

PRINCIPLES & LEARNINGS

March 2016

About this Publication

This fact sheet is intended to provide information to farmers wanting to explore the use of Unmanned Aerial Vehicles (UAV) or “drones” as a tool to support their farming system. It has been generated as part of a project delivered by Leighton Pearce of Growing Solutions through funding from the Australian Government’s National Landcare Programme and the South Australian Murray-Darling Basin Natural Resources Management Board.

The information is general in nature and provided as reference material only and is not intended to be relied upon as, or be a substitution for specific professional advice.

Information was true and correct as of March 2016, however as this is an area of such rapid growth, it is advisable that information, particularly that relating to CASA rules & regulations, is double-checked before any action is taken.

About the author

Leighton Pearce of Growing Solutions has 18 months’ experience in flying UAVs in an agricultural setting. He has delivered many demonstrations to farmers groups, covering approximately 1,300 individuals, and is a recognised expert in the field in South Australia. He has an Operators Certificate and a Remote Pilot Aerial Systems licence, as well as appropriate insurances to work in this field. This knowledge and experience of UAVs is supported by his Bachelor of Applied Science in Agriculture, and his Advanced Diploma of Business Management.

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Executive Summary

The project “Investigating the application of unmanned aerial vehicles (UAV) in agriculture in the SAMDB region” has resulted in a significant increase in the skills and knowledge of landholders across the region.

The project involved identifying pioneer farmers from the region to become involved with this innovative project and learn with Growing Solutions consultant and pilot, Leighton Pearce.

As a result of the project, a number of products have been produced to support local landholders wishing to implement UAV systems into their farming system.

“Anatomy of a UAV” provide a quick & easy to read resource of information detailing the components of UAVs and how each component contributes to the complex system.

This document, “Principles and Learnings” provides local landholders with the do’s and don’ts of UAVs. The guide provides information to landholders interested in purchasing a UAV, imagery types, accreditation and the law, as well as highlighting the uses that UAVs have in agriculture, horticulture and livestock. We have also addressed the extensive number of uses that UAVs provide to the environmental industry.

As part of the project, a survey of the three project partner farmers was conducted; the results of this survey have been included as an appendix to the project report. From the survey, three case studies have been developed to highlight how these farmers are using, or intend to use UAVs on their properties.

This project has provided both NR SAMDB and Growing Solutions the opportunity to test and demonstrate this innovative practice. From our findings, we can identify the following steps to increase the adoption of UAVs on farms. The next steps involve the preparation of maps prior to Nitrogen applications and following Nitrogen applications and demonstrating to farmers how the maps are created, and interpreted. To date, no one has provided this information in a clear manner to farmers.

**SIGNIFICANT USERS OF UAVs
CURRENTLY INCLUDE POLICE,
LAND AGENTS, INSURANCE
COMPANIES AND THE
ENTERTAINMENT AND MEDIA
INDUSTRIES**

Terminology

When reviewing or researching information concerning UAVs, it soon becomes apparent that there is a myriad of terms used to describe these machines. They are often referred to as “drones” amongst those outside of the industry, however those within the industry are prefer the terms Unmanned Aerial Vehicles (UAVs) or Remotely Piloted Aerial systems (RPAS). These alternative names are primarily due to the use of drones in warfare, and UAV users wanting to place some distance between the commercial and recreation uses of these system versus the delivery system of a missile.

WHENEVER POSSIBLE, TRY TO GET THE MOST OUT OF A UAV BY PERFORMING MULTIPLE TASKS WHILE IN THE AIR (E.G. ATTACHING A BIRD SCARER AND CAMERA WILL PROVIDE TWO ACTIVITIES DURING ONE FLIGHT). REMEMBER THOUGH, THAT AS PAYLOAD IS INCREASED, FLIGHT TIME DECREASES SIGNIFICANTLY.

Types of UAVs

Before deciding on purchasing a UAV, the user must determine the most suitable UAV for their situation. The first decision is a choice between a fixed wing UAV or a multi rotor UAV. This decision can be made simpler by determining what is required from the UAV. Below is a generalisation of the advantages and disadvantages of each system. Please note that each system should be judged on it's merits when making a final decision.

