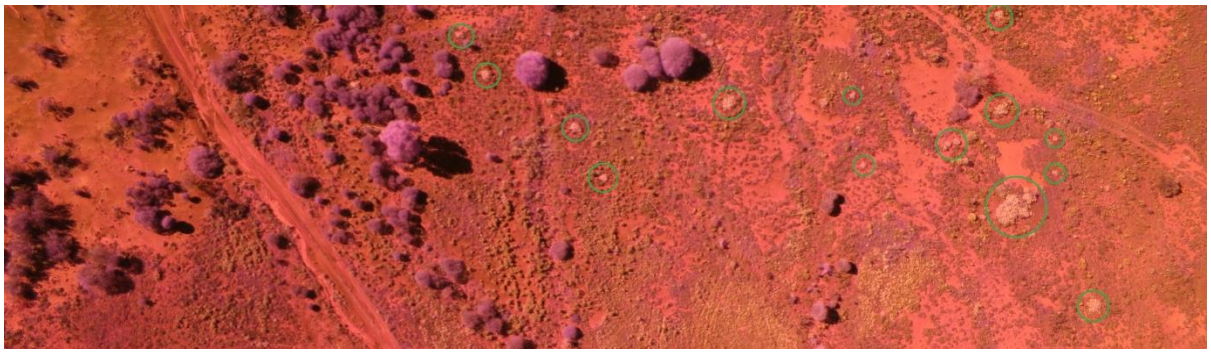
Summary of final report for Biosecurity R&D Fund[1] research project:

Using interactive technologies to identify and map invasive cacti in the southern rangelands of WA

Proponent: Goldfields Nullarbor Rangelands Biosecurity Association

Compiled by Jenny Crisp (DPIRD Biosecurity R&D Fund manager) in February 2018[2]



Project information

Project manager and contact person	Name: Ross Wood Email: ceo@gnrba.com.au or admin@gnrba.com.au
R&D Fund contribution	$158,500
Other contributions	$15,000
Total investment into project	$173,500
Start date	1st July 2015
Finish date	31st December 2017

Introduction and justification

The Goldfields Nullarbor Rangelands Biosecurity Association (GNRBA) is the largest biosecurity region in WA, covering an area of about 934,000 square km and representing 37% of the area of Western Australia (WA). The GNRBA recently completed a research project in which unmanned aerial vehicles (UAVs) carrying cameras were flown across rangeland sites to trial image capture technology on invasive cacti. Cutting-edge image analysis techniques were then applied to the images to differentiate the target cacti from other plants, culminating in the production of user-friendly maps for on-ground follow up and control. The potential value of technologies which support more cost-effective and efficient ways to identify and map invasive weeds is multiplied across such vast and unpopulated landscapes as the GNRBA region.

The two cactus species targeted in this research were Coral cactus (*Cylindropuntia fulgida var.mamillata*) and Brown-spined Hudson Pear (*Cylindropuntia tunicata*). These are both members of the invasive opuntioid family, are declared weeds under Western Australian legislation, and Weeds of National Significance. Cacti form dense infestations that degrade

[1] The Biosecurity R&D Fund is part of the Boosting Biosecurity Defences project, supported by Royalties for Regions and the Department of Primary Industries and Regional Development (DPIRD).

[2] Using information from GNRBA final report Dec 2017, Precision Agronomics Australia final report Nov 2017, past milestone reports and conversations with Ross Wood, Erin Gorter and Frank D'Emden in Feb 2018.

native vegetation and reduce grazing productivity, and the sharp spines can cause serious injury to humans, stock and native animals. Current practices to find and manage cacti infestations in the GNRBA region are labour intensive and expensive. There is also a high risk of many plants not being found (and therefore not treated) where the terrain is difficult to penetrate from the ground.

