UTILISING UNMANNED AERIAL VEHICLES (UAV) FOR REMOTELY ASSESSING AND EFFECTIVELY CONTROLLING EMERGENT WEEDS IN AQUATIC SYSTEMS USING HERBICIDES

S.D. Setter[1], M.J. Setter[1], M. Bulstrode[2], W.D. Vogler[3] and C. Warren[3]
[1]Centre for Wet Tropics Agriculture, Biosecurity Queensland, Department of Primary Industries, South Johnstone, Queensland 4859.
[2]Centre for Wet Tropics Agriculture, Agri-Science Queensland, Department of Primary Industries, South Johnstone, Queensland 4859.
[3]Tropical Weeds Research Centre, Biosecurity Queensland, Department of Primary Industries, Charters Towers, Queensland 4820.

ABSTRACT

The use of emerging Unmanned Aerial Vehicle (UAV) technologies in weed control has been readily adopted as a complementary new tool by land managers. The functionality, availability and affordability of UAV's has meant that their use is no longer restricted to highly skilled research and commercial operators but accessible to farmers, local councils and Government agencies. There remain questions about the value and efficacy of herbicide treatments when applied by UAVs in terrestrial and more specifically aquatic situations. Of equal importance, from an assessment perspective, is the ability to assess herbicide efficacy remotely using UAVs. In this paper, we use the latest photogrammetry software to assess a previously captured data set to assess the efficacy of several herbicides applied by UAV to an infestation of the invasive ponded pasture species Aleman grass (*Echinochloa polystachya*) in North Queensland. The entire process of pre-mapping, treating and assessing efficacy by UAV proved the validity of this approach for use in emergent aquatic weed control.

Keywords: Aleman grass, *Echinochloa polystachya*, remote sensing, orthomosaics, vegetation indices, UAV.

INTRODUCTION

The use of UAV technology to augment traditional assessment methodologies for aquatic weed control was proven in our previous work (Setter *et al* 2024). Other work has explored the use of UAVs to apply herbicides, e.g. Howell *et al* "Data from both case studies indicate that UAAS can provide an effective and efficient treatment strategy for floating-leaved and submersed plant control among common herbicide treatment scenarios.", Milling 2018 "Using the UAV as a tool to apply herbicide from above has enabled deep and full application of herbicide. Results to date have shown 80–90 % brownout of giant reed after a single treatment using glyphosate".

When time and money is invested in weed control, irrespective of the circumstances, confidence in value for money is essential.

Spray drone technology is developing rapidly with many contractors as well as growers adopting the technology. In many cases this form of aerial application can be considered novel. Though there are Civil Aviation Safety Authority (CASA) and Biosecurity Queensland (BQ) specific regulations around operating UAVs, agricultural product labelling, regulated by the APVMA, only considers aerial application down to the resolution of “aircraft”; with no specific classification for “UAV” application. The newness of the technology coupled with the rapid uptake requires rigorous testing around the general differences in application when compared with manned aircraft as well as efficacy.

This paper explores the validity of new and emerging technologies available for aquatic weed control. This approach incorporates 4 distinct steps, all performed by UAV or with data collected by UAV.
A. the infestation was pre-mapped by UAV
B. treatment zone selection and spray mission planning were derived from UAV data
C. aerial herbicide application was done utilizing a commercial spray drone
D. post-treatment, UAV-acquired imagery was processed into zonal statistics to quantify treatment efficacy.

MATERIALS AND METHODS

A monoculture of Aleman grass growing in a permanent slow flowing creek between sugarcane farms within the lower Herbert River basin was selected for the trial. After general site selection, several mapping UAVs were used to assess the trial area and to conduct mission planning. The mapping UAVs were a DJI Phantom 4 Multispectral (Blue: 450 nm; Green: 560 nm; Red: 650 nm; Red edge: 730 nm; Near-infrared: 840 nm), a DJI M300 with a P1 (45MP RGB) camera and a DJI Mavic 2 Pro with a 20MP RGB camera.

The UAV RGB imagery was processed through PIX4Dfields photogrammetry software to select treatment zones across ponded areas that were of similar condition. These treatment zones were 9 m wide and 25 m long. Twelve flight mission polygons were created as well as 4 control polygons. The mission was then exported as a shapefile to the spray UAV controller.

A DJI Agras T16 spray drone (16 L capacity) was used to apply the herbicide treatments (Table 1) at an altitude of 3 m above the Aleman grass. Herbicide was applied on 11/11/2022 between 09:00 and 11:00 with light wind conditions and medium humidity. All herbicide mixtures used water as a carrier and contained Cocamidopropyl betaine (Nemo®) wetter (at a rate of 2.92 mL/25 m^2).

Table 1. Herbicides and application rates used in the trial.

