LCA Land Capability Assessment (Vic)
OSMS Site & Soil Assessment (NSW)
Onsite Wastewater Consultancy Services
Bushfire Management Statements (BMS, BALs)
Biodiversity Assessment Services
Drone Mapping & GIS Analysis

Client: Heytesbury Landcare Network

Project: Lake Cobrico Drone Seeding Monitoring (Drone Mapping) Project – Dec 2020-Jan 2022.

Date: 7 February 2022

Contact: Kate Leslie

Landtech: Peter Austin peteraustin.landtech@hotmail.com
161 Skene St, Warrnambool.Vic.3280.
Ph. 0408-615677.

Figure 1 – Drone survey results of unburnt areas displaying varied sedge, shrub, and tree species compositions.

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SUMMARY

Landtech Consulting was commissioned in 2021 to collect drone mapping data to determine the success of drone-seeding operations and monitor land cover change since the last similar data collection project in 2019-2020.

In March 2018, embers ignited a bushfire within Lake Cobrico and its peat-based soil profile, to change the composition and distribution of key vegetation and related habitats forever.

To assist restoration planning within a site highly fragmented due to historic agricultural activity, drone-seeding of *scoria cone woodland* species has occurred at various rates, and within a varied fire intensity mosaic.

This follow-up monitoring data collection and analysis process aims to provide an insight into optimum seeding rates and resulting comparison of vegetation cover change using drone technologies.

Utilising fire extent and fire intensity maps, previous and 2022 sub-2cm drone mapping data collected by Landtech Consulting (2020), and drone-seeding coverage/seeding intensity data within such areas, analysis produced the following findings:

1. Increased indigenous vegetation cover over the recent two-year period (2020-2022);
2. Increased cover with assisted drone seeding; and
3. Increased cover with increased seed concentrations.

Such data confirmed the utility of drone technologies integrating site ecology to achieve low impact and remote-based revegetation operations. Various projects around Australia have recently utilised either methods however not used together providing a future sustainable and innovative approach to on-ground land management activities and their monitoring.

The following report and attached PDF poster summary will detail methodologies used to support the ongoing ecosystem restorative processes within this highly significant site.

Figure 2 – Transitional areas to the west of the lake depicting change from shrubland on the left through to dry grassland areas (right).

SUMMARY RESULT

+General land cover comparisons 2020-2022 – land cover and species diversity has markedly increased since the previous mapping data collection project in 2020;

+Drone-seeding varied seed concentration comparisons – Although not quantified, outputs from data collected clearly display increased cover in areas of increased seed concentration/rates;

+Comparison of cover change drone-seeded and non-drone seeded areas – Although not quantified, increases in cover were evident as expected in areas that are seeded enhancing already effective natural regeneration processes;

+Responses of severely burnt areas – increase grassland species as expected, increase in bare earth and lichen crust cover, in addition to more sparse native vegetation natural regeneration.

CONTENTS

Figure 3 – Tea Tree shrub death and natural renewal within partly-burnt sites.

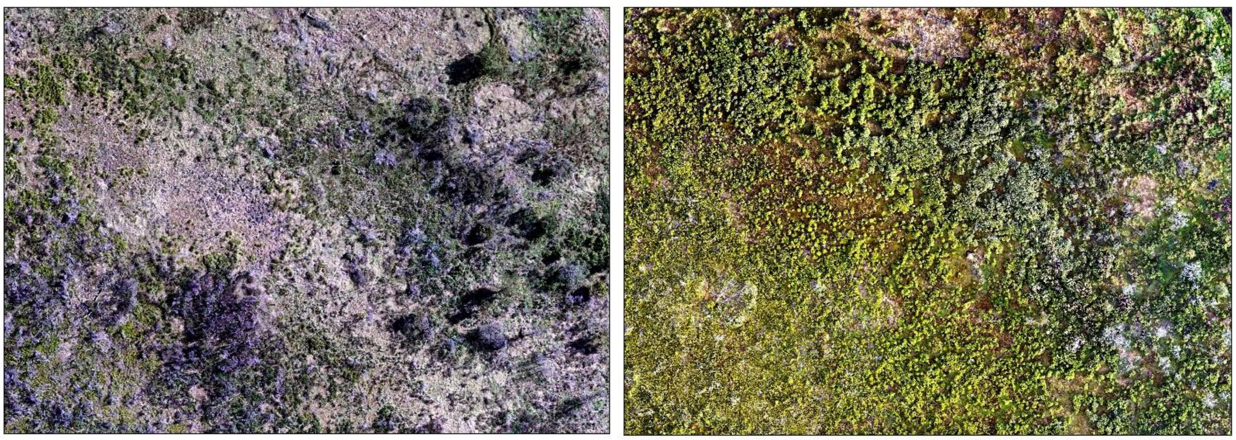
1. PROJECT BACKGROUND

The following report is based on a request from Kate Leslie (Heytesbury Landcare Network) to complete follow-up drone-seeding vegetation response monitoring, using true-colour cameras, onboard quadcopter drones at Lake Cobrico (also known as *Cobrico Swamp Wildlife Reserve*).

The 13.14 hectare site consists of a highly fragmented lakebed and regrowth scoria cone woodland vegetation, including non-reversible impacts of long-term agricultural use (see *Figures 4 & 5*).

The site includes elements of an endangered Ecological Vegetation Class 894 *Scoria Cone Woodland,*[1] that has been reduced to isolated small patches, with lake-associated herb and aquatic vegetation also significantly reduced. Cobrico Swamp is typical of many isolated remnants and consists of varied vegetation regrowth within a history of integrating threats and changes to natural disturbance regimes.

Incremental fragmentation (grazing) and patch isolation inhibits local and regional vegetation connections that allow dispersal of key species propagule and genetic transfer processes, increasing the vulnerability of reduced-size faunal populations and species extinctions, and the destructive effects of inbreeding depression.



Figures 4 & 5 – Post-fire (March 2018) impact and the two-year recovery and land cover change.

Natural and assisted vegetation regeneration patterns can be analysed via the collection of sequential imagery with drones, providing a platform for repeatable remote and low impact ecological surveillance. Impacts from peat fire control measures such as trenching, clearing, and vehicle movement can also be analysed for the regenerative response in vegetation composition.

Effectively managing such impacts can utilise improving camera and drone technologies to support adaptive environmental management processes. Numerous references propose the use of this method in addition to textural-based characteristics for drone-based image collection.[2] [3] The quality, health, and progress of each direct seeded area can be analysed using multispectral imagery[4] with the ability to analyse such layers for a range of indicators such as heat and drought stress, plant height and health, and the nitrogen and chlorophyll content of plants.[5]
A combination of multispectral and thermal imaging cameras and sensors allows depiction of many different analytical layers which are optimal in sensing germination development.

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[1] Department of Environment, Land, Water & Planning (DELWP) 2019. Bioregional Conservation Status, Victorian Bioregions; Accessed from: https://www.environment.vic.gov.au/__data/assets/pdf_file/0012/50511/Bioregional-Conservation-Status-for-each-BioEVC.pdf

[2] Yong-Gu H, Se-Hoon J & Ohseok Kwon O (2017). How to utilize vegetation survey using drone image and image analysis software, Journal of Ecology & the Environment. Accessed from: https://link.springer.com/article/10.1186/s41610-017-0035-2

[3] Researchgate Forum (2015). What is the best solution in vegetation association mapping based on high quality, low altitude aerial imagery? Accessed from: https://www.researchgate.net/post/What_is_the_best_solution_in_vegetation_association_mapping_based_high_quality_low_altitude_aerial_imagery

[4] Buters T 2019; Drone-based remote sensing as a novel tool to assess restoration trajectory at fine-scale by identifying and monitoring seedling emergence and performance; Curtin University WA; Accessed from: https://espace.curtin.edu.au/bitstream/handle/20.500.11937/78329/Buters%20T%202019.pdf?sequence=1

[5] Buters T 2019; Drone-based remote sensing as a novel tool to assess restoration trajectory at fine-scale by identifying and monitoring seedling emergence and performance; Curtin University WA; Accessed from: https://espace.curtin.edu.au/bitstream/handle/20.500.11937/78329/Buters%20T%202019.pdf?sequence=1

The application of drones in plant health monitoring is well established for agriculture and forestry however, there is little evidence of translational research applying these approaches to ecological restoration, with drone use in the monitoring of ecological recovery comprising less than 7% of studies.

Figure 6 – Natural restoration in many areas has increased significantly and where large tree death is a feature of the data collected.

Traditional methods of monitoring the success of revegetation involve on ground assessments of vegetation survival, species mix and abundance. These methods can be time consuming and can also include elements of subjectivity due to differences in the on ground conditions of the day and the experience of the assessor.[6]

Conservation agencies such as Bush Heritage (Monjebup Reserve) utilise drones to simply monitor the progress of restoration from paddock back to natural vegetation. With modern drone technologies and assorted sensors, it is possible to get accurate and repeatable information regarding the extent of cover, height of the canopy, and number of plants occurring within set plots, in a way that provides non-subjective and repeatable monitoring data. With the addition of high precision (RTK) positioning systems, accurate canopy height models via digital surface analysis can enhance site interpretation.

References suggest stocking count models can be used to identify the individual native plants in the plot, which can then be used to calculate the number of stems per hectare.[7] Additionally the extent of cover of vegetation within a transect plot supports quantifying percentage change over time and/or post intervention.

Drones produce information in a number of different formats allowing data to be further manipulated with mapping programs such as ArcGIS, ENVI, GlobalMapper etc. Subjectivity issues will remain however where it is necessary to user define boundaries within the software applications.

US-based land cover studies include the use of drones and multispectral imagery providing the opportunity to improve upon satellite imagery for resource management because of the very high spatial resolution, multispectral capability, and opportunity to collect real-time observations.[8]

High resolution mapping of chosen habitats is invaluable for resource inventory and change detection in difficult to access sites with advanced information of the physical conditions of the study area and improved land feature delineation.[9]

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[6] South Coast NRM 2016; Bush Heritage Australia's Monjebup Reserve drone seeding project; Accessed from: https://southcoastnrm.com.au/wp-content/uploads/2018/07/drone_case_study_2016.pdf

[7] South Coast NRM 2016; Bush Heritage Australia's Monjebup Reserve drone seeding project; Accessed from: https://southcoastnrm.com.au/wp-content/uploads/2018/07/drone_case_study_2016.pdf

[8] Yang B, Hawthorne TL, Torres H, Feinman M. Using Object-Oriented Classification for Coastal Management in the East Central Coast of Florida: A Quantitative Comparison between UAV, Satellite, and Aerial Data. *Drones*. 2019; 3(3):60. https://doi.org/10.3390/drones3030060

[9] Yang B, Hawthorne TL, Torres H, Feinman M. Using Object-Oriented Classification for Coastal Management in the East Central Coast of Florida: A Quantitative Comparison between UAV, Satellite, and Aerial Data. *Drones*. 2019; 3(3):60. https://doi.org/10.3390/drones3030060

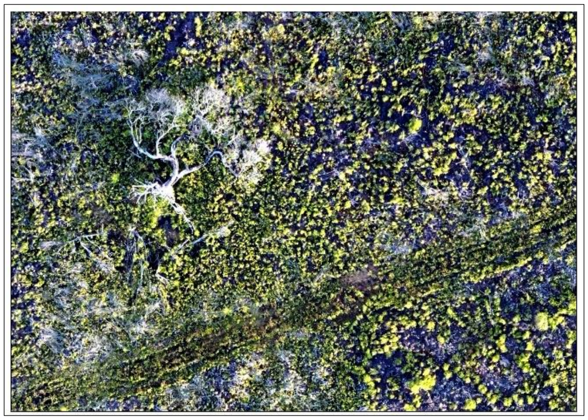
Mapping of coastal vegetation and weed infestations such as (Five Islands) near Port Kembla in NSW[10] use recreation-based drone technology to analyse key indicator vegetation survival rate post-disturbance events, with the ability to focus on single species due to spectral interrogation and analysis processes. In this project data was able to be analysed to understand vegetation distribution patterns within the reserve including weed invasiveness, weed treatment effectiveness, and ultimately used to solve broader managerial issues associated with delicate island ecosystems.