Approach and key findings

Precision Agronomics Australia (PAA) were contracted to conduct the work, and they liaised with UWA and Luminis Analytics for image analysis and algorithm development. The methodology involved flying three types of unmanned aerial vehicles (UAV's), with near infra-red and/or RBG camera capability attached, at a range of altitudes over two sites of known cacti infestation. The images captured were interpreted, and algorithms developed to differentiate individual cacti from other vegetation in the images. Site 1 (Tarmoola Station/Leonora) was 20ha of low open shrubland with a typical infestation of Coral cactus. Site 2 (Kangaroo Hills Timber Reserve/Coolgardie) was 20ha of tall open woodland/low open shrubland with a typical infestation of Brown-spined Hudson Pear cactus. Maps were then developed that can be used on the ground to seek and destroy cacti plants (to within 4m). Ground-truthing was conducted to check that the maps were accurate.

UAVs

In this trial, for all altitudes and camera types, the multirotor UAVs provided a more stable platform than the fixed wing UAVs and enabled sharper imagery acquisition. The multirotor UAVs were also able to be flown in windier conditions, were less prone to eagle attack, could take off vertically and are more commonly available as consumer devices. The downside of multirotor UAVs in the rangelands context is that they currently have less efficient battery usage and shorter flight times than the fixed wing UAV trialled. (NB Rapid advances in short timeframes are expected of UAV technology, so limitations associated with any model could potentially be overcome fairly quickly.)

Image capture and mapping

The Coral cactus infestation at the Tarmoola Station low open shrubland site was mapped relatively easily with the multirotor UAV (DJI Inspire) flying at 20m altitude using near infrared camera. The Hudson Pear infestation at the Coolgardie tall open woodland/low open shrubland site was more difficult to map due to more complex vegetation and a similar looking non-cactus plant species at the site (similar in terms of the RGB histograms). An accurate map was produced in the end, with the multirotor UAV (DJI Inspire) flying at 20m altitude using RBG imagery. It is expected these combinations of UAV, camera and altitude (for image capture) and algorithm will be directly transferable to similar vegetation systems/terrains. Any new data sets run through the algorithm will continue to improve the algorithm.

Ground based thermal sensing

An additional ground-based infra-red thermal sensing trial was set up at the Coolgardie site to test whether cacti obscured from aerial UAV view by shrub or tree canopies could be distinguished by canopy temperature using thermal cameras. The species compared were Brown-spined Hudson Pear with a neighbouring native Acacia. Data gathered from this preliminary work was inconclusive, with a range of environmental factors suggesting the approach is unlikely to have the flexibility required for weed control programs in remote areas.

Communications/awareness-raising

A communications strategy was developed and implemented to raise awareness about the research project and the impact and spread of invasive cacti infestations in the GNRBA region. As well as the GNRBA, PAA and associates, many other groups have had some involvement in the project, including Department of Biodiversity, Conservation and

Attractions, DPIRD, Kalgoorlie Boulder Urban Landcare Group, Shires of Leonora, Menzies and Coolgardie, Rangelands NRM, and pastoralists.

General communications included media releases about project progress and information materials about the project and invasive cacti generally, such as posters, video, case study document, GNRBA website and newsletter. Presentations and demonstrations about the project were delivered by PAA at the GNRBA Kalgoorlie Innovation Conference in September 2015, October 2016 and October 2017, to between 50-80 attendees each time, and to the Carnarvon Rangelands Biosecurity Association Innovation Conference in November 2015. A bus tour, hosted by the Shires of Leonora and Menzies in July 2017, was valuable in highlighting the problem of invasive cacti and promoting the project. Two workshops/training sessions were held to train pastoralists in the process/operation of UAVs; one at each research site.

A 'participatory surveillance strategy' was also planned and implemented by the GNRBA to encourage and provide a process for members of the public to report invasive cactus in the region. The strategy involved posters and rip-off pads being distributed to key access points such as roadhouses and shire offices. All information products related to project will continue to be accessible and promoted post-project, including the PAA Final Report, 2-page case study, video, participatory and surveillance package.

Unexpected benefits

A pastoralist from Winning Station in the Gascoyne heard of this project and after contact with GNRBA visited the PAA offices in Midland to learn how to use the UAV equipment. She intends to share her knowledge further in the Gascoyne region, which GNRBA are more than happy to assist with further information where required.

