Making remote sense of wetland vegetation change over time

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Key Points

- Historical satellite imagery is a valuable source of data for assessing wetland vegetation and change.
- Supervised classification of imagery using existing tools in GIS produces accurate vegetation maps.
- LiDAR data provides important information on water extents and depths at different water levels.
- LiDAR data provides important information on elevation associations of different vegetation types.
- This data can be used to assess the efficacy of wetland environmental watering regimes.

Acknowledgement

We respectfully acknowledge the Traditional Custodians of Reedy Lake, the Wadawurrung People of the Kulin Nation. We pay our respects to Elders past, to Elders present and to emerging leaders, recognising their continuing connection to land, water, culture, and community.

Abstract

Reedy Lake, near Geelong (Figure 1), is the largest brackish wetland in central Victoria. In 1983, the significance of floristic diversity of the wetland system was recognised with Reedy Lake being designated as a Ramsar site. To support the community's use of the wetland between 1983 and 2016, the wetlands hydrology was manipulated to sustain high water levels every summer, effectively creating lake conditions. In 2016, Corangamite Catchment Management Authority (CCMA) modified the water regime, to partially dry the wetland each summer and autumn by seasonally lowering water levels. This was done to maintain the diversity of habitats so that one habitat type does not dominate the wetland. In 2022, the CCMA wanted to understand whether the new water regime was having an effect in maintaining the ecological character of the wetland within the Ramsar Limits of Acceptable Change (LAC).

A comparative analysis was undertaken to understand the implications (and changes if any) of the modified water regime on several different habitat types, assessed between the following historical intervals: 1983 - 2016 and 2016 - 2022, respectively. This was achieved using historical satellite imagery and applied an innovative semi-automated imagery classification technique to detect vegetation types and extents for each timestep to generate a time-series of change.

The results of the analysis demonstrated the following:

- The tall reed, sedge, and rush vegetation communities of Reedy Lake are dynamic, exhibiting strong seasonal and inter-annual variations in extents, in response to water level changes.
- The pattern of variation has persisted since 1983 and has remained within the LAC.

Keywords

Remotely sensed data, Geographical Information Systems (GIS), wetland ecological character, environmental watering, time series analysis, Ramsar Limits of Acceptable Change

Ramsar Limit of Acceptable Change

The Ramsar site management plan (DELWP, 2018) defines the Limit of Acceptable Change (LAC) as: *A habitat mosaic will be maintained at Reedy Lake that comprises open water, emergent native vegetation (sedges, rushes, and reeds), submerged vegetation and lignum shrubland with no habitat comprising more than 70 percent of the total wetland area for more than five successive years*. The vegetation extent mapping by Yugovic (1985) provides the benchmark for assessing the LAC.

Figure 1 – Aerial imagery of Reedy Lake in 1984 (left) and 2022 (right)