Advantages of a fixed wing UAV

- Longer flight time / covers more acreage
- Requires less power (less motors, less propellers)
- Faster speeds
- Light weight
- Ideal for large areas



Advantages of a multi-rotor UAV

- In-built redundancy (if any motor fails, a skilled operator can land aircraft)
- Can carry heavier payloads (e.g. cameras)
- Can land on, and launch from a small area
- Ability to hover
- Multi-purpose
- Cheaper
- Ideal for smaller areas



Types of UAVs (cont...)

Considerations when purchasing

When making this decision, consideration should also be given to the payload (cameras, sensors or alarms) which the UAV will be required to carry. The UAV is merely a vehicle to transport the payload and collect appropriate data that can be used to increase knowledge, make informed management decisions or perform duties on the property. Growing Solutions has adopted the multi-rotor flying system due to it being a multi-purpose vehicle with the ability to fly autonomously, manually, hover in a fixed position and launch and land in a small area.

For users who decide to venture into the fixed wing vehicles, there are a number of platforms available that have been designed with the agricultural industry in mind, including:

- E-bee
- Trimble
- Ag Eagle

Each of these products includes the entire system, including flying platform, cameras (additional cameras can be purchased), software and hardware. The fixed wing system is straightforward; platforms are generally flown in autonomous flight mode (i.e. a mission derived via flight control software is uploaded to the flying platform and the computer flies and lands the platform).

When purchasing a multi-rotor, there are many more decisions to make. The most important decision is the number of motors/propellers. Multi-rotors come in a wide array of configurations, from quadcopters (4 motors & 4 propellers in a X or Y configuration) to large 12 – 16 motor/propellers UAVs with adjacent motors/propellers located on either 6 – 8 arms respectively. Growing Solutions has several hexa-copters (6 motors/propellers on 6 arms), to account for redundancy, in the case one motor or propeller fails in flight.

There are a number of multi-rotor flight systems available for landholders to further investigate:

- Agribotix
- DJI
- 3DR
- Perth RC

Types of UAVs (cont...)

Maintenance

An important part of owning a UAV is ongoing mechanical maintenance of the platform. There are companies within Australia that provide services to UAV users for parts, servicing and sales. Listed below are a few reputable companies that Growing Solutions is happy to recommend:

- Rise Above Aerials
- Model Flight
- Perth RC

**THE UAV MARKET IS
EXPECTED TO BE A 82 BILLION
DOLLAR INDUSTRY BY 2025
85% OF UAV USAGE WILL BE
IN THE AGRICULTURAL INDUSTRY**

*Source: AUVSI's The Economic Impact of Unmanned Aircraft
Systems Integration in the United States report*

The Law

Regardless of the size/weight of the UAV, all pilots of UAVs **must** adhere to these laws.

- Do not fly over populated area, including townships, houses, schools, or any kind of sporting activity
- Do not fly 400 feet (120metres) above ground level (AGL) from the launch site
- Do not fly within 3nm (5.5Km) from an aerodrome
- All observers must be 30 metres from the pilot in control of the aircraft
- The UAV must not be operated in a way that creates a hazard to other aircraft, people, assets and property
- The UAV must only be operated during daylight hours
- Line of sight must be maintained at all times (i.e. the operator must be able to see the UAV at all times)
- Nothing can be discharged from a UAV (this includes spraying chemical)

\$\$\$\$ **IT IS ILLEGAL** to fly a DRONE/UAV/RPA for money or economic gain unless you have an Unmanned Operator's Certificate issued by the Civil Aviation Safety Authority (CASA)

IMPORTANT SAFETY INFORMATION

HOW CLOSE? DO NOT fly closer than 30 metres to vehicles, boats, buildings or people

WHERE? DO NOT fly over any populated areas such as beaches, other people's backyards, heavily populated parks or sports ovals where there is a game in progress

AIRFIELDS DO NOT operate within 3nm or 4.5km of an aerodrome or helicopter landing site without approval