Figures 7 & 8 – Comparative 2020 and 2022 image within a seeded/unseeded area showing potential cover increase.

[10] Barlow P 2018: A comparative study of raster and vector based approaches in vegetation mapping on Five Islands off the coast of Port Kembla; University of Wollongong. Accessed from: https://ro.uow.edu.au/cgi/viewcontent.cgi?article=1162&context=thsci

2. SITE CONTEXT

Scoria Cone Woodland is a sparsely-wooded grassy woodland typically dominated by non-eucalypt trees to 10m. Canopy (15% cover) species include Drooping She-oak (*Allocasuarina verticillata*) with Silver Banksia (*Banksia marginata)* and Blackwood (*Acacia melanoxylon*) over a grassy to bracken-dominated understorey with a range of herbs. *Scoria Cone Woodland* occurs on the slopes of freely-draining scoria cones and spatter areas of coarse boulder-forming flow sources. Soils are fertile but often skeletal.[11]



Figures 9 & 10 – Comparative images from a significantly burnt site and increases in land cover between 2020 and 2022.

The *Cobrico Swamp* comprises a tuff ring 2 km in diameter and 15m high enclosing the shallow crater of maar.[12] The tuff ring is semi-circular and of even height in the north and west but is lower in the south-west. The crater floor is occupied by a small lake on the eastern side and the rest is drained swampland. The floor is peaty and overlies white clay. Recent mapping indicates the tuff is surrounded by limestone.[13]

Figure 11 – Varied vegetation composition within partially burnt sites reflecting the endemic nature of many species.

Typical remnant species[14] of woodland and lakebed under and groundstorey include: *Bursaria spinosa* (Sweet Bursaria), *Senecio pinnatifolius* (Variable Groundsel), *Rumex brownii* (Wiry Dock), *Senecio quadridentatus* (Cotton Fireweed), *Acaena novae-zelandiae* (Bidgee-widgee), *Geranium potentilloides* (Cinquefoil Cranesbill), *Acaena echinata* (Sheep's Burr), *Viola hederacea* (Willis 1972) (Ivy-leaf Violet), *Dichondra repens* (Kidney-weed), *Oxalis exilis* (Shady Wood-sorrel), *Poa labillardierei* (Common Tussock-grass), *Lomandra filiformis* (Wattle Mat-rush), *Dianella revoluta s.l.* (Black-anther Flax-lily), *Carex breviculmis* (Short-stem Sedge), *Austrodanthonia pilosa* (Velvet Wallaby-grass), *Microlaena stipoides var. stipoides* (Weeping Grass), and *Pteridium esculentum* (Austral Bracken). Persistent weeds within the study area include: *Lycium ferocissimum* (African Box-thorn), *Hypochoeris radicata* (Cat's Ear), *Briza maxima* (Large Quaking-grass), *Romulea rosea* (Onion Grass), and *Holcus lanatus* (Yorkshire Fog).

[11] Department of Environment, Land, Water & Planning (DELWP) 2019; Victorian Volcanic Plains; EVC 894 Scoria Cone Woodland; Accessed from: https://www.environment.vic.gov.au/__data/assets/pdf_file/0029/48755/VVP_EVCs_combined.pdf
[12] Ollier, C.D. & Joyce, E.B. 1964. Volcanic physiography of the Western Plains of Victoria. *Proceedings of the Royal Society of Victoria* pp 357-376.
[13] Edwards, J. 1991b. Geology of the Cudgee 1:25 000 map, Port Campbell Embayment, East Otway Basin, Victoria. *Geological Survey of Victoria Unpublished Report* 1991.
[14] Department of Environment, Land, Water & Planning (DELWP) 2019; Victorian Volcanic Plains; EVC 894 Scoria Cone Woodland; Accessed from: https://www.environment.vic.gov.au/__data/assets/pdf_file/0029/48755/VVP_EVCs_combined.pdf

2.1 BUSHFIRE IMPACT

Figure 12 – Long smouldering high-intensity fires have clearly impacted vegetation regeneration in key areas (DELWP 2018).

Bushfire ember attack in from the north-west in March 2018 ignited peat fires within the lakebed which burnt a relatively large proportion of the existing vegetation. Areas within the lakebed were burnt severely in western sections with fire extending into some broad indigenous vegetation sites to the east. As one of the world's largest terrestrial carbon reserves, peatlands have been experiencing drainage and fires contributing to 5% of global carbon emissions.[15]

Drone imagery collected in severely, partially, or unburnt areas can be analysed to determine impact of various fire coverages and intensities and follow-up natural regenerative responses. Google imagery (see *Figures 13-14*) collected in the weeks following the fire also provide insight into burn patterns in addition to data provided by DELWP (see *Figure 18*). Brief analysis has been provided later in the report and where further interpretation is beyond the resourcing of this report/project.

Figures 13-15 – Google imagery was coincidentally collected in the weeks post the bushfire providing insight into fire burn patterns.

Figures 16-17 – Deep burn impact was a key feature of the fire potentially changing vegetation distribution patterns into the future.

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[15] XAG Australia 2020; https://www.xagaustralia.com.au/post/lake-cobrico

Figure 18 – Map provided by DELWP showing fire coverage and burn intensities within various lakebed areas (Source: DELWP).

2.2 DRONE-SEEDING REVEGETATION ACTIVITIES

Drone-seeding has been carried out by XAG Australia in 2020[16] with varying seeding rates per hectare (see *Figure 19*). Drone mapping prior to this in 2020 was completed by Landtech Consulting within the study area.

Drones have been used for many years to sow seed in broad acre agriculture-based contexts however rarely seeding natural areas. Drones with intelligent spreading systems were used to distribute seeds directly into the difficult-to-access areas. Seeding by hand or ground equipment is inapplicable to the study site due to fire impacts, ground instability, and restrained access, and where remote seeding (drone-seeding) may reduce disturbance to vulnerable post-fire landscapes.

Based on accepted direct-seeding rates (see *Figure 19)* the site was seeded in three different zones utilising multiple drones to disseminate seed at varying rates per hectare (0.5kg to 1kg/ha). Zones 1 and 3 shown below consisted of both partially and several burnt areas to the north and south of the study area.

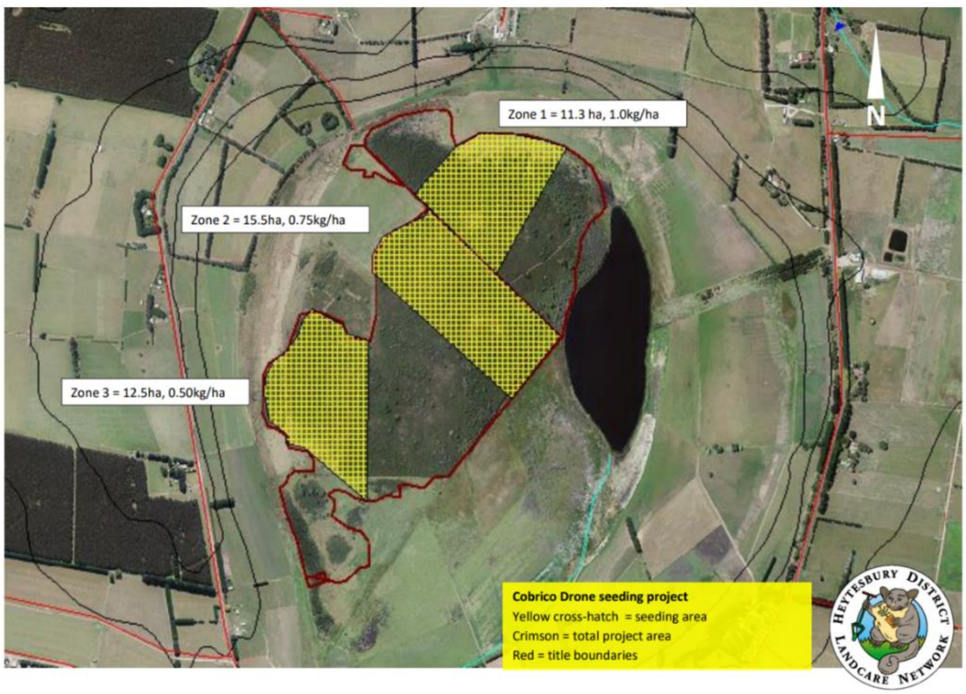


Figure 19 – Drone survey areas covering varying direct-seed treatment rates (Source: Heytesbury Landcare Network 2021).

Figures 20-21 – Drone seeding, and seed spreader being filled (Source: XAG Australia 2020).

[16] XAG Australia 2020; https://www.xagaustralia.com.au/post/lake-cobrico

3. METHODS

The following methodology was used to complete this project:

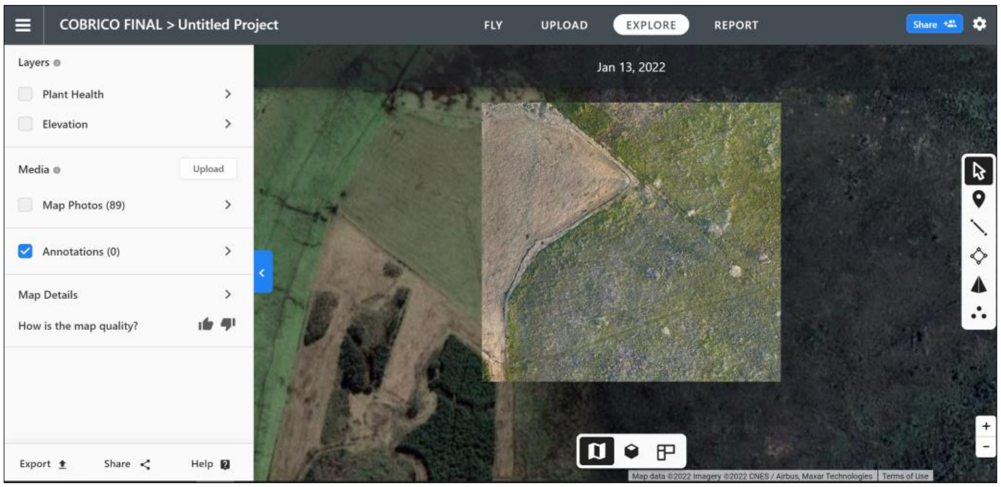
Table 1 – Study methodology – Stage 1.