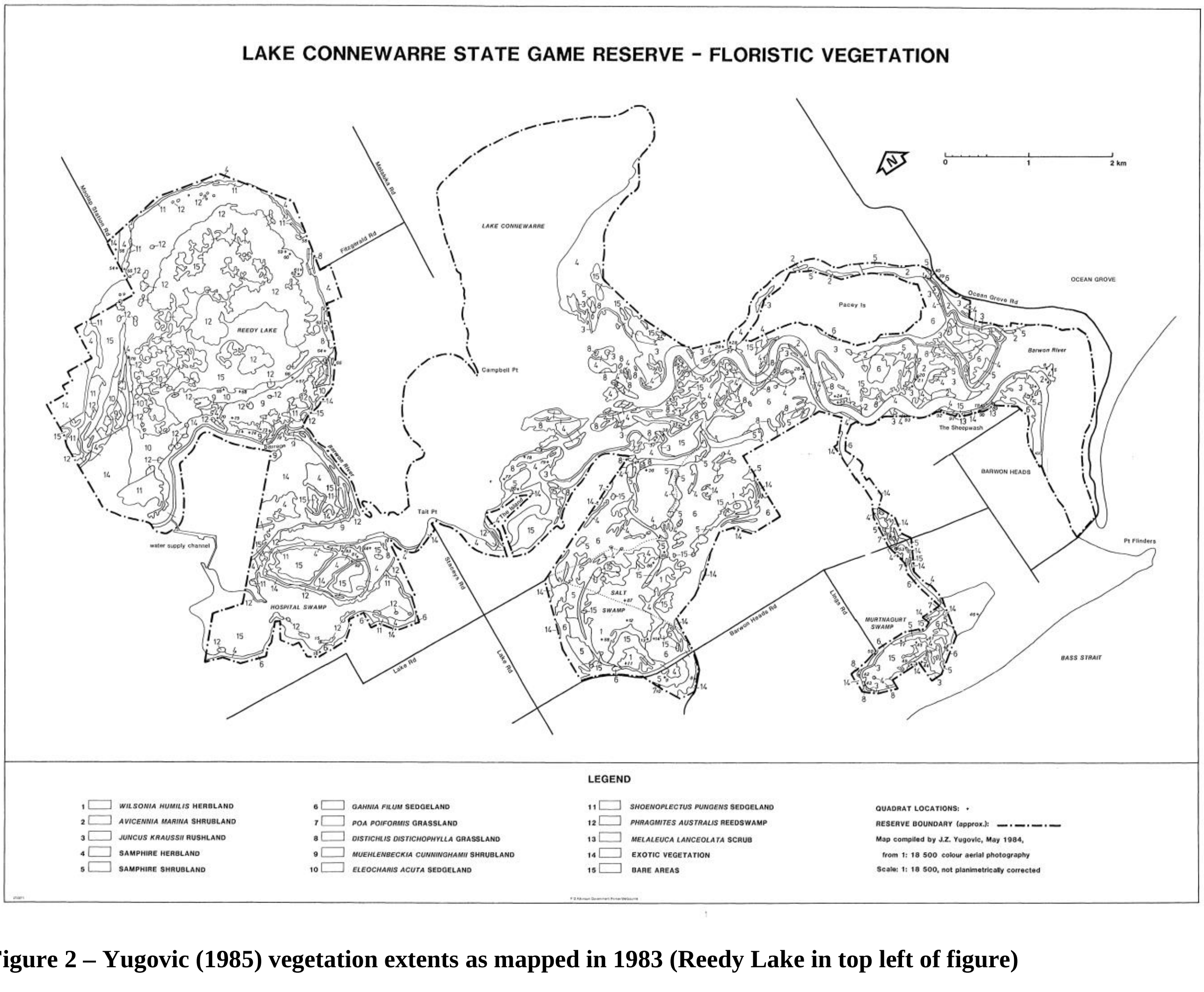


Figure 2 – Yugovic (1985) vegetation extents as mapped in 1983 (Reedy Lake in top left of figure)

Introduction

Several studies have previously mapped vegetation cover at Reedy Lake since the baseline mapping by Yugovic (1985), each adopting a slightly different vegetation classification and all relying on field-based and aerial photo interpretation. Review of the results of these mapping efforts revealed differences in vegetation extents at different points in time.

However, the degree to which these changes were real changes and not the artefact of the difference in mapping approaches, and expert interpretation, was uncertain. What was missing was the application of a consistent mapping approach over that timeframe to increase confidence in the changes being seen over time.

Historical wetland imagery collected from satellite remote sensing, and recent wetland surface elevation data collected from aerial light detection and ranging survey (LiDAR) combined with established imagery and elevation analysis techniques in ArcGIS, were used to perform a retrospective analysis. The results were used to assist with determining the degree to which the wetlands water regime was likely to be influencing vegetation extent changes over time.

This paper focuses on the first of three questions asked in this study:

1. What does a more complete history of vegetation change at Reedy Lake, derived using a consistent method, tell us about the dominance of tall reeds; the dynamics of key wetland vegetation types; and the efficacy of the environmental watering regime in maintaining the wetlands ecological character?

2. What appear to be the key vegetation lifecycle characteristics and environmental variables influencing wetland vegetation extents and their change over time?

3. Based on current drivers and trends, and in response to climate change projections, what does information on historic and recent changes in wetland vegetation tell us about how the wetland may respond in the future.

Wetland vegetation communities and habitat types

The key vegetation communities investigated within the wetland were:

- *Phragmites australis*, and *Typha orientalis* dominated tall reed beds, *Bolboschoenus caldwellii* dominated beds of sedges/rushes and *Duma florulenta* (tangled lignum).
- Open water habitat is also an important component of the wetland ecology and is represented by areas inundated by water without a dominant cover of reeds or sedges/rushes. The open water habitat is typically shallow, with a fluctuating water level, and is characterised by clumps of the emergent rush *Schoenoplectus tabernaemontani*, isolated *Duma florulenta* bushes, and several floating and submergent species. Several areas of permanent deeper water exist.