VISIBILITY ONLY operate your RPA during daylight, good weather and in Visual-Line-of-Sight

HOW HIGH? DO NOT fly above 400ft

FPV FPV Flying may be illegal without an Advanced Amateur Radio License

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RPAS AUSTRALIA

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Accreditation

At the time of preparing this report (March 2016), farmers are currently not required to undertake any accreditation under the Civil Aviation Safety Authority (CASA) rules, but **MUST** adhere to the laws governing the use of UAVs and **MUST** only fly on their own property. CASA currently classifies farmers with UAVs as hobbyists. New laws surrounding the use of UAVs are currently being developed and are expected to change in the future. These changes may involve farmers having to undertake a short course and accreditation to use a UAV on their property if the UAV (plus payload) exceeds 2kg in weight.

Controller Certificate

Everybody else (other than farmers) flying a platform greater than 2kg **MUST** undertake a course to accredit them to fly. Today there are a number of choices people have to undertake these courses:

- Two week structured courses,
- Courses linked to the purchase of a specific UAV, and
- Self-paced courses available through CASA.

On successful completion of one these courses, the operator will hold a license to fly the UAV. It must be noted that this does not allow the operator to work for commercial gain/reward with the UAV.

OBTAINING YOUR CASA

UAV CONTROLLER CERTIFICATE

<p>OBTAIN your ARN. <small>An ARN is an Aviation Reference Number. It is similar to an account or customer number & should be quoted with all official communication with CASA.</small></p>	1	<p>PURCHASE PPL THEORY BOOKS & EXAM TOOLS.</p>
<p>STUDY for the PRIVATE PILOT THEORY EXAM <small>You can self study or join our UAV focused PPL Theory Course covering the official CASA requirements.</small></p>	3	<p>Get AROCP. <small>An AROCP allows the certificate holder to communicate via an airband radio from the ground to all aircraft & helicopters in normal & emergency operations. <small>Note: The ICOM A0 handheld radio is certified for Australian ground to air communication & the A15 is NOT.</small></small></p>
<p>Get a BAK EXAM EXEMPTION. <small>Apply for a "Letter of Introduction" from CASA to receive this exemption.</small></p>	5	<p>BOOK the PPL THEORY EXAM DATE. <small>Book your CASA PPL Theory exam date online via ASL or at an authorised flying school.</small></p>
<p>PASS the PPL THEORY EXAM. <small>Pass: 70 % Duration: 3.5 hours Multi-choice questions</small></p>	7	<p>Obtain your UAV MANUFACTURER'S ASSESSMENT. <small>This includes flying skills, checks, planning & safety requirements according to the specifications of the RPA manufacturer.</small></p>
<p>LOG 5 HOURS of Flying Experience. <small>Use a spreadsheet or "RPAS Logger", a mobile app enabling you to log all your air-frame, controllers / remote pilots, batteries etc.</small></p>	9	<p>Obtain a Class 2 MEDICAL CERTIFICATE. <small>This is optional (depending on your company).</small></p>
<p>SUBMIT your UAV Controllers Certificate Application Form to CASA.</p>	11	<p>Legend: [Icon] = Services we offer. AROCP = Aircraft Radio Operator Certificate of Proficiency RPA = Remotely Piloted Aircraft UAV = Unmanned Aerial Vehicle PPL = Private Pilot License</p>