Method	Detail
Scope site	Survey methods was guided by previous site survey and site scoping works to determine: □ study area to be mapped compared with previous drone-seeded coverage □ site access and staging □ equipment, conditions required □ mapping workflows Scoping 1 ■ determine project coverage ■ preview potential launch sites, site access ■ review equipment applicable to task Scoping 2 □ Equipment selection determined – project drone, camera/sensor, SD card size/speed, mission planning and flight apps used, site internet coverage, batteries required/charging, post-process software types   Scoping 3 ■ setup Pix4D flight paths (based on previous mapped coverage and direct-seeded areas). ■ determine drone settings – flight height (80m), flight speed (3m/s), image overlap (70%). ■ planning included utilising optimum day/time, light/luminance level, shadowing, windspeed, wind direction, low cloud/fog/mist/smoke, aircraft drag, nesting Wedge-Tailed Eagles. Wind scheduling was problematic due to overarching recent weather patterns across the south of Australia. Wind speeds of up to 35km/hr were experienced during the two-days of data collection.
Capture drone image data	Data was captured on the 12th and 13th of January (2022) in less than optimum wind and weather conditions. Landtech used the following drone to gather 2.5cm resolution true colour imagery utilising a DJI Mavic Pro 2 (Hasselblad) with 20-megapixel system cameras. ■ A launch station was created within the western lake-bed edge (Erreys Road) from the back of a dual-cab utility vehicle. ■ Drones were hand-launched due to ground cover obstructions with automated missions of 15-20 mins. ■ Over 12 missions where required at 80m altitude to cover the study area. Pix4D mission planner app was used to fly automated missions with particular settings to optimize data collection to include consideration of: ■ Line of sight was maintained at all times using binoculars to coverage, aggressive birds, mission completion, and drone battery levels.

Table 2 (cont.) – Study methodology – Stage 2.

<table>
<tr><th>Method</th><th>Detail</th></tr>
<tr><td>Process imagery</td><td>
Drone imagery was collected on SD cards allowing efficient transfer to computer. Data was initially analysed for coverage and quality issues from the 12 missions.

1. Imagery drone data was then uploaded to Drone Deploy for online image stitching and mosaicking resulting in GeoTIFF images requiring final georeferencing checks and stitching together.



2. Combining of the georeferenced image outputs was completed using Global Mapper software with final mapping outputs created of the study area in various data formats (.ecw, .jp2000, .tif).

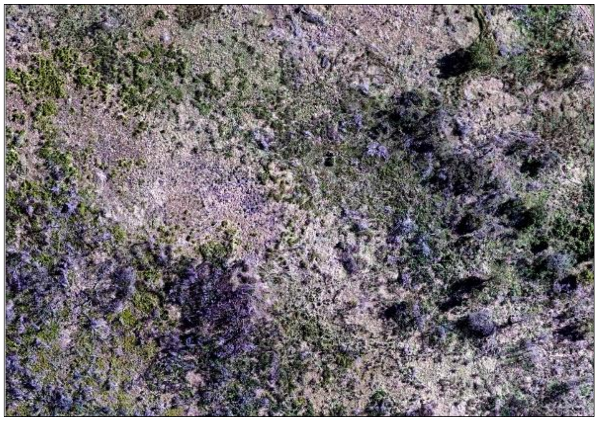
3. Analysis of image data (in ArcMap 10.8.2 & Global Mapper) included land cover change analysis, multivariate classification, and image analysis to determine natural regeneration cover change, impact of direct seeding, and varied fire intensity analysis.

4. Data was validated at the desktop-level via ArcMap 10.8 data validation tools.[17]
</td></tr>
<tr><td>Project outputs</td><td>

- Georeferenced image tiles
- Mosaic georeferenced image
- Mapping and analysis products
- Report
</td></tr>
</table>

[17] ESRI 2019. ArcMap 10.7 Image Classification, Accessed from: https://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/image-classification/what-is-image-classification-.htm

4. RESULTS




Figures 22-23 – Images from 2020 and 2022 clearly depicting enhanced land cover with this area.

The response of drone-seeding between zones is qualitative in nature with quantitative comparison beyond the scope of this report. Site context and burn history/intensity influences responses of drone-seeded areas, which must be factored into any interpretation of the results (see *Figures 22-23*).

A number of useful GIS analysis methods however can be used to provide information regarding land cover change and the potential of improved regeneration using assisted revegetation methods.

Suffice to suggest also is the natural ability of each zone seeded to naturally trigger post-fire in mosaic distributions, providing further complexity to gleaning lasting vegetation interpretation.

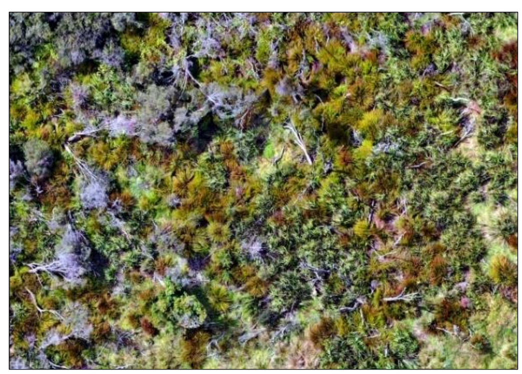
Overall land cover and complexity within all areas mapped and all three zones treated depicted significantly increased native vegetation land cover. This was to be expected due to a preceding favourable La Nina higher than average rainfall period between the 2020 and 2022 drone mapping periods.

In addition, the increased seed concentration treatment (1kg/ha) reflected an increase in land cover of native vegetation (notwithstanding the influence of additional natural regeneration post-fire and altered vegetation distribution when fire intensity is factored in). The following series of images sets from the same area within the site depict such change.

Figures 24–25

Land cover change between 2020-2022 in areas partly unburnt.

A significant patch of sedges/tussocks is shown and increased cover within this period.

Figures 26–27

Land cover change between 2020-2022 in areas partly unburnt (within 50m x 50m area)

Area within partly burnt native zones showing increased shrub and sedge/rush cover response.

Figures 28–29

Land cover change between 2020-2022 in areas of fire coverage.

Significant responses can be seen from Tea-Trees patch increases within this lakebed area.

Figures 30–31

Land cover change between 2020-2022 in areas more intensely burnt.

Regeneration of shrubs, grasses, and lichen crust has increased in area between data collection periods.

GENERAL FINDINGS

The following broad findings were also observed through image analysis processes such as:

- Expected increased biomass noticeable from viewing imagery within all parts of the study site;
- Key aged and hollow-bearing Eucalypts re-shooting and establishing regenerating clusters across the site;
- Ground cover species such as Lomandra, Sedges, Dianella species with increased cover;
- La Nina weather pattern has contributed to higher than typical soil water levels rendering the site less accessible;
- Drone imagery collection impacted by 30-40km/hour wind speeds contributing to image resolution issues;
- Image quality/resolution is high considering the utilization of an 80m flight altitude; and
- Infra-red cameras were not able to be used due to high winds.

Figure 32 – True colour imagery depicting Pinus sp. tree death and enhanced microclimates created for natural regeneration.

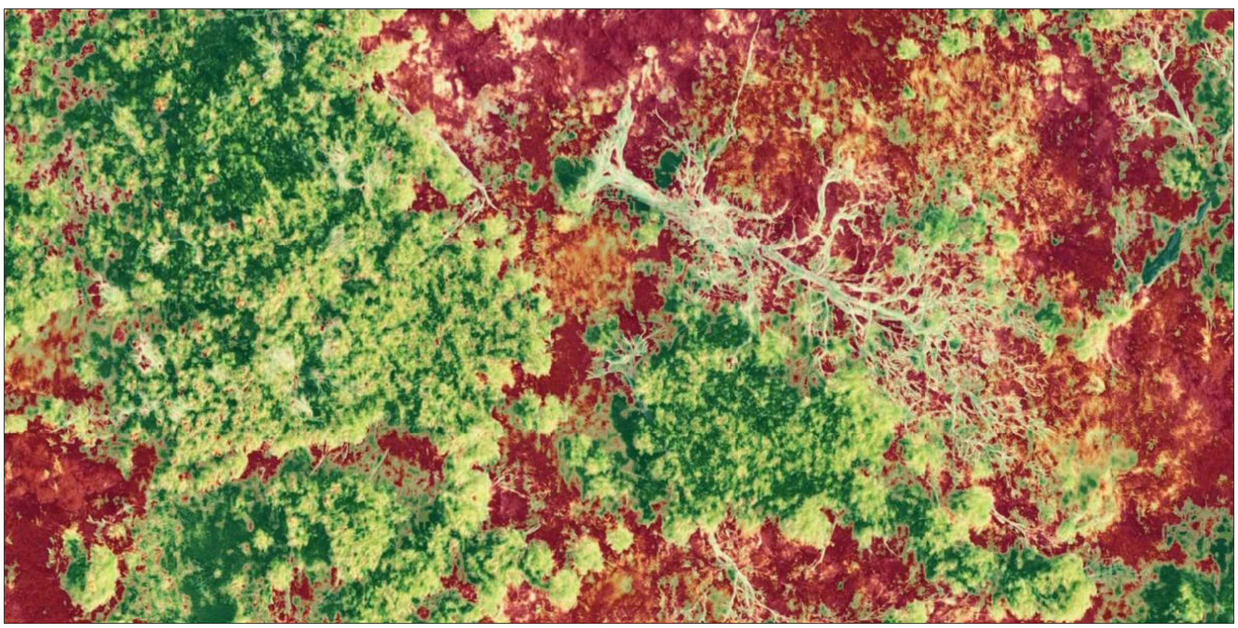


Figure 33 – NDVI filters can be applied to imagery to depict land cover delineation and biomass increase.

4.1 DRONE-SEEDING LAND COVER CHANGE - SEED CONCENTRATION

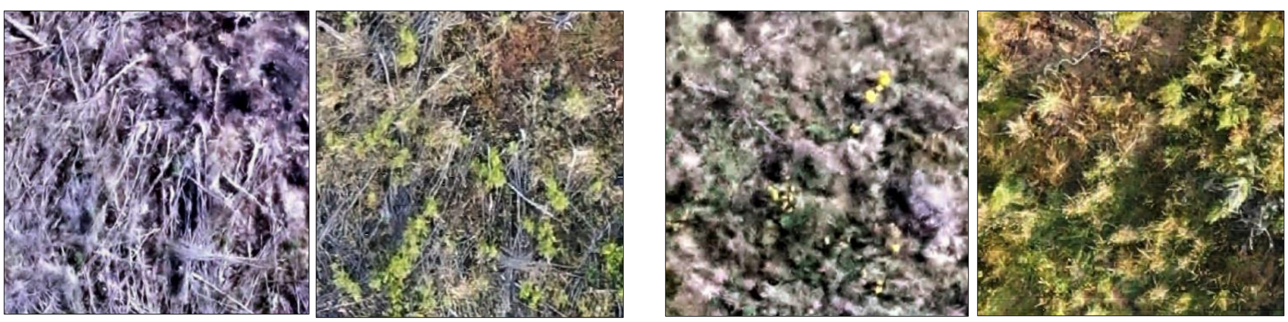
Random 10m x 10m sites within seeded zones only were analysed to determine effectiveness of various seeding rates across various micro-habitats within the study site. The aim was to identify optimum seeding rates for this ecosystem type which could be extrapolated to other habitat contexts.

Quantifying change is beyond the resourcing of this study however the data produced below provides a guide to the trajectory of land cover change and the influences via varying seeding rates. Seeded and unseeded site comparison will be detailed further in this report.

