COGGO Council of Grain Grower Organisations Limited ACN 091 122 039	**Final Report** **COGGO Research Fund 2014** **A project completion report covering the project. The acceptance of a satisfactory report against the objectives of the project, and agreement on the sharing of any commercial returns and/or IP will trigger payment within 4 weeks, by COGGO for any outstanding payments.**

This Final Report should be completed with reference to the Research and Intellectual Property Agreement (the Research Agreement) signed between the proponent and COGGO Pty Ltd.

1. Project information

Project title	**State Wide Implementation of Australia's First Agricultural Unmanned Aerial Vehicles (UAVs)**
Commencement Date	November 2013
Completion Date	January 2014

IMPORTANT: Only amend details in the rest of this section 1, i.e. any project information that has changed since the project was approved

Name of Proponent	
ACN/Legal Name or ABN	
Mailing Address	

Administrative Contact	
Position	
Telephone	
Fax	
Email	

Project Supervisor/Principal Researcher	
Position	
Telephone	
Fax	
Email	

COGGO Use Only

Project Number	
Date Received	

2. Project results	This section provides a final report against the Project Aim and the Planned Outputs for the Project.

Achievement of the Project Aim	Brief statement of achievement in relation to the aim of the project

The aim of this project was to equip Western Australia's grain growers with UAV technology and its corresponding IT Software (Crop Manager) to allow them to take preventative action, and implement 'best management practice' to improve soil salinity, soil erosion, pest/ weed management and chemical/fertiliser applications; as well as saving time/resources/emissions by relying less on farm vehicles and machinery.

The project has been successful as it is now possible to:

- Collect data by flying UAVS,
- Set an aim: weed detection in this case,
- Analyse the imagery through the Software (Crop Manager)
- Produce files for use by farm vehicle manufacturers,
- Provide information to the growers in a comprehensive and yeat easy to understand format
- Allow the growers to make informed decision: targeted spray as opposed to blanket spray in this case.
- Provide growers with daily paddock information on their computers, phones and tablets.

Project Outputs		Please provide a report on the achievement, or otherwise, of the project outputs as per the planned outputs provided in the Project Proposal.
1	-	Output 1 (from Project proposal) 3 intensive community workshops
		Comment: A workshop was held at the MIG office for the MIG board members and staff (March 14). Feedback on the research was positive and the members were enthusiastic about more research in this area. The second workshop was held at the MLA Meat Profit Day "in the Yards" (April 14) with over 80 attendees and generated interest from producers for UAVs to be used for stock management. The third workshop was held at the end of the year (December 10, 2014), at the Agricultural Education Conference at the WA College of Agriculture Morawa where DataIntoProfit manager, Richard Riddle, presented over 110 representatives of WA Colleges of Agriculture, private

		agricultural colleges and metropolitan schools running agricultural programs. DataIntoProfit also conducted additional presentations throughout the year detailing the process of getting the imagery from the drones, analyzing it and presenting it to growers in a simple and useful manner.
2	-	Output 2 (from Project proposal) Spring Field Day September 14.
		Comment: With over 250 attendees, Spring Field Day is MIG's largest event. On the day, Data Into Profit demonstrated how Crop Manager can be used on a mobile or tablet, in the paddock rather than just being limited to a desktop
3	-	Output 3 (from Project proposal) Project communication
		Comment: MIG carried out the communication aspect of the project through the publications of updates on MIG website, MIG links, MIG Facebook and Twitter pages and in articles with the local press. Also MIG hosted a number of events throughout the year where the UAV/Crop manager project featured such as Crop Updates, MLA Meat for Profit Days, workshops at MIG, NACC Sustainable Agricultural Forum.

Project results	Please provide brief statements on the results of the Project

This section should cover aspects identified in *Section 7.3* of the Research Agreement

- the results of the Project, including discoveries made and other achievements (including any Project IP and Project Confidential Information);
- the potential application of the outputs of the Project to the Western Australian grains industry and broader community;
- the actual or potential economic benefits flowing to the Western Australian grains industry and broader community from the Project;
- the difficulties encountered;
- the conclusions reached;
- the Researcher's recommendations for any further research;
- a list of scientific papers or publications resulting from the Project; and
- attach copies of any photos, diagrams or other artworks (including, if requested by COGGO, negatives, bromides or the like) which the Researcher has and which may be of assistance to COGGO in the dissemination of information concerning the Project to COGGO's stakeholders.

