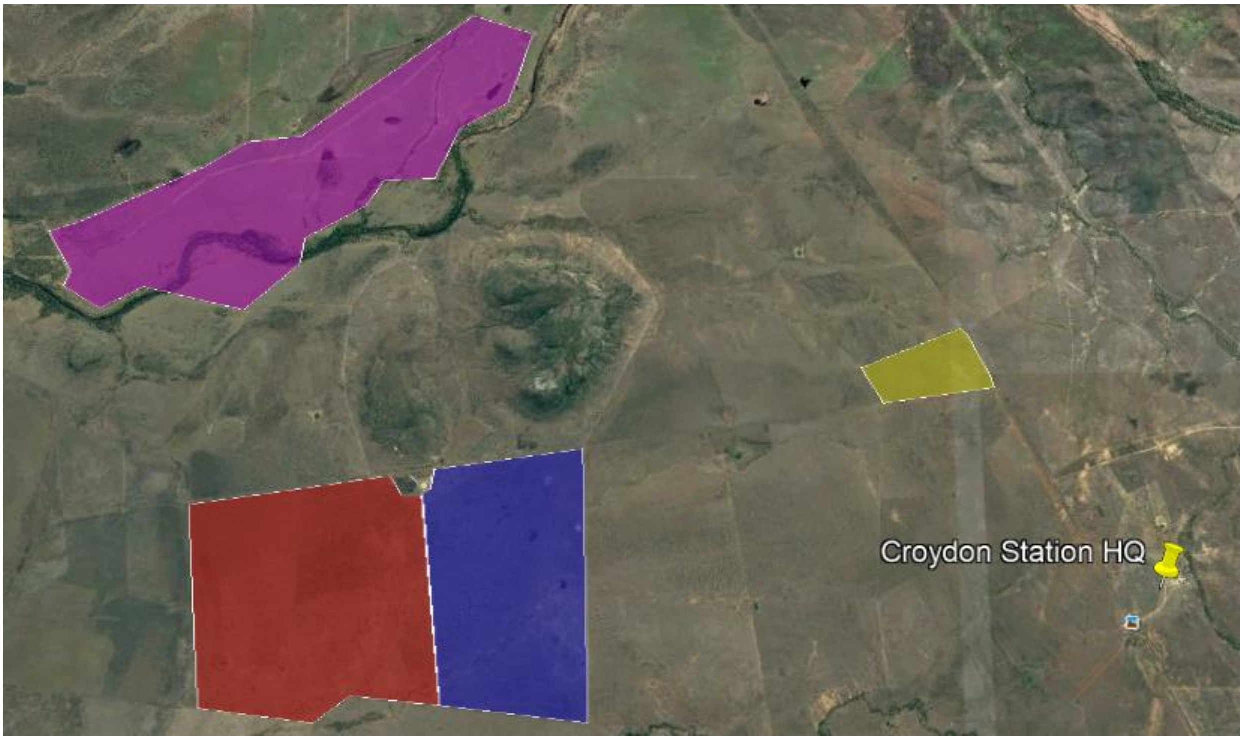


Figure 16 Paddocks Surveyed by LiDAR at ACBH Croydon. Blackbutt (blue), Bull (red), First Camp (yellow) and Receiver (purple) paddocks highlighted

RGB Optical Survey

Two optical surveys were conducted

- Fence line/ Road survey along the laneway from the Bull Paddock to the main road;
- Aerial survey of recent brigalow poisoning on Bull Paddock.

Figure 17 Road and Fence Line Infrastructure Survey flight path SCVH Croydon

Thermal Survey

The Infrared survey was completed at ACC Brisbane Valley feedlot, near Esk, Queensland. The actual cattle numbers in each pen was known. This Survey was conducted early morning 04:30 – 06:30 and was performed by a multi-rotor RPA, Seeker, with a FLIR Thermal IR camera .

Fixed Wing Endurance Test

The Goshawk fixed wing survey RPA was loaded up with a single battery bank and endurance tested with a minimum target of 145 km at an altitude 120 m, duration 1 h 51 m. Figure 18 shows the flight path of the fixed wing endurance test which consisted of a repeated box formation. Line of sight restrictions constrained flight path for safe operation.

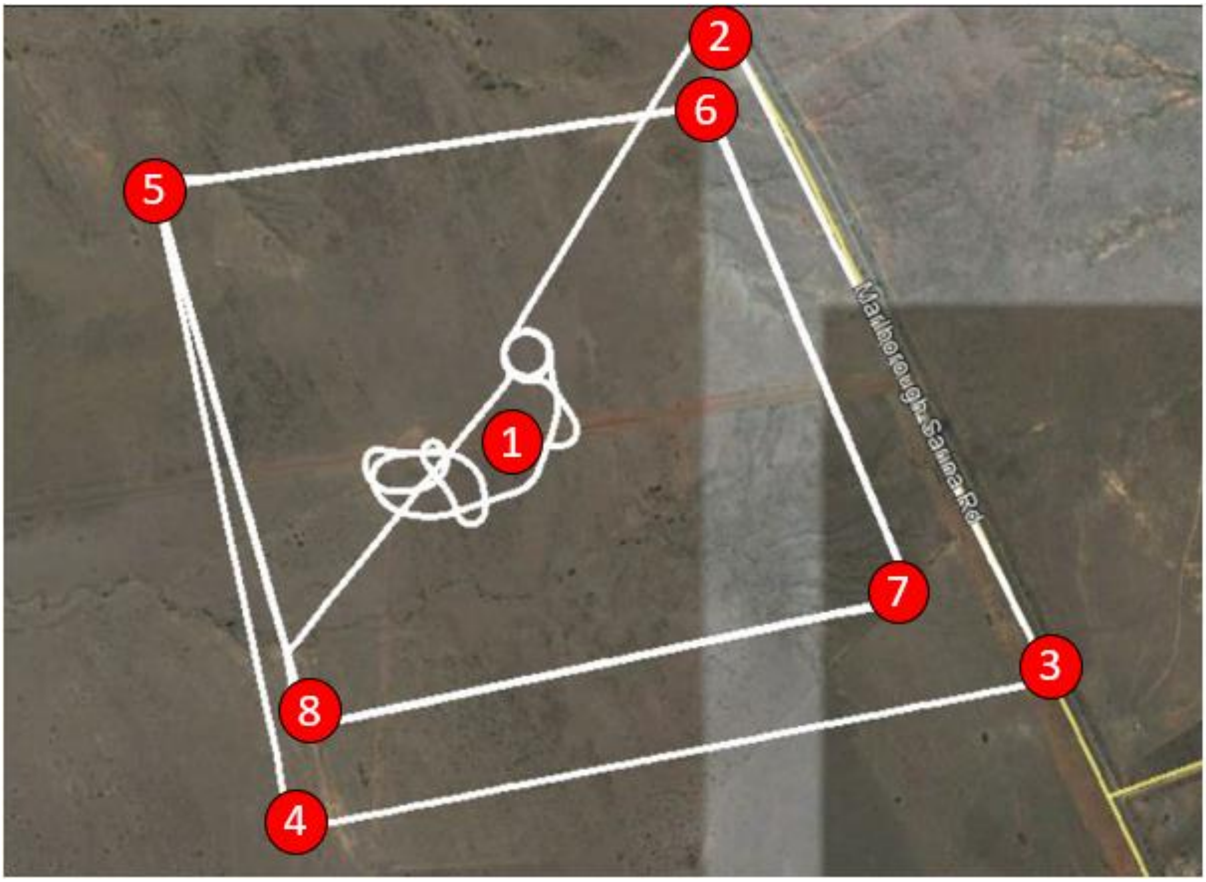


Figure 18. Flight path of endurance test performed at ACBH Croydon. In order of operation: (1) RPA take off and holding pattern, (2) start of flight path, (3, 4, 5) RPA follows GPS waypoints to start of testing circuit, (5,6,7,8) RPA follows this set of markers which are spaced 2 km from each other until low battery (20% charge), (1) RPA returns to take off point for landing.

3.6.3 Calliope Station

Operations at Calliope Station commenced on 19th of April 2018 and ceased on the 20th of April 2018. Planned objectives were:

- Conduct Botanal sampling for imaging calibration and data validation.
- Perform two fence line surveys:
  - south side of back of Lockerbie Paddock (shown as red in Figure 19)
  - west side of the back of Lockerbie Paddock (shown as yellow in Figure 19)
- Multispectral surveys completed on:
  - Back of Lockerbie paddock (shown as grey in Figure 19)
  - Berwick paddock (Shown as blue in Figure 19)
- Infrastructure survey of a dam

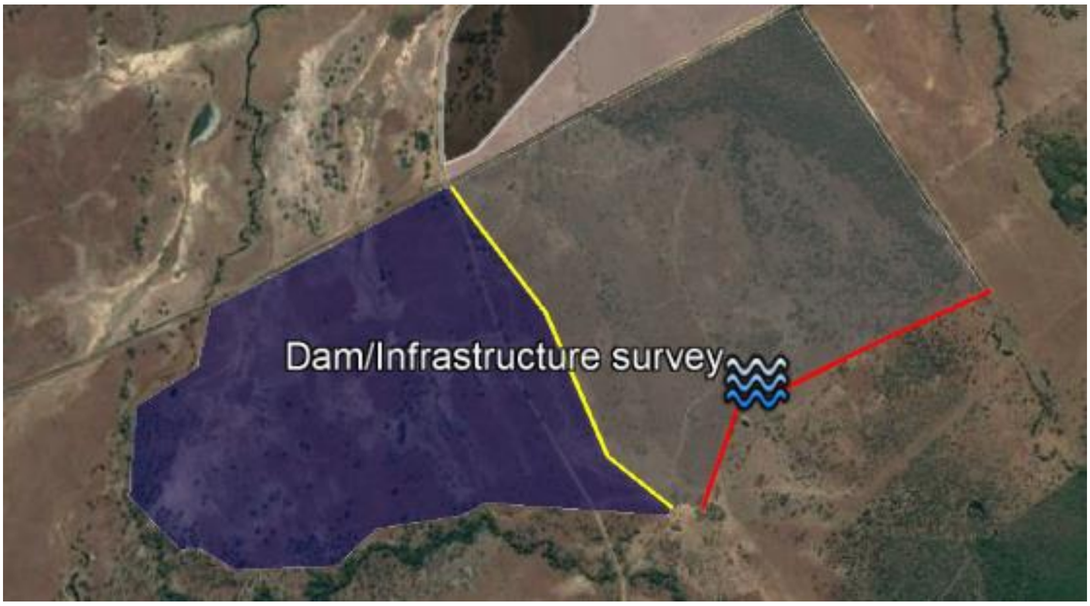


Figure 19. Proposed flight plans for ACBH Calliope Station

During operational time, missions were revised. A mob of cattle had been mustered between two paddocks and it was suspected that some cattle had been left on the paddock to be spelled. The missions were then changed to a multispectral survey of:

- Front of Lockerbie paddock shown as black (Figure 20)
- Selection paddock shown as beige (Figure 20)

Figure 20. Paddocks to be surveyed for ACBH Calliope Station

This survey would then be used to perform a head count from the imaged paddocks. Due to the size of the paddocks two missions were conducted.