By way of background, *Phragmites* and *Typha* co-exist with the open water habitat, *Phragmites* typically as large, dense circular clumps and *Typha* as large patches. *Bolboschoenus* beds occur around the wetland margins and *Duma* occurs on higher ground to the south and south west of the wetland above the wetland water extent. There are also several areas of temperate coastal saltmarsh around the wetland perimeter.

Wetland morphology, elevation and water regime

The wetland is a relatively shallow feature (Figure 3). The lowest point is -0.05mAHD whilst much of the wetland bed is between 0.3-0.6mAHD. The western-northern-eastern perimeter is typically between 0.6mAHD and 1.5mAHD. There is a natural levee that runs along the left bank of the Barwon River forming the southern perimeter of the wetland that is typically between 1.5mAHD and 2.0 mAHD. Large areas of the southern perimeter range between 1.5 and 4.4mAHD.

Water enters and exits the wetland through two regulated channels. Water can be diverted from the Barwon River into Reedy Lake when river levels are above 0.7 m AHD. In times of flood, water from the Barwon River can spill into the wetland and the wetland can fill and spill back into the Barwon River. Wetland water levels typically vary seasonally between 0.1mAHD and 0.8mAHD.

The basin of Reedy Lake forms a topographic low in the regional landscape that acts as a groundwater discharge zone, with flow from several groundwater systems converging and terminating at or around the wetlands (Ecological Associates, 2014). Saline groundwater (20,000-70,000 EC) is an important water source to the wetland bed, especially during low freshwater levels.