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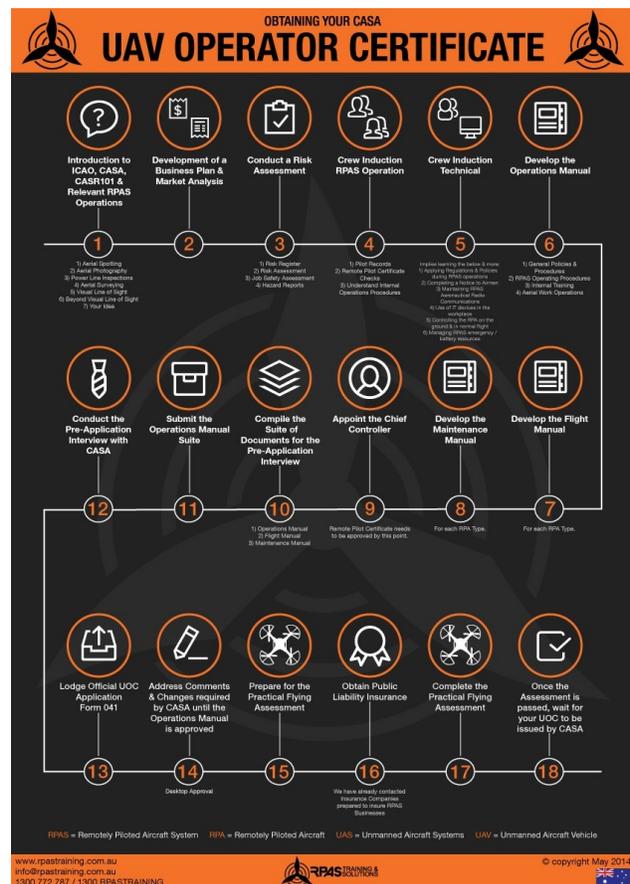
Source: www.rpastraining.com.au

Accreditation (cont...)

Operators Certificate

To work in the industry commercially, a company must hold an Operators Certificate (OC). This accreditation is achieved by the company developing a number of manuals that are audited by CASA, along with both a theory and practical flight examination. The process of gaining accreditation to fly a UAV can be lengthy and expensive. CASA maintains a register on their website of all accredited training facilities and holders of Operator Certificates. Further information concerning courses and accreditation can be found at the websites for:

- [Civil Aviation Safety Authority](#)
- [Australian Unmanned System Academy](#)
- [UPG solutions](#)



Source: www.rpastraining.com.au

Why UAVs in agriculture?

UAVs can provide users (farmers, landholders, agronomists, consultants, advisors, agribusiness, resellers, environmental officers, insurance companies, farming system groups, researchers) with data that is:

- On demand
- Timely
- Detailed imagery
- Low cost
- Versatile and flexible

The data collected covers 100% of a landholder's paddock, has a minimal carbon footprint, allows labour savings, provides a safe working environment and causes no compaction to soil, compared to the alternatives of gathering paddock data.

Alternative methods

Alternative methods to collect data include the use of tractor mounted ground sensors that often do not cover the entire paddock, contribute to soil compaction, require fossil fuels to transport the sensors and take significant time to collect data. The data collected through the sensors on UAVs is as reliable as the data collected from tractor mounted ground sensors, at a fraction of the overall cost.

The use of light airplanes and satellites to collect data are also growth industries. Whether a landholder uses a light airplane, and satellite or UAV is entirely dependent on the resolution required make informed decision on their property.

Resolution for satellite imagery is generally 10 metre square pixels, fly overs are infrequent, the farmer has no control over timing, and the images may be disrupted by cloud cover. Satellite imagery will cost approximately \$1,000 per year annual subscription, making this option the cheapest, but lowest in resolution.

The use of light planes is very expensive. Resolution is generally 5 metres square and access to light planes in some areas is limited. Hire of a light plane will cost upwards of \$300 per hour, making this the most expensive option.

Why UAVs in agriculture? (cont...)

Using UAV technology, the farmer can make decisions about what resolution is required in any given situation, and adjust the flying conditions to suit that need. By flying at 80 metres with simple cameras, one-inch square resolution can be attained. However, it is important to note that the lower the UAV flies, the more passes it will be required to record data in that paddock, which then results in the more batteries being used, and an increase in time taken to carry out the task.

Employing a UAV operator to perform imagery costs \$4-\$10 per hectare (based on flying at greater than 30m AGL), making it an attractive option in terms of cost. The cost will vary depending on the sensors on board and the resolution required. Further information on costing can be found on pages 24-25.

