Mapping refugia pools using remote sensing

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Key Points

- Aquatic flora and fauna seek refuge in refugia pools during unfavourable environmental conditions.
- Mapping refugia pool locations is an important step in managing river ecosystems.
- Satellite remote sensing offers an insight to map and monitor refugia pools.
- Once baseline refugia pools dataset is established, it will be possible to map their spatial extent and monitor temporal change over longer timeframes using freely available satellite imagery.

Abstract

Drought is an environmental disturbance of aquatic ecosystems which negatively impacts aquatic life and overall river health. As such, flow events in arid and semi-arid zone streams and rivers are highly unpredictable and these environments are considered to have a boom-bust ecology. Therefore, between routine extreme episodic flow events, aquatic communities are restricted to small permanent aquatic habitats called refugia pools.

Identifying, mapping and monitoring the presence and both spatial and temporal extent of these pools using remotely sensed satellite imagery provides valuable insights to inform further field-based monitoring and management actions. Depending on the long-term persistence of these pools, protection zones may be established to ensure long-term sustainability of some key rivers of NSW.

This paper puts forth a concept and demonstrates the ability of remotely sensed satellite imagery to create a baseline data representing refugia pools for various rivers in NSW.

Keywords

Remote sensing, refugia pools, river health, river rejuvenation, Landsat 8, Sentinel-2

Introduction

Drought is a significant environmental disturbance of aquatic systems negatively impacting aquatic life and river health. Aquatic flora and fauna have to seek refuge to persist in disturbed and unfavourable environments (Magoulick et al., 2003). These refuge features include pools, waterholes and billabongs. According to Lancaster & Belyea (1997), refugia exist at a range of spatial and temporal scales. They function to reduce population losses during a disturbance event whilst acting as a source of recolonisation once disturbance subsides thus leading to increased resilience (Cottingham et al., 2005). Mapping refugia pools is an important first step in ensuring stream management strategies are successful in preventing further degradation of river ecosystems and threat to the aquatic life.

Although there is value in mapping and monitoring the spatial extent and temporal changes of refugia pools during specific drought events, this exercise is futile in the absence of a baseline refugia pools dataset to compare against. Generating this baseline dataset assumes significance by which remote sensing offers a cost-effective method to acquire detailed data over large and remote geographies combined with analytical methods which leverage 'super-computing' style platforms for speed of response and delivery of strategic insights. This is in contrast to previously utilized expensive and labour-intensive field measurements (Verbesselt et al., 2006) which are often difficult and slow to implement in remote areas.

In addition, the prevalence and expansion of both commercial and government owned satellite programs and platforms provides a historic archive of images which can be consumed to observe past environmental events and trends – the most commonly of which used (Landsat) stretches back some 30 years. Recent attempts at

utilising remotely sensed satellite imagery to map and monitor change in river surface water has shown great promise (for example Maillard, 2020, Seaton et al., 2020).

Datasets

The method to map refugia pools utilises several key datasets including:

Satellite imagery

High resolution Cloud-free imagery such as SPOT 6/7 (1.5m pixel) and Planet Labs (3m pixel) will be sourced for mid-2019 and early 2020 to coincide with the decade long drought in NSW.

Vector data

One Vector dataset will be used. The *rivers* dataset will be from the Department of Customer Service (DCS) spatial services and forms part of the NSW Foundation dataset.

Ancillary data

River flow data from WaterNSW's online portal[1] will be obtained to allow for validation of remotely sensed observations of refugia pools and validate inflows and outflows (within the gauged network). Water Observations from Space[2] (WOfS) product by Geoscience Australia will also be used as a second source of validation to identify the presence of water in the landscape.

Data processing and analysis

A two phase methodology is proposed.

Phase I: Data preparation & Image processing

This phase involves processing SPOT 6/7 satellite imagery including testing a number of water sensitive indices to identify refugia pools. Different thresholds will be tested to ensure optimal extraction of refugia pools in the rivers from satellite imagery. Figure 1 gives a diagrammatic representation of the various steps to be undertaken to derive the refugia pools.