On the bus tour, the trial release site of the Cochineal bug (for biological control of Coral cactus at Tarmoola) was also inspected. This led to discussion regarding the need for a project to assist in the spread of the bug to other known infestations. On return from the bus tour, GNRBA immediately applied for funds from State NRM to do this, which was successful, and this project is currently in development.

Following an article about this project in the Society of Precision Agriculture Australia news, North West Local Land Services in Tamworth NSW saw the potential for mapping Hudson Pear infestations in their own region, and contacted PAA to discuss possibilities. North West Local Land Services have now provided imagery to the PAA/Luminis Analytics/UWA team to further test and refine the Hudson Pear algorithm.

Changes to initial plan

The project initially identified four sites of 80ha each to be flown and mapped, whereas two sites of about 20ha each were actually flown and mapped. This is because the first round of image capture on the four sites determined there were insufficient live cacti at two of the proposed sites to enable training of the image recognition algorithm. It was also identified that the fixed wing UAV trialled in the first flights was not sufficiently stable for the required level of image acquisition, and that a multirotor UAV would be needed. The current multirotor UAVs have less efficient battery usage and shorter flight times than the fixed wing; and it was agreed to reduce the flight area size for the remaining two sites (Tarmoola and Coolgardie) from 80ha to 20ha.

Next steps

Targeted surveillance - UAVs, image capture, mapping

In the immediate future (pending available funds), the model for the GNRBA going forward might look like:

- Land managers identify cacti infestations of concern and approach the GNRBA.

- GNRBA support land managers with small contracts to strategically fly the site (particularly looking for outliers in relation to hub/core) and produce a map of the infestation/s.
- *Or* - there could be efficiencies in GNRBA purchasing a drone, training a local pilot and sending digital images for external analysis and map production. The speed of technological advances in UAVs and their capacity though, could outdate the purchase in a fairly short timeframe.
- Land managers commit to controlling mapped infestation in a targeted way.
- It should be noted the technologies trialled in this project are unlikely to be used in isolation by the GNRBA; they would be applied strategically for targeted identification of problem areas, potentially in conjunction with new biological, and traditional chemical and mechanical control methods.

The more sites/vegetation systems that are successfully mapped in this way, the more transferable the algorithm will be to a broader range of vegetation systems. Should opportunities arise for further mapping in the GNRBA region arise, not only will declared weed management in the region be supported, but further technology development will also be supported, as outlined in recommendations 1, 2 and 3 from the PAA final report below.

- Recommendation 1 - Continue to develop the Hudson Pear neural network algorithm to reduce the proportion of type I errors and processing time to acceptable levels.
- Recommendation 2 - Collect image datasets from other infestations of Coral Cactus and Hudson Pear to test the effectiveness of the algorithms in different vegetation assemblages. A conscious effort was made to balance the image analysis efforts between constructing useful algorithms for identifying the two types of cactus, and a procedure would enable relatively easy refinement of the model to different vegetation assemblages. Further work to automate these procedures and create a user interface would create a valuable resource for biosecurity organisations.
- Recommendation 3 - Refine the image analysis procedures to a point where they can be used by an experienced QGIS user. The neural network algorithms are currently implemented in a Linux operating system environment. Further development is required to enable the algorithms to be implemented through a user-friendly Windows-based operating system.

Technological advances in the realms of UAVs, miniaturised imaging devices and graphics processors are expected to continue at a fast pace. The fields of image analysis and artificial intelligence are also rapidly evolving with the demands of emerging technologies such as autonomous vehicles and automated security/surveillance. Increases in the availability of low cost data storage and computing power means increasing capacity to analyse large amounts of data and run image recognition applications by more users.

Economic analysis work

DPIRD is planning to conduct some economic analysis work on invasive cacti using information from this project in March/April 2018, which is expected to add value to this research and support decision-making about cacti management in the rangelands.

Biological control work

The GNRBA, with DPIRD, is continuing to trial the biological control of Coral cactus at Tarmoola with the Cochineal insect, with promising results. It is possible that a future cacti management model could look something like biological control of the core/hub of the cactus, in conjunction with drone mapping to identify outlier infestations for direct chemical or mechanical control. Other biological control of cacti trials are also underway in the rangelands; but at an earlier stage of development.