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NSW GOVERNMENT

Groundwater dependent ecosystems

Environmental Outcomes Monitoring and Research Program Report 2022- 2024

Acknowledgement of Country

The Department of Climate Change, Energy, the Environment and Water acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land and we show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

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Contents

Monitoring groundwater dependent ecosystems

What are groundwater dependent ecosystems?

Groundwater dependent ecosystems (GDEs) are ‘ecosystems that need access to groundwater to meet all or some of their water requirements to maintain their communities of plants and animals, their ecological processes and ecosystem services’ (NSW DPE 2023). The dependence of GDEs on groundwater varies from seasonal or episodic, to continual (Howe et al. 2007). GDEs can range in size from a few metres to many square kilometres.

GDEs can be grouped into three broad types (Eamus et al. 2006; Richardson et al. 2011):

1. Groundwater dependent vegetation (also referred to as terrestrial GDEs), are ecosystems that depend on the sub-surface presence of groundwater, often accessed via the capillary fringe or vadose zone (that is, the subsurface water just above the water table that is not completely saturated) (Naumburg et al. 2005; Eamus et al. 2006a). Plant species within a community may exhibit differing degrees of groundwater dependency (Hatton and Evans 1998) and can range from being entirely dependent on the groundwater to partial or infrequent dependency (Zencich et al. 2002; Eamus et al. 2006; Froend and Drake 2006).
2. Aquatic GDEs, are environments where the groundwater meets the surface such as rivers, wetlands, and springs. These GDEs are considered dependent on groundwater if the presence of groundwater is essential to the biota and ecological processes of that wetland at some stage of their life span (Howe et al. 2007).
3. Subterranean GDEs are those that occur in saturated zones of an aquifer. These include water-filled voids in a variety of geological matrices such as karst (caves), fractured rock and alluvial ecosystems. They also include ‘hyporheic’ ecosystems that occur in the sediments of surface waters and form an ecotone between surface and groundwater ecosystems (Hose et al. 2022).

Why are we monitoring groundwater dependent ecosystems?

The condition of groundwater dependent ecosystems is dependent upon access to groundwater. That access can be influenced by water management decisions such as changed surface water flow regimes, groundwater recharge, groundwater drawdown, and groundwater quality. Hence, understanding the location, extent, and condition of GDEs is essential for surface and groundwater water planning and management. This information allows the NSW Department of Climate Change, Energy, the Environment and Water - Water (the department), to consider and protect the needs of ecosystems dependent on groundwater when making resource management decisions and developing plans to share water between people and the environment.

Image credit: John Spencer NSW DCCEEW

Report purpose

The 2022-24 biennial report for the groundwater dependent ecosystem theme (this document) outlines activities and their findings under the Environmental Outcomes Monitoring and Research Program between July 2022 and June 2024.

This biennial report is one of a set of 5 different themes for the Environmental Outcomes Monitoring and Research Program. The themes are:

1. Floodplain connectivity and inundation
2. Ecosystem processes
3. Water dependent native vegetation
4. Water dependent fauna
5. Groundwater dependent ecosystems (this report).

The Environmental Outcomes Monitoring and Research Program delivers information annually to meet several requirements. These include NSW reporting obligations under the Basin Plan Schedule 12, performance indicator research, data collection and analysis to inform and evaluate water sharing plans and floodplain management plans. It also contributes to the NSW River Condition Index tool, the High Ecological Value Aquatic Ecosystems spatial layer, and the NSW State of the Environment Reports.

The Environmental Outcomes Monitoring and Research Program projects are staged over several years, building knowledge about water dependent ecosystems and their responses to water management plans, actions and decisions. This document provides an update for ongoing projects reported in the previous reporting round for the groundwater dependent ecosystems theme (DPE 2023). For further information Environmental Outcomes Monitoring and Research Program website. Technical reports for each research project will be published separately and made available on the department's website.

The Environmental Outcomes Monitoring and Research Program was designed to implement the NSW Water Management Monitoring, Evaluation and Reporting (MER) framework (DCCEEW Water 2024) which addressed Basin Plan requirements and the evaluation of all NSW Water Sharing Plans. The department is completing this work in response to the Natural Resources Commission findings and recommendations about the way we monitor, evaluate, and report information about water sharing plan outcomes.

Report structure

The GDE theme incorporates monitoring of groundwater dependent vegetation and groundwater ecosystem health which link to the Basin Plan's basin-wide environmental watering strategy (MDBA 2019) and NSW water sharing plan objectives. This report presents information from projects under the GDE theme in the NSW groundwater sources (Figure 1):

1. Change in cover of high priority groundwater dependent vegetation in the NSW Murray Darling Basin.
2. Investigating the use of remote sensing for monitoring groundwater dependent vegetation condition in data poor areas of the NSW Murray Darling Basin.
3. Reanalysis of groundwater health index for alluvial aquifers in the NSW Murray Darling Basin.
4. Impacts of groundwater extraction on groundwater dependent ecosystems.
5. Establishing the links between groundwater ecosystem health, and groundwater dependent vegetation and wetland health.
6. Determining groundwater use by vegetation using environmental DNA.

Image credit: NSW DCCEEW

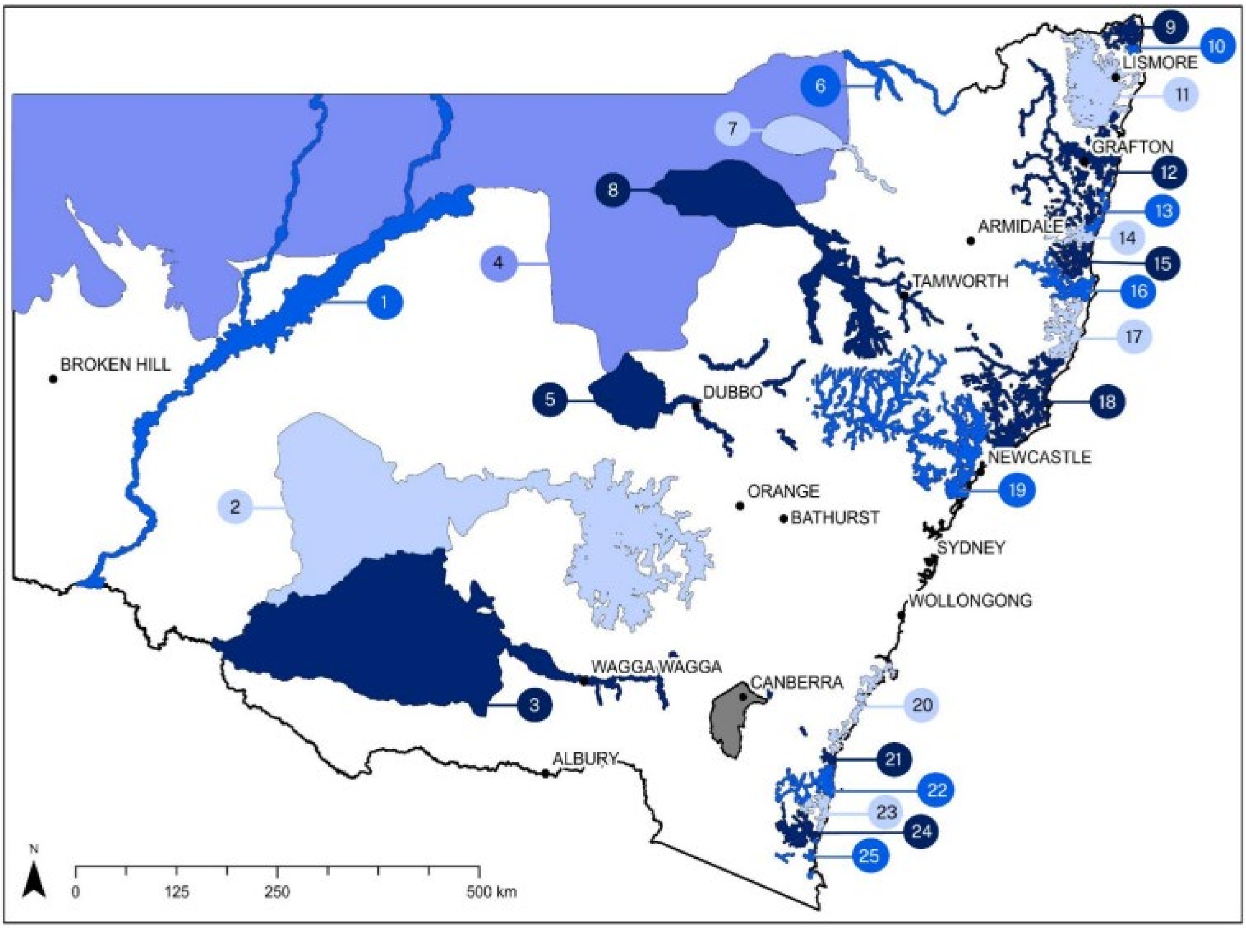

Figure 1. Map of NSW showing NSW Groundwater Water Sharing Plan areas. Note: Fractured and porous rock, and buried water sources not shown.