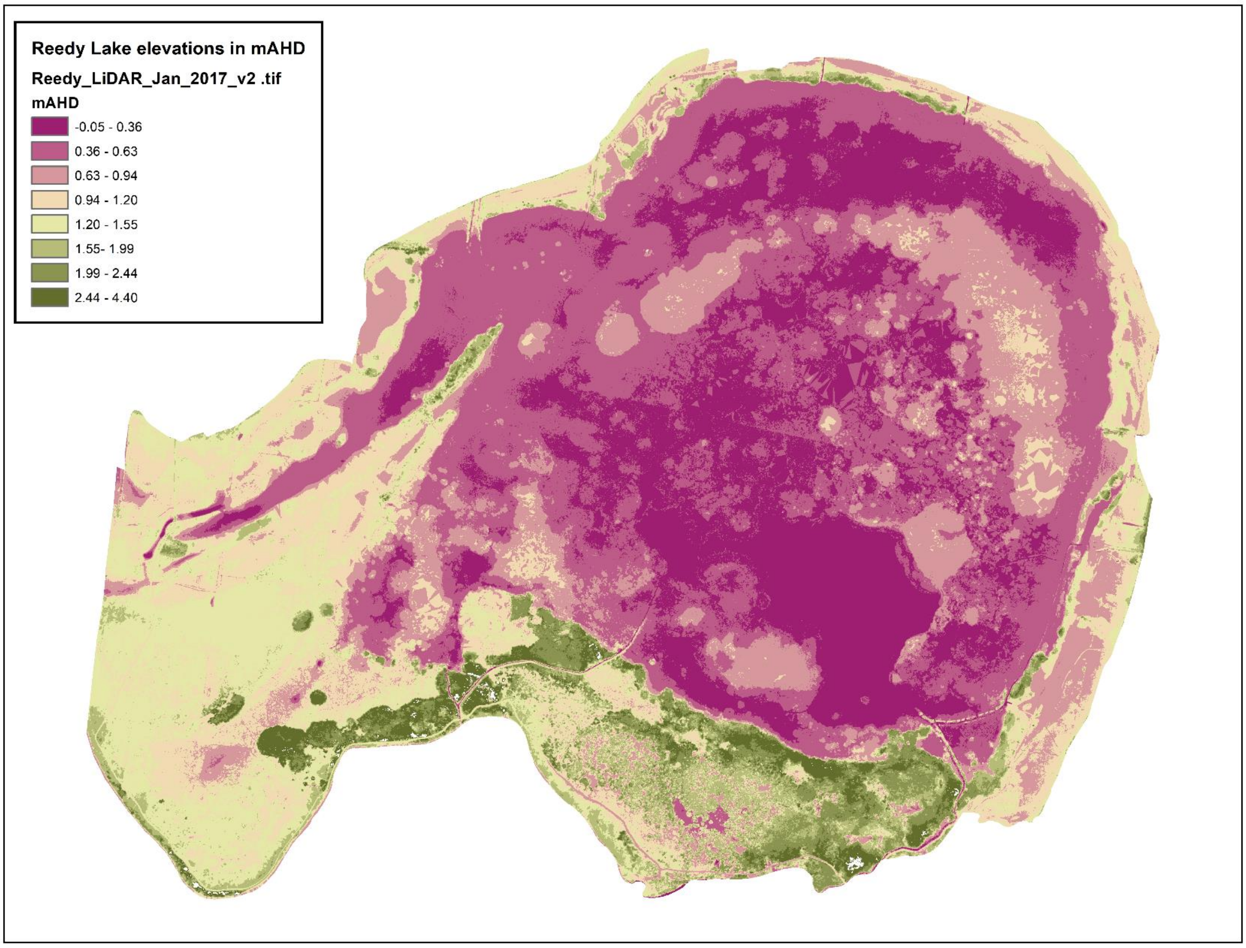


Figure 3 – DEM showing wetland morphology and elevation derived using 1m resolution LiDAR

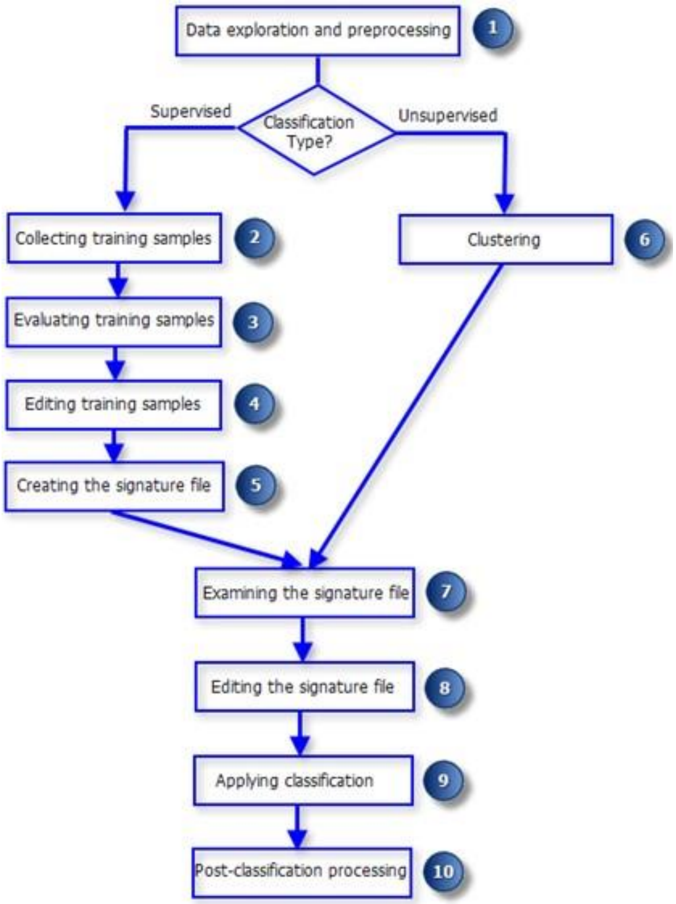
Imagery analysis approach

To derive a consistent record of change in extents of the key vegetation types since 1983, a combination of 'analysis ready' Landsat and Sentinel-2 satellite imagery sourced from Geoscience Australia, was used.

- 30m resolution Landsat images were sourced at 5-yearly timesteps from 1983 to 2018.
- 10m resolution Sentinel-2 images were sourced at 6 monthly timesteps from 2016 to 2022.

Each satellite image consists of pixels and several bands (layers) representing different parts of the electromagnetic spectrum. In this study we used composite images consisting of red, green, blue, near infra-red, red-edge and shortwave infra-red bands to provide sufficient spectral information on each vegetation type, known as their spectral profile, or signature.

All images were analysed using a process called 'supervised classification' (Figure 4), where a computer algorithm (in this case Maximum Likelihood) is trained by an operator to recognise the key vegetation types based on the spectral characteristics of the pixels in the imagery that represent each vegetation type. Appropriate training samples were derived from previous vegetation maps and aerial photo interpretation.