This project has demonstrated that UAVs can successfully be flown and collect imagery from grower's paddocks. The imagery can then be utilized through the IT software (Crop Manager) to detect weeds (see Appendix 1)

This information can be provided to growers in easily understood formats. Files can be produced with weed locations and uploaded to spraying equipment for the boom spray to be accurately initiated (see Appendix 3 and 4).

For this trial, over a small 60 ha paddock, using UAVs and analyzing the data instead of using a blanket spray (spraying of the whole paddock) resulted in a saving of $$563.1 (see Appendix 2).

It has also shown that Crop Manager can collect up-to date/real-time information from your paddock and deliver them on your mobile/tablet or computer allowing growers to make informed decisions (see Appendix 5).

This result demonstrates the potential of the technology to increase grower's bottom line as well as improve their time management/efficiency.

The project outputs carried by MIG and DataIntoProfit (community workshops, field days and communication/extension) allowed for these results to be demonstrated to growers. Indeed this unique partnership has removed the risk and guess work farmers would usually have to make when adopting new technology. Seeing the results first-hand, without taking the initial risk of investing, increased adoption rates in WA and will add to the success and uptake of UAVs in Australia's agricultural industry.

One of the main difficulties encountered was the actual flying of the drones. Indeed, At the moment the future of UAV's in Australia is still being debated by CASA (Civil Aviation Safety Authority) and other interested stakeholders. Agriculture has been highlighted as an industry that would be able to benefit significantly from the use of UAV's and CASA is actively working with members of the Agricultural sector to FastTrack acceptable legislation. Until this has been finalized, there is an element of risk associated with operating UAV's on commercial properties.

Also the cost and time associated with collecting data with a UAV for a farm that is cultivating more than 1,000 hectares of cereal crop begins becoming inhibitive as the current UAV's can only collect up to 400 hectares a day. Multiple UAV's can be introduced to address the time issue, but this will not lower the cost of collecting the data over large growing areas. Future technology improvements allowing for UAVs to fly over a larger surface in reduced time will help solving this issue.

The main conclusion of this project is that the technology to detect weeds using UAVs exists and in the future, it will be a profitable farming practice for farmers when the correct legislation is in place and UAV technology has advanced further regarding the area that can be covered in a day. The main recommendation would be to wait for these improvements to be implemented before developing further projects.

3. Project resources

This section describes use of the funding listed in the initial plan and any refunds due to COGGO

Expenditure of funds requested from COGGO	$ Total funds budgeted	$ Total funds expended (actual)	$ Total funds requested from COGGO*	$ Total COGGO funds expended	$ Refund due to COGGO of any unexpended COGGO funds
Salary/Contractors			30,000	30,000	
Operating costs			18,940	18,940	
Capital			560	560	
TOTAL			**49,500**	**49,500**	**0**

*Funding provided by COGGO.

IMPORTANT: Return of unused funds to COGGO is required as per *Clause 3.3* of the Research Agreement.

4. Commercialisation	Insert details of the proposed commercialisation process,as applicable, with reference back to the planned commercialisation plan in the project proposal) for any outputs from the project. This should include recommendations for the commercialisation of the results of the project and the registration or other protection of Project IP and Project Confidential Information as per the Research Agreement.

The work undertaken on this project has allowed DataIntoProfit to establish three very important propositions for Crop Manager.