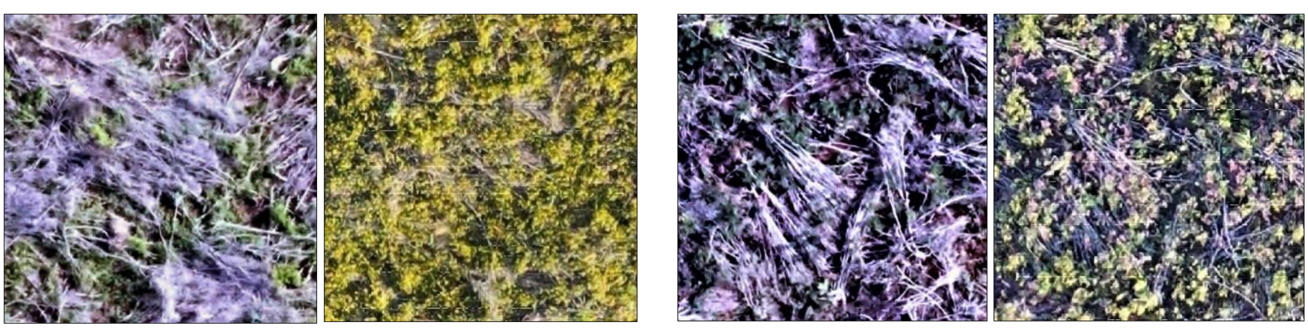
ZONE 1 - 1kg/hectare (11.3 ha)

Zone 1 was seeded with 1kg per hectare (see *Appendix 1*) as per detail provided in section 1.3 of this report. Within each zone, both burnt and unburnt sites were compared. Significant increases in vegetation cover were observed within this zone potentially due to higher seeding rates.

Figures 34 & 35 – Parts of Zone 1 were impacted by fire with gaps in 2020 imagery now (2022 right) covered with regenerating vegetation.



Figures 36-39 – Areas more significantly burnt included grassy regrowth coupled with sparse indigenous shrub regeneration.



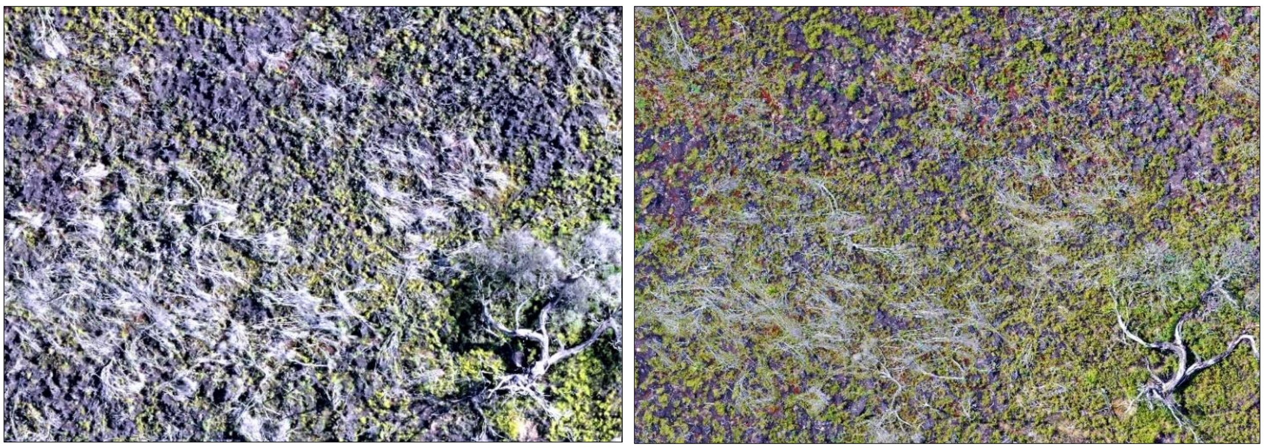
Figures 40-43 – Increased shrub death provides indication of fire intensity and where cover increases coupled with fire was significant.

ZONE 2 – 0.75kg/hectare (15.5ha)

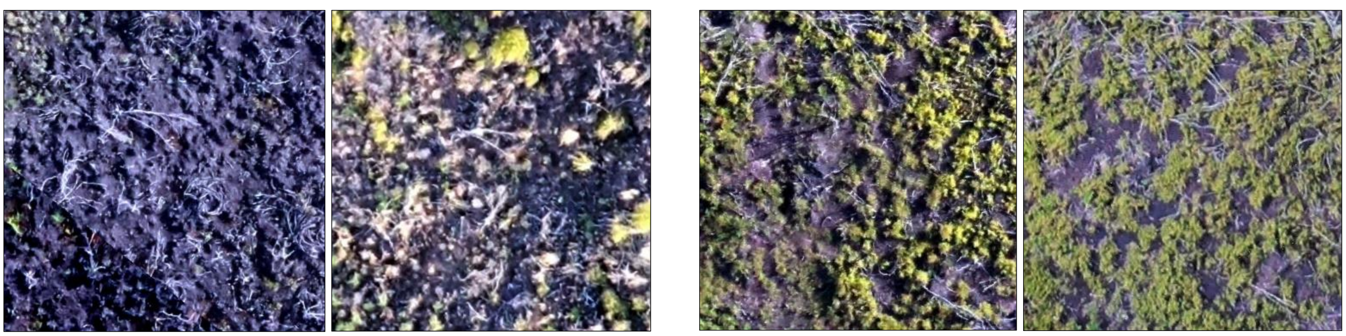
Located closer to the central part of the Lake Cobrico site, Zone 2 was seeded with 0.75kg per hectare (see *Appendix 1*) as per detail provided in section 1.3 of this report.

Within each zone, both burnt and unburnt sites were compared, as can be seen below. Significant increases in vegetation cover were observed within this zone potentially due to higher seeding rates and seed-store stimulation by fire.

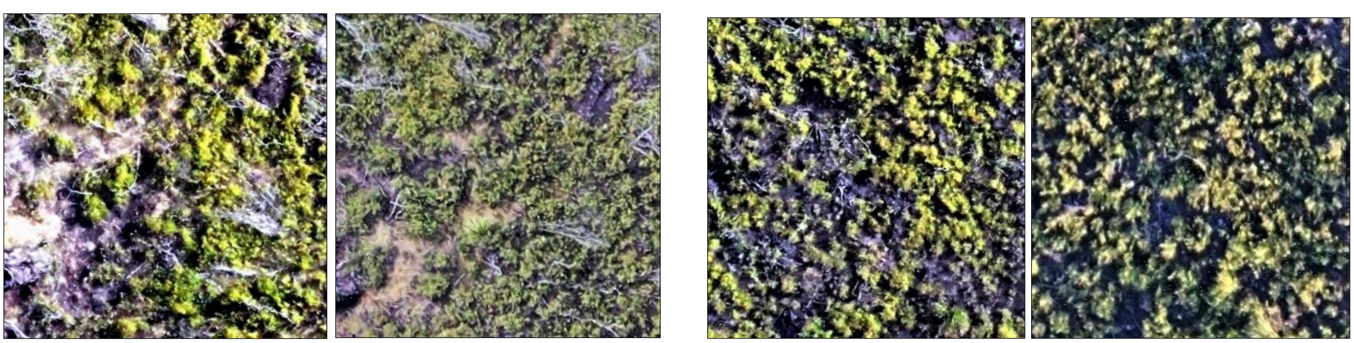
Figures 44 & 45 below depict an area extensively burnt in 2020 with significant germination and regrowth resulting. A closer view in *Figures 46-49* illustrates the regenerative capacity of this landscape.



Figures 44 & 45 – Partially burnt and seeded site depicting relative increases in vegetation cover.



Figures 46-49 – More intensely burnt peat sites displaying relatively poor regeneration however is improved with seeding.

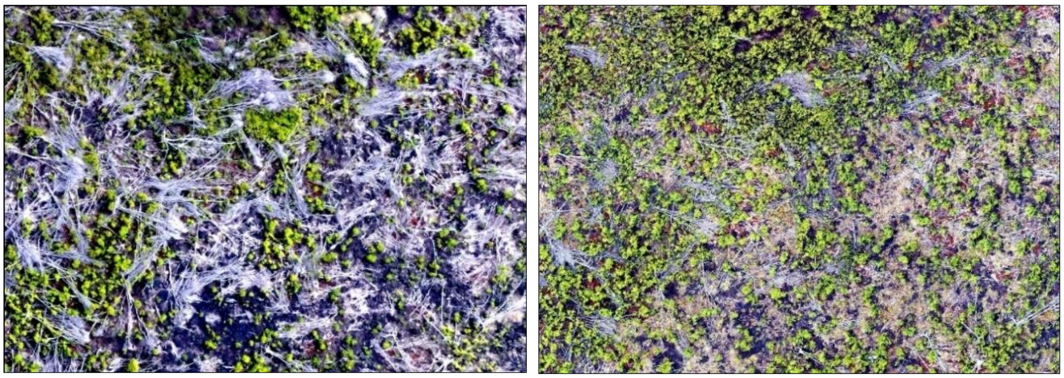


Figures 50-53 – Even in less fired sites assisted regeneration has produced significantly increased vegetation cover.

ZONE 3 – 0.5kg /hectare (12.5ha)

Zone 3 was seeded with 0.5kg per hectare (see *Appendix 1*) as per detail provided in section 1.3 of this report. This site includes impact of high fire intensity to both peat/pasture and indigenous revegetated areas.

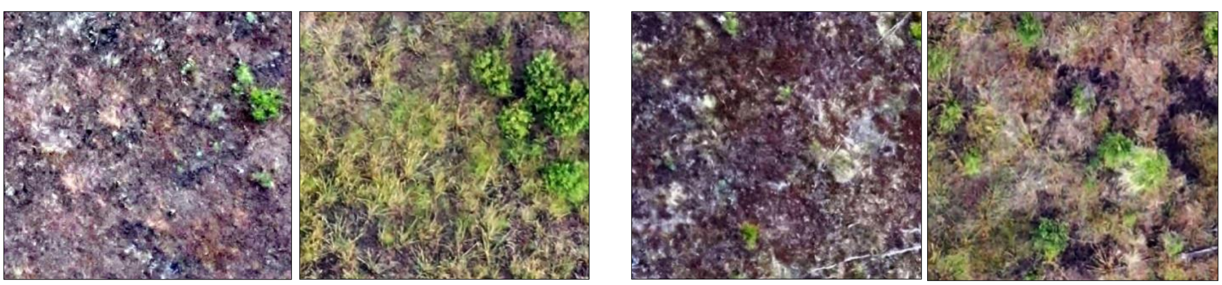
It is clear from the images of both 2020 and 2022 that natural or assisted drone-seeding or elements of both has seen an increase in structural species cover (see *Figures 54-55*). Significantly interspaced herbs and grasses have also increased if the bare dark peat-based soil are considered as compared to the development of such layers in the 2022 image on the right.



Figures 54-55 – Prior to seeding the image depicts some natural regeneration; and although sparser, regeneration has occurred.

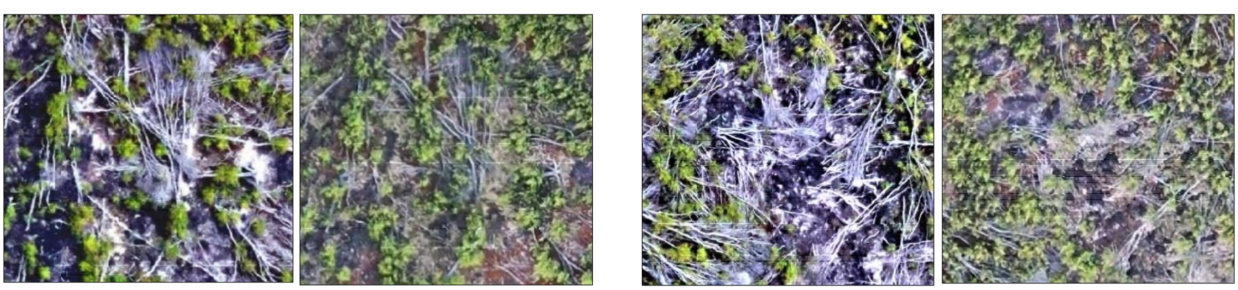
Severely burnt peat, pasture

As can be seen from the severely burnt areas (2020 & 2022), intense and smouldering fires tend to promote grassland species however the increase in all land cover is significant. Drone-seeding at 0.5kg/hectare occurred within this area where responses will be influenced by both burn impact to soil structure, soil chemical composition, and remaining competing seed-store.