The below classification schema was used, and sufficient training samples were created for each of the five major classes:

- *Phragmites australis* (tall reed)
- *Typha orientalis* (tall reed)
- *Bolboschoenus spp.* (sedges/rushes)
- *Duma florulenta* (tangled lignum)
- Open water habitat (with submerged and floating vegetation)

Because of the large number of images being classified (22) a batch process was run using ModelBuilder.

To further assist with highlighting change over time, two time series animations were generated using the available Geoscience Australia tool. These animations collated individual satellite images from Landsat and Sentinel-2 respectively, for the two periods of interest.

Figure 4 - image classification in ArcGIS using the Spatial Analyst extension (ESRI, 2021)

Results

The efficacy of the satellite mapping was first validated against the previous mapping for those timesteps where such mapping was available. This showed very good agreement between the mapped extents (Figure 5 and Figure 6), giving confidence that the supervised classification was accurate.

To allow comparison with the previous mapping, the vegetation classes in Figure 5 and Figure 6 are mapped as: *Phragmites australis* and *Typha orientalis* together (yellow), *Bolboschoenus spp*. (green), *Duma florulenta* (orange) and open water (blue, where present).

The results of the supervised classification of all images created a time series of vegetation extent maps. To allow for further analysis and interpretation of the results, the classified vegetation extents were exported to MS Excel to enable the changes in extents over time for each vegetation type to be charted and visualised.

These times series maps and charts were analysed to determine:

- Changes in vegetation extent over time.
- The location of vegetation extent changes within the wetland.
- Significant trends (if any).