3.7 Assessment of Pasture Biomass

Imagery assessment approaches

The objective was to develop a scalable approach to estimating pasture biomass and potential yield, based on a combination of time-series satellite imaging and targeted RPA imagery. The calibration of imagery data was optimised by field data collection. The combined data sets were then used with machine learning processes to develop a model for prediction for pasture biomass (Figure 21).

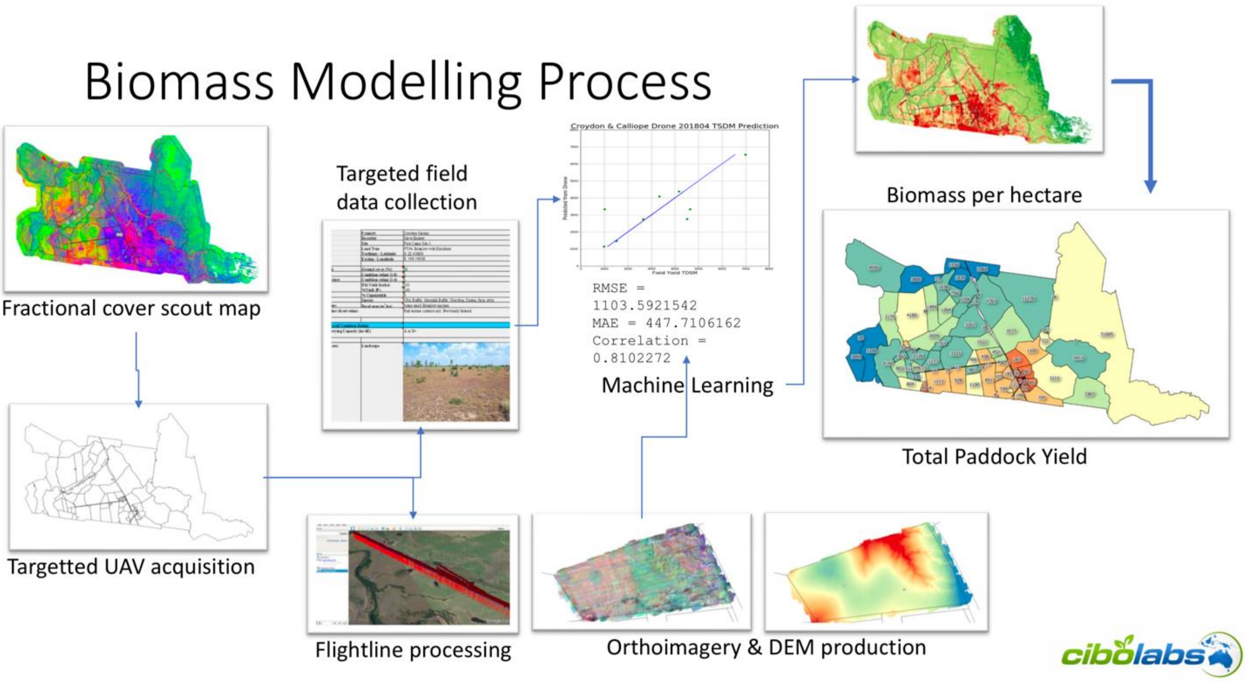


Figure 21. Biomass Modelling Process

The methods for imagery analysis involved the use of Digital Elevation Models (DEM) to correct the bundled multispectral data to build orthomosaic imagery across each site. Once generated, the 5 band multispectral data, combined with each of the field sites, was extracted to give a mean and variance for each site. This was then used to train a stacked ensemble within the machine and deep learning process. This model was then applied back to the imagery to inform the biomass prediction.

LiDAR Survey

LiDAR was used to measure the distance to a target by illuminating that target with a pulsed laser light and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths were used to make digital 3D-representations of the target (surface map).

LiDAR used from RPA was primarily used for measuring available pasture biomass (DM kg/ha). A LiDAR survey generated two models simultaneously; the digital terrain mapping (DTM) and digital surface mapping (DSM). These models created a volumetric estimation of the measurement of biomass.

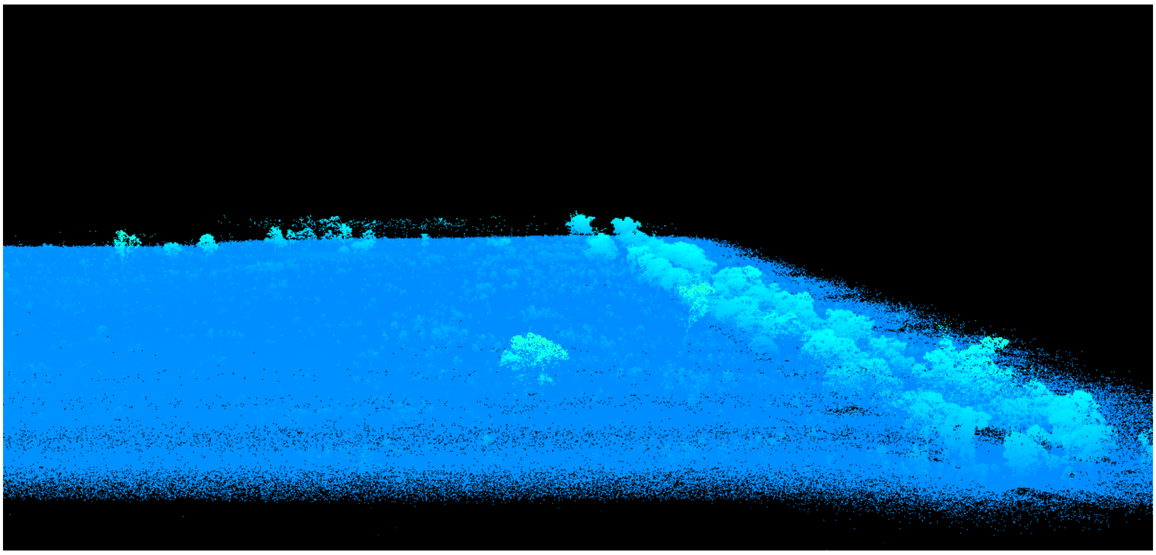


Figure 22. LiDAR mapping taken in Receiver paddock at ACBH Croydon with V-TOL Seeker RPA

Pasture Sampling, Ground Truthing and Botanal

Pasture sampling (Tothill, et al.,1992) was used for ground truthing and calibration by obtaining estimates of the quantity of herbage dry matter present and the composition of the herbage, expressed as the proportions of different components (individual species, grouped categories such as grasses and weeds, or green and non-green material).

The Botanal methodology allowed for the estimation of yield and composition by weight and other attributes, such as frequency, cover and density.

Figure 23. Botanal assessment site, ACBH Croydon

Pasture assessment included sampling 0.25m² quadrats, cut at a nominal grazing height. Collected grass and weeds species were recorded and dried at 30°C for 8 hours and weighed for pasture biomass calculations. The percentage weed and unpalatable grasses was subtracted to allow accurate calculations of available palatable biomass per hectare.

Visual site level assessments were undertaken for land type, ground cover, land condition, dry matter yield; percentage (%) grasses, percentage (%) unpalatable; dominant species and basal area. For each site 5-10 pasture cuts were dried and weighed to provide a site level estimate.

With a sample size of 4 sites across two paddocks at Calliope and 7 sites across two paddocks at Croydon, all data were pooled for analysis. Mean Dry Matter (kg/ha) estimates were calculated for each site from the quadrat data, spectral data from the RPA and Sentinel imagery were summarised for each site for analysis.

Correlation of image and Botanal data

Machine Learning methods were used to analyse the raw spectral data (RPA and Sentinel), fractional cover (Sentinel) and numerous band combinations and transformations with botanal assessments. This allowed selected grass species to be identified from imagery analysis and algorithms to be developed for biomass mean dry matter (kg/ha).

3.8 Assessment of Livestock

To assess animals using RPA flights, both optical and multispectral imagery were used. The combination of imagery was used within machine learning approaches to obtain classification and subsequent identification.

3.9 Fence Line Surveys

The RPA was flown overhead and at a defined offset distance to the fence line and the images taken at an oblique angle (Figure 24). A Sony a6000 camera mounted under the RPA was used to take photos when imaging fence lines.

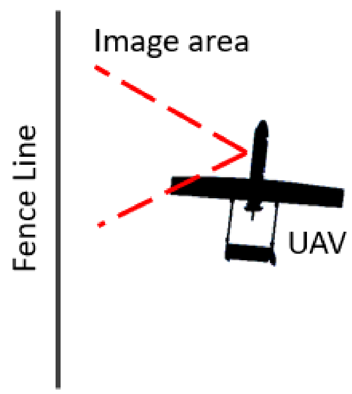


Figure 24. RPA using an offset flight path to gain an oblique camera angle for fence line inspections

3.10 Assessment of General Infrastructure

Camera Used for Infrastructure Survey

The high-resolution digital imagery was used for monitoring of:

- The gate status i.e. open or closed.

- The location of the cattle (if the entire paddock was surveyed the whole mob could be observed).
- Position of farm equipment.
- Condition of roads.

4 Results

4.1 Pasture Biomass

4.1.1 Imagery analysis

Initially results of vegetation biomass assessments where made via multispectral imagery from the Sentinel satellite platform across Calliope (Figures 25 and 26) and Croydon (April 2018 flights)

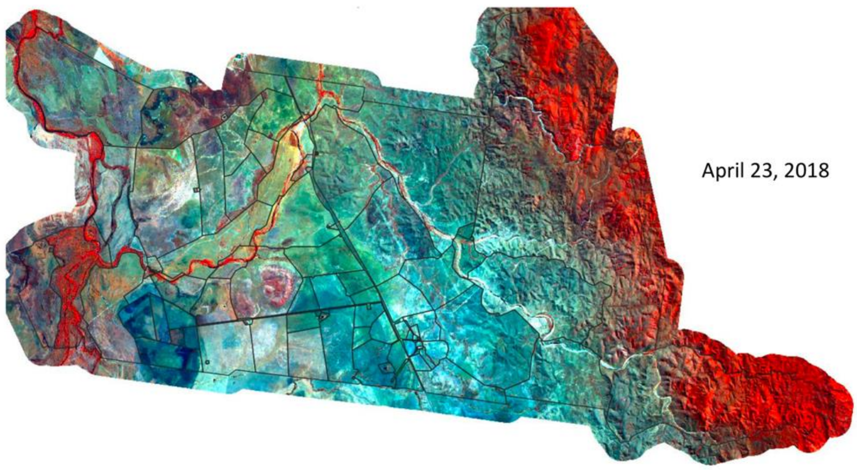


Figure 25. Sentinel multispectural satellite map of the Croydon Station property

The raw imagery was processed through the fractional ground cover (bare, photosynthetic (PV) and non-photosynthetic cover (NPV). The Fractional cover products were then used to identify the variability in cover to target RPA acquisition and field data collection.