Groundwater Water Sharing Plan Legend:

1. Darling Alluvial Groundwater Sources
2. Lachlan Alluvial Groundwater Sources
3. Murrumbidgee Alluvial Groundwater Sources
4. NSW Great Artesian Basin Shallow Groundwater Sources
5. Macquarie-Castlereagh Groundwater Sources
6. NSW Border Rivers Alluvial Groundwater Sources
7. Gwydir Alluvial Groundwater Sources
8. Namoi Alluvial Groundwater Sources
9. Tweed River Area Unregulated and Alluvial Water Sources
10. Brunswick Unregulated and Alluvial Water Sources
11. Richmond River Area Unregulated and Alluvial Water Sources
12. Clarence River Unregulated and Alluvial Water Sources
13. Coffs Harbour Area Unregulated and Alluvial Water Sources
14. Bellinger River Area Unregulated and Alluvial Water Sources
15. Nambucca Unregulated and Alluvial Water Sources
16. Macleay Unregulated and Alluvial Water Sources
17. Hastings Unregulated and Alluvial Water Sources
18. Lower North Coast Unregulated and Alluvial Water Sources
19. Hunter Unregulated and Alluvial Water Sources
20.Clyde River Unregulated and Alluvial Water Sources
21. Deua River Unregulated and Alluvial Water Sources
22. Tuross River Unregulated and Alluvial Water Sources
23.Murrah-Wallaga Area Unregulated and Alluvial Water Sources
24.Bega and Brogo Rivers Area Regulated, Unregulated and Alluvial Water Sources
25.Towamba River Unregulated and Alluvial Water Sources

Drivers of environmental outcomes

Groundwater is a valuable resource that supports a range of plants and animals in a diversity of environments (for example, above ground vegetation communities and underground specialised animals and microbial communities) (Figure 2). It is also a source of water that can be extracted for use in agriculture, industry, and households. The extraction of groundwater in NSW is regulated by the Water Management Act (2000). This Act and the Basin Plan (2012) set rules and limits around how much groundwater can be sustainably taken without adversely impacting the plants and animals that rely on groundwater. Water management also includes consideration of connectivity between rivers and aquifers which is critical for local groundwater recharge. This is key for allowing groundwater to refill to levels sufficient to be sustained during dry conditions. High rainfall events contribute to the overall regional groundwater recharge; however, these events are sporadic in nature. This report focuses on providing baseline data on the extent of groundwater dependent vegetation in NSW.

The quality of groundwater also impacts on reliant plants and animals. Factors that influence groundwater quality is often outside of the control of water managers.

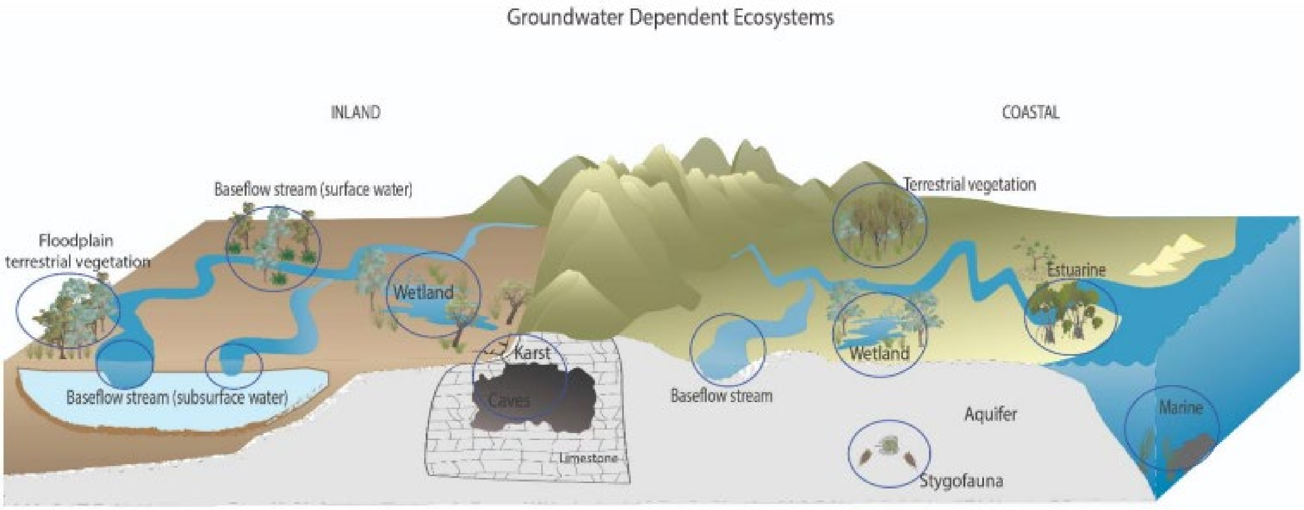

Figure 2. Landscape position of groundwater dependent ecosystems. Source https://water.dpie.nsw.gov.au/science-dataand-modelling/surface-water/environmental-outcomes-monitoring-and-research-program/groundwater-dependentecosystems.

Projects

Change in cover (extent) of high priority groundwater dependent vegetation in the NSW Murray Darling Basin

Project Team

Jodie Dabovic

Project aims

Groundwater sharing plans have environmental outcomes to protect the extent and condition of high priority groundwater dependent ecosystems. The aim of this project was to investigate a method for monitoring the change in extent of high priority groundwater dependent vegetation across the alluvial groundwater sources in the NSW Murray Darling Basin.

Key project questions

- Is this method suitable to monitor changes in the extent of high priority groundwater dependent vegetation from baseline conditions established prior to 2020 in the NSW Murray Darling Basin alluvial groundwater areas?

Link to water management activities

- Do the changes in extent of high priority groundwater dependent vegetation ecosystems detected by this method relate to current groundwater access rules in water sharing plans?

Methods

The method focuses on the analysis of fractional cover change (live tree, dead material, bare ground and total cover) as a surrogate of change in extent of high priority groundwater dependent vegetation from the baseline established in April 2020 (prior to the commencement of the 2020 water sharing plans in the NSW Murray Darling Basin) and April 2023 using the mapped groundwater dependent vegetation and remote sensing data.

The 2020 baseline spatial extent of groundwater dependent vegetation was determined by selecting polygons of the NSW State Wide Vegetation map (DPE 2023a), using the methods of Kuginis et al. (2016) and Dabovic et al. (2019). These methods identified the vegetation communities that have a high probability of being groundwater dependent and assigned an ecological value to those communities. A subset of this dataset was selected based on very high and high ecological value and was then classified as high priority for management actions in NSW under the *NSW Water Management Act 2000*.

The high priority groundwater dependent vegetation spatial data was overlayed onto a remote sensing online analysis tool developed by Australia's Terrestrial Ecosystem Research Network Ecosystem Research Infrastructure called VegMachine (Beutel et al. 2019; https://vegmachine.net/#). VegMachine is an online tool that uses satellite imagery to summarise decades of change in Australia's landscape. The tool allowed for analysis of vegetation across the landscape and provides outputs that range from live (green band) to bare ground (red band).

Image credit: NSW DCCEEW

The high priority data for each alluvial water source in the NSW Murray Darling Basin was selected into small areas (VegMachine only accepts small file sizes) and the features dissolved to make one feature (polygon) in ArcGIS and saved as shapefiles. Each shape file was uploaded into VegMachine using the import polygons tab of the online tool. The polygons were selected and analysed for fractional cover within the seasonal timeframe tab. Outputs were produced as a graph and download file. The results were further analysed for trends and change comparison from April 2020 to April 2023. Rainfall was also captured with the fractional cover analysis in VegMachine.