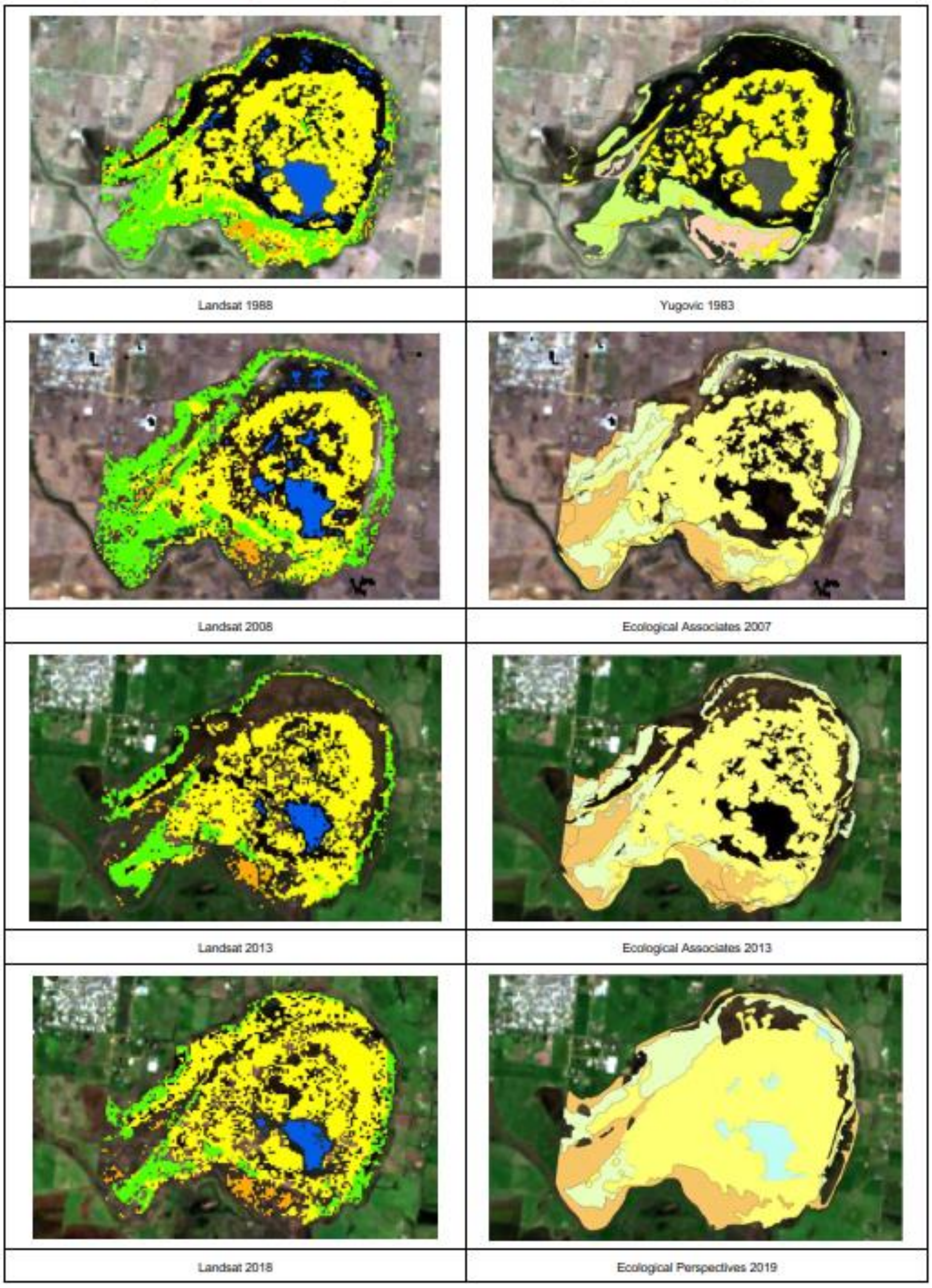


Figure 5 – comparison between the classification results using Landsat imagery (left) and mapped extents (right).

Figure 6 – comparison between the classification results using Sentinel-2 imagery (left) and mapped extents (right).

Key findings

The dominance of tall reeds

Results for tall reeds for the periods:

- 1988 to 2018 (Figure 7) indicated an overall *increasing* trend yet overall extents were within the Limit of Acceptable Change for the entirety of that period.
- 2016 to 2022 (Figure 8) indicated an overall *decreasing* trend that was within the Limit of Acceptable Change for that period.

In summary, the figures indicate that, of the total wetland area of 876Ha assessed for vegetation cover:

(i) at no time since 1983 has tall reed extent exceeded 62%. Historically tall reed extent has typically been <40% however more recently, tall reed extent fluctuated around 55-60%.

(ii) greater tall reed extents are being classified in the Sentinel-2 imagery from 2016 than with the Landsat imagery to 2018. This is due to the finer spatial and spectral resolution of the Sentinel-2 imagery resulting in improved detection of the different vegetation types.

With the environmental watering regime in place, tall reeds are not taking over the wetland.

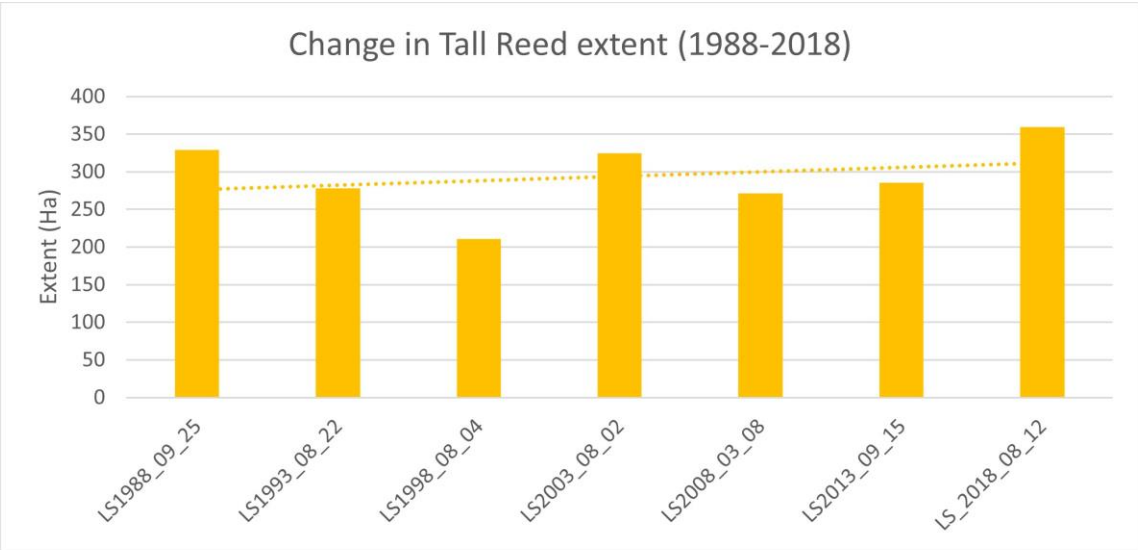


Figure 7 – Change in extent (Ha) of tall reeds every 5-years between 1988 and 2018. Trend line shown.