**AN IDAHO-BASED AMMUNITION
SUPPLIER IS MARKETING
“DRONE MUNITION” - BULLETS
TO SHOOT DOWN UAVS**

Uses for UAVs in Broadacre Agriculture

The applications for UAVs in agriculture are extensive and continuing to increase as users develop new ideas to utilise their UAV and manufacturers develop innovative technologies incorporated into UAVs.

Agriculture - general uses:

- Identification of different zones within the farm
- Attachment of alarm system to ward off feral pests
- Monitor property infrastructure
- Provide evidence and information to insurance companies following incidents
- Assess on-farm research from the sky
- Monitor precision of plantings and machinery
- Development aid for prescription maps

Agriculture - RGB imagery:

- Aerial photography for promotional purposes
- Pre-purchase inspection of properties (ensuring approval is sought)
- Identifying invertebrate pest invasions
- Mapping the entire property at a specified resolution
- Monitoring dune soaks
- Uniformity of cropping program

Agriculture - NDVI imagery:

- Assessment of nutritional requirement of crops for management
- Determination of crop health two weeks earlier than that which can be seen by the naked eye

Uses for UAVs in Broadacre Agriculture (cont..)

Agriculture - Thermal imagery:

- Assessment of crops following frost events
- Assessment of crops following heat events

Agriculture - Video:

- Inspection of assets, shed roofs, gutters, solar panels, silos
- Promotional activities

Agriculture - LINDAR imagery:

- 2D and 3D mapping
- Measuring of crop yield

IN 2013, A SMALL COLORADO
TOWN WAS OFFERING A \$100
BOUNTY ON UAVS

Uses for UAVs in Livestock Properties

The use of UAVs in the livestock industry is increasing. Many intensive animal industries have begun using UAVs to monitor stock with relative ease in small allotments. Many other uses for UAVs in livestock are outlined below.

Livestock - general uses:

- Herding and mustering of livestock
- Searching for missing livestock
- Monitor stock movement over time

Livestock - NDVI imagery:

- Monitor pasture health
- Monitor availability of feed in paddock
- Monitor grazing preferences

Livestock - Thermal imagery:

- Identify stock that have given birth
- Monitor mothers in distress
- Identify stock in poor health
- Manage stocking rate

Livestock - Video:

- Monitoring fence lines
- Inspection water points

Livestock - LINDAR imagery:

- Assessment of feed availability in paddock

Uses for UAVs in Horticulture

Horticultural properties lend themselves to the use of UAVs due to their smaller acreage. A significant amount of field work is being carried out commercially with UAVs in horticulture.

Horticulture - general uses:

- Attachment of bird scarer
- In the future – spraying crops
- Development of drainage map

Horticulture - RGB imagery:

- Counting plant numbers following seeding
- Identifying yield limiting issues immediately
- Identifying weed areas on-farm
- Monitor ripening of crops
- Identify poor plants or genetically inferior individuals
- Uniformity with plantings and crops
- Gain information for replanting

Horticulture - NDVI imagery:

- Measuring crop health under irrigation
- Monitoring water distribution
- Determination of harvest peaks/timing
- Drainage mapping
- Inspection water points

**WHEN OPERATING UAV AS A
COMMERCIAL ENTERPRISE,
SPECIFIC UAV INSURANCE IS
REQUIRED. ONLY A LIMITED
NUMBER OF COMPANIES
PROVIDE THIS CLASS OF
INSURANCE CURRENTLY**

Uses for UAVs in Horticulture (cont...)

Horticulture - Thermal imagery:

- Monitor transpiration of crops

Horticulture - LINDAR imagery:

- 2D and 3D mapping
- Measuring of crop yields
- 3D modeling for laser leveling
- 3D modeling to determine water movement across landscape

SOME USEFUL UAV-RELATED MAGAZINES INCLUDE:

- ROTOR DRONE MAGAZINE (USA)
 - DRONE MAGAZINE (UK)
 - DRONEZONE (UK)
- DRONE MAGAZINE (AUS)

Uses for UAVs in the Environmental Industry

Separately to this project, Growing Solutions flew over some wetlands to monitor water inundation. UAVs are used extensively throughout the world in environmental works. Environmental monitoring & surveillance provides a number of options to the environmental industry.