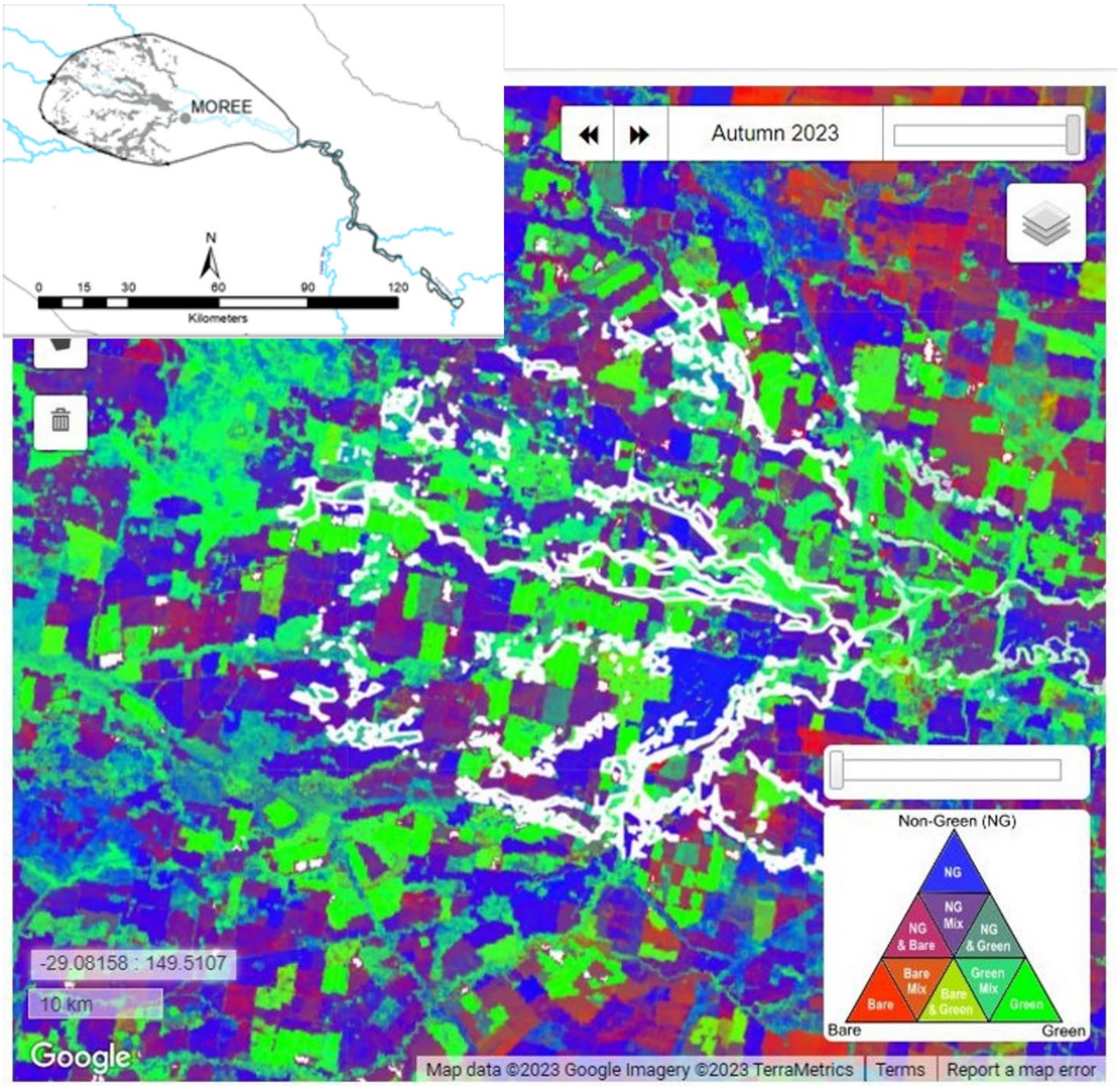

Figure 3. Example of remote sensing outputs are represented as colours with green representing live cover, blue representing dead matter and red representing bare ground with gradients in between (the extent of high priority groundwater dependent ecosystems (white boundaries) located in the western portion of the lower Gwydir alluvial water source in autumn 2023).

The rainfall from each high priority groundwater dependent ecosystem area used in the fractional cover analysis was averaged and cumulative rainfall per year from 2020 to 2023 calculated.

Groundwater level and groundwater usage were extracted from the NSW Department of Planning and Environment annual groundwater reports (DPE 2023b).

Results

The VegMachine tool identified that canopy cover remained relatively constant in most alluvial groundwater sources except the lower Murrumbidgee, lower Murray, Lachlan and Darling. Groundwater dependent vegetation canopy cover (represented by mean percentage total cover) in these catchments experienced a decline in total cover in winter 2021, with recovery in spring 2021, before larger declines in winter 2022 and summer 2023 (Figure 4).

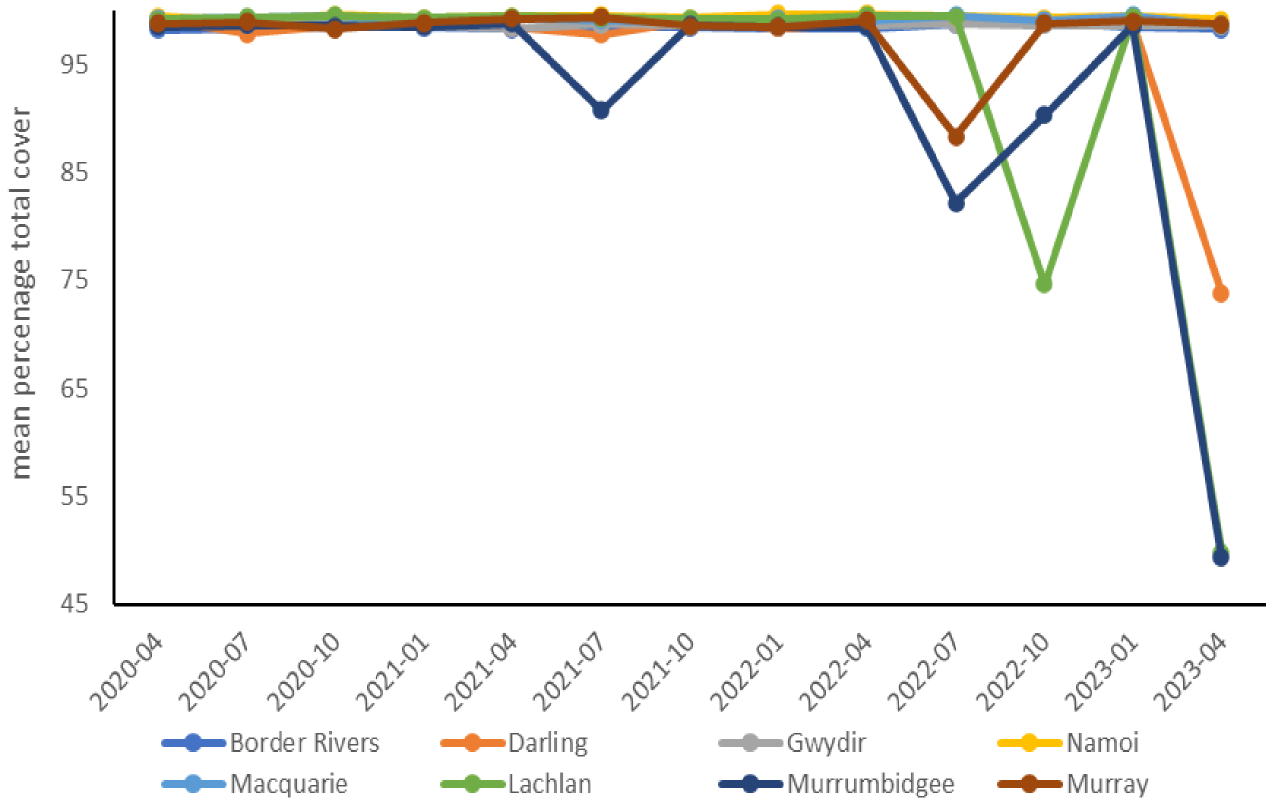

Figure 4. Mean percentage cover for total cover of high priority groundwater dependent vegetation in the NSW Murray Darling Basin.

Increases in total cover occurred in nine groundwater sources (NSW Border Rivers, NSW Border rivers Tributaries, Lower Gwydir, Lower Namoi, Castlereagh, Bell, Mid Murrumbidgee, Billabong and Upper Murray (as indicated green in Figure 5).

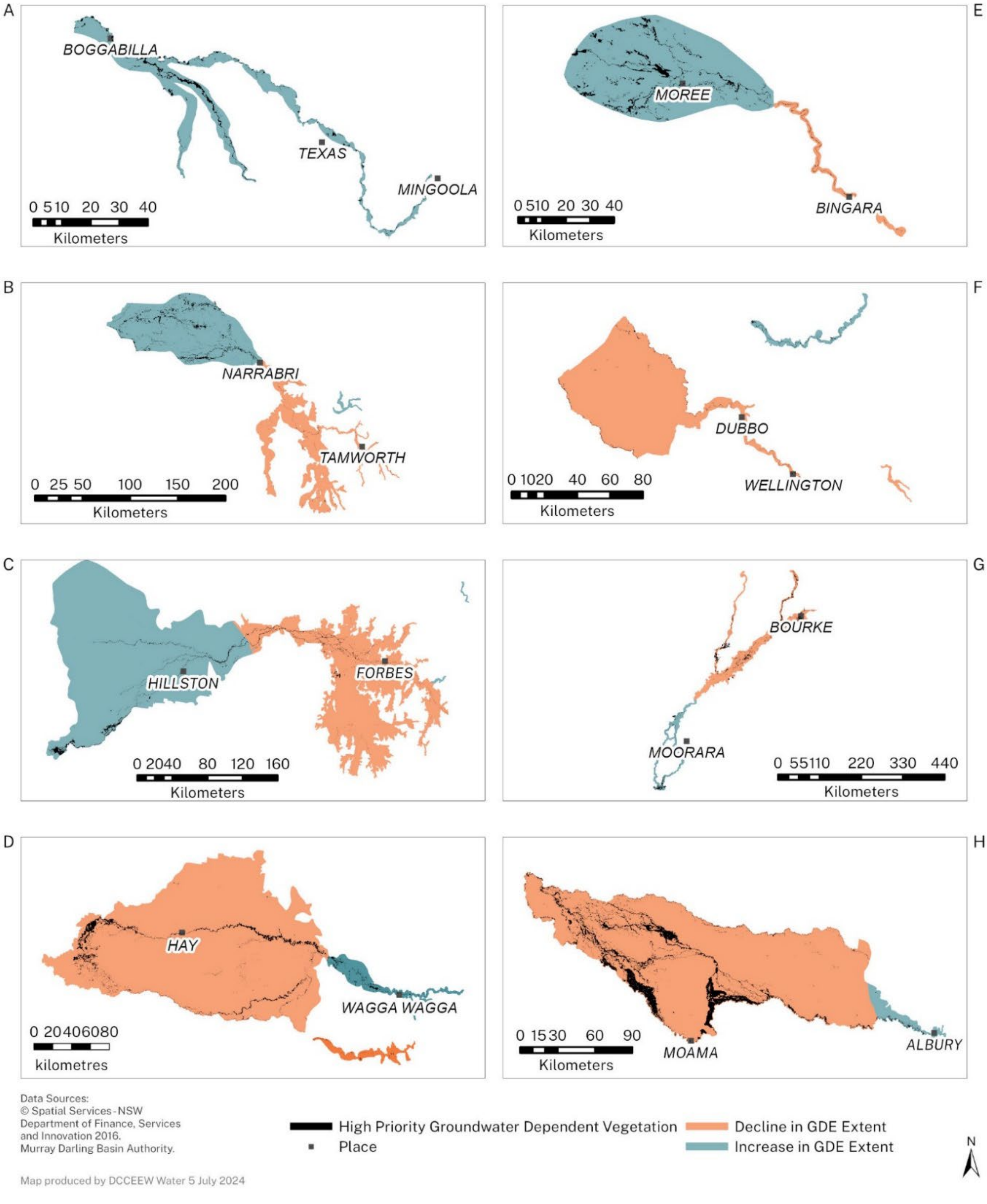

Figure 5. Change in total cover from 2020 to 2023 for high priority groundwater dependent vegetation in a) Border Rivers Alluvium, b) Namoi Alluvium, c) Lachlan Alluvium, d) Murrumbidgee Alluvium, e) Gwydir Alluvium, f) Macquarie-Castlereagh Alluvium, g) Darling Alluvium, h) Murray Alluvium.