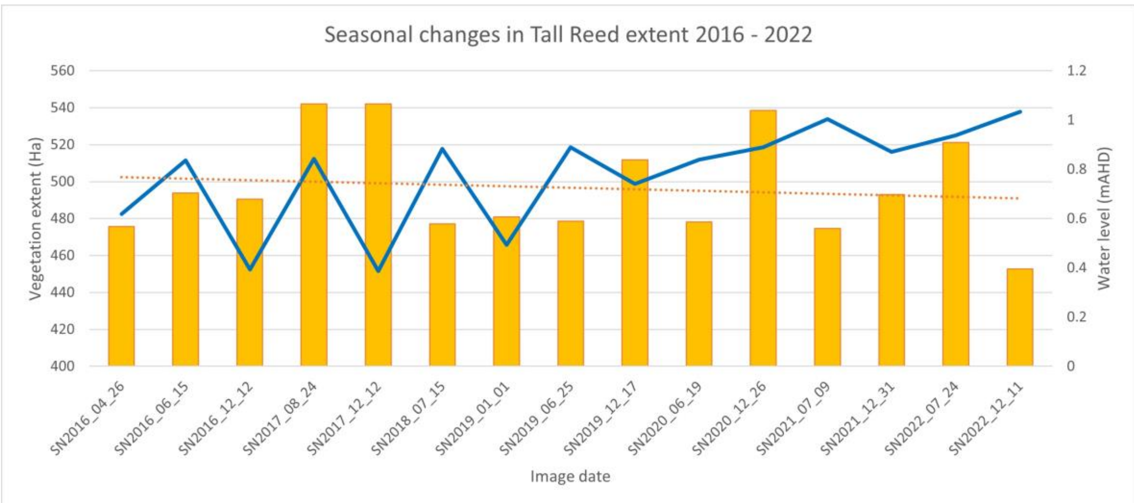


Figure 8 – Change in extent (Ha) of tall reeds 2016 to 2022. Trend line shown. Water level (mAHD) shown (blue line)

The dynamics of key wetland vegetation types

Of the key wetland vegetation communities investigated:

- *Phragmites* and *Duma* extents have remained relatively stable over time.
- *Typha* and *Bolboschoenus spp.* extents have exhibited the greatest variation in extent over time.
- Variation in the extent of open water habitat is related to changing water levels and its constituent species tolerance to seasonal variation in drying and wetting cycles.

Relating the mapped vegetation extents to wetland bed elevations, reveals the following patterns:

- *Phragmites* occurs at elevations less frequently inundated by freshwater, typically at 0.8-1.0mAHD, indicating a preference for saline groundwater as its primary water source.
- *Typha* occurs at elevations that are frequently wetted and prefers inundation depths fluctuating between 0.1 and 0.5m. *Typha* is less tolerant of salinity compared to *Phragmites*.
- *Bolboschoenus spp.* prefer the wetland perimeter at elevations >1.0mAHD, have a higher tolerance to salinity and exhibit a dynamic response to changing water level conditions over time.
- *Duma florulenta* also occurs above 1.0mAHD and its roots systems must be connected to groundwater given the relative infrequency with which these areas are wetted with freshwater.

Given the preference of *Phragmites, Bolboschoenus spp.* and *Duma* for higher elevation and saline groundwater, it is unlikely these vegetation types will dominate the wetland.

Typha however prefers fresh water, especially within the frequently inundated parts of the wetland, and as a result it is the vegetation type that poses the greatest threat to the open water habitat. *Typha* extent needs to be carefully managed through techniques such as drawing down the water depth of the wetland during the *Typha* growing season (spring/summer) to make the conditions less favourable for seed germination.

The efficacy of the watering regime in maintaining wetland ecological character

The watering regime for Reedy Lake requires summer draw down to 0.3mAHD every three years out of four, to support achievement of the environmental objectives (VEWH, 2022). For one year in every four, the wetland is kept full over summer. Flow data for the Reedy Lake gauge (the blue line in Figure 8) showed that the environmental watering regime was maintained between 2016 and 2020, with water levels reducing over summer and increasing in winter; with 2020 being the planned full year. With the onset of La Nina conditions in 2020 this resulted in high water levels all year in 2021-22 (i.e., summer drawdown could not be achieved).