1. The interaction between MIG and DataIntoProfit on this project has allowed Crop Manager to be viewed by a number of other interested parties in the data provision side of the Agriculture Sector and DataIntoProfit is currently working with the suppliers of Yield Prophet to benefit from Crop Managers ability to deliver information to selected people on different technology platforms. There are more than 500 Yield Prophet users/farmers in Australia and the majority of these will be exposed to Crop Manager in 2015.
2. The largest independent reseller of herbicides in WA, David Grays, has chosen to standardize on Crop Manager for all their resellers throughout the state. There are more than 40 different stores across WA and they service more than 2,000 broad acre farmers. The work done on recognizing weeds in a paddock provided by this project was the main reason for David Grays' decision.
3. MIG Members will also benefit from the work that has been undertaken in this project as MIG has successfully signed an agreement with DataIntoProit that will see MIG providing and supporting Crop Manager to the members. The agreement will not only generate revenue for MIG, but it will continue to distribute technology advancements to the members in the most efficient manner possible.

It is understood that this may require further discussion and agreement with COGGO via its' agent GIWA, as per the undertakings given and terms agreed, in the project proposal. This can be the subject of an appended letter and attachments. In all cases such discussion and subsequent agreements need to be governed by *Section 8 Project IP, Improvements and Project Confidential information* of the Research Agreement.

5. Communication/ Extension	Insert details of how the communication and extension of the project outcomes has been achieved to date and recommendations for future activities to disseminate and promote adoption of the results of the Project.

MIG carried out the communication/extension aspect of the project.

MIG hosted a number of events where the UAV/Crop Manager project has featured as well as producing a number of publications throughout the year:

- Regional Crop Updates, 4 March 2014, demonstrations/presentation
- Spring Field Day,4th September 2014, demonstration/results from current trial
- Correspondence with Grower Group Alliance (MIG is a member along with 38 other WA grower groups)
- Agricultural shows
- MIG newsletter, quarterly publication

- MIG e-links, fortnightly email to members
- MIG and Data into Profit website
- MIG social pages (Facebook and Twitter).
- Correspondence with all media contacts
- Printed material for community workshops

The Community workshops held throughout the project plan offered additional extension support for MIG members and the wider grain growing region. This unique partnership has removed the risk and guess work farmers would usually have to make when adopting new technology. Seeing the results first-hand, without taking the initial risk of investing, increased adoption rates exponentially, further adding to the uptake of UAVs in Australia's agricultural industry.

Note: As per *Clause 7.3 (b) (ii)* of the Research Agreement COGGO may require the Researcher to produce an edition of the Final Report in a form suitable for general distribution. If so required by COGGO, the Researcher must produce a non-confidential version of the Final Report within 28 days of receiving a request to that effect from COGGO.

6. Certification

The Project Supervisor and the Research Organisation certify that all information contained in, and forming part of, this final project report is complete and accurate. The project supervisor and research organisation further warrant that the project complied with all the relevant guidelines affecting the conduct of research, for example in relation to ethics, bio-safety, environmental legislation, GMAC or National Health and Medical Research Council Codes.

Project Supervisor's signature

Name (in Capitals)

_____Sheila Charlesworth____ Date: 10/03/2015

Research Organisation signature

Name and title of authorised signatory (in Capitals)

_____Mingenew Irwin Group_____

___Sheila Charlesworth, Executive Officer._____Date: 10/03/2015

Recommend acceptance
10/3/2015

Completed Final Project reports

Email to coggoresearchfund@giwa.org.au or mail to
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Or phone (08) 6262 2128

COGGO representative

For the purpose of this Project agreement contract, COGGO will be represented by Grains Industry Association of Western Australia (GIWA), or such other representative that is nominated by COGGO as authorised to operate on behalf of COGGO.

Executive Summary

The objective of this project was to use new technology, Unmanned Aerial Vehicles (UAV), to maximise financial benefits to Western Australia's growers. Through the use of UAVs, and processing the available data, the project aimed to provide grain growers with a tool for making confident and cost-effective crop management decisions, based upon the provision of location specific information, eg the location of weeds in a paddock.

There are three phases in this project:

1. To fly UAVs and capture the data.
2. To process the data using the CropManager decision support platform.
3. To extend the data to the growers.

A MIG long-term trial site comprising 60 hectares was chosen for the project and the process focused on summer weeds.