Environmental Operations - general uses:

- Monitoring back burning exercises
- Collecting samples for analysis
- Feral Judas tracking and following
- Ground cover profiling

Inspection of Environmental Assets :

- Monitoring of threatened species
- Monitoring of vertebrate pest species
- Before and after photos for on ground works
- Assessment of waterway erosion
- Monitoring of urban expansion
- Assessment of landslide risk
- Assessment of flooding risk
- Monitoring of illegal activities
- Monitoring of migration patterns
- Drainage mapping

Uses for UAVs in the Environmental Industry (cont...)

Environmental Operations - NDVI imagery:

- Assessment of re-vegetation sites, health
- Monitor health of river system

Environmental Operations - Thermal imagery:

- Identification of unwanted plant species in wooded areas

Environmental Operations - Video:

- Monitoring movement of invertebrate pests
- Monitor water resources, environmental waterings

Environmental Operations - LINDAR imagery:

- 2D and 3D mapping
- Assessment of areas following bushfires
- Assessment of water storage areas
- Assessment of land movement during erosion events
- 3D modeling to determine the requirement for water runoff and capture

What to look for in a UAV

When purchasing a UAV for the first time, the user may want to consider purchasing a cheaper and smaller UAV to practice with and improve flying skills. Some attributes to look for when purchasing a UAV include:

- **Autonomous flight mode** By loading a pre-set flight mission from an iPad or laptop to the UAV's flight controller, the UAV will launch, fly and land by itself. Having autonomous flight allows the user to repeat missions as many times as needed.
- **Robust and sturdy frame** All UAV pilots will crash the UAV at some time and it is important that the aircraft can be fixed, and allows for ongoing maintenance.
- **Long flight time** A significant factor for most users when looking to purchase a UVA, however if flying manually, most pilots find that a flight time over 15 minutes is long enough. While flying autonomously, most agree that around 30 minutes is long enough. Remember that the UAV must be in line of sight at all times.
- **Fail-safes** need to be incorporated into the system; return to home in the case that navigation control or GPS signal is lost, or the battery charge is low. Each system has a number of inbuilt fail-safes to aid the users. It is very important to practice using the fail-safes, so they can be operated with confidence in the event that they are needed.
- **Decision support and backup** is essential. Ensure that the supplier of the UAV can provide backup support for the platform, software and hardware.
- **Training** in the operation of the UAV and software is also required. Ensure that the supplier can provide manufacturer training in the UAV and additional training in the use of software.
- **Value for money** is always a requirement when purchasing an expensive capital item. Check out the reputation of a supplier, their experience in the agricultural industry and warranty provided.
- **First person view (FPV)** allows the pilot to view what the UAV's on board camera is viewing in real time. This is a vital addition if needing to frame photography. FPV can be achieved through the use of iPads, mini DV screen or goggles that can be worn.

The science of sensors

As previously mentioned, the UAV is merely a vehicle on which to attach sensors, cameras and alarms. In this section, further information is provided relating to sensors/cameras which can be attached to UAVs.

RGB Cameras

RGB cameras are standard cameras which take a photo or video in the light spectrum visible to the human eye: Red, Green and Blue (RGB). These are the cheapest form of sensor available and perform well under most conditions. The user can learn a lot from RGB imagery, while RGB video can provide the UAV pilot with a live feed. RGB imagery is the most widely used imagery with UAVs today. Many UAVs come with RGB cameras already fitted that produce great results.



A typical RGB image of a crop, note the images on the following pages have been taken from the same site, but with different types of cameras

The science of sensors (cont...)