Figures 56-59 – Significant vegetation cover increases have occurred whether due to fire and seeding or both.

Severely burnt native vegetation



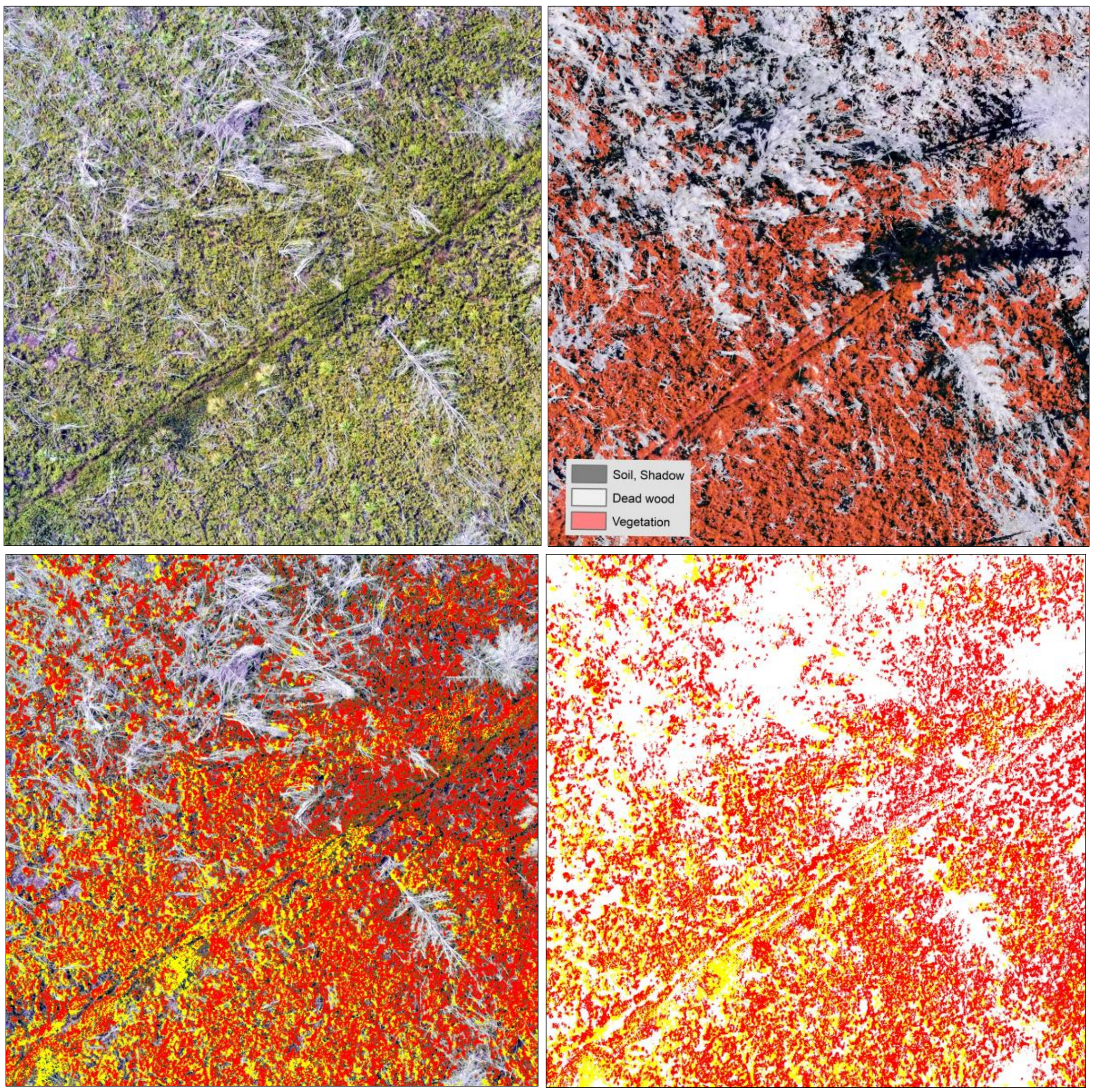
Figures 60-63 – Although a reduced grassy response, land cover change with seeding at 0.5kg/ha is detectable.

4.2 SEEDED VS UNSEEDED SITES

A comparative study regarding responses to seeded and unseeded areas was analysed using seven 50m x 50m plots. Each plot was located so as to compare seed and unseeded responses within the same broad vegetation type (see *Appendix 1*).

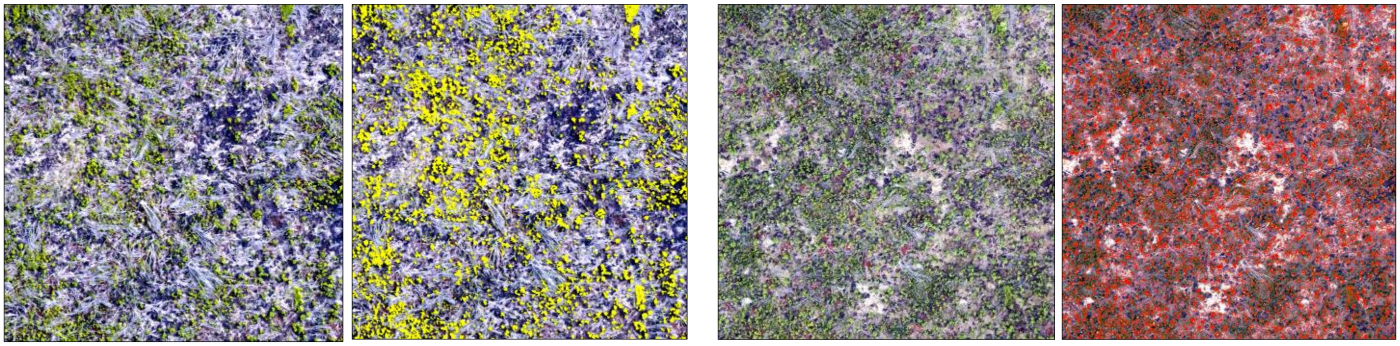
Multivariate classification is a significant GIS tool that can be used to delineate single or multiple land cover types and individual species. Comparative data provided here consists of multivariate classification analysis, based on 10 land cover types, that were later reclassified (to reduced classes) to reflect land cover change between sites (from 2020-2022 within recent seeded and naturally regenerating areas).

As with other indicators provided previously, drone-seeded assisted areas depicted an increased cover through natural regeneration and seeding. Determining whether drone-seeding is a cost effective enhancement to natural regenerative processes is another question best answered via permanent plot monitoring within selected comparative sites.



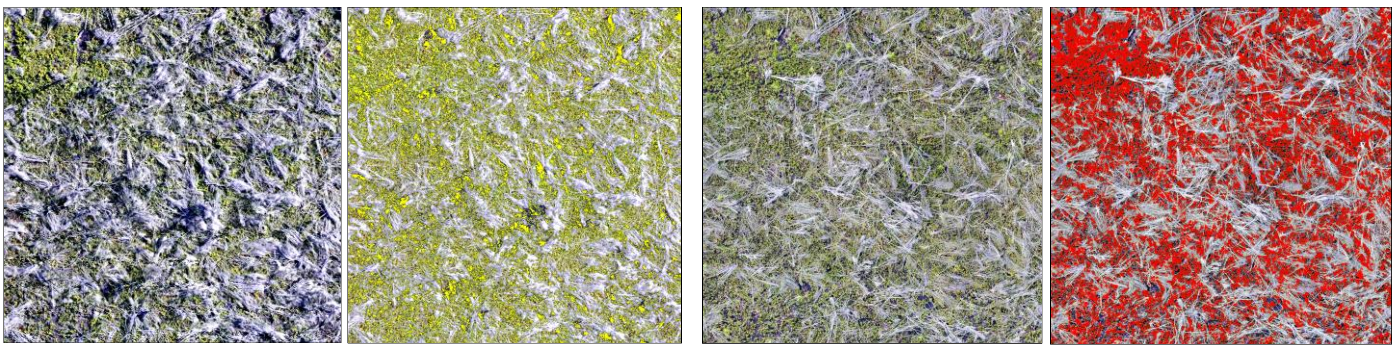
Figures 64 & 67 – True colour imagery can be analysed to determine cluster of like reflectance. Figure 64 depicts the 2022 image that in Figure 65 has been classified to show basic land cover classes/types/features. Figures 66 & 67 are depicting the same site again with yellow shown as growth to 2020, with red colouration depicting biomass growth and vegetation regeneration since then. Figure 67 shows the difference clearly without a background.

SITE 1 - SEEDED (0.5kg/ha) – 2020 to 2022



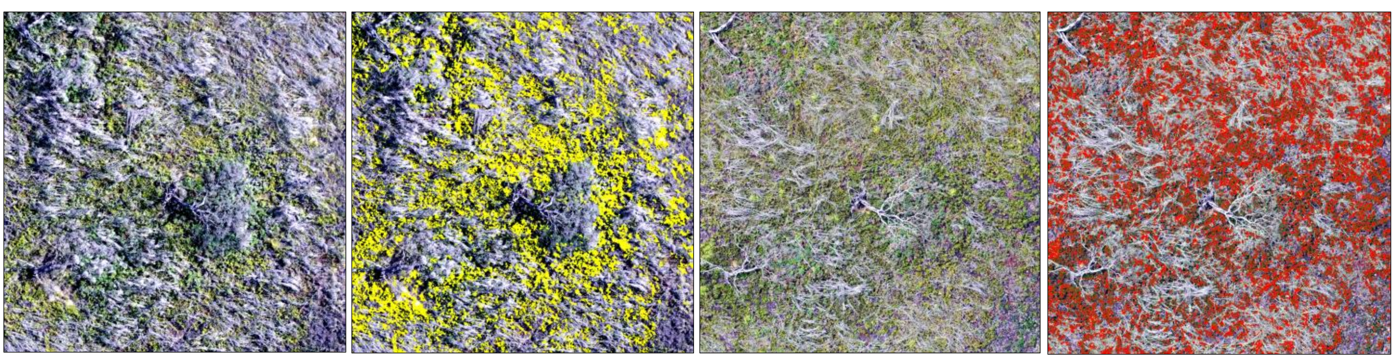
Figures 68-71 – Seeded site with fire impact with classification clearly depicting increases in cover between 2020 and 2022 (post seeding).