Phase 1:Flying UAV's to capture the data

The term "UAV" is similar to the term "tractor". There are many different makes and models and their potential depends on the users' requirements and their budget. Because of this, 4 different UAV's, supplied by three different companies, were flown over the project site. Two were multi-copter machines and two were fixed wing machines (see Appendix 1).

The following key points were established;

- All 4 UAV's could easily fly the 60 hectare site. (See performance table)
- The type of camera used was a critical success factor.
- The flying process was influenced by the weather but it wasn't a major hindrance (similar to spraying process).
- Flight time and the area covered by the individual UAV was a major contributor to the overall delivery process.

The project established that utilising UAV's to collect aerial imagery was a very viable option and that the type of UAV and camera combination needed would depend on the specific requirements of the grower, in particular, the area being flown and the data being analysed.

Phase 2: Processing the data using the Crop Manager Decision Support Platform

It was important in this project to establish that different UAV's could be utilised to capture aerial data and to ensure that the data collected was meaningful and could be interpreted for use by the grower.

The following key points were established;

- The type of camera being used was a critical success factor.
- The time taken to process the data collected was a critical success factor.
- A clear definition of what was required from the data and within what time frame is needed.

Phase 3: To extend the data to growers

In order to deliver benefits to a grower, the aerial data collected needs to be integrated into a broader process that both analyses the data and then presents the data in a format that can be used in a variety of different ways (See appendix 3, 4 and 5)

The project established that the time taken to deliver a benefit was crucial to success. The delivery time needs to be confirmed at the start of the process with the decision made on the data that needs to be collected. Most data collected from the flights could be used but the processing time varied considerably and affected the quality of the final outcome. The project produced accurate data that delivered benefits to the grower and in a format that could be read by all major agriculture and technology suppliers.

This project also demonstrated that the grower wants real-time and easy to understand information. Following this trial, CropManager has now an app on both phones and tablets to allow the user to check his paddock information anywhere (see Appendix 5).

A summary of the information resulting from this work includes:

Appendix 1: UAV capabilities based upon 220 ft flights.
Appendix 2: Analysis of selective versus blanket spraying application.
Appendix 3: The process followed to analyse the data.
Appendix 4: The process followed to create the data files needed by the machinery manufacturers to deliver these benefits.
Appendix 5: Delivery of real-time data to growers.

Appendix 1: UAV's capabilities based upon 220 ft flights.

Instrument	Hectares per Flight *	Flights per day **	Hectares per day	Cost Per day	Cost per hectare
UX5	50	6	300	$3,600	$12
eBee	45	9	405	$3,200	$8
S800	30	9	270	$3,000	$11
F550	25	10	250	$3,000	$12

Assumptions:

- Flights had to be done at 220 ft to detect weeds. Flights conducted at a greater altitude would reduce cost significantly. The cost of flights lower than 220 ft is increased because the amount of area covered is reduced. The height flown depends on the objective of the flight. If for example, plant count is the objective, then the UAV will have to fly lower than 220 ft because the resolution of the picture will have to be at sub 1 cm. At a height of 220 ft weeds could be detected and identified in the paddock being used for this trial.

*Hectares per flight are based upon the flight time per UAV, directly related to the battery life and the weight of the camera(s) that the UAV is carrying.

** Flights per day are based on an 8 hour day and the time taken to prepare a UAV for flight. This includes the actual flight and downloading data, charging batteries, preparation for launching and flight administration.

- Costs include processing data and flight costs. Processing includes image production, data analysis and the labour required.

- Costs are based on a single machine flying one paddock. Multiple machines could reduce the cost by up to 30%. This is because a single team of operators could fly more than one UAV at the same time. Therefore the cost of the operators will be shared across multiple UAV's. Depending on the UAV, it is possible to fly up to five UAV's at the same time.

- Based upon information provided by growers, we estimated that an area of between 370 and 400 hectares can be sprayed in a day. Therefore to be efficient, the UAV's would need to be able to process data for a similar area per day.