Water extent mapping (Figure 9) has shown that the target summer draw down level of 0.3mAHD is a critical water level given the drastically reduced extent of water across the bed of the wetland compared to 0.4mAHD. At a water level of 0.4mAHD, large areas of the wetland bed are covered with 0.1-0.2m of water. If this water level occurs during the spring-summer growth season, where temperatures are warmer, this provides ideal conditions for germination of *Typha* from seed.

Reducing the water level to 0.3mAHD in summer will assist in drying large areas of the wetland bed helping to increase soil salinity by preferencing the influence of shallow saline groundwater and constraining the successful germination of Typha seeds. Periodic drawing down to 0.3m AHD is required to achieve a balance in vegetation types between tall reed and other vegetation communities. This water regime will assist with maintaining vegetation extents and habitat proportions within the LAC.

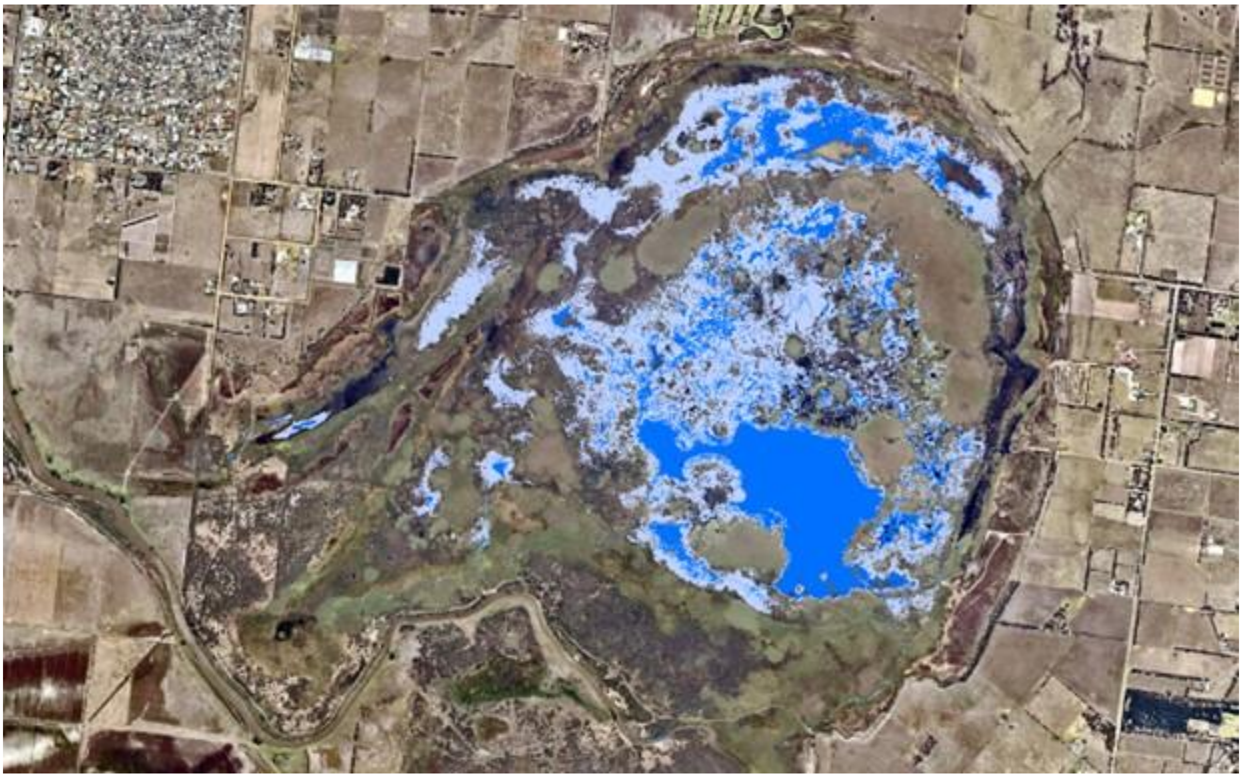


Figure 9 – water extents at 0.3mAHD (dark blue) and 0.4mAHD (light blue).

Conclusions

The study has demonstrated that analysing remotely sensed data is an efficient and effective way to:

- Retrospectively investigate historical change
- Generate critical insights into wetland vegetation dynamics to inform management decisions; and
- Consistently monitor future change relative to the established baseline

Acknowledgments

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