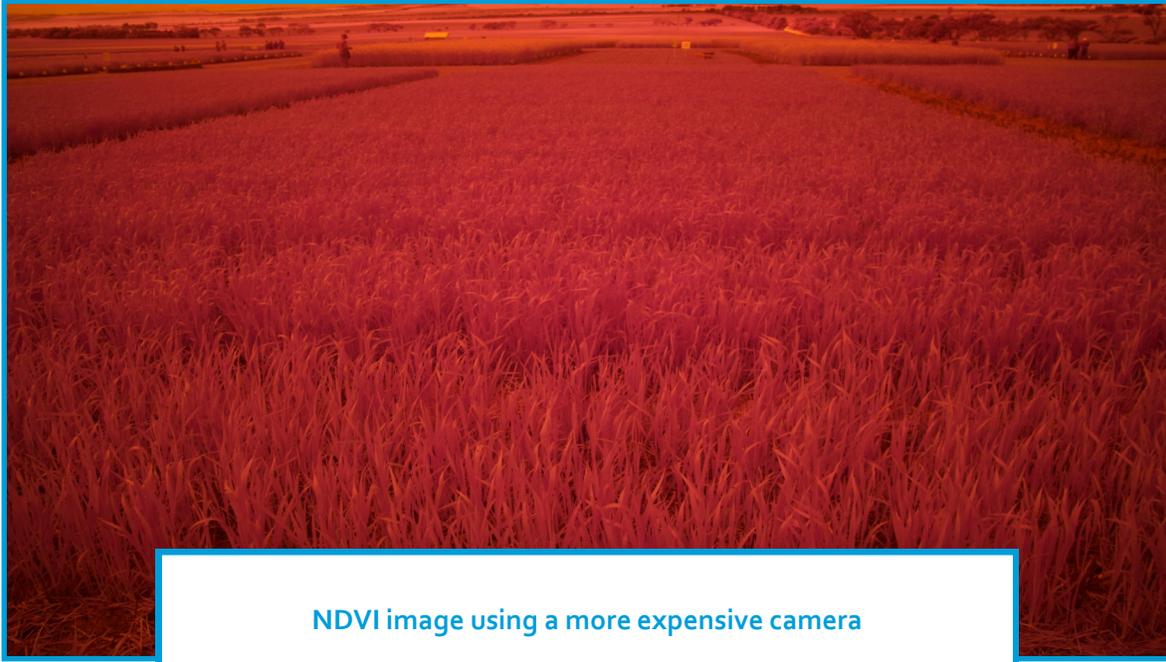
NDVI

Normalised Difference Vegetation Index (NDVI imagery) uses both the visible and near infra red (NIR) light spectrum to allow users to determine the health of a crop via chlorophyll production (how green a plant is).