Conclusions

The reduction in total cover during the 2020 to 2023 period was likely due to the damage caused from large flooding events during La Niña weather events and land clearing, rather than from dieback due to groundwater extraction and associated changes in groundwater levels. Groundwater extraction during this period generally decreased and the associated groundwater levels remained relatively constant or experienced small amounts of recharge (DPE 2023).

There was consecutive La Niña events across NSW between 2020 and 2023, resulting in record rainfall and inundation events across the Murray Darling Basin. Due to these unprecedented events, it is unknown if environmental water contributed to changes in groundwater dependent vegetation extent.

Groundwater extraction between 2022 and 2023 water years was low due to the climatic conditions. Therefore, the outcomes were likely not influenced by the current Sustainable Diversion Limits set by the Basin Plan. These limits are likely to have more influence during drier periods.

This method of monitoring change in high priority groundwater dependent vegetation is a cost and resource effective surrogate to the traditional field survey methods. This method allows all mapped groundwater dependent vegetation to be monitored especially in data poor and remote locations where field surveys are not practical.

Next steps

The next steps for this project are to publish full details of the methods and results for the NSW Murray Darling Basin and to expand this method into the monitoring extent of high priority groundwater dependent vegetation in coastal areas.

Investigating the use of remote sensing for monitoring groundwater dependent vegetation condition in data poor areas of the NSW Murray Darling Basin

Project Team

Jodie Dabovic, Grant Hose (Macquarie University), Benoit Liquet-Weiland (Macquarie University), Sharon Bowen, Yi Yu.

Project collaborators

Macquarie University

Project aims

This project investigates the use of remote sensing indices to infer the condition of groundwater dependent vegetation in data poor areas in the NSW Murray Darling Basin. The 2022 to 2024 project focused on black box (*Eucalyptus largiflorens*) communities. The specific aims of the project relate to the following questions.

Key project questions

- Can the health of groundwater dependent vegetation be assessed using remote sensing indices in water sharing plan areas? Specifically:
    - Can we determine the suitability of normalised difference vegetation index (greenness remote sensing index) to predict the condition of black box communities in the NSW Murray Darling Basin?
    - Can we determine if other combinations of remote sensing indices and environmental variables improved the prediction of black box condition?

Link to water management activities

- Do current groundwater access rules in the water sharing plans adequately protect the health of groundwater dependent vegetation ecosystems?

Methods

Field surveys for black box were conducted under the Commonwealth Environmental Watering and NSW wetland inundation monitoring programs from 2014 to 2019 (Figure 6). The field surveys captured floristic vegetation community condition parameters for the lower, middle, and upper vegetation strata within 0.04 ha plots (Figure 7). Condition scores were calculated using the field survey data following the method of Bowen (2019). Environmental variables were collated for the period including rainfall, stream flow, groundwater level and evapotranspiration. The survey period coincided with below average rainfall and drought conditions (BOM 2024) (Figure 8).

Image credit: Sharon Bowen NSW DCCEEW

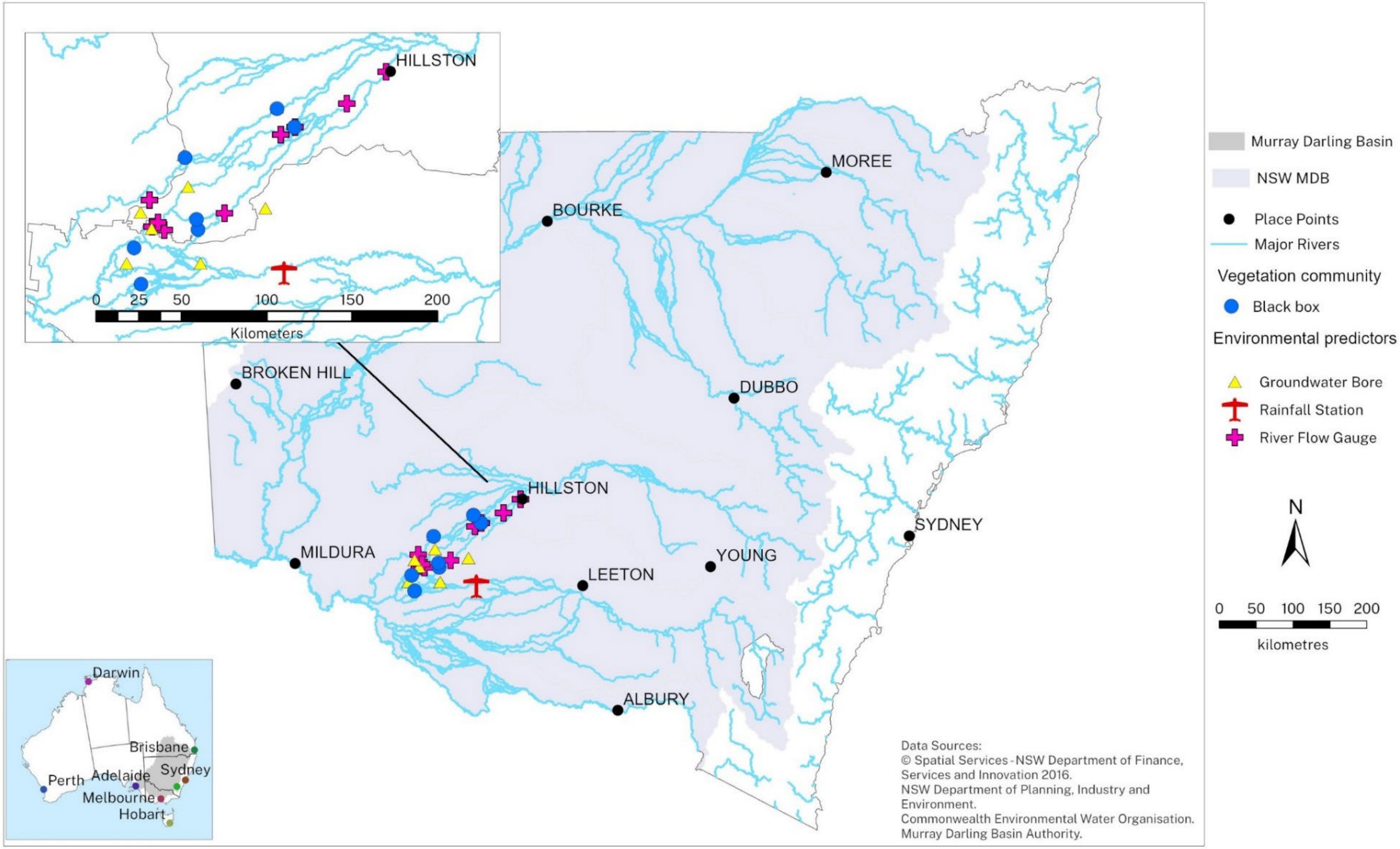

Figure 6. Location of black box condition sites across the NSW Murray Darling Basin.

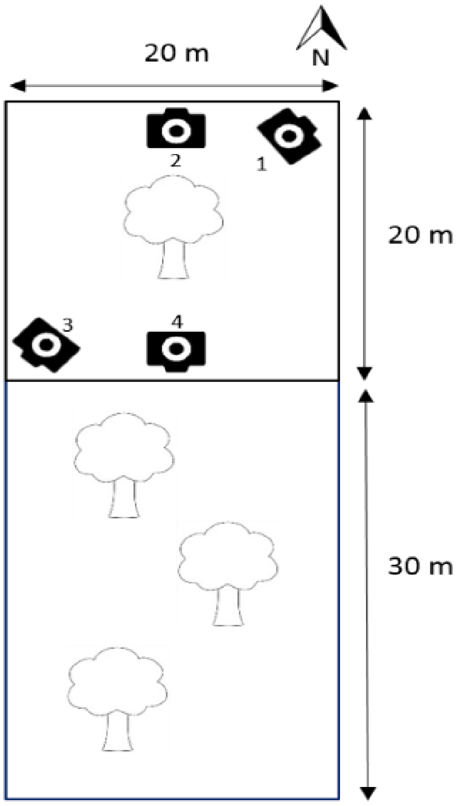

Figure 7 Example of a survey plot.