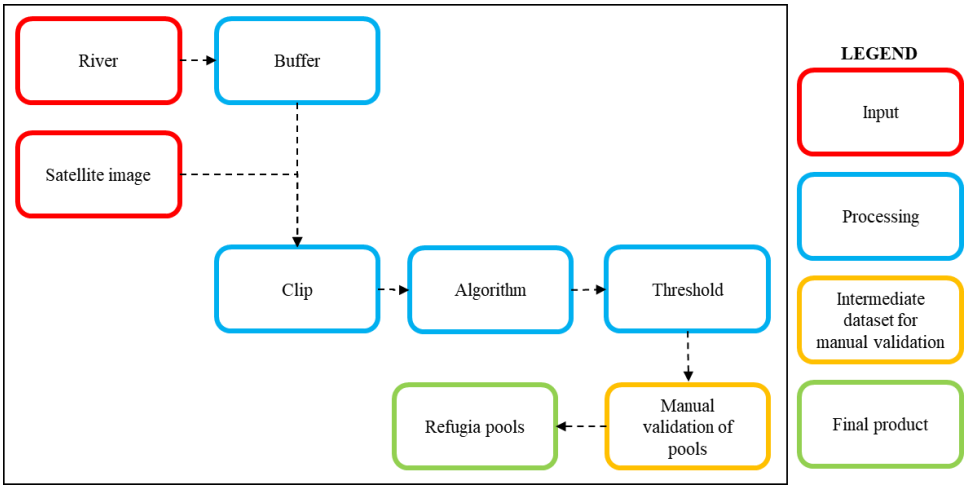

Figure 1 Diagrammatic representation of the steps undertaken to process and prepare the refugia pools dataset

[1] https://realtimedata.waternsw.com.au/

[2] https://maps.dea.ga.gov.au/

Phase II: Refugia pools validation

Manual validation will be achieved by comparing refugia pools obtained in Phase I and comparing them to false colour composites of Planet Labs imagery. The individual refugia pools will be validated and their shapes edited to match that of Planet Labs imagery. Experts from the Department of Primary Industries – Fisheries will also be consulted given their extensive local knowledge.

Preliminary Results and Discussions

Figure 2, 3 and 4 show the extraction of refugia pools using the methods described above. The backdrop satellite imagery used is SPOT 6/7 captured in July 2019. The green outline shows the extent of a stretch of the lower Darling river in NSW. Figure 2 shows the water bodies as blue in colour obtained from testing one of the remote sensing algorithms.

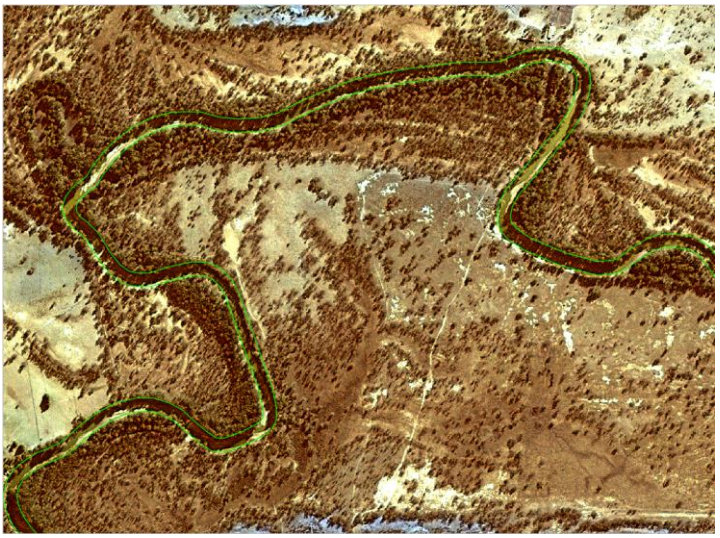

Figure 2 Extent of a stretch of the lower Darling river with SPOT 6/7 satellite imagery captured in July2019 as the backdrop.

Figure 3 Water bodies (red) obtained from testing one of the remote sensing algorithms.

Figure 3 shows the refugia pools obtained after applying a threshold to restrict them to show up only within the extents of the river. This dataset needs to be further validated against other ancillary datasets to accurately ascertain the spatial extent of the refugia pools.

As is evident, this automated extraction of refugia pools has merits including cost and time efficiencies. However, the resultant refugia pools dataset does require manual validation. This is most evident where shadowing from riparian vegetation obscures observation of water and at times misrepresents the size of the water body. It is critical to build an accurate baseline dataset to compare the spatial and temporal change in these pools against it over decadal time-scales. Once such a dataset has been established, multi-temporal analysis can be undertaken using satellite imagery from both Sentinel-2 and Landsat series of satellites which are publically available. It is envisaged that this phase of the project which involves processing satellite imagery over multi-temporal timescales would most efficiently be processed in Google Earth Engine (GEE).