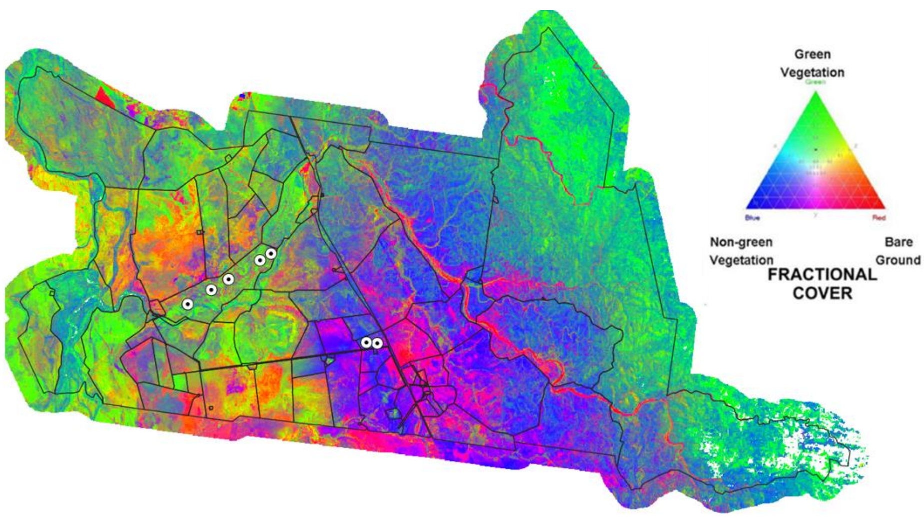


Figure 26. Sentinel satellite map for fractional ground cover of the Croydon. Botonal sampling points are highlighted by the circles.

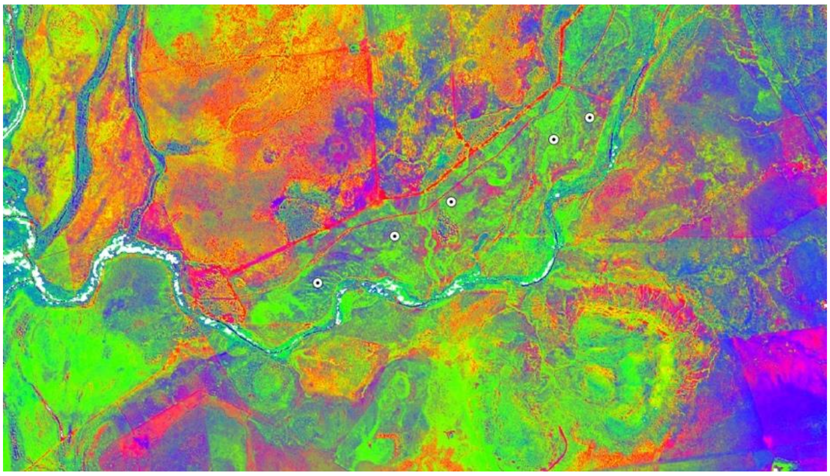
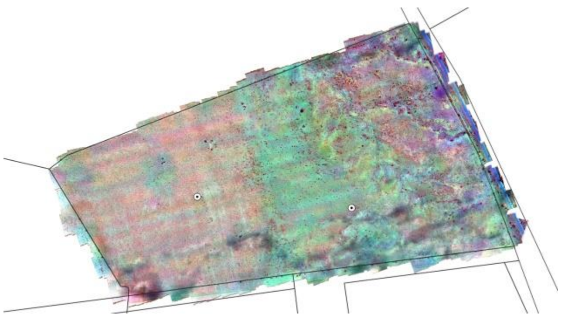


Figure 27. Fractional Ground Cover Models from Sentinel satellite data (red represents bare ground; green is photosynthetic material and blue non-green vegetation colours vary if they are combinations of these 3 terrain types.)

Vegetative zones from satellite data was used to select optimum RPA flight paths. The RPA data was processed using ancillary positioning and Inertial Measurement Unit (IMU) data to create a Digital Elevation Model (DEM) and orthorectified multispectral imagery for each site, Figure 28.



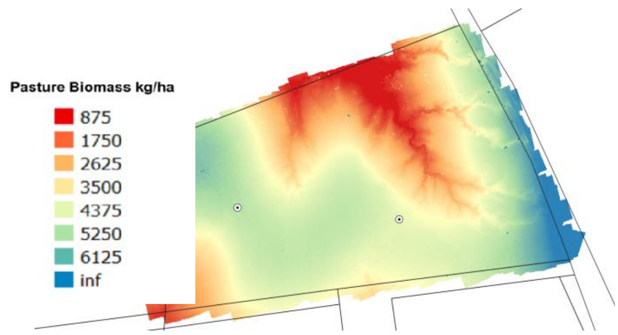


Figure 28. ACBH Croydon First Camp Paddock DEM (left) and Multispectral (right)

4.1.2 Botanal assessments

Correlation data from field sites were collected. The locations for pasture sampling is shown (Figures 26-28) by the white outer and black centre circles. Figures 29 and 30 outline the key outcomes from selected pasture sampling used for validation of the multispectral imagery and the satellite imagery.

	Date	19 April 2018
	Property	Calliope Station
	Recorder	Steve Banney
	Site	Front Lockabie 1
	Land Type	FT03, Box flats
	Northings / Latitiude	S 24.03632
	Easting / Longitude	E 151.01337
Soil	**Ground cover (%)**	100
	Condition rating (1-5)	1
Pasture	**Condition rating (1-4)**	1
	DM Yield (kg/ha)	6997
	%Yield 3Ps	100
	% Unpalatable	5
	Species	Native blue grass and common couch grass
Trees	**Basal area (m^2/ha)**	
Other observations		Low lying flat, heavily grassed
Overall Condition Rating		
Carrying Capacity (ha/AE)		A
Photos	**Landscape**	
	Trayback	

Figure 29. Botanal results for ACBH Calliope Station Front Lockerbie 1 paddock

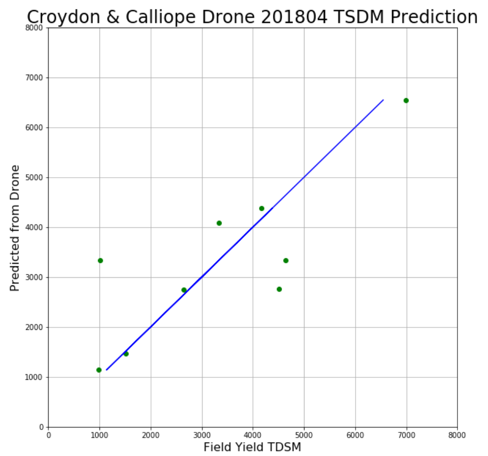
The assessment for pasture condition was based on a subjective visual ranking of 1 to 4, where 1 was considered as excellent (good height and density) and a ranking of 4 was poor (low height and density). The use of % Yield 3Ps relates to ranking of the pasture based on percentage (%) of perennial pasture content, productive and palatability.

	Date	12 December 2017
	Property	Croydon Station
	Recorder	Steve Banney
	Site	Blackbutt
	Land Type	Brigalow Blackbutt
	Northings / Latitiude	22 27 17.3
	Easting / Longitude	149 04 31.7
Soil	**Ground cover (%)**	80
	Condition rating (1-5)	2
Pasture	**Condition rating (1-4)**	2
	DM Yield (kg/ha)	500
	%Yield 3Ps	40
	% Unpalatable	10
	Species	Gayndah Buffel, Indian couch
Trees	**Basal area (m^2/ha)**	
Other observations		Lime bush and Brigalow regrowth
Overall Condition Rating		
Carrying Capacity (ha/AE)		C
Photos	**Landscape**	Missing
	Trayback	Missing

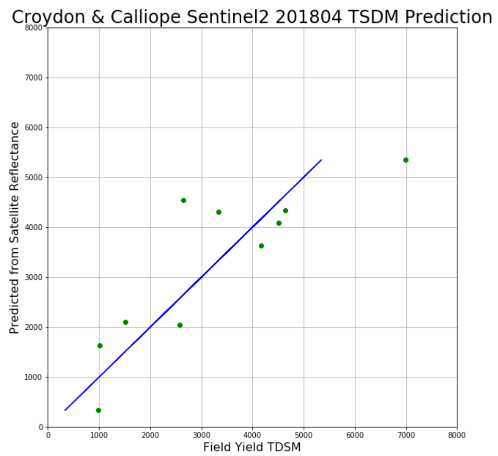
Figure 30. Botanal results for ACBH Croydon Station Blackbutt paddock

4.1.3 Biomass modelling

Machine Learning methods were used to analyse the raw spectral data (RPA and Sentinel), fractional cover (Sentinel) and numerous colour band combinations and transformations. Summaries of model predictions from assessment at Croydon and Calliope properties are shown in Figure 31.



RMSE = 1103.59 MAE = 447.71
Correlation = 0.81



RMSE = 836.11 MAE = 643.00
Correlation = 0.89

Figure. 31 Model Prediction Summaries of Mean Dry Matter

Despite the relatively small sample size, model correlations for both the RPA (drone) (R^2 = 0.81) and Sentinel (R^2 = 0.89) Fractional Cover products, the RPA model provided an overall accuracy around +/-10% and the Sentinel predictions were around +/- 15% across the biomass range of up to 7000 kg/ha.

Figure 32 provides the overall Sentinel correlated biomass image for ACBH Croydon Station. Figure 33 shows analysed image of collected data from RPA for one field. The data were combined and analysed to provide an overall property map of average pasture biomass across each paddock, (Figure 34).