Image 1: UX5 - fixed wing
Weight: 2.5 kg
Dimensions: 100 x 65 x 10 cm
Endurance: 50 min
Range: 60 km

Image 2: S800 – multi copter
Weight: 2.6 kg
Dimensions: 320 x 800 x 460 mm
Endurance: 20 min
Range: 20 km

Image 3: eBee – Fixed wings
Weight: 0.7kg
Dimensions: 910cm wing span
Endurance: 45 min
Range: 10km^2

Image 4: F550 – multi copter
Weight: 1.8 kg
Dimensions: 280 x 320 x 280 mm
Endurance: 185 min
Range: 6 km^2

Appendix 2: Analysis of selective versus blanket spraying application.

Resource	Cost per hectare	Total hectares	Blanket spraying Cost	Hectares saved	Cost Saved
Application Costs*	$9.85	60	$591.00	42	$413.70
Herbicide cost**	$16.10	60	$966.00	54	$869.40
Total			$1,557.00		$1,283.10

	Cost Saved	Cost of Process ***	Total Saving
Totals	1283.1	720	**563.1**

Assumptions:

- UAV flights indicated that a small percentage of the paddock required spraying as opposed to the entire area.

*Application costs cover all machinery and labour costs.
** Herbicide cost is based on a combination of Ester, Garlon and Glyphosate.
*** The cost of process is based upon the cost of flying and processing the imagery for 1 hectare. The total is for 60 hectares.

- The Total Saving in the trial area is $ 563.10. This equates to $ 9.39 per hectare for the trail area.
- To further enhance costs saving, the grower could decide to only drive over the heavy populated areas.

Appendix 3: Weed detection process.

Step 1. Receive standard Image from UAV based camera

There are three detectable weeds in this image (highlighted with a red circle).

Step 2. Process Imagery through detection algorithm's.

There are 12 different algorithms run against every image (see examples on following page).Note: Weeds can be detected only in some algorithms, hence the need to use a variety of them. The final result (see below) is calculated by combining all of the results.

The red circles were the three areas where weeds were correctly identified. The areas circled in yellow were areas that were detected as possibly being weeds. The vegetation depicted under the blue line is the vegetation outside of the field. On site ground proofing carried out after the processing was completed proved that this interpretation was 100% correct.

Examples of different algorithms:

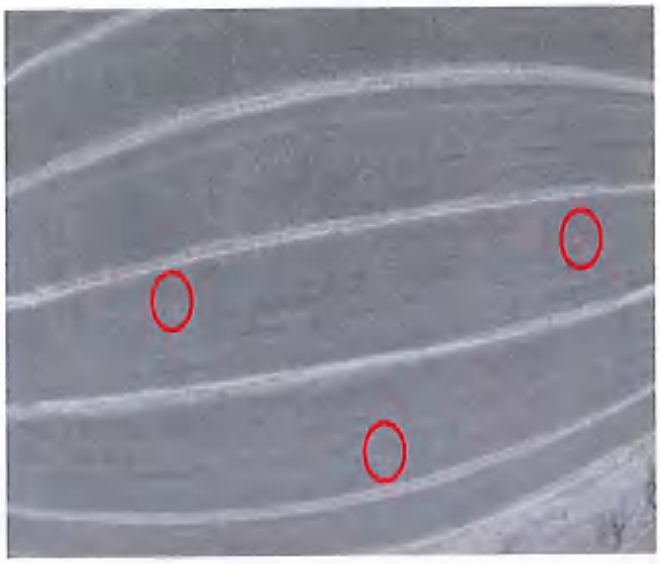


Figure 1: Monochrome comparison.

Figure 2: Green filter.