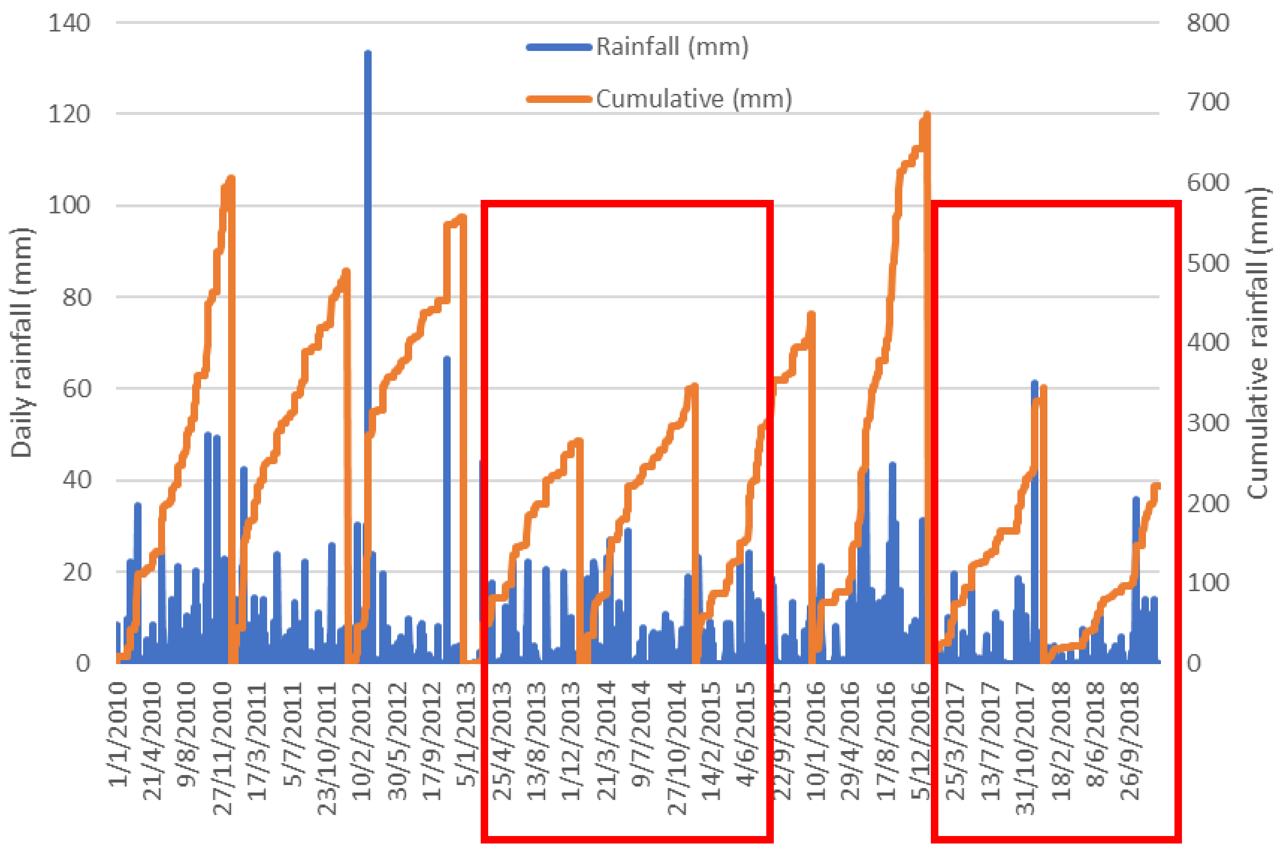

Figure 8. Rainfall at the Griffith weather station showing the below average/drought periods in the red boxes.

Landsat 7 and 8 images were selected due to their 30 m resolution and 16-day revisiting circle with imagery available for the sampling period. Time series images which have less than 10% cloud cover were used to calculate the normalised difference vegetation index (NDVI), tasselled cap greenness (TCG) and wetness (TCW) indices for the black box survey sites across the NSW Murray Darling Basin. Index data were collected approximately 6 weeks prior to and after a field survey date and averaged to account for variability from the satellite imagery. Figure 9 shows the conceptual model of remote sensing imagery capture for vegetation.

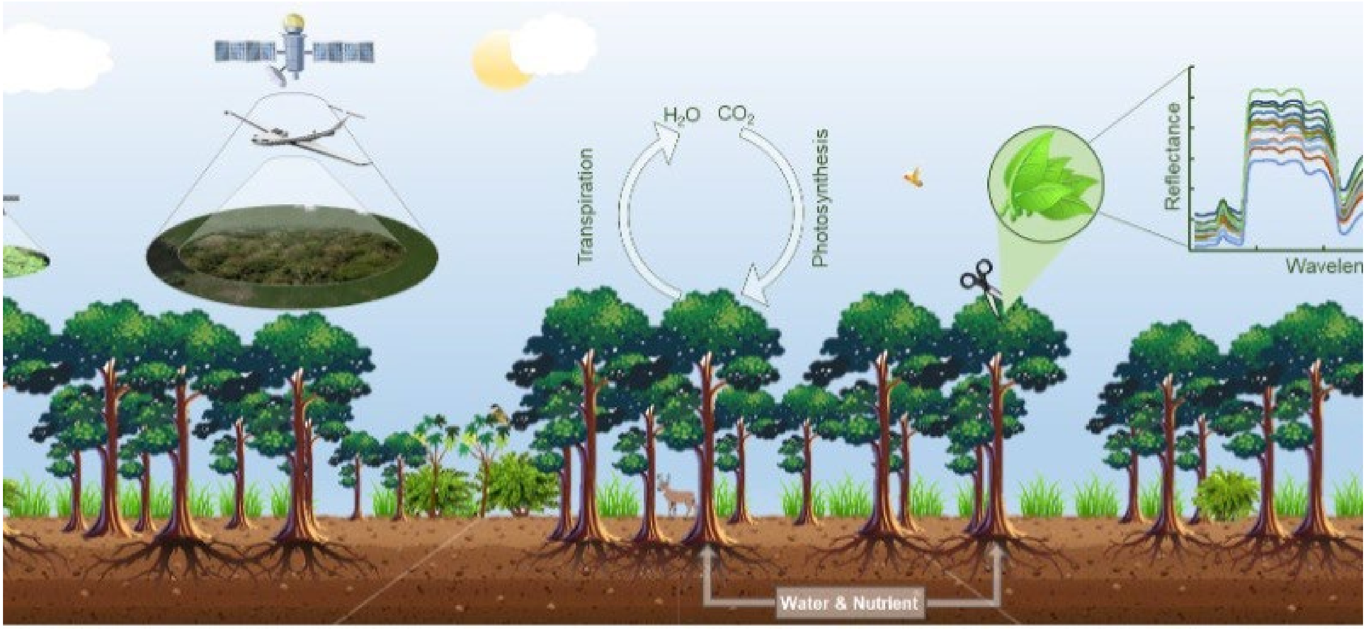

Figure 9. Conceptual model of how remote sensing captures canopy reflectance (Image source: Cambridge Earth Observation).

Statistical analysis

The following statistical analyses were undertaken using the R program (RStudio Team, 2020):

1. Linear correlations and regressions to understand the association of environmental variables, particularly the remote sensing greenness index (normalised difference vegetation index) with vegetation condition scores
2. Multiple regressions to understand how the environmental variables (normalised difference vegetation index + tasselled cap greenness + tasselled cap wetness + evapotranspiration + groundwater level + stream flow + rainfall) contributed to the vegetation condition score
3. Partial least squares regression (which builds new scores (linear combination of the environmental variables)) to determine what variables are correlated to the vegetation condition score) where component 1 = normalised difference vegetation index + tasselled cap greenness + tasselled cap wetness + evapotranspiration + groundwater + stream + rainfall
4. Random forest modelling (forest of trees) which operates multiple decision trees. Average prediction of individuals decision trees is given as output (see Figure 10 for an example of a decision tree).

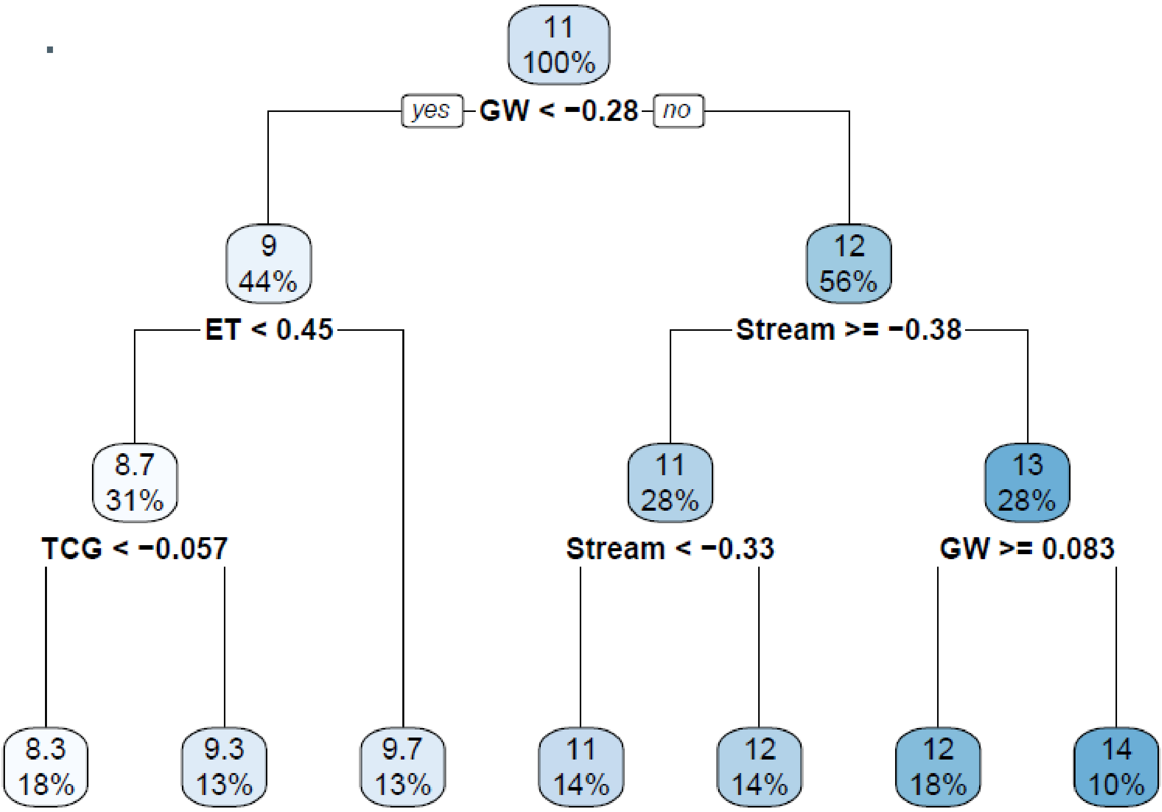

Figure 10. Example decision tree for random forest modelling. ET = evapotranspiration, TCG = tasselled cap greenness