Herbicide	Trade Name	Group	Active ingredient application rate (g a.i. ha^{-1})
Glyphosate 360 g/L	Weed master Duo®	9	5040
Imazapyr 750g/kg	Poacher® 750	2	2250
Haloxyfop 520g/L	Verdict® 520	1	400

A series of UAV assessment flights were conducted in the weeks and months following treatment application. UAV assessment flights occurred on 05/12/2022, 23/12/2022 and 14/03/2023. The assessments were conducted utilising a range of mapping UAVs

including a DJI Phantom 4 Multispectral, a DJI M300 with a P1 camera and a DJI Mavic 2 Pro.
Due to advancements in photogrammetry processing software the UAV imagery was processed during March 2025 using PIX4Dfields (version 2.8.5) and PIX4Dmatic (version 1.71.0). Equal sized assessment polygons were created within the various photogrammetry mapping outputs that were 8 m wide and 23 m long and placed within the treated areas as well as 4 controls. PIX4Dfields was used to produce zonal statistics for both the multispectral and RGB data sets.

The zonal statistics were produced for a range of vegetation indices. These indices included: NDVI, GNDVI and LCI from multispectral images and VARI and TGI for RGB images. Brief explanations of these follow.

NDVI (Normalised Difference Vegetation Index) is used to quantify vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health. NDVI is calculated from spectrometric data at two specific bands: red and near-infrared. NDVI is calculated as a ratio between the red (R) and near infrared (NIR) values. NDVI = (NIR - R) / (NIR + R).

GNDVI (Green Normalized Difference Vegetation) is an index of plant “greenness” or photosynthetic activity. It is a chlorophyll index used at later stages of development, as it saturates later than NDVI. The GNDVI is more sensitive to the variation of chlorophyll in the crop than the NDVI and has a higher saturation point. GNDVI = (NIR - GREEN) / (NDVI + GREEN). The GNDVI can be used in crops with dense canopies or in more advanced stages of development, while the NDVI is adequate to estimate the vigour of the crop during the initial stages.

LCI (Leaf Chlorophyll Index) is calculated to measure the chlorophyll content in leaves in areas of complete leaf coverage. There are different methods to calculate LCI, often depending on the specific wavelengths used in the analysis. In this case we used (NIR – Red edge) / (NIR + R).

VARI (Visible Atmospherically Resistant Index) is a vegetation index that evaluates the 'greenness' in plants, where greener plants are assumed to be in healthier condition. VARI is useful for mitigating atmospheric interference which enhances the ability to detect coloration differences between plants. VARI uses Red, Green, and Blue bands to assess plant health. Since VARI only uses bands in the visible spectrum, this index is appropriate for cameras that capture in standard RGB. VARI = (NIR - R) / (NIR + R)

TGI (Triangular Greenness Index) is calculated to measure the chlorophyll content in leaves. TGI index relies on reflectance values at visible wavelengths (RGB). It is a good proxy for chlorophyll content in areas of high leaf cover. TGI = 0.5 (190 (R670 - R550) – 120 (R670 - R480)).

Indices values were exported from PIX4Dfields as zonal statistics and analysed using the open-source statistical computing software package R (version 4.4.2). Linear models were fitted with factors representing treatments and replicate blocks. All significance testing was performed at the $\alpha = 0.05$ level and Fisher’s protected 95 % least significant difference (lsd) was used to make pairwise comparisons. The ’lm’ function in the R package ‘stats’ was used to fit the model and pairwise comparisons were performed using the R package ‘predictmeans’.

RESULTS

Various multispectral and RGB vegetation indices were used to assess the trial. Over the last few decades, NDVI index has been the primary assessment algorithm for both satellite and airborne sensors. As digital agriculture advances, more vegetation assessment indices are becoming available. This trial provided an opportunity to compare several vegetation indices including ones that only utilise RGB cameras.

Comparisons were made between indices as well as across temporal changes in the trial. Assessment flights occurred before and multiple times after the treatments were applied. Below are tables showing the statistical difference between the treated area and the control at varying times.

To confirm that there was reasonable uniformity in the treatment areas, the site was assessed using a high resolution RGB mapping UAV. Results in Table 2 show no significant difference between treatment plots or the control plots prior to spraying.

Table 2. Vegetation indices comparison for statistical difference 11/11/2022 (a = highest mean). Treatments with a letter in common are not significantly different.

	11/11/2022				
Treatment	NDVI	GNDVI	LCI	VARI	TGI
Control	na	na	na	a	a
Poacher®	na	na	na	a	a
Weedmaster Duo®	na	na	na	a	a
Verdict®	na	na	na	a	a

Twenty-four days after application the significant difference between treatments is shown in Table 3. The three distinct groups are: the Control, Poacher®/Weedmaster Duo® and Verdict® which separates out with the lowest mean indicating the greatest reduction in photosynthesis.

Table 3. Vegetation indices comparison for statistical difference 05/12/2022 (a = highest mean). Treatments with a letter in common are not significantly different.

	05/12/2022				
Treatment	NDVI	GNDVI	LCI	VARI	TGI
Control	a	a	a	a	a
Poacher®	b	b	b	b	b
Weedmaster Duo®	b	b	bc	b	b
Verdict®	c	c	c	c	c

Forty-two days after treatment there are now two significantly different groups (Table 4). The two distinct groups are: the Control then Poacher®/Weedmaster Duo®/Verdict®.