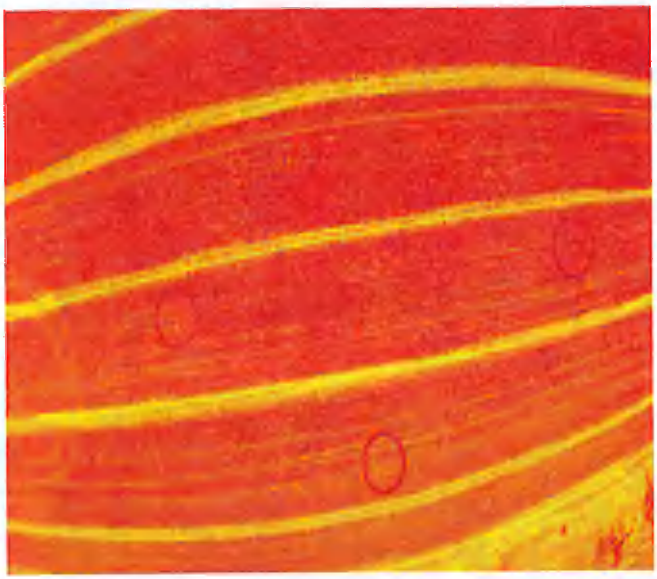


Figure 3: Orange filter.

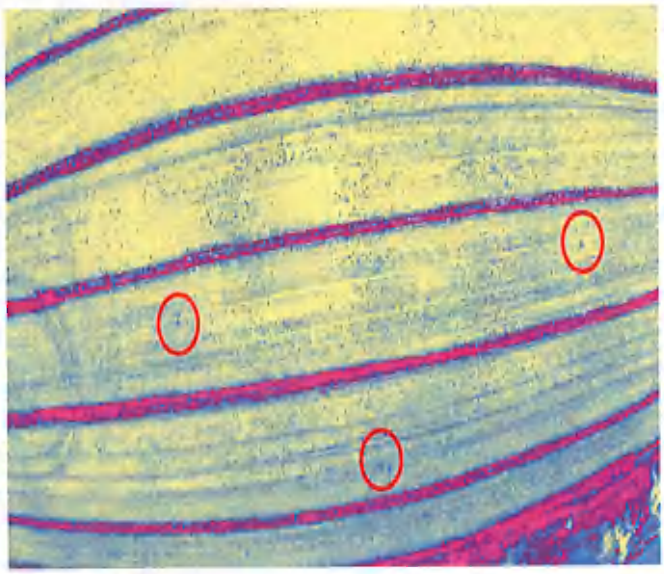


Figure 4: Shape Filter.

Appendix 4: Production of File for use by Vehicle Manufacturers.

The grower participating in this process utilises John Deere equipment and therefore the output from the Weed Detection process needed to be in what is known as a "Shape File". A shape file (referred to as ".shp" file) is actually the description of a file type created by ESRI, the leading GIS Company.

While a .shp file is accepted as an industry standard, most users in the world are actually familiar with Google Earth, and Google produces what is known as a ".kml file". In order to accommodate multiple suppliers, MIG decided that both a .shp file and a .kml file should be produced as the input into vehicles as this would cover all options.

The first image below shows the three weeds detected in the trial area as a .kml file while the second image is a .shp file depicting the three weeds. For this process a weed was detected and then a three meter circle drawn around the weed. This is to ensure that the spray booms were accurately initiated.

Image 1: Weeds depicted in a .kml format and shown in Google Earth.