SITE 2 - UNSEEDED – 2020 to 2022



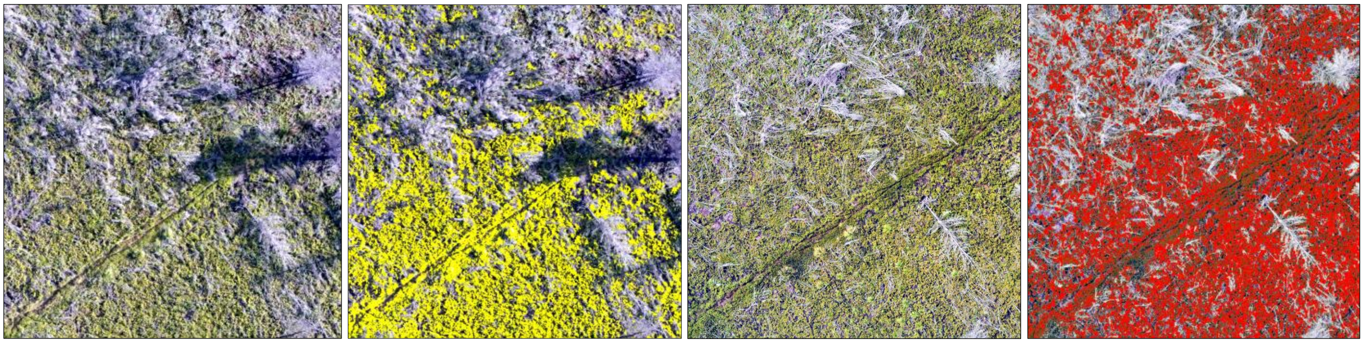
Figures 72-75 – Unseeded parts of the same vegetation type depicting intense fire and reduced cover regeneration.

SITE 3 – SEEDED (0.75kg/ha) – 2020 to 2022



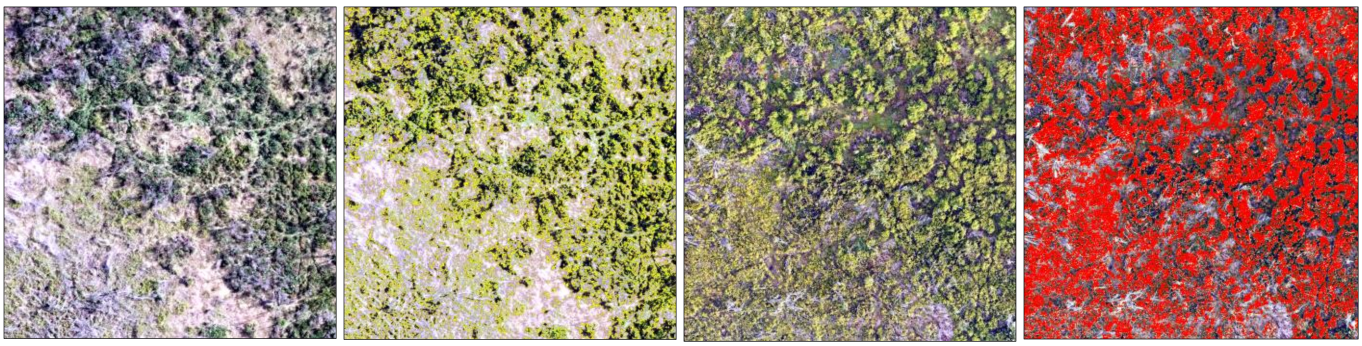
Figures 76-79 – Seeded site with partly burnt areas and relatively patchy regeneration within the time interval.

SITE 4 – UNSEEDED – 2020 to 2022



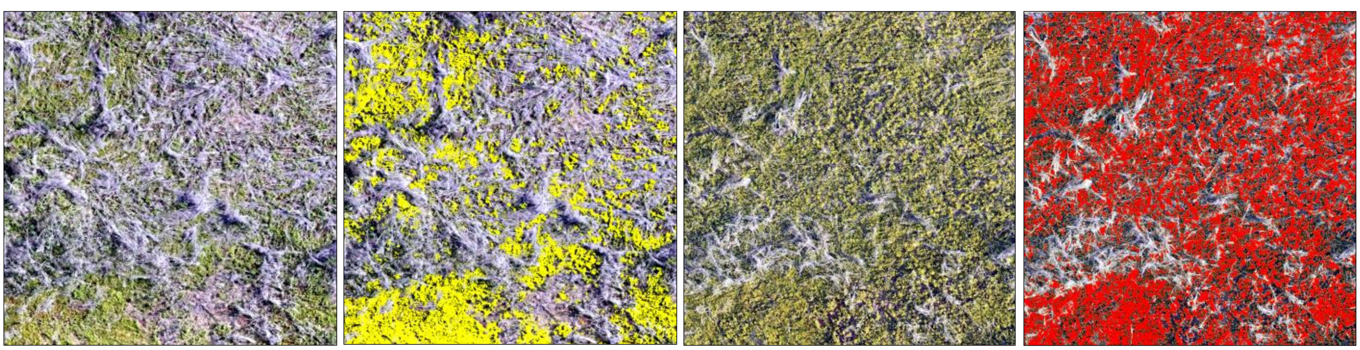
Figures 80-83 – Unseeded site with obvious higher intensity fire but with increased moisture depicts an effective land cover regeneration.

SITE 5 – UNSEEDED – 2020 to 2022



Figures 84-87 – Partly burnt pair of sites with clear increases in vegetation cover between the 2020 and 2022 images.

SITE 6 – SEEDED (1kg/ha) – 2020 to 2022



Figures 88 - 91 – Seeded site (1kg/ha) displaying significantly increased vegetation cover including previous impact of fire.

SITE 7 – UNSEEDED – 2020 to 2022

Figure 92

Unseeded additional site analysed due to being an intense fire site with mixed bare soil crust, shrub, and sedge-type cover features. Such areas are high priority for revegetation due to potential weed invasion.

Figure 93

Multivariate unsupervised classification was used to delineate at least vegetation cover from shadowing and bare soil. Such data can be overlain with 2022 data to quantify change in land cover.

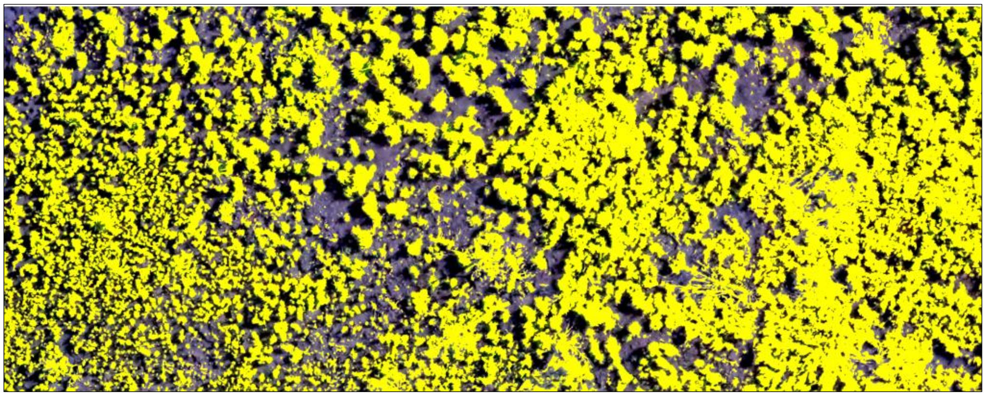


Figure 94

Even as an unseeded site this 2020 image depicts significant increases in at least two land cover types; sedges and shrub vegetation. Raw counts within such areas can determine single plant count and cover increases.

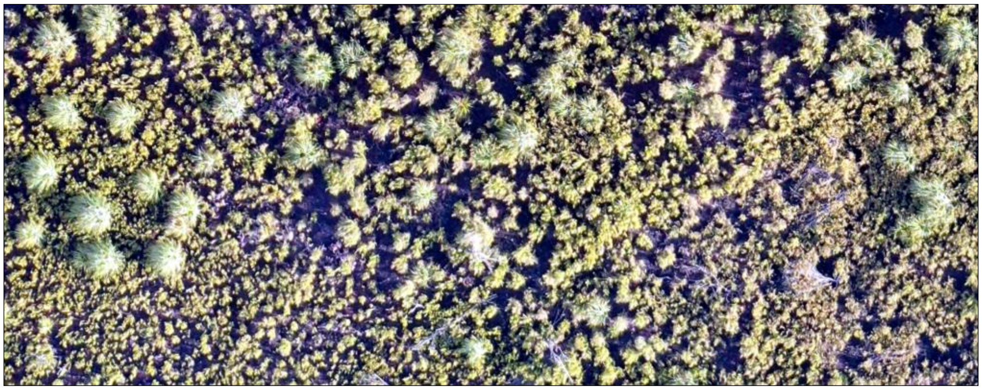
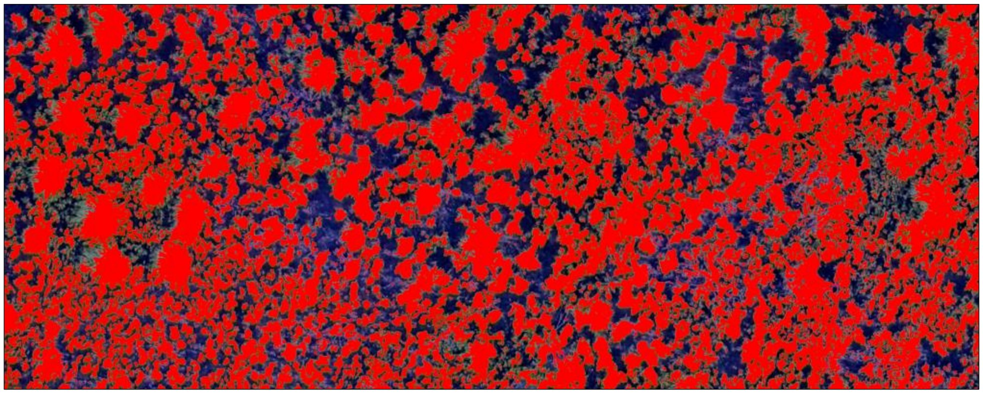


Figure 95

Various display and analysis options exist within most GIS software to assist in delineating or quantifying changes in inaccessible land cover. Further mapping events in future years could provide useful management insights.

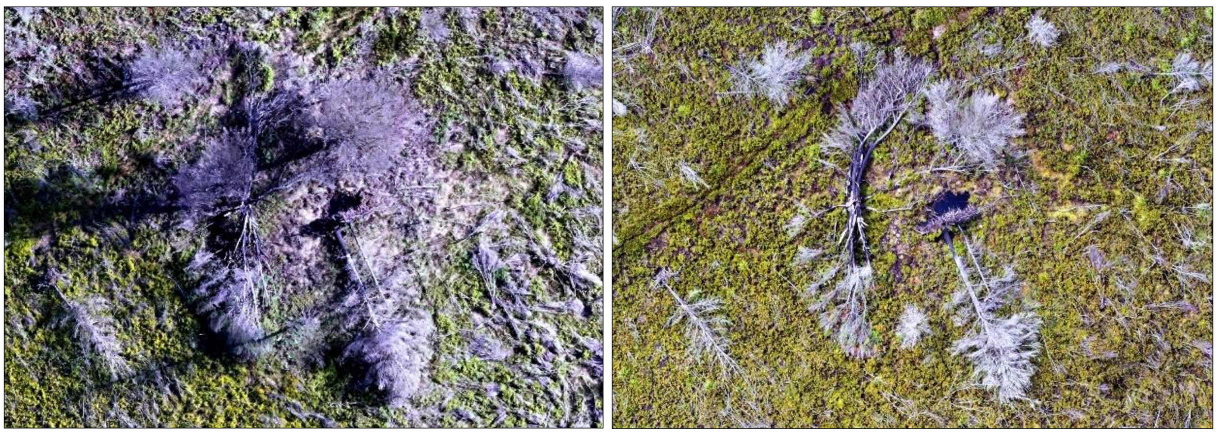


5. DISCUSSION / RECOMMENDATIONS

Sequential drone monitoring of vegetation change after site disturbance or assisted revegetation can provide valuable management insights. This allows adaptive environmental management to be utilised to maximise environmental outcomes and apply flexible and intuitive management options based on drone imagery captured.