Results

Condition scores for black box within the NSW Murray Darling Basin survey sites ranged from poor to intermediate across all survey sites (Figure 11). Over the sampling period two sites were constantly in the poor condition category with the remaining sites within the intermediate category (Figure 11). Figure 12 shows examples of black box communities within each of the three condition categories. As there were no good condition site, the black box photo presented for good condition is just used as an example and was not located in any of the survey site.

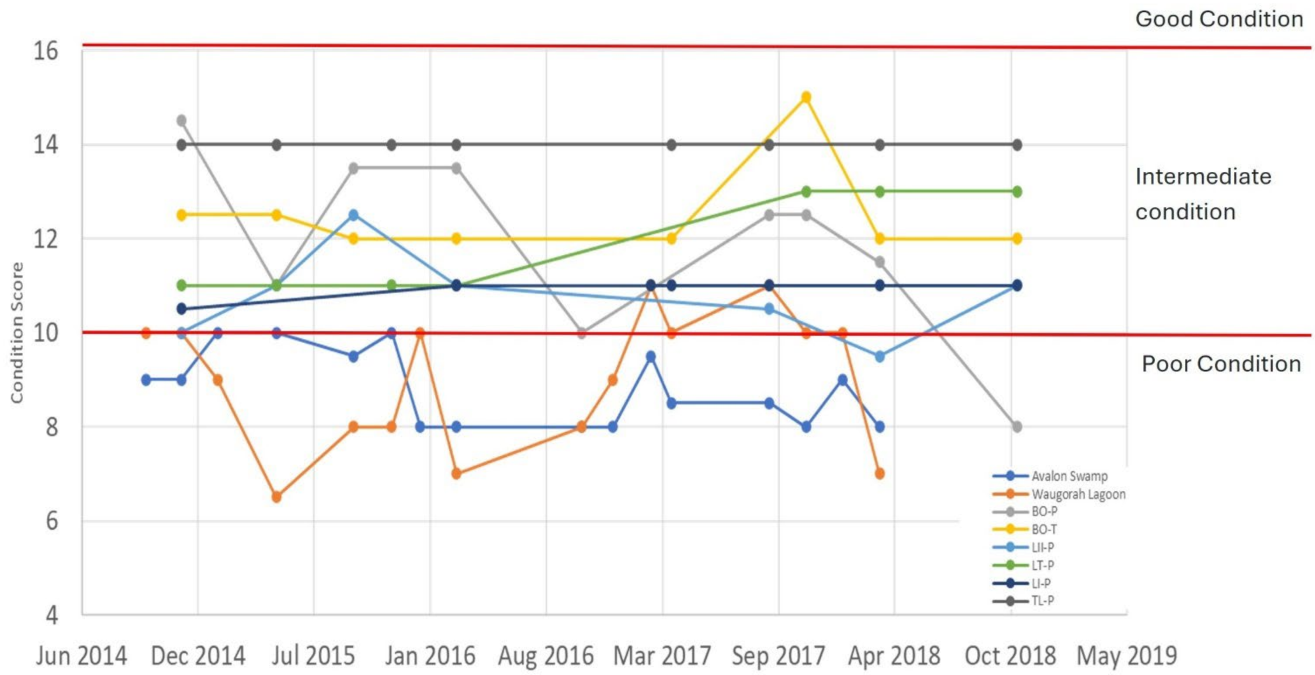

Figure 11. Black box condition at survey sites within the Murray Darling Basin. Red lines indicate the condition category. BO is Booligal, LT is Lake Tarwong, TL is Toms Lake and Li is Lake Ita.

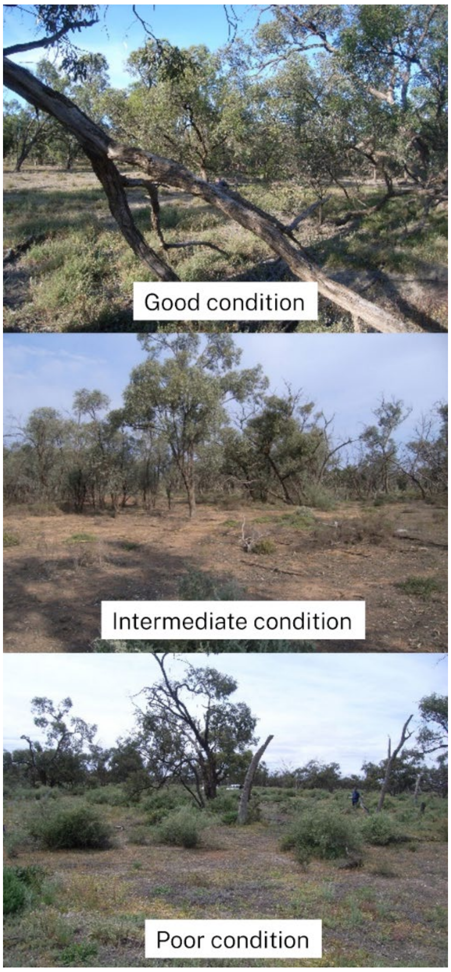

Figure 12. Examples of black box condition in the field (Photo Credit: Sharon Bowen)

Pairwise correlation analysis was undertaken to determine which remote sensing indices (predictor variables) best explained black box condition. This analysis showed that the remote sensing indices alone were poor predictors of black box condition. The greenness indices of normalised difference vegetation index had a R^2 value of 0.1, tasselled cap greenness a R^2 value on 0.05 and the wetness index of tasselled cap wetness had a R^2 value of 0.19. These all indicate low correlations to black box condition scores. Importantly, depth to groundwater (GW) was the single variable that best explained black box condition (R^2 = 0.59) followed by stream flow (R^2 = -0.34) (Figure 13).

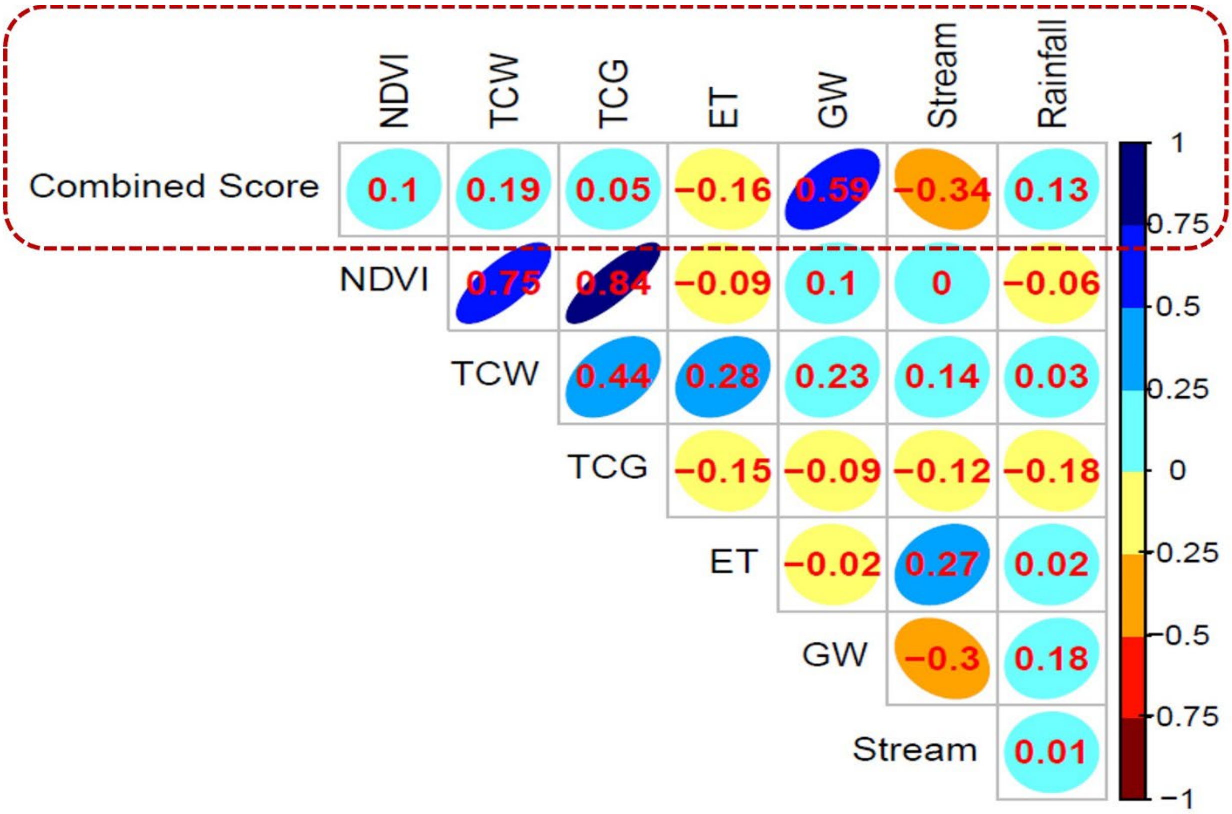

Figure 13. Pairwise correlation of the predictor variables of remote sensing indices (NDVI, TCW, TCG), evapotranspiration (ET), groundwater (GW), stream flow and rainfall with black box condition score. Normalised difference vegetation index (NDVI), tasselled cap greenness (TCG) and wetness (TCW) indices.