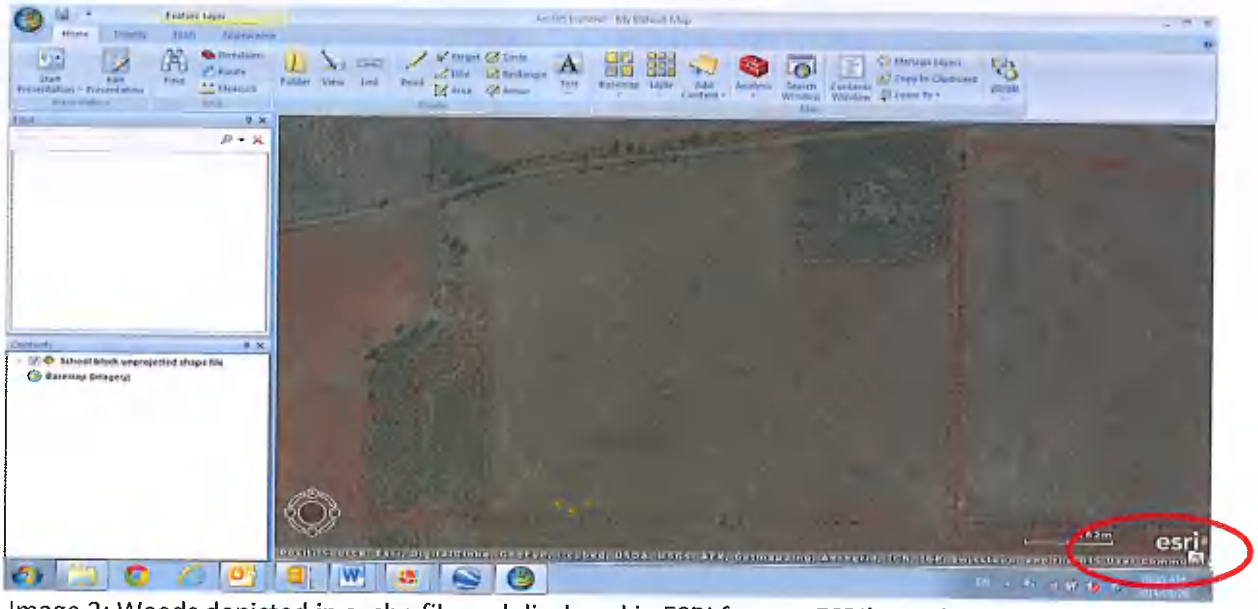


Image 2: Weeds depicted in a .shp file and displayed in ESRI format. ESRI's product is called ARCGIS as above.

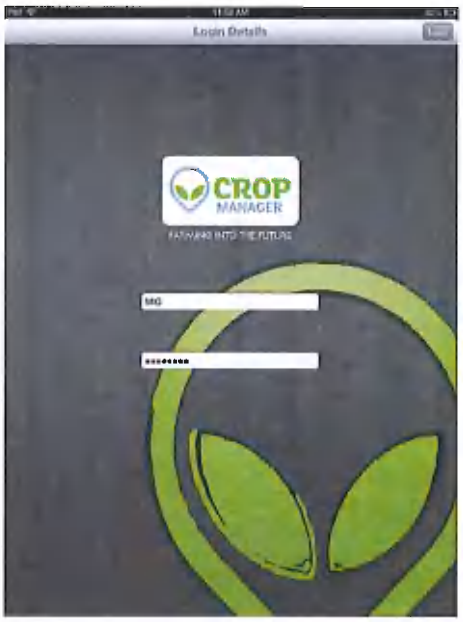
Appendix 5: Delivery of real-time data to growers.

The project has proved that data collected from UAV's can be interpreted by Crop Manager to establish where weeds are in a paddock. This information has been successfully converted into Industry Standard Spatial Images that can be used by all vehicle manufacturers and this has been displayed earlier. The final element of the process is the actual interaction with the farmer, and how MIG has worked with Crop Manager to provide this interaction.

Crop Manager provides three different forms of user interaction.

- A web -based application:

- A tablet application



- A Smart phone application:

The Web based application is where the vast majority of the system and data administration is performed, while the Tablet application has been developed primarily for consultants to record in-field information. The Smart Phone application has been developed to keep the farmer linked to their operation 24 hours a day by providing automated alerts that are based upon established benchmarks. The phone application will also allow the easy capture of the data that is necessary to deliver a profitable farming enterprise.

All the platforms are interlinked and the user security within Crop Manager allows MIG to present their data to all of their members or specific groups, depending on their requirements.

The following examples show how the information collected in this project can be shared with the members based on the different Crop Manager applications.

Summary

The message from this project to growers is that UAVS can be used to minimise costs associated with summer spraying. The techniques and technology described in this report describe another tool in weed management package.

If you can improve the efficiency of summer spray applications through targeting the areas of the paddock with high density weed populations you can reduce the cost and improve the effectiveness of your summer weed management package.

The main conclusion of this project is that the technology to detect weeds using UAVs exists and in the future, it will be a profitable farming practice for farmers when the correct legislation is in place and UAV technology has advanced further regarding the area that can be covered in a day. The main recommendation from this project would be to wait for these improvements to be implemented before developing further projects.