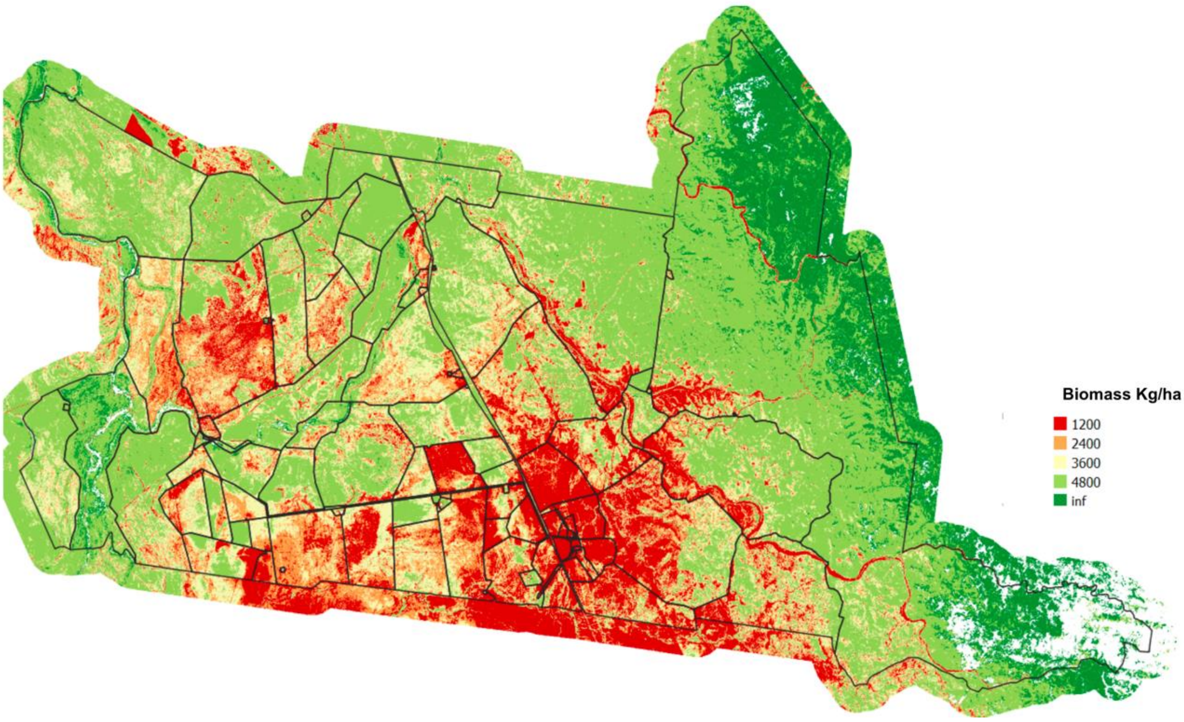


Figure 32. Sentinel pasture biomass imagery for ACBH Croydon Station

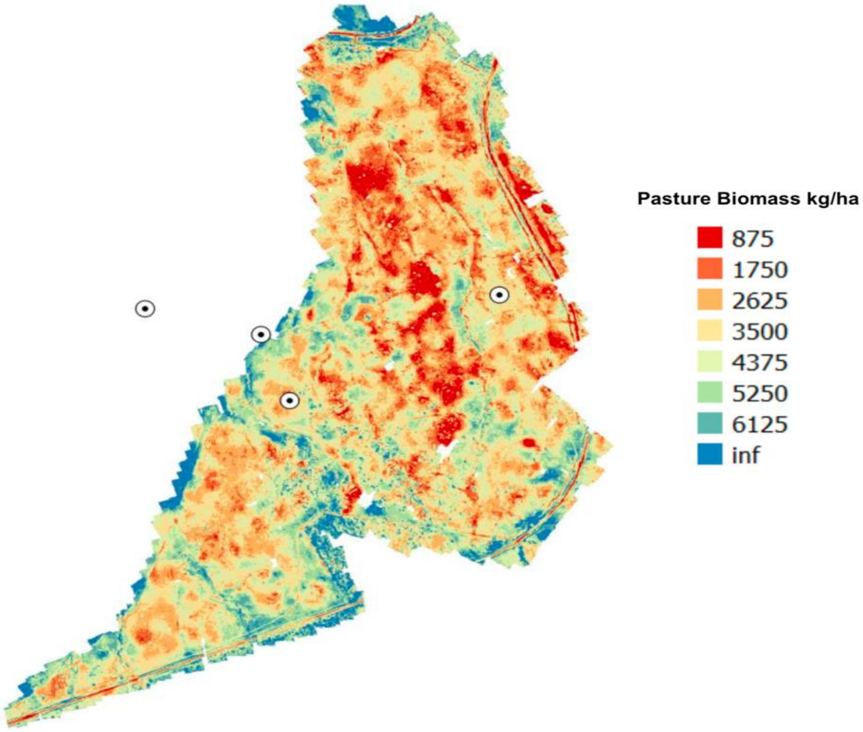


Figure 33. Correlated pasture biomass from UAV imagery for ACBH Croydon Station

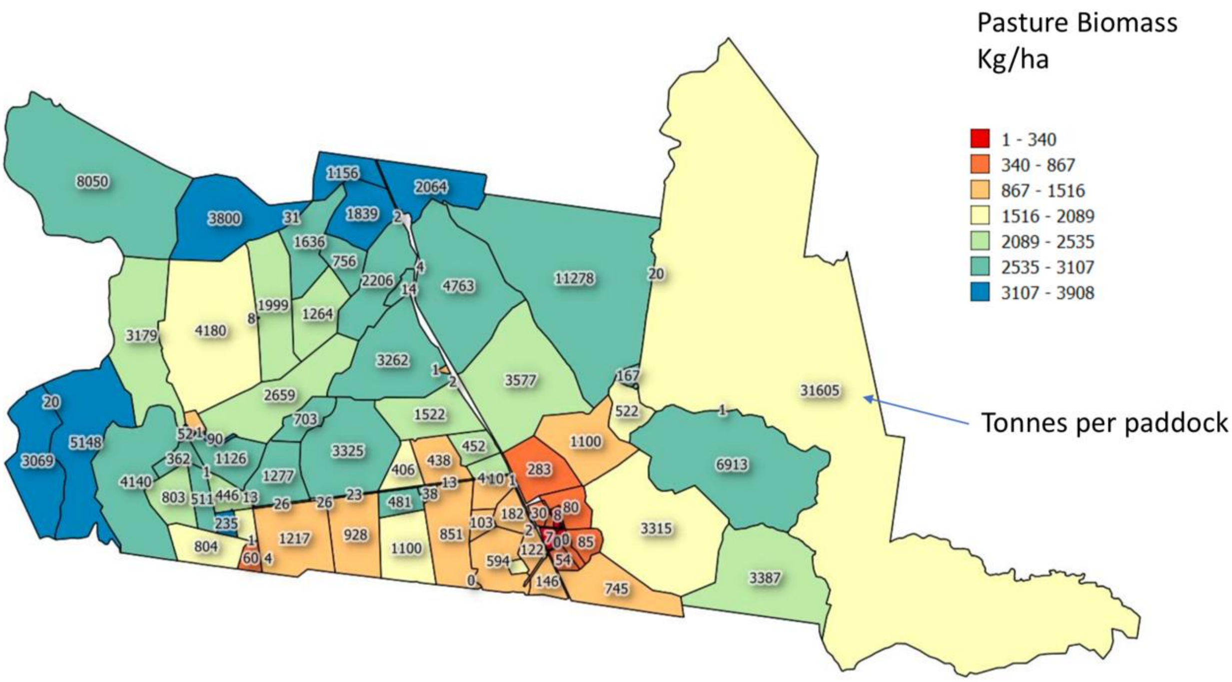


Figure 34. Correlated pasture biomass for ACBH Croydon Station by paddock (Pasture biomass kg/ha)

4.1.4 Pasture species assessment

To expand the benefits gained from pasture assessments, a small side project was conducted with 14 plant species imaged across the various properties using a small RPA with a RGB camera. These assessments included several species of Buffel grass (Biloela, Gayndah); Black Spear Grass; Kangaroo Grass; Creeping Blue Grass and other key improved pastures : Rhodes ; Kikuyu ; Setaria , Barley ; Phalaris, Clover; Rye Grass; Lucerne and common chicory.

Machine Learning methods were used to analyse the image collected from the RPA camera. The analysis was used for species identification. While the sample sizes are small, initial results are promising, with up to 95% accuracy in species identification being achieved from use of the techniques for selected pasture types. Species identification was also completed across areas of mixed pastures to allow effective species compositions to be determined for selected areas of a paddock or property. The results of this small side projects suggest that small RPA's may be capable of conducting a "digital pasturel assessment" in the future to provide ground truthing and calibration information for both satellite imagery as well as the RPA's conducting biomass surveys.

4.2 Assessment of livestock

Optical and multispectral imagery was combined with machine learning methods to develop specific algorithms for identification of livestock, (Figure 35). Accuracy of 98% was achieved in animal identification. In was noted that errors can occur when assessing animals that are densely packed together and as a result the image analysis methods are unable to differentiate between animals. Future research in the use of Deep Learning techniques for image classification would allow for part image recognition and resolve issues of animal identification where there are overlapping images.

Animal conditions may be subjectively assessed based on movement over time. This will require continual monitoring over short periods.

Figure 35. Survey Picture captured by a Sony a6000 optical camera taken at 45 m AGL showing cattle, fence lines and farm equipment, ACBH Croydon

4.3 Assessment of fence line

RPA imagery directly above a fence line proved ineffective in assessing the integrity of a fence. (Figure 36). When the RPA was flown offset to the fence line and the images taken at an oblique angle more accurate assessment could be achieved, (Figure 37).

After experimenting with flight altitudes, it was found that 45 m Above Ground Level (AGL) was an ideal height to avoid potential obstacles and gain enough detail. Using the oblique images with a Sony a6000 (Hi-Res) allowed the system to produce details of individual strands of wire on a fence.

Figure 36. Fence line captured from the Volanti directly overhead. The red box indicates the area where the fence line is located.

Figure 37. ACBH Croydon fence line Volanti survey from back of Receiver paddock

Figure 38. ACBH Croydon fence line Volanti survey from back of Receiver paddock, (Figure 37 zoomed in)

4.4 Assessment of infrastructure

The high-resolution digital imagery was used to successfully monitor key infrastructure such as gates, equipment and road conditions.

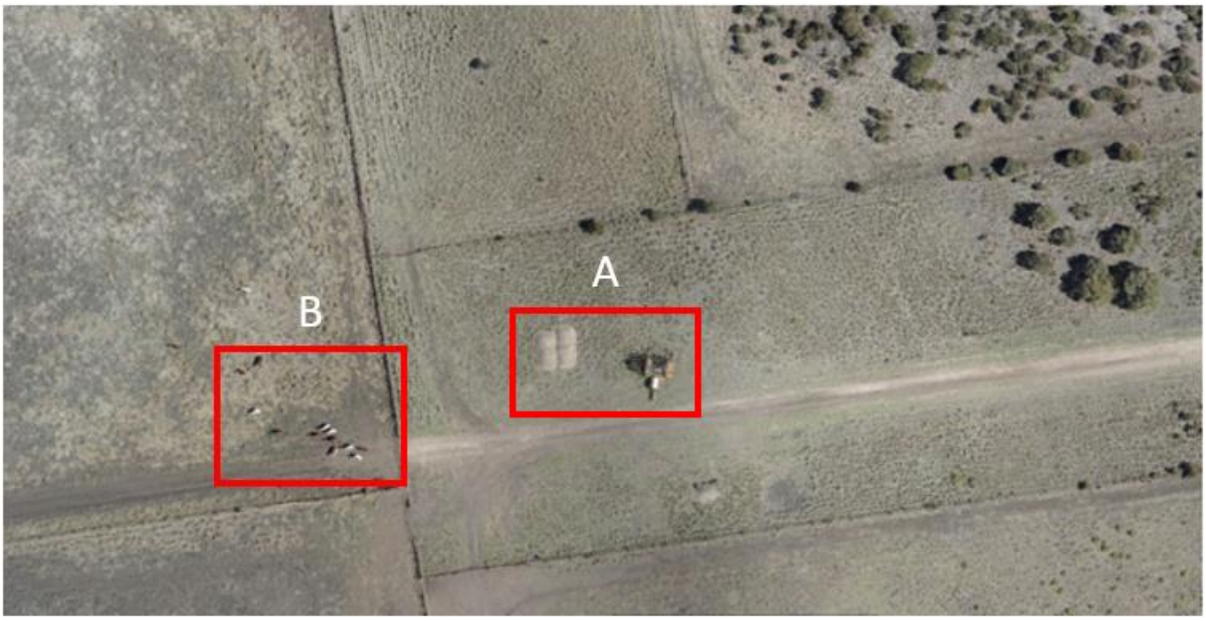


Figure 39. Survey Picture captured by a Sony a6000 optical camera taken at 45 m AGL showing cattle, fence lines and farm equipment, ACBH Croydon

At this altitude each pixel represents approximately 3 cm^2. This detail allows details extrapolated from the image in Figure 39 for specific targets which are enhanced or focused on (Figure 40a & 40b).