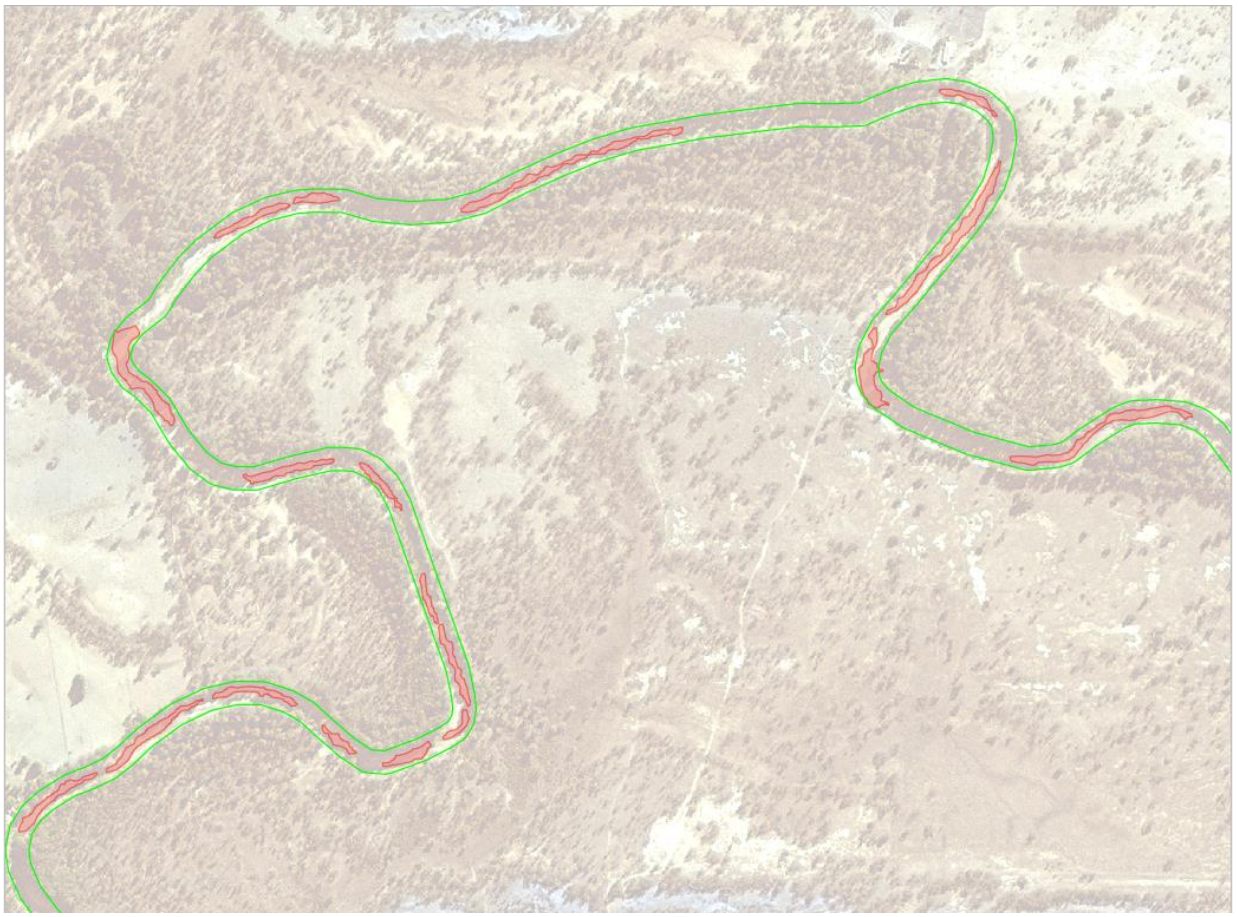

Figure 4 Refugia pools mapped after applying a threshold.

Conclusions

This concept paper demonstrated the potential of remotely sensed satellite imagery to identify and monitor refugia pools. Mapping the spatial extent and location of refugia pools is an important step in managing river systems and their inhabitants. Satellite remote sensing offers an inexpensive alternative to manual fieldwork. Preliminary results presented in this paper indicate that remote sensing is a promising technology to map and monitor refugia pools. Upon further refining of the remote sensing algorithms used in this paper and validating refugia pools using ancillary data, it should be possible to map the spatial extent and monitor temporal changes in these pools over longitudinal time periods using a combination of satellite imagery obtained from Landsat and Sentinel-2 series of satellites.

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