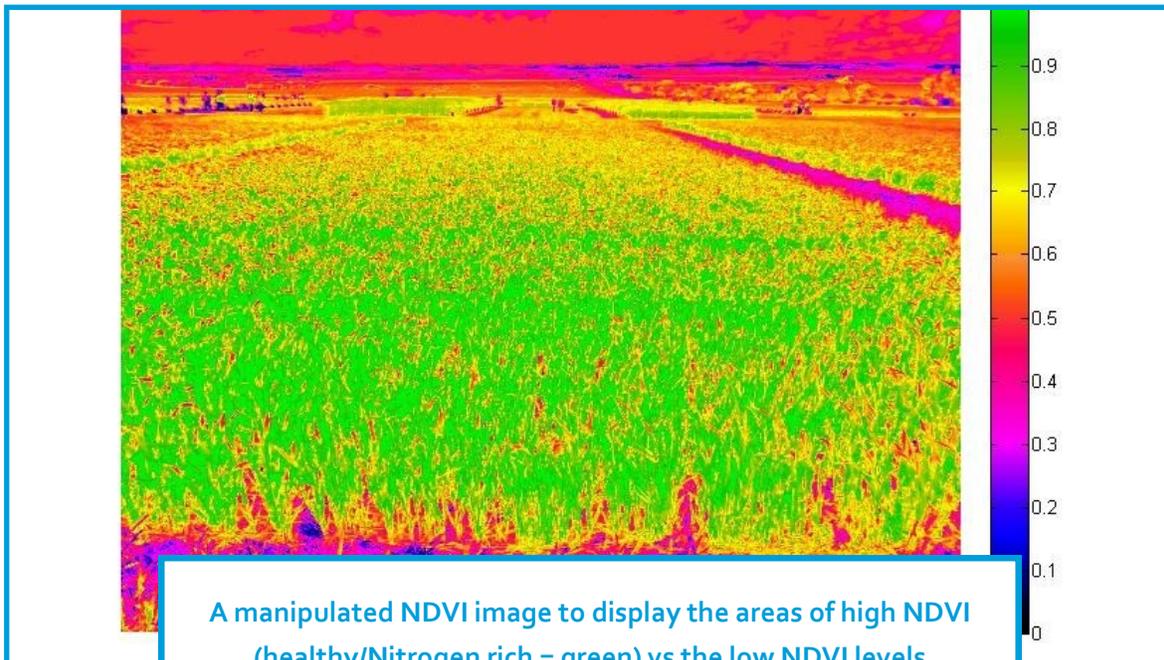


NDVI image using a cheaper camera

The science of sensors (cont...)



NDVI image using a more expensive camera



A manipulated NDVI image to display the areas of high NDVI (healthy/Nitrogen rich = green) vs the low NDVI levels (unhealthy/Nitrogen poor = yellow)

The science of sensors (cont...)

Other options

Thermal cameras are another option for use with UAVs. Thermal cameras can be used extensively in the environmental industry to identify animals in scrub or in livestock, animals who are unwell or giving birth, or in agriculture/horticulture, areas affected by frost or heat. As thermal cameras become more affordable, they will become more commonly used in this area.



The ultimate camera to attach to a UAV today is a LIDAR sensor, which operates in 3 dimensions. These are currently very expensive, but as the price decreases over time, landholders will be able to make use of them to make assessments of available feed for livestock or yield predictions for cropping properties.

Costings

Costing the use of UAVs is dependent on many variables including:

- Camera type, model and focal length
- Altitude of flying
- Type of aircraft used
- Batteries used and amount of power
- Maintenance on aircraft (e.g. are the motor and propellers balanced and in good order)
- Wind conditions on the day. If the UAV is small, wind will have a significant effect on flight duration. Wind speeds over 15Km should be avoided

Given this, it is difficult to quantify exactly what the cost to the end user might be in a hypothetical situation, however the following table has been prepared as a guide.

Altitude of flying (m)	Hectare per Hr	Cm per pixel	Cost of exercise \$ per
10	8	0.34	\$30
20	15	0.67	\$15
30	20	1.01	\$10
40	25	1.35	\$9
50	30	1.69	\$7
60	40	2.02	\$5
70	60	2.36	\$5
80	60	2.7	\$5
90	70	3.03	\$5
100	70	3.37	\$5
110	80	3.71	\$5
120	90	4.04	\$5

Costings (cont...)

Assumptions for this exercise:

- Large, well maintained hexa-copter used
- Good quality batteries and propellers used
- No wind
- Flight speed at 5 m/sec (optimum speed for motor and propeller efficiency)
- Canon SX260 HS used (mid range camera) with a focal length of 4.5mm
- Square paddock
- No down time for changing batteries has been incorporated into this exercise
- Only tested up to 120 metres due to legal requirement
- Contractor rate used is \$200/hour

From the table on the previous page, it is evident that if 1cm pixel resolution is required, the UAV needs to fly at an altitude of 30 metres, in which it will fly over 20 Ha in one hour. Four batteries would most likely be required for this.

While this example relates to using a contract UAV service, the other option is for farmers to purchase a UAV and determine its payback period.

Several organisations have developed in-house tools to determine the payback period for purchasing a UAV. Using a model such as this, returns of \$20-\$30 per hectare can be expected based on timely Nitrogen applications informed by the data supplied by the NDVI camera on board.

Useful Links

Websites

www.casa.gov.au

www.airservicesaustralia.com

www.diydrones.com

www.dji.com

3dr.com

www.riseabove.com.au

www.ausacademy.org

Facebook

[AgEagle Aerial Systems](#)

[Rise Above Custom Drone Solutions](#)

[UAVs and Drones](#)

[FPV Australia](#)

[CHDK \(Canon Hack Development Kit\)](#)

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