Figure 40a Farm Equipment enhanced from Figure 39 labelled: A

Figure 40b. 12 Head of cattle next to the paddock gate enhanced from Figure 39 labelled: B

4.5 Assessment for RPA systems

Each of the RPA systems where tested for endurance and range of use. It was determined that recharging a Volanti platform using a touch pad may be unviable because of the time taken to recharge the airframe. The downtime in recharging was estimated to result in a loss of 50% in productivity of the RPAS. The time it took to charge a set of batteries for the Volanti was two hours minimum. During this time the RPAS was stationary on the ground.

To overcome this issue, a battery bank charging system was developed and successfully deployed. By using this system the Volanti was back in the air in 10 minutes after the battery and camera Micro SD card were exchanged. (See Section 5.3.1 and Figure 43).

The Sunbird Solar powered RPA proved to be more productive than the Volanti but limited to sunny days when batteries are automatically recharged from the solar panels. During conditions of overcast and heavy cloud the Sunbird Solar was limited to a flight time of 1 hour or less due to the inability to recharge the onboard batteries.

4.6 Requirements for use of RPA

All necessary CASA flight protocols and operational requirements were used to conduct the trials.

4.7 Demonstration and trial flights

Demonstration and trial flights were conducted with the Seeker and Goshawk airframes during November and December 2017.

- The Goshawk fixed wing RPA was flown at Croydon Station with an RGB camera payload for imaging fence lines and a multispectral camera payload for imaging pastures. All missions were run under visual line of site and extended visual line of site protocols.

- The Seeker multi rotor RPA was flown at Croydon Station with a LIDAR payload to determine volumetric biomass.
- The Seeker was also flown at the ACC Brisbane Valley Feedlot with a thermal camera payload to count animals.
- The Goshawk was flown at Marburg (Latitude 27°34'0.00"S, Longitude 152°34'60.00"E), a restricted airspace where permission was obtained from CASA as well as the Royal Australian Airforce to demonstrate beyond visual line of sight operations.

The Marburg BVLOS operation was filmed by a professional film crew as part MLA's nomination for a Global Hitachi Digital Transformation Award. MLA subsequently won this award. The video was produced by:
PAUL SUPPLEE Productions, San Francisco, CA. The YouTube Video is available for viewing:
https://www.youtube.com/watch?v=xBxF8BBIwWo&t=6s

A demonstration of the Volanti airframe's capabilities included a fully automated flight, which was performed over the period of 16th to the 19th of April 2018 at Croydon and Calliope Stations. The demonstration included:

- Planning of an automated flight in auto pilot software (ARDUPilot);
- Pre-flight Check;
- Initialisation of mission from remote control (all stages from here are fully automated);
- Automated Vertical take-off;
- Transition into fixed wing flight;
- Completion of a survey mission planned onsite;
- Return to take-off position and transition into vertical landing;
- Accurate landing to a specified location.

The flight operations were also filmed by a professional videographer. See YouTube video:
https://www.youtube.com/watch?v=k0maz4qeSfg&feature=youtu

A demonstration of the Sunbirds capabilities took place on Calliope Station in September 2018. The demonstrations which were also filmed by a professional videographer included:

- Demonstration of Sunbirds operation including training the Calliope Manager in take-off and flight control;
- Imaging of cattle for overall health and wellbeing;
- Imaging water points.

The video which was produced by Vodafone Global Enterprise as part of their collaboration in the Hitachi-Vodafone terrestrial based digital connectivity project (P.PSH. 1077) has been distributed. https://www.youtube.com/watch?v=WSfGkCSQcLM&feature=youtu.be

4.8 Economic modelling

Through discussions with property managers data was collected to predict the benefits provided through the use of the additional data gained via remote sensing and HPI systems. Particular focus was placed on savings to the business operational costs (salaries and vehicle operations) and productivity gains. Productivity gains were highlighted in general stock management and identification of stray animals.

Overall increases in animal productivity (weight gains and turn off rates/numbers) have been evaluated in a previous project (P.PSH. 0815). These assessments were used for estimating total benefits gained from use of the RPA systems. The capital and operating costs for both the Volanti and Sunbird systems were considered in the economic analysis.

Final analysis of benefit and costs for each of the RPA systems is provided in Tables 3 and 4. The data was used for calculation of 5-year Net Present Values (NPV) of returns, Return of Investment (ROI), Internal Rate for Return (IRR), Modified Internal Rates for Return (MIRR) and Benefit Cost Ratios (BCR). This analysis is shown in Table 2. *(5% discount for NPV, ROI and IRR calculations. A 7% reinvestment rates applies for MIRR)*

Economic analysis criteria	**RPA Platform**	
	Sunbird	**Volanti**
Net Present Value (NPV of returns)	$341,808	$285,123
Return on Investment (ROI)	345%	185%
Internal Rate of Return (IRR)	173%	83%
Modified Internal Rate of Return (MIRR)	37%	28%
Benefit Cost Ratio	4.9:1	3.0:1

Table 2 Economic analysis of returns from use respective RPA platforms over five years

Cost Benefits Considerations	RPA VOLANTI					
QUANTITATIVE ANALYSIS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
NON-RECURRING COSTS						
Hardware including sensors	$100,000					$ 100,000
RPA Pilot	$ 9,100	$ 9,100	$ 9,100	$ 9,100	$ 9,100	$ 45,500
Training of employees (pre-implementation)	$ 8,000					$ 8,000
TOTAL NON-RECURRING COSTS	$ 117,100	$ 9,100	$ 9,100	$ 9,100	$ 9,100	$ 153,500
RECURRING COSTS						
Aircraft maintenance and upgrades	$ 2,500	$ 2,500	$ 2,500	$ 2,500	$ 2,500	$ 12,500
TOTAL RECURRING COSTS	$ 2,500	$ 2,500	$ 2,500	$ 2,500	$ 2,500	$ 12,500
TOTAL COSTS	**$ 119,600**	**$ 11,600**	**$ 11,600**	**$ 11,600**	**$ 11,600**	**$ 166,000**
QUANTITATIVE BENEFITS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
REVENUES						
Productivity gains - reducing stock loss	$ 24,000	$ 24,000	$24,000	$24,000	$24,000	$ 120,000
Productivity gains increase animal production	$ 58,000	$58,000	$58,000	$58,000	$58,000	$ 290,000
TOTAL REVENUES	$ 82,000	$ 82,000	$ 82,000	$ 82,000	$ 82,000	$ 410,000
COST SAVINGS						
Savings from Business process improvements	$ 5,499	$ 5,499	$ 5,499	$ 5,499.00	$ 5,499	$ 27,495
Reduced staffing cost (incl. overtime)	$ 18,200	$ 18,200	$ 18,200	$ 18,200	$ 18,200	$91,000
TOTAL COST SAVINGS	$ 23,699	$ 23,699	$ 23,699	$ 23,699	$ 23,699	$ 118,495
TOTAL BENEFITS	**$ 105,699**	**$ 105,699**	**$ 105,699**	**$ 105,699**	**$ 105,699**	**$ 528,495**

Table 3 Benefit costs assessment of Volanti RPA

Cost Benefits Considerations	RPA SUNBIRD					
QUANTITATIVE ANALYSIS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
NON-RECURRING COSTS						
Hardware including sensors	$40,000					$ 40,000
RPA Pilot	$ 9,100	$ 9,100	$ 9,100	$ 9,100	$ 9,100	$ 45,500
Training of employees (pre-implementation)	$ 5,880					$ 5,880
TOTAL NON-RECURRING COSTS	$ 117,100	$ 9,100	$ 9,100	$ 9,100	$ 9,100	$ 91,380
RECURRING COSTS						
Aircraft maintenance and upgrades	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 5,000
TOTAL RECURRING COSTS	$ 2,500	$ 2,500	$ 2,500	$ 2,500	$ 2,500	$ 12,500
TOTAL COSTS	$ 55,980	$ 10,100	$ 10,100	$ 10,100	$ 10,100	$ 96,380
QUANTITATIVE BENEFITS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
REVENUES						
Productivity gains - reducing stock loss	$ 24,000	$ 24,000	$24,000	$24,000	$24,000	$ 120,000
Productivity gains – increase animal production	$ 58,000	$58,000	$58,000	$58,000	$58,000	$ 290,000
TOTAL REVENUES	$ 82,000	$ 82,000	$ 82,000	$ 82,000	$ 82,000	$ 410,000
COST SAVINGS						
Savings from Business process improvements	$ 5,499.00	$ 5,499	$ 5,499	$ 5,499	$ 5,499	$ 27,495
Reduced staffing cost (incl. overtime)	$ 18,200	$ 18,200	$ 18,200	$ 18,200	$ 18,200	$91,000
TOTAL COST SAVINGS	$ 23,699	$ 23,699	$ 23,699	$ 23,699	$ 23,699	$ 118,495
TOTAL BENEFITS	**$ 105,699**	**$ 105,699**	**$ 105,699**	**$ 105,699**	**$ 105,699**	**$ 528,495**

Table 4 Benefit costs assessment of Sunbird RPA

5 Discussion

The transformation of data collected across a property into useful decision support tools will help deliver significant gains in business productivity. These gains may be driven by improved pasture management, animal and herd management, resource and labour management. A key challenge in adopting such tools across extensive grazing lands is developing cost effective methods for remote monitoring of livestock, infrastructure and land productivity. The use of autonomous Remotely Piloted Air (RPA) systems or more commonly called UAVs or drones provides one solution to this challenge.

The intent of this project was to evaluate a range for RPA platforms as a means for gathering key data on animal location, pasture growth and infrastructure assets across a property. The results have highlighted that an RPA may be used as an effective tool for collecting key data. Significant economic benefits may be achieved from the use of an RPA.

However, current government regulations controlling the use for an RPA is expected to limit a wide spread adoption for such platforms. The standards imposed by CASA are a major limitation to the commercial application of RPA across extensive grazing properties. To fly an RPA beyond visual line of sight, which is an essential requirement for RPA operations on extensive properties, current CASA standards require the pilot to hold an Instrument Rating Exam (IREX) certificate. The IREX course curriculum covers learnings for the entire aviation industry, which is inclusive of comprehensive content that is not relevant to RPA.

5.1 Biomass assessment

Management decisions in extensive farming operations are reliant on accurate knowledge about pasture quantity or biomass and its quality across a property. The development of appropriate imagery systems has been clearly demonstrated in this project to allow remote assessment of pasture density and biomass. The use of Sentinel Satellite imagery may be used as a low-cost assessment tool for general assessment of vegetative cover. This imagery may then be used for targeted RPA (drone) flights for more accurate pasture and biomass assessment.