Models were developed to determine the relative importance of the environmental variables for predicting black box condition. These models were univariate linear (Figure 14), multivariate linear (Figure 15), partial least squares (Figure 16) and random forest (Figure 17). These models demonstrate that normalised difference vegetation index alone is not a strong predictor of black box condition (R^2 = 0.011) and that other environmental variables are required. As model complexity increased (linear to random forest) the predictability increased with random forest having a R^2 value of 0.812.

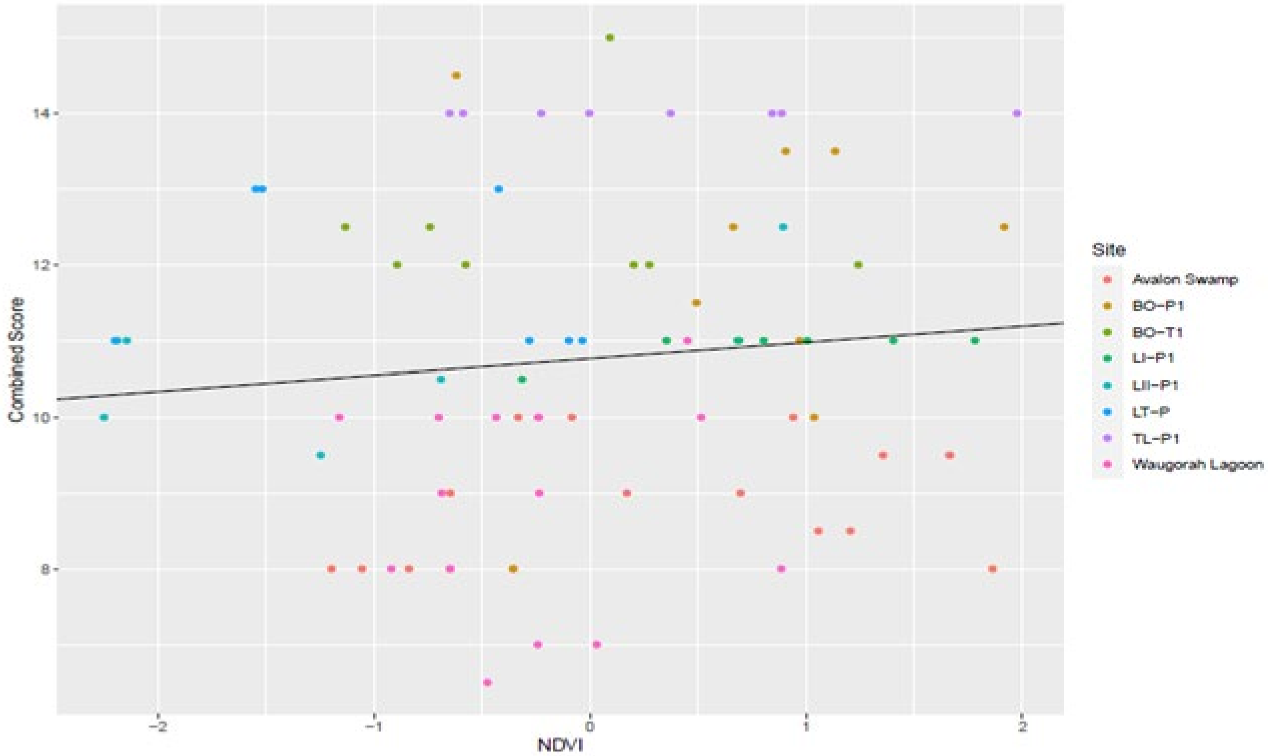

Figure 14 Model predictions for univariate linear (A). The trendline R^2 = 0.011. BO is Booligal, LT is Lake Tarwong, TL is Toms Lake and Li is Lake Ita.

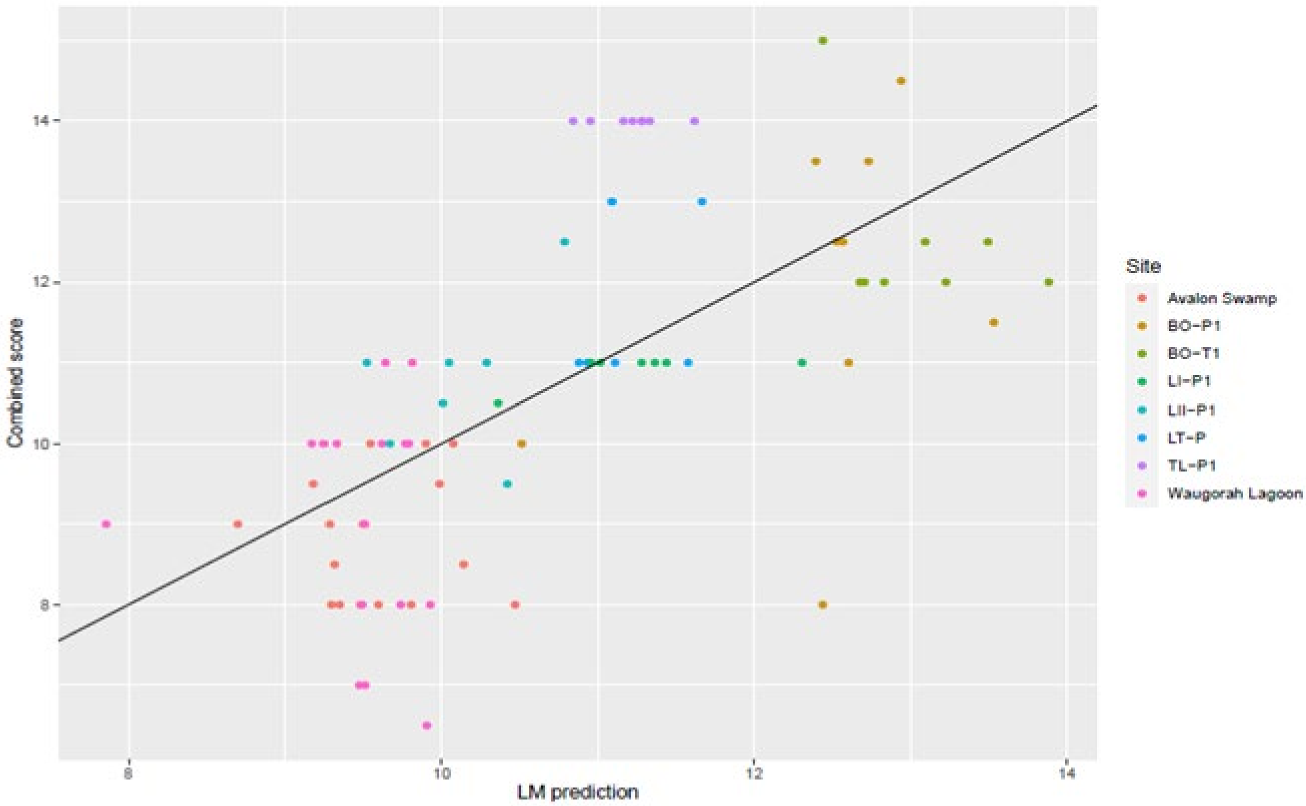

Figure 15 Model predictions for multivariate linear (B). The trendline R^2 = 0.427. BO is Booligal, LT is Lake Tarwong, TL is Toms Lake and Li is Lake Ita.