When such imagery is then further analysed spectrally and spatially, key site processes can be identified and experimental activities such as drone-seeding to assist natural post-fire triggers based on mapped ground data applied. Such projects can be effectively planned, costed, scheduled, and monitored for efficient and evidenced-based outcomes.

Information gleaned from this project will guide future site management activities and allow efficient and effective drone-seeding techniques are utilised in similar environments.



Figures 96 & 97 – Large conifers typically killed by fire provide insight into possible fire intensity and are useful georeferencing markers during mapping and GIS analysis.

Recommendations from this project include the following:

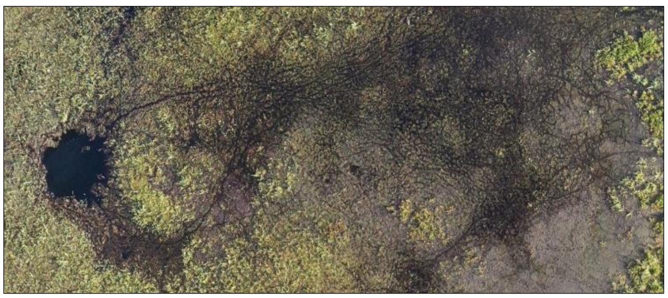
- It is clear from the sequential data collected (2020-2021) that natural regeneration processes have established successfully in all areas with supportive La Nina rainfall events. Drone-seeding has enhanced this increase in land cover and in future could be utilised in areas failing to regenerate.
- Determination of cost-effectiveness versus germination success and seeding rates should be determined via permanent plot monitoring (if resources allow).
- Permanent plot studies can provide information regarding the impact of increased bushfire regularity on species compositions coupled with the potential drying of the peat-based soils with potential changed/reduced rainfall and increased temperatures.
- Increased and in-depth understanding of effectiveness of drone-seeding requires site-based permanent plot monitoring backed by periodic drone-based image collection. Various parameters could be measured to determine cost and resource effectiveness (compared to unseeded areas).
- Drone-seeded species composition monitoring to compare to unseeded areas and accepted EVC benchmarks/structure/composition suggested.
- Consider one-off data collection of entire site using infra-red and thermal drone sensors to provide further site benchmarking and provide insight into longer-term impact of peat fires on species compositions.

- Consider pairing permanent plot studies with integrated fauna benchmark survey, utilising web-based remote cameras, audio recording, and field survey; would be a useful adjunct to further drone image collection and site environmental management works. This may increase understanding of response to fire within flora and dependent fauna species, and support future management actions via identification of key faunal populations and associated distribution patterns.

- The cessation of grazing within adjoining lakebed areas to the south of the study area is obviously advisable for enhanced ecosystem resilience and effective function, notwithstanding the isolated nature of the remnant indigenous vegetation. Although not palatable to many, future investment into a site such as Lake Cobrico could be questioned as wasted resourcing where grazing is allowed to continue.

- Mapping data such as that generated from this project provides information regarding enhancing natural area ecological quality/structural attributes and the potential reinstatement of partial natural disturbance regimes such as patch mosaic burns.

- Periodic image data capture in various formats can also be effectively analysed and utilised for planning integrated and strategic pest animal and weed control programs. This is supportive of effective adaptive environmental management processes and can provide qualitative and quantitative support for NRM funding.




Figures 98 & 99 – Drone imagery provides insight into often not seen animal behaviours and site usage patterns.

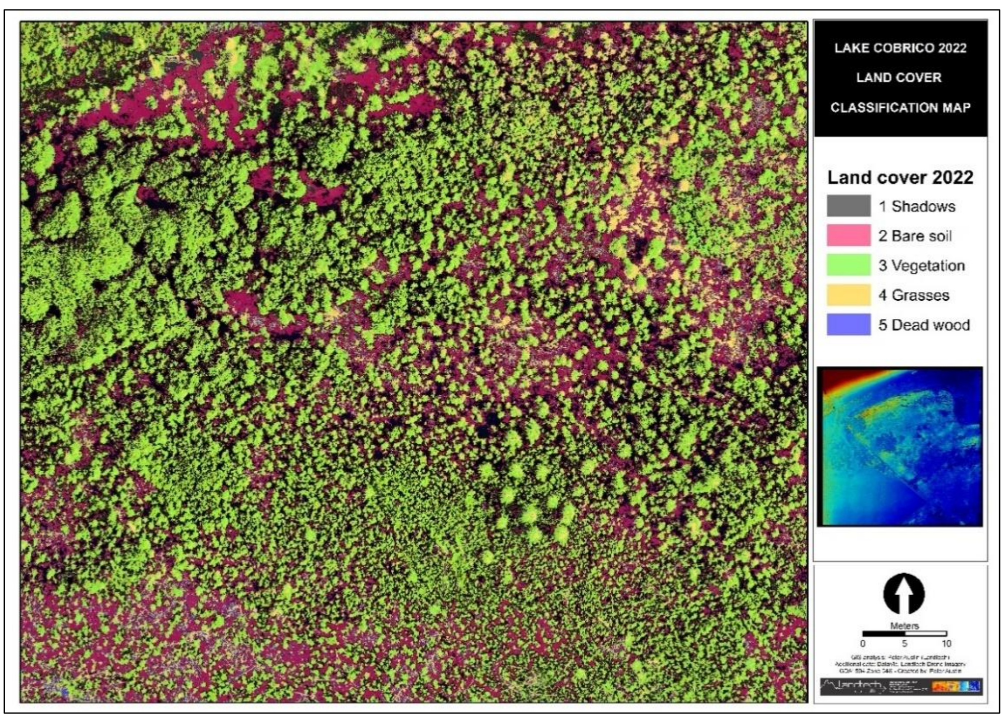
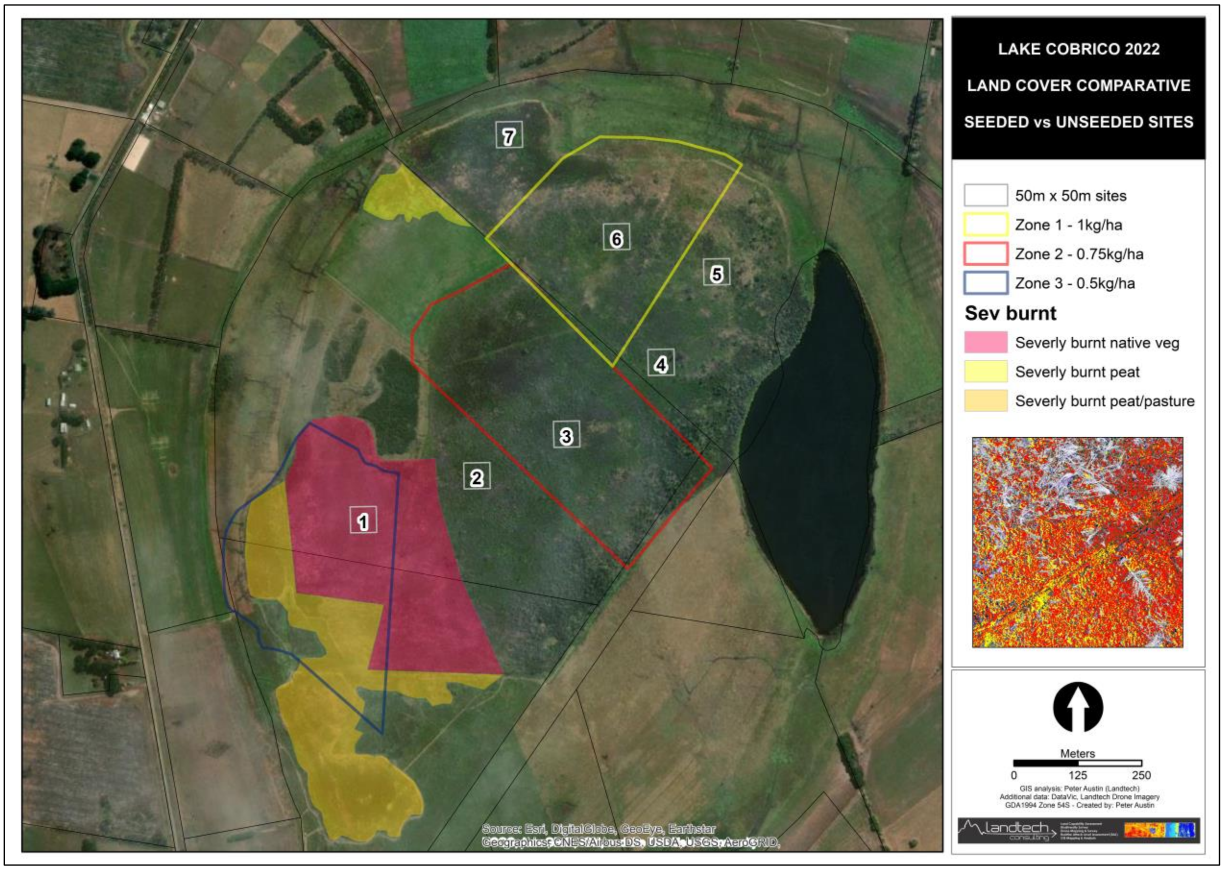
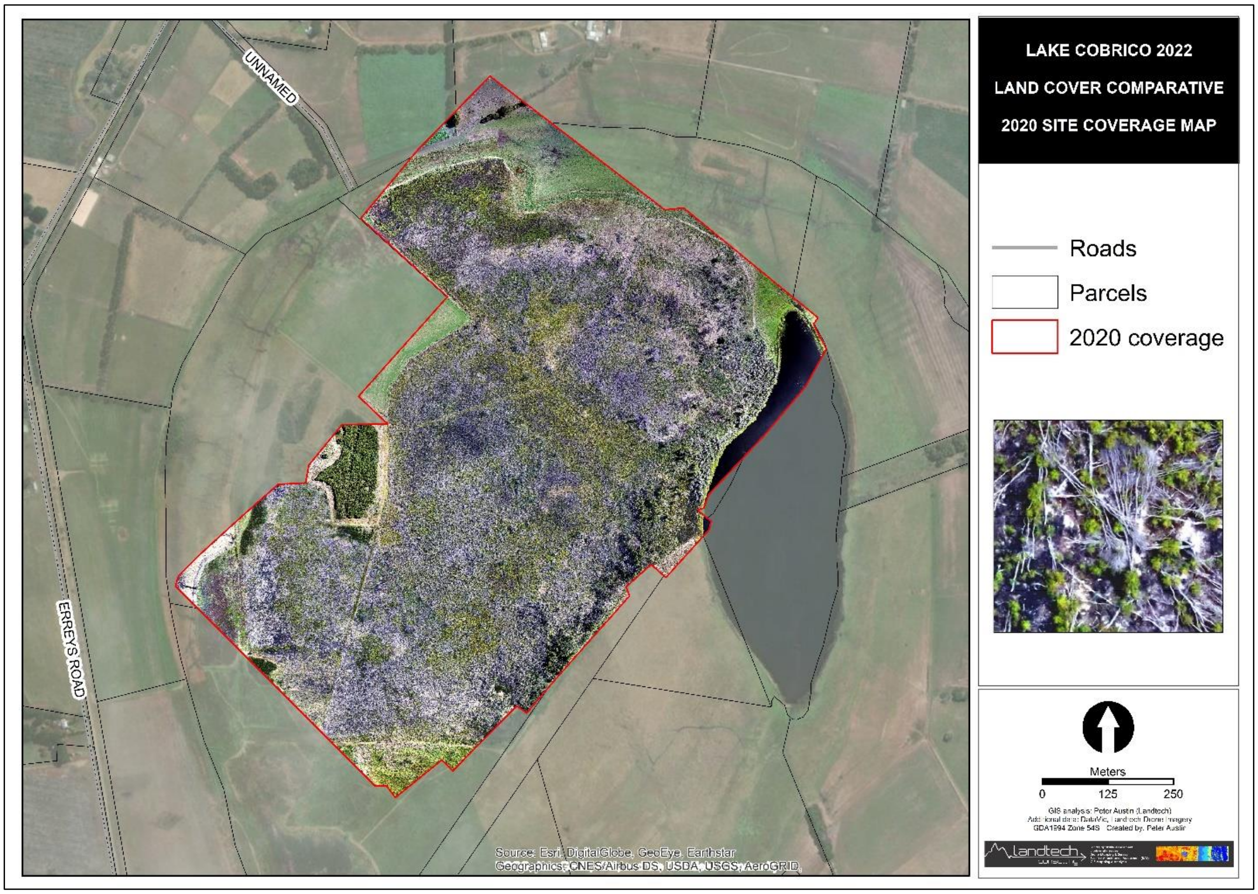


Figure 100 – Result of unsupervised classification to determine land cover classes.