By using RPA imagery, specific details regarding a pasture may be developed. The use of multispectral imagery of a resolution of 3.6 MP and a pixel size 8 cm X 8 cm at 120 m AGL may be used for vegetation assessment. The 5 light bands of the camera make it ideal for biomass estimation and pasture quality assessment.

Quality of a pasture is dependent on pasture growth, dry matter and nutritional content. While growth and total dry matter (kg DM/ha) may be measured from imagery, nutritional content is dependent on pasture species composition. For the first time the project has used data fusion and machine learning techniques to enable the identification of individual grass species and their biomass. These predictive algorithms for each species may be incorporated into Hitachi’s HPI system to allow new pasture growth modelling to be completed. The outcomes from such models will lead to improvements in animal grazing management decisions and overall business profitability (Figure 41). The new datasets and algorithms may be incorporated across the HPI program.

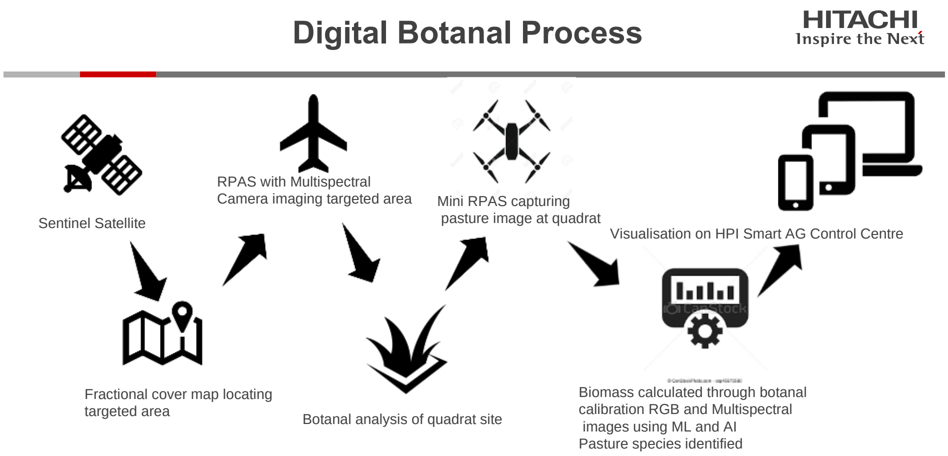


Figure 41. Digital pasture assessment and HPI Smart solutions

To progress outcomes developed from this project there is a need to continue the development and refinement of plant species identification and biomass predictions. This can occur through validation across a number of properties and pasture species. Challenges in doing such work exist where northern pastures are highly heterogeneous.

To estimate the final carrying capacity, it is important to not only have accurate assessment of biomass, but also the quality of the pasture. Quality will not only depend on the age of the pasture and its growth stage, but also the percentage of new growth compared to existing older dry pasture content. Factors such as energy content (MJ ME/kg DM) and digestibility may be developed from future data collection and through machine learning based on new imagery analysis. Options also exit to combine imagery analysis will biophysical models for pasture.

5.2 Fence line and Infrastructure assessment

The RPA fence line survey techniques examined in this project were designed to reduce the manned labour required to check paddock boundaries. The use of digital imagery captured from RPA to assess a fence line was partially successful. To allow accurate assessment, imagery must be captured at the correct angle to the fence line and the fence must not be covered by vegetation.

Two camera systems proved to be the ideal minimum requirements for assessing all key property infrastructure. The optical RGB camera is best used for infrastructure inspections with its high pixel resolution of 24 MP which delivers a pixel size of 3 cm X 3 cm at 120 m AGL.

Overall, general infrastructure inspections with optical RGB cameras were successfully completed. The use of RPA may be used to verify water resource levels, fence lines for breakages, gate positions and cattle location.

5.3 Gaps in existing capabilities of RPA platforms

Endurance, payload capacity and automatic recharging are the biggest challenges of existing RPA platforms.

The Volanti RPA was extensively tested for autonomous flight and endurance for this project. Recharging the Volanti from a touch pad was extensively researched but proven not viable because of the time taken to recharge the batteries. Section 5.3.1 describes the original recharging platform design and the subsequent battery recharger station development.

The Sunbird Solar powered RPA proved to be more productive than the Volanti but limited to sunny days and limited range of 1 hour or less if there are heavy clouds and limited sunshine.

5.3.1 Eagles Nest Recharging Platform

In the original design phase of Eagles Nest, Hitachi designed a solar powered recharging station. The concept design is shown in Figure 42. The initial concept was for the RPA to autonomously charge via an inductive charging system in the station. After a thorough analysis of the design, including the time to recharge the batteries, estimated at two hours, the design team realised that the charging would reduce the productive operational time of the RPA by 50%. To prevent such a loss in productivity, an alternative design was developed. In this design, a portable charging station powered by a generator is used to charge spare batteries. When the RPA lands after a mission, the batteries are manually exchanged in a matter of minutes and the RPA redeployed. The actual charging station is shown in Figure 43. Future opportunities exist to automate battery exchanges to reduce labour demands in managing any RPA.

This design proved to be highly efficient with the RPA being redeployed in less than 15 minutes in operational conditions. While the concept of remote recharge stations is still possible from the perspective of a RPA being able to travel vast distances by leap frogging from recharge station to recharge station, possibly recharging in the vicinity of a water point where it can still transmit images and analysis, the establishment and maintenance of the recharging infrastructure will be an initial challenge.

Possible solutions to overcoming this challenge include using longer endurance RPA's such as the Sunbird and Carbonix Domani which have a duration of up to 7.5 hours and 350 km. These RPA's have the range to reach large areas of extensive properties and return back to the main station for the exchange of batteries as well as safe overnight storage.

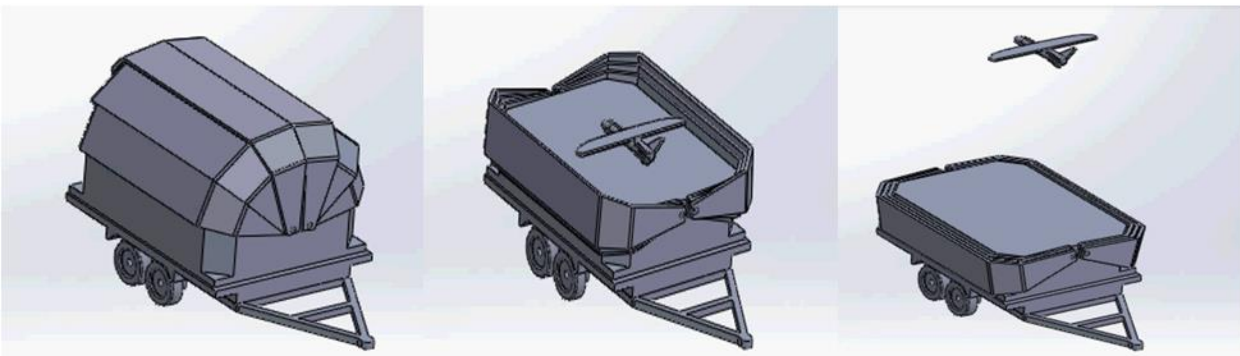


Figure 42 Concept design of a future Mobile Autonomous Recharging Platform for RPA applications

Figure 43. The Portable Recharging Station

5.3.2 RPA regulations

CASA flight protocols and operational requirements pose a major limitation on the commercial application of RPA across extensive grazing properties. The restrictions on the use of the technology were considered by two key partners to the project, Mark Xavier, Managing Director V-TOL Aerospace and Cortney Thomson, Carbonix Business Operations. Comments on the use of RPAs are outlined:

5.3.2.1 RPA Project Recommendations by V-TOL Aerospace and an experienced RPA Operator with hundreds of commercial missions undertaken.

V-TOL Aerospace believes that to make the use of RPA viable in remote locations, certain technologies, training, permissions and procedures need to be agreed to by the user-industry and the regulator.

Each beef grower that will benefit from RPA technology will have certain variables, which include:

a. Location(s);
b. Property / Area Size;
c. Herd, pasture and infrastructure of interest – priorities and frequency of data capture be determined via business programming;
d. Terrain – AGL (height above ground) will change requiring systems to maintain separation from ground;
e. Proximity to external population – knowing where to avoid overflights unless necessary;
f. Internal GA (general aviation) and flyover activity – such R22 helicopters that may operate below <500 ft AGL during day VMC (visual meteorological conditions).

Key items that typically won’t change for each property – survey in each RPA capability:

a. Boundaries;
b. Terrain;
c. Launch and Recovery sites;
d. Typical routes for various tasks – create a library of pre-programmed flight routes that can be viewed on-line or registered as part of an active RPA area and property;

e. Natural features and most man-made assets.

A suggested approach to enabling BVLOS Day/Night operations include:

1. Surveying each property for such operations based on < 400 ft AGL day operations & <1000 ft AGL operations at night – determine flight planning program by day, week, months.
2. Locating and installing RPA data-relays so that control and visual awareness can be maintained – note that Flight Radar 24 can be used to track ADBS fitted RPA via the satellite network that monitors ADSB.
3. Agreeing to NOTAM (notice to airmen) all properties approved for such operations by CASA/Air Services – maybe all rural producers are covered by a blanket cover in certain regions.
4. Education program for all GA operators and pilots regarding sharing the sky aimed at rural operators <1000 ft AGL day ops.
5. Replacing the IREX with fit-for-purpose BVLOS RPA pilot training course such as the one created by V-TOL.
6. Approving the Certificate IV as a career pathway qualification.
7. Installing UTMs (Unmanned Traffic Management) on all RPA ops < 1000 ft AGL & add ADSB for all >1000 ft AGL.
8. Installing TCAS/UTM on all manned GA aircraft with some form of TCAS that work < 500 ft AGL during daylight hours and <1500 ft AGL at night.
9. Establishing a basic airworthiness certificate for BVLOS RPA to be based on a fit-for-purpose standard – this has appeared in the new manual of standards (MoS).
10. For remotely controlled BVLOS operations – establish an OEM standard for airworthiness and procedures that meet the needs of the regulator and level of technology.

5.3.2.2 Recommendations by Carbonix Business Operations *(Carbonix is chairing a new sub-committee of Australian UAS Manufacturing for The Australian Association for Unmanned Systems (AAUS)*

1. CASA will be bringing out a new application process for BVLOS operations. That process follows the Joint Authorities Rulemaking for Unmanned Systems - Specific Operation Risk Assessment (JARUS SORA) program, which is an internationally recognised system and has the potential to enable wider adoption of BVLOS.
2. Carbonix sees JARUS SORA as a set of documented guidelines being progressively introduced across the world for both UAS Operators and Regulators. Many believe it will help align as many countries as possible.
3. In its simplest form, these guidelines may be likened to those in place for manned commercial aviation (under ICAO guidelines) which operates across the world and then locally adopted by Regulators and AOC holders. Also, under International Aviation Law (or the 'Chicago convention'), to which most countries are signatories.
4. In manned aviation, every Aircraft Type/Model, must firstly be 'Certified' to operate against a very detailed set of Airworthiness Standards, so these JARUS-SORA guidelines are designed to effectively fill a gap until a UAS can eventually be assessed for full

certification to fly in shared (non-segregated) airspace (albeit there are currently no UAS certification airworthiness standards), so a UAS would otherwise have to meet all the manned standards, which is not impossible but incredibly costly and arduous. JARUS-SORA does not cover or address UAS Airworthiness/certification standards.