Table 4. Vegetation indices for 23/12/2022 (a = highest mean). Treatments with a letter in common are not significantly different.

Treatment	23/12/2022 NDVI	GNDVI	LCI	VARI	TGI
Control	a	a	a	a	a
Poacher®	b	b	b	b	b
Weedmaster Duo®	b	b	b	b	bc
Verdict®	b	b	b	b	c

At 82 days after treatment there are two significantly different groups (Table 5). The distinct groups are the Control and Poacher®/Weedmaster Duo®/Verdict®.

Table 5. Vegetation indices for 14/03/2023 (a = highest mean). Treatments with a letter in common are not significantly different.

Treatment	14/03/2023 NDVI	GNDVI	LCI	VARI	TGI
Control	a	a	a	a	a
Poacher®	b	b	b	b	b
Weedmaster Duo®	b	b	b	b	b
Verdict®	b	b	b	b	b

DISCUSSION

Utilising vegetation indices to assess treatment effect clearly showed this approach to be a valid technique when assessing Aleman grass control. The initial assessment flight conducted 24 days after treatment showed a statistically significant difference between treatments and between treatments and the control. The Verdict® treatment mean showed a statistically significant reduction in photosynthesis compared to the group of Poacher® and Weedmaster Duo®; where no statistical difference between them was found.

At 42 days after treatment all herbicide treatments showed no statistical difference between their reflectance means but all were significantly lower than the control. This indicated that though Verdict® caused a faster initial reduction in photosynthesis, all herbicides eventually caused a similar reduction.

All herbicide/wetter treatments applied by UAV effectively killed the Aleman grass with the only difference being the speed to which the kill became measurable. Irrespective of whether multispectral or RGB indices were used, a significant difference between the control and herbicide efficacy was recorded. The specific herbicide chemistry, as defined by their mode of action, showed group 1 haloxofop (Verdict®) to be the fastest. Although slower acting, the group 9 glyphosate (Weedmaster Duo®) and group 2 imazapyr (Poacher®) also showed a significant effect 82 days after treatment.

Different species of aquatic plants with varying biological traits would dictate the suitability or otherwise of using specific vegetation indices as a measure of plant health. Of interest here is that a broad range of indices produced statistically similar results. Both the more complex multispectral sensors as well as RGB bands were able to differentiate reflectance changes.

Some of the most important technological improvements have been with airborne sensors and image processing software. Current multispectral sensors have 4 times the resolution of the DJI Phantom 4 M used in this trail. Higher resolution may support more in-depth analysis; particularly when coupled with the latest processing software such as was used in this trial.

The technology around UAV-based spray delivery systems is starting to mature with relatively small changes occurring. This is partially because current systems are very effective at delivering agricultural chemicals particularly when precision application (PA) is required. The adoption of Controlled Droplet Application (CDA) has been a step change to the previous hydraulic nozzles, facilitating precise droplet spectrum control (Walker, 1986). Managing droplet spectrum improves pesticide efficacy through properties such absorption time as well as reducing drift, therefore better meeting label requirements.

Potential impediments to the adoption of UAVs for aquatic weed control are similar to those of other control methods and may include parameters such as weather conditions, site access, off target impacts and limitations to registered herbicides. Additional consideration can be CASA visual line of sight (VLOS) flying requirements and the scale of the area to be treated. There are potential benefits from herbicide volume reductions using UAVs. Paul *et al*. (2024) found that UAVs were highly effective at lower water rates. The inherent nature of aquatic systems would indicate that a PA approach should provide ecological benefits.

ACKNOWLEDGMENTS

Romano family for the use of their land and advice about site access and crocodiles etc. Dr Carole Wright (DPI) for assistance with statistical analysis.

REFERENCES

Howell AW, Leon RG, Everman WJ, Mitasova H, Nelson SAC, Richardson RJ (2023) Performance of unoccupied aerial application systems for aquatic weed management: Two novel case studies. Weed Technol. 37: 277–286. doi: 10.1017/wet.2023.32

Milling, Philip. "Unmanned Aerial Vehicles used to control giant reed (*Arundo donax* L.)." (2018): 177-180. in Proceedings of the 21st Australasian Weeds Conference. New South Wales, Australia

Paul, R.A.I., Palanisamy, M.A., Peramaiyan, P., Kumar, V., Bagavathiannan, M., Gurjar, B., Vijayakumar, S., Djanaguiraman, M., Pazhanivelan, S. & Ramasamy, K. 2024. Spray volume optimization with UAV-based herbicide application for effective droplet deposition and weed control in direct-seeded rice. Frontiers in Agronomy, 6.

Setter, S. D., Setter, M. J., Bulstrode, M., Vogler, W. D. and Warren, C. (2024) Comparing traditional and unmanned aerial vehicles (UAV) assessment methodologies in aquatic weed control research. In: 23rd Australasian Weeds

Conference; Breaking the cycle: Towards sustainable weed management, 25-29 August 2024, Brisbane, Qld.

Walker, S. 1986 Comparison of controlled droplet and conventional application of postemergence herbicides. Queensland Journal of Agricultural and Animal Sciences, 43, 135-139.