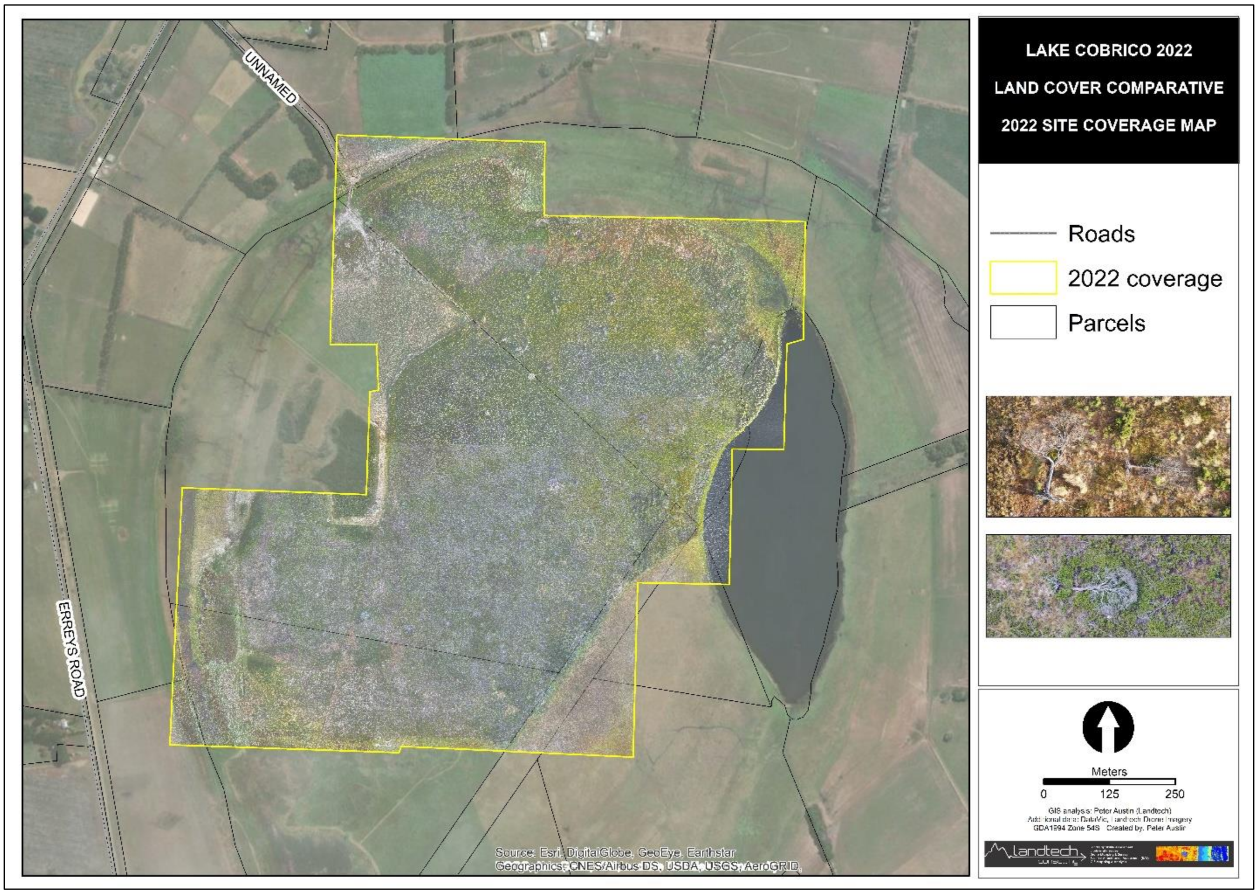
APPENDIX 1 – SEEDING ZONES MAP



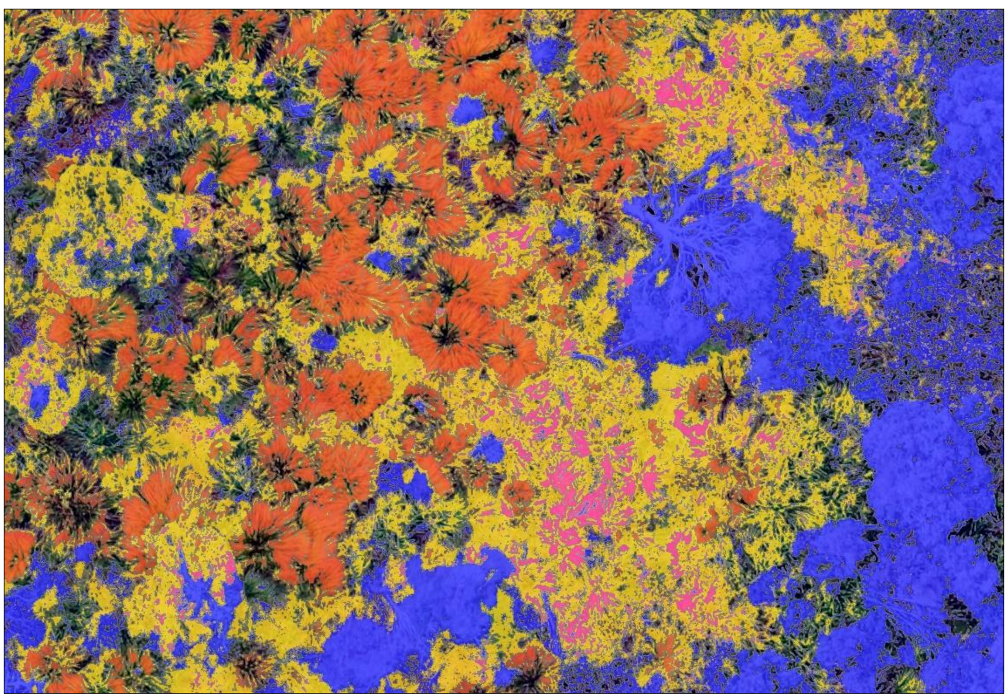
APPENDIX 2 – 2020 LAND COVER MAPPING

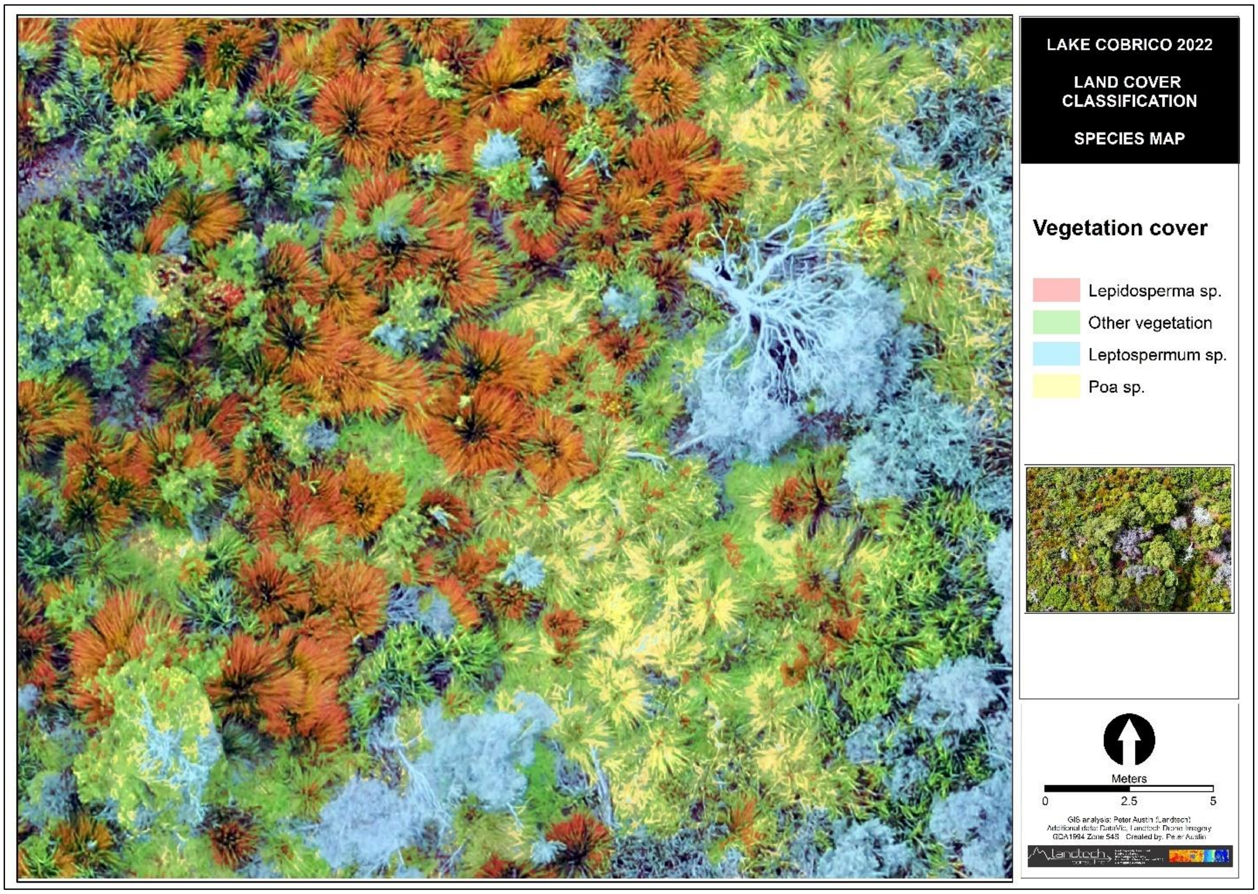


APPENDIX 3 – 2022 LAND COVER MAPPING



APPENDIX 4 – LAND COVER CLASSIFICATION




LAKE COBRICO 2022
LAND COVER CLASSIFICATION
SPECIES MAP
Vegetation cover
Lepidosperma sp.
Other vegetation
Leptospermum sp.
Poa sp.
Meters
0
2.5
5
GIS analysis: Peter Austin (Landtech)
Additional data: DataVic, Landtech Drone Imagery
GDA1994 Zone 54S Created by: Peter Austin
landtech