5. Whilst the intention is actually to simplify the operational process, by way of pre-meditating and documenting standard perceived risks for operating under defined scenarios or ‘Concepts of Operations’ (CONOPS), it is necessarily quite complex and demanding (particularly for RPA Operator applications), as it is designed to work for the largest RPA’s, which will progressively seek to operate more and more in non-segregated airspace.
6. Important for Hitachi Consulting and partners to understand, particularly as customers and prospects ask ‘are your RPA’s are certified, or can they operate BVLOS’, the first response will be all RPA Operations will need to meet CASA’s adopted JARUS-SORA regulations.

5.4 Economic evaluation

A key challenge for the adoption for any new technology is demonstrating the return on investment. The data collected on the potential benefits provided through the use of RPAs clearly shows the potential for high rates of returns on investment. Particular focus was placed on savings to the business operational costs (salaries and vehicle operations) and productivity gains. Based on improvements in stock, pasture and labour management, the two RPA platforms provided a high level of return. Benefit to cost ratios of between 3.0 and 4.9 and a return on investment (ROI) of between 185% to 345% over 5 years were estimated.

Productivity gains are indirectly related to the collection for imagery data on animal location and for the estimation of pasture biomass. To be effective, property managers require real-time estimated on pasture growth and animal performance. It is for this reason that tools such as Hitachi’s HPI system become critical. These tools enable plant growth models and income scenarios to be generated so that property owners can implement systems for improved stock and pasture management.

6 Conclusions and Recommendations

6.1 Remotely Piloted Aircraft (RPA) as a tool in managing extensive grazing

The project has demonstrated the capacity for RPA systems to be used in the management for extensive grazing properties. Their use extends to infrastructure assessment, animal identification and location monitoring, and pasture assessments. The capacity to accurately map pasture biomass provides significant opportunities to improve land and livestock management.

The project has demonstrated for the first time the capacity for remote identification for pasture species. While further research is needed to validate use of the methods across different pastures growth stages, mixed communities and pasture quality, it is expected to provide added advantages over existing methods use in pasture monitoring. The use of additional data developed from animal, pasture and infrastructure monitoring can be incorporated within Hitachi HPI systems to improve overall property management.

To allow efficient use of RPA systems, opportunities exist and have been demonstrated for their application in combination with satellite remote sensing data. This allows targeted application of RPAs for assessment of pasture and other vegetation.

The use of RPA across extensive areas is limited by their endurance and requirements for refuelling and/or recharging of batteries. The development of a portable charging station or "Eagles Nest" provides the capacity for an RPA to be redeployed in less than 15 minutes in operational conditions. While the concept of remote recharge stations is possible from the perspective of an RPA being able to travel vast distances by leap frogging from recharge station to recharge station, the establishment and maintenance of the recharging infrastructure will be required. These recharging will need to be designed to allow fully automated servicing of the RPA and data capture. Base data processing (edge computing) may also occur at each recharge station so that only analysed or output data is required to be sent to central control HPI system.

If the development of automated recharge stations is cost prohibitive, an alternative solution is to use longer endurance RPA's such as the Sunbird which has a duration of up to 7.5 hours and can cover some 350 km and the Carbonix Domani when fitted with a petrol engine will have an endurance of 10 and 15 hours and a minimum range of 800 km. These RPA's have the range to reach large areas of extensive properties and return back to the main or central base station.

To progress the outcomes achieved from this project it is recommended that future investments be made across:

1. Imagery systems and machine learning approaches for pasture growth rate and quality assessments;
2. Imagery systems and machine learning approaches for greater efficiency in fence wire identification;
3. Control systems for automated integration for satellite imagery to allow flight plans for RPA to be automated for more effective use;
4. Extending the trial for RPA and integrated HPI systems for more diverse grazing systems.

6.2 Recommendations for future regulation over use of RPA

An essential requirement for RPA operations on extensive properties is the ability to fly RPA beyond visual line of sight. Current CASA standards require the pilot to hold an IREX certificate. In order to simplify the approval process, Hitachi Consulting recommends that a course be created for operators that is specifically designed for RPA BVLOS flight approval.

More comprehensive airworthiness standards are needed for airframes. At this current time, CASA is unable to clearly define airworthiness standard for airframes. The creation of such standards will prevent poor quality airframes being introduced to the industry which could have a major negative impact in the case of failure of such an airframe.

One possible model could be to use a system like that developed by the EU aviation authority. This standard groups three different types of aircrafts according to their specifications: small, medium, and

large. The specifications of the aircrafts within these groups are regulated based on their flight ability. This defines their operational range and the approval needed. Link to EU standards:
https://www.easa.europa.eu/easa-and-you/civil-drones-rpas
A key safety factor in deploying RPA BVLOS is aircraft operating VFR and not using their radios or reading their NOTAM’s. Specifically, in relation to helicopters and light aircraft operating in large scale cattle properties across northern Australia. Radio communications and flight path tracking should be mandatory.

There is a need for CASA to define its risk parameters for an approval process for operators to better understand how they can fly commercially. A comprehensive risk assessment protocol is recommended for all RPA operations. It is also recommended that CASA introduce an online approval process instead of engaging in a costly manual process. The United States Federal Aviation Administration (FAA) has used an automated online approval process for RPA flights. Link to US FAA approval process:
https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8130.34D.pdf
Low Altitude Authorization and Notification Capability (LAANC) and Federal Aviation Administration (FAA) is an online application process for low altitude RPA operations online approvals currently used in the USA. CASA could follow a similar approach to BVLOS approvals. Link to BVLOS approval process:
https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8130.34D.pdf
ADS-B Transponders

- Automatic Dependent Surveillance Broadcast (ADS-B) transponders must be fitted and mandatory for all commercial and civilian aircraft.
- RPA must be equipped with ADS-B transponders for BVLOS operations.
- RPA operators conducting BVLOS operations should have a dedicated computer with software to monitor all aircraft ADS-B signals locations within a 40 km radius of their RPA operational area.
- The RPA control centre must have a dedicated 2-way radio for aircraft communication within the BVLOS operational area.
- Currently private aircraft, fixed wing and helicopters, are not required to have their radios switched on below 5000 feet which is a major air safety risk for RPA BVLOS operations.
- Notice to Airman (NOTAM) should be issued to areas where BVLOS operations will be taking place.

6.3 Commercialisation and Industry Adoption

For commercialisation of RPA solutions to deliver value for extensive beef production operations across northern Australia, the current regulatory challenges documented in this report have to be overcome. The current restrictions on BVLOS operations remain the biggest barrier to both commercialisation as well as industry adoption. Even early adopters have faced major challenges in the application for BVLOS operations.

This project applied all safety protocols including advanced safety features such as fitting the RPA with an ADS-B (Automatic Dependant Surveillance Broadcast) which broadcast the precise position of the RPA to aircraft in the vicinity as well as providing notification to private helicopter and airplane operators in the vicinity of the area of operation, notification of RPA operations on radio as well as the issuing of NOTAMs (Notice to Airmen).

All aircraft flying under IFR (Instrument Flight Rules) at all altitudes are required to have ADS-B systems. This does not apply to aircraft flying under VFR (Visual Flight Rules) which includes mustering helicopters and private small aircraft. Operators of such aircraft pose a risk to BVLOS operations especially when such operators are not following safety protocols and do not read NOTAMs or monitor radios. These risks will continue to hamper commercialisation and industry adoption and will only be alleviated with the introduction of stricter safety protocols for aircraft flying under VFR as well as the introduction of UTM (Unmanned Aircraft System Traffic Management) systems.

Once these hurdles have been overcome, there will be a significant increase in RPA operations with the extensive beef operations being one of the larger beneficiaries of these solutions. With the safety concerns and the solutions to these being a key focus of CASA and RPA, associations such as AAUS (Australian Association for Unmanned Systems) https://aaus.org.au and ACUO (Australian Certified UAV Operators) https://www.acuo.org.au, indicate that there will be a more streamlined approach to BVLOS from 2020 onwards. This will significantly boost long distance capable RPA sales as well as significantly increase the provision of services around BVLOS operations on extensive properties.

Key areas of use that will drive adoption will be:

- RPA being deployed to survey pastures for biomass determination. Individual paddocks could be surveyed very regularly:
  - Prior to animals entering the paddock;
  - At approximately the 50% of biomass consumed point; this is a key measure point to ascertain if the initial biomass algorithm is correct or does adjustments need to be made with regards to the exit date of the mob from the paddock
  - When animals exit the paddock.
- Weekly surveying of mobs to check animal condition;
- Water point surveys (three times a week in summer, twice a week in winter);
- Mob surveys prior to muster to improve resource planning.

Adoption will be driven by the innovators starting with the above applications, realising the benefits and expanding the applications within their businesses, setting up the infrastructure to train more RPA pilots and later establishing central control rooms and operations as the regulators become comfortable with their operating procedures and protocols.

The cost of RPA’s is expected to significantly decrease in the future. RPA systems will also become more capable with onboard processing capability, not only of information such as the calculation of biomass or the counting of animals but also in the safety and autonomous operation with autonomous detect and collision avoidance systems. These factors will support wider adoption of the technology.

7 Appendix

7.1 Camera Functionality Summary

7.1.1 Optical Payload: Sony a6000/a6300

Figure 43. Sony a6000 RGB Optical Camera

Feature	Sony a6000	Sony a6300
Cost (Body Only)	$650	$1,000
Pixel count	24MP	24MP
Continuous shooting rate	11 fps	11 fps
Movie Resolution	1920 x 1080 / 60p	4K 3840 x 2160 / 30p, 1920 x 1080 / 120p, 60p
Weight (w/battery)	344 g	404 g

Table 5. Sony Camera Specifications

7.1.2 MicaSense Rededge Multispectral Camera

Figure 45. MicaSense Rededge Multispectral Camera

Feature	MicaSense
Cost	$5,200
Weight	180g
Spectral Bands	Blue, green, red, red edge, near IR
RGB Colour Output	3.6 MP (global shutter, aligned with all bands)
Ground Sample Distance	8 cm per pixel (per band) at 120 m
Interfaces	Serial, Ethernet, WiFi, GPS, External Trigger
Capture Rate	1 capture per second

Table 6. MicaSense Rededge Multispectral Camera Specifications

The Multispectral camera currently has five lenses each concentrating on a separate band of the colour spectrum. Figure 47 and 48 summarises the application of these sensors.

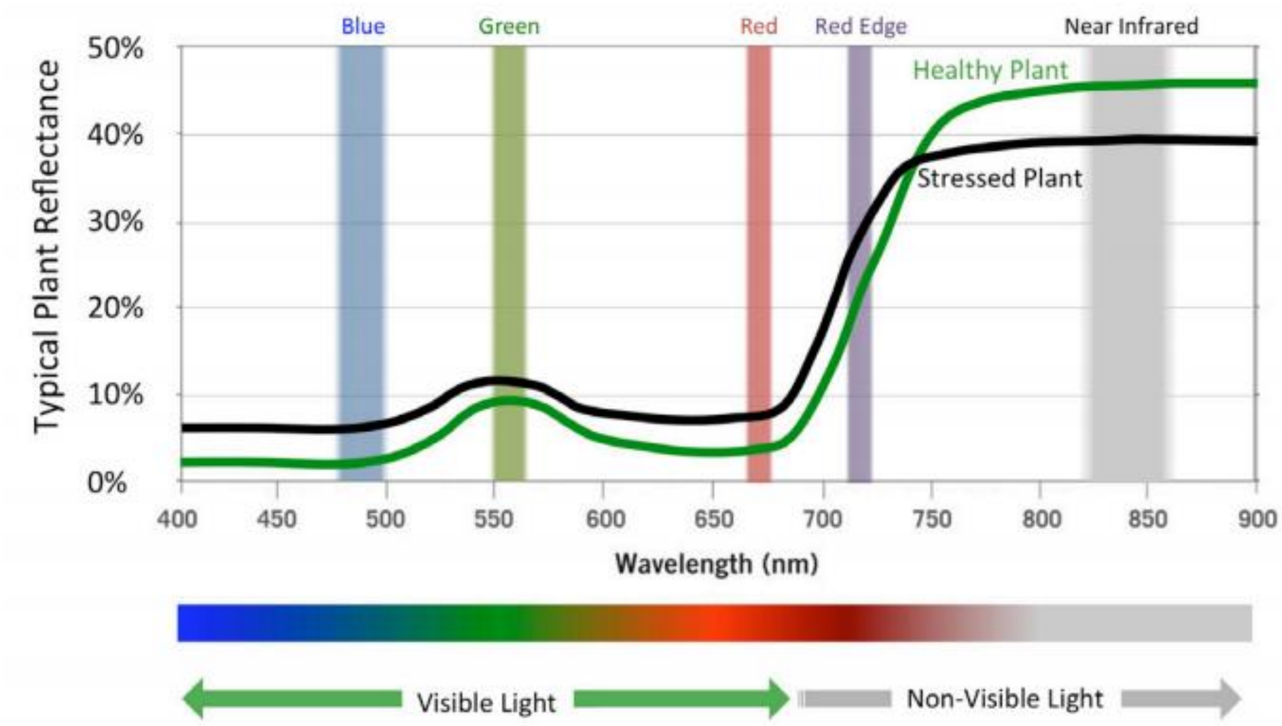


Figure 47. Multispectral Camera Wavelength Bands

The healthy/stressed plant curves represent the reflectance (visibility) within respective optical bands. Healthy bands are more visible in infrared bands and unhealthy plants are more visible in isolated bands of visible light.

Rededge and Near Infrared (NIR) are both bandwidths of the infrared (IR) spectrum which spans 700 nm to 1 mm (Figure 48). The IR range is broad compared with other bands but becomes specifically useful after post processing for analysis in agriculture as materials such as nitrogen, chlorophyll, clay, sand, water and others become visible. The bandwidth of light is that is visible to the human eye ranges from 400 to 800 nm.
https://www.gigahertz-optik.de/en-us/basics-light-measurement/light-color/opt-rad-wavelength-range/

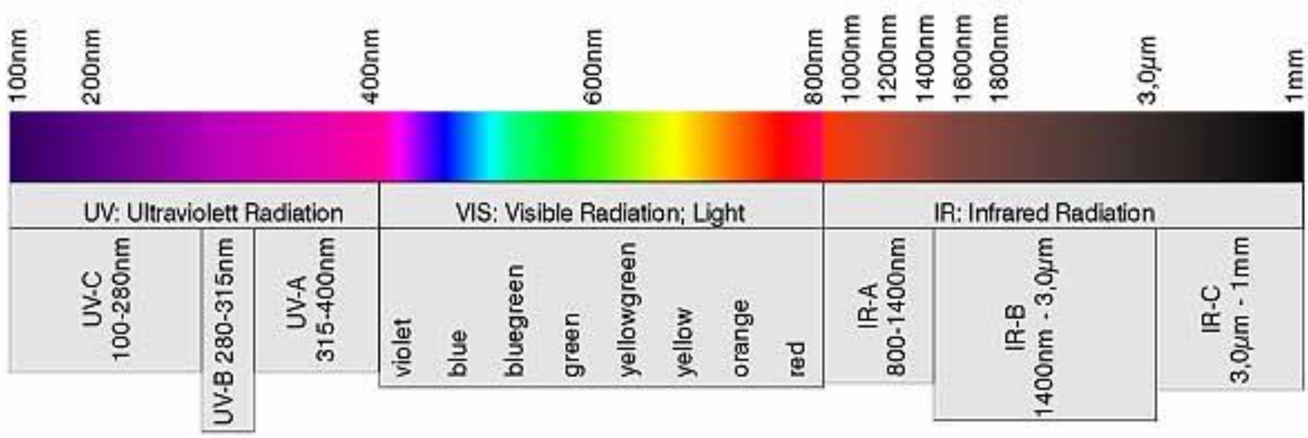


Figure 48. Light wavelength Bands

Specific Operation Risk Assessment

Consensus is required on how to safely create, evaluate and conduct an Unmanned Aircraft System (UAS) operation. The SORA provides a methodology to guide both the applicant and the competent authority in determining whether an operation can be conducted in a safe manner. The document shall not be used as a checklist, nor be expected to provide answers to all the challenges related to integration of the UAS in the airspace. The SORA is a tailoring guide that allows an operation to find a best fit mitigation means and hence reduce risk to an acceptable level. For this reason, it does not contain prescriptive requirements but rather safety objectives to be met at various levels of robustness commensurate with risk.

The SORA is meant to inspire operators and competent authorities and highlight the benefits of a harmonized risk assessment methodology. The feedback collected from real-life operations will form the backbone of updates to the upcoming revisions of the document.

- The purpose of the SORA is to propose a methodology for the risk assessment to support an application for authorization to operate a UAS within the specification’s category.
- Due to the operational differences and expanded level of risk, the specific category cannot automatically take credit for the safety and performance data demonstrated with the large number of UA operating in the open category. Therefore, the SORA provides a consistent approach to assess the additional risks associated with the expanded and new operations not covered by the open category.
- This methodology is proposed as an acceptable means to evaluate the risks and determine the acceptability of a proposed operation of UAS within the specific category.
- The SORA is not intended as a one-stop-shop for full integration of all type of drones in all classes of airspace.
- This methodology may be applied where the traditional approach to aircraft certification (approving the design, issuing an airworthiness approval and type certificate) may not be appropriate due to an applicant’s desire to operate a UAS in a limited or restricted manner. This methodology may also support activities necessary to determine associated airworthiness requirements. This assumes that safety objectives set forth in or derived from those applicable for the Certified category, are consistent with the ones set forth or derived for the Specific category.
- The methodology is based on the principle of a holistic/total system safety risk-based assessment model used to evaluate the risks related to a given operation. The model considers all natures of threats associated with a specified hazard, the relevant design, and the proposed operational mitigations for a specific operation. The SORA then helps to evaluate the risks systematically and determine the boundaries required for a safe operation. This method allows the applicant to determine acceptable risk levels and to validate that those levels are complied with by the proposed operations. The competent authority may also apply this methodology to gain confidence that the operator can conduct the operation safely.

- UAS Manufacturer – For the purposes of the SORA, the UAS manufacturer is the party that designs and manufactures the UAS. The manufacturer/designer has unique design evidence (e.g. system performance, system architecture, software/hardware development documentation, test/analysis documentation, etc.) that they may choose to make available to one or many UAS operator(s) or the competent authority to help substantiate the operator's safety case. Alternatively, a potential UAS manufacturer may utilize the SORA to target design objectives for specific or generalized operations. To obtain airworthiness approval(s), these design objectives could be complemented by use of JARUS Certification Specifications (CS) or industry consensus standards if they are found acceptable by the competent authority.
- Component Manufacturer – The component manufacturer is the party that designs and manufactures components for use in UAS operations. The component manufacturer has unique design evidence (e.g. system performance, system architecture, software/hardware development documentation, test/analysis documentation, etc.) that they may choose to make available to one or many UAS operator(s) to substantiate a safety case

7.2 Operating Flight Protocols and Civil Aviation Safety Authority (CASA) regulations

7.2.1 General Rules for Flying an RPA in Australia

- You must only fly during the day and keep your RPA within visual line-of-sight. This means being able to see the aircraft with your own eyes (rather than through a device) at all times.
- You must not fly your RPA higher than 120 meters (400ft) above the ground.
- You must keep your RPA at least 30 meters away from other people.
- You must not fly your RPA over or near an area affecting public safety or where emergency operations are underway (without prior approval). This could include situations such as a car crash, police operations, a fire and associated firefighting efforts, and search and rescue.
- You must only fly one RPA at a time.
- You must not fly over or above people. This could include beaches, parks, events, or sport ovals where there is a game in progress.

7.2.2 Operational Flight Preparations

7.2.2.1 Flight Permissions

With the exception of the CASA approved BVLOS demonstrations at Marburg, all other operations were performed under Visual Line of Sight or Extended Visual Line of Sight (EVLoS) protocols.

EVLoS allowed Hitachi and Carbonix to still test all BVLoS hardware and functionality. Missions were limited to an area where a ground vehicle could drive or within 5km of the take off point.

7.2.2.2 Site and Operational Safety Assessment and Review

For all properties, site and operational safety reviews were produced and distributed for all members attending flight testing. These reviews were to ensure all party members were aware of the risks of operating in rural areas as well as setting guidelines for safe working conditions on-site.

7.2.3 Pre-flight RPA Protocols

All deployments operated in class G airspace uncontrolled. At ACBH Croydon the ceiling for class G is 10,000 ft above mean sea level (AMSL) stopping at the lower limit of commercial airspace. The RPA was operating at a maximum of 400 ft above ground level (AGL) when traveling to mission sites and performing missions around the 140 to 180 ft height range. Beyond Visual Line of Sight (BVLoS) flight operations operated with CASA approval.

7.2.3.1 Pre-flight Checks

Pre-flight checks are designed to ensure that the RPA's basic functions and environmental conditions are in a suitable condition before start of mission. These include:

- Weather conditions under guidelines by RPA manufacturer
- Satellite connectivity (at least 7 GPS satellites)
- Battery condition check
- Inspection for physical damage of RPA prior to flight, which would inhibit flight ability
- Motor Check
- Flaps check
- Flight sensors check (gyros, pitot tube and compass)
- Check operational airspace for potential traffic

7.2.4 Post Flight Protocols

Post flight protocols consisted of a post-flight check:

- Battery condition check
- Inspection for physical damage and report
- Motor check
- Flaps check
- Flight sensors check (gyros, pitot tube and compass)

Other aircrafts in the area were notified that RPA operations have ceased. After this the flight batteries would be recharged, and the mission data downloaded for post processing.