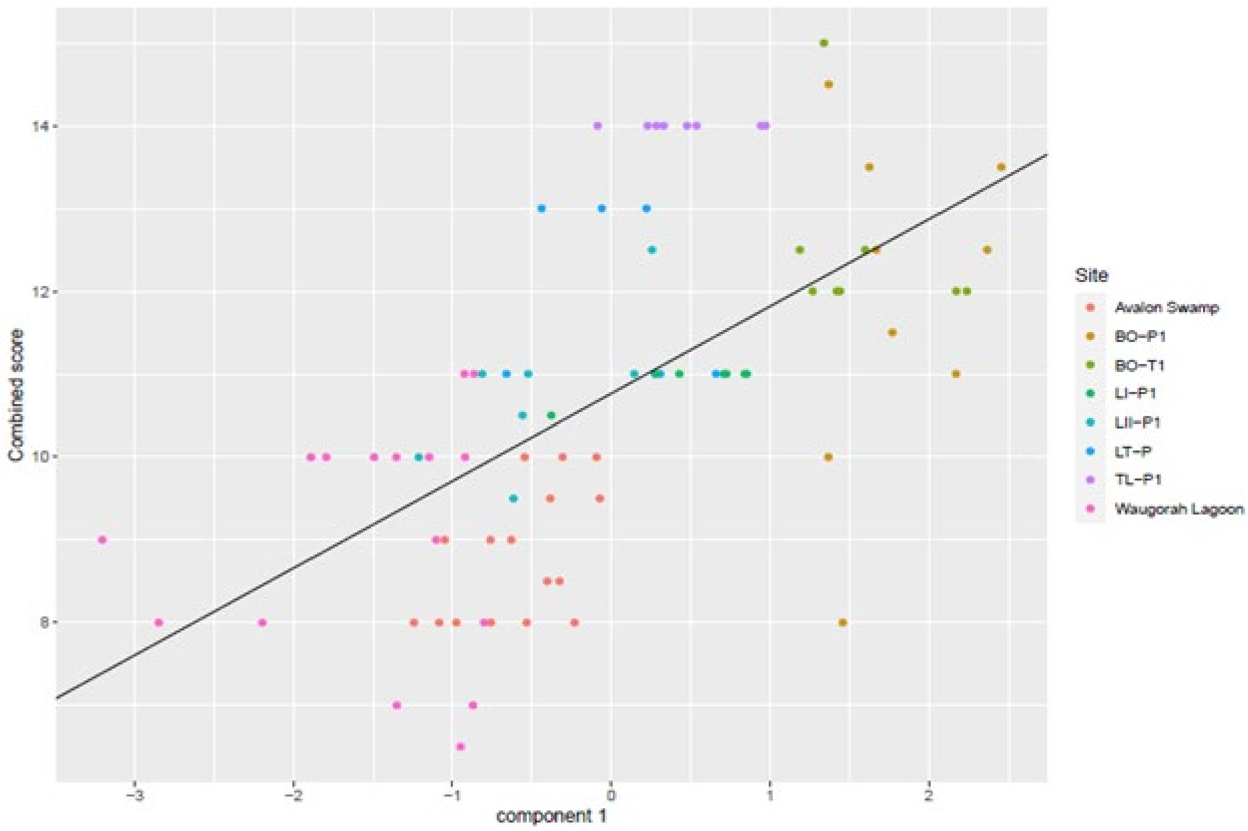

Figure 16 Model predictions partial least squares (A). The trendline $R^2 = 0.378$. BO is Booligal, LT is Lake Tarwong, TL is Toms Lake and Li is Lake Ita.

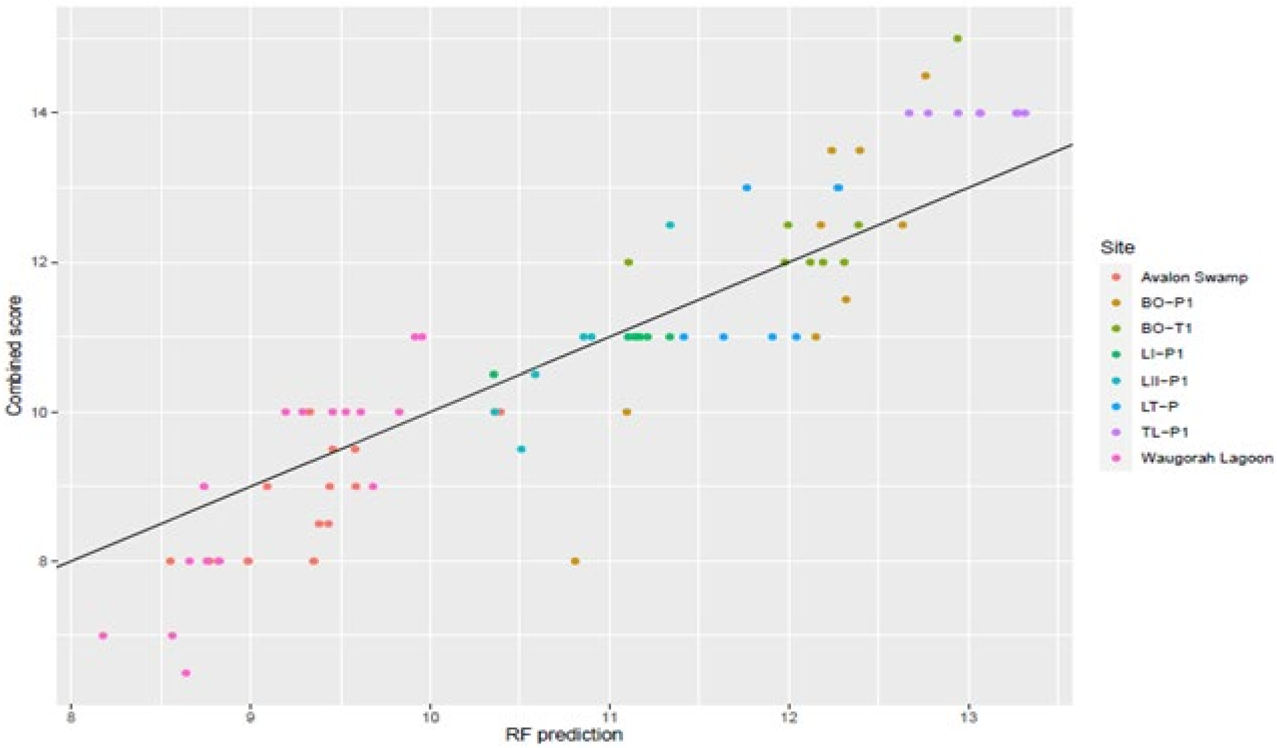

Figure 17 Model predictions random forest (B). The trendline $R^2 = 0.812$. BO is Booligal, LT is Lake Tarwong, TL is Toms Lake and Li is Lake Ita.

Conclusions

This pilot study using black box demonstrates the possibility of monitoring groundwater dependent vegetation condition using remote sensing and environmental variables. The use of random forest regression modelling provides the highest predictability of all the regression models tested within this study. This method relies on readily available data and offers a cost and resource effective monitoring of large-scale areas, especially in remote areas where access is problematic.

Importantly, the use of normalised difference vegetation index as an individual variable was a poor predictor of black box community condition and was the least important of all the environmental variables tested. The most important remote sensing indices for predicting black box community condition was the wetness index of tasselled cap.

The most pertinent finding was that depth to groundwater was the most important predictor variable for black box followed by stream flow. This highlights the importance of maintaining groundwater levels in areas where black box communities overlay groundwater sources.

Next Steps

The next step is to complete the analysis for river red gum (*Eucalyptus camaldulensis),* coolibah (*E. coolabah), r*iver cooba (*Acacia stenophylla)* and mixed marsh. This analysis will provide information on what the best remote sensing/environmental variables for each vegetation type are. Once the statistical analysis has been completed, vegetation condition ranges will be refined and tested against future field survey data.

This will then allow future assessments of whether current groundwater access rules in the water sharing plans adequately protect the health of groundwater dependent vegetation ecosystems.

Reanalysis of groundwater health index for the alluvial aquifers in the NSW Murray Darling Basin

Project Team

Grant Hose (Macquarie University), Kathryn Korbel (Macquarie University), Jodie Dabovic.

Project collaborators

Macquarie University

Project aims

The aim of this project was to assess the health of groundwater ecosystems within the alluvial groundwater sources of the Gwydir, Namoi, Macquarie, Lachlan, Murrumbidgee and Murray. We did this by applying a suite of techniques and indicators to provide comparative information to monitor for a change in health over time to meet the Basin Plan reporting requirements. The specific aims of the project are provided below.

Key project questions

- Has groundwater ecosystem health changed from baseline conditions established prior to 2020 in the NSW Murray Darling Basin?

Link to water management activities

- Do current groundwater access rules in water sharing plans adequately protect the health of groundwater ecosystems?

Methods

This project applied the groundwater health index (Korbel & Hose 2011, 2017) to identify the specific impacts of changes in groundwater level and groundwater quality in catchments of the NSW Murray Darling Basin. Field data was collected at selected sites across the NSW Murray Darling Basin to provide a comparative data set to compliment the baseline data capture prior to 2020.

Field work was undertaken in the Gwydir, Namoi, Macquarie, Murray, Murrumbidgee and Lachlan River catchments across 90 WaterNSW bores in the 2022-2023 year. Bores were sampled using a motorised inertia pump and 180 L was passed through a 63 μm sieve to collect stygofauna. Samples were also collected for stygofauna community (using eDNA), microbial community (using eDNA and cellulose degradation), water quality, and groundwater levels using the methods of Korbel & Hose (2017). Stygofauna collected in the sieve at the time of sampling were preserved in 100% ethanol, stained with Rose Bengal, and later sorted and counted under a microscope (960x magnification). Stygofauna were identified to family/genus taxonomic level using relevant keys. Identifications were confirmed by taxonomic experts.

Water samples for environmental DNA (eDNA) analysis were collected after purging, by pumping an additional 2 L of groundwater directly into a sterile container, which was stored on ice in the dark until processing. Samples were processed within 7 hours of sampling by vacuum filtration (in duplicate) through sterile 0.2 µm mixed cellulose-ester membranes (Pall Corporation, Port Washington, NV, USA).

Changes in groundwater ecosystem health were determined by comparing baseline condition (pre-2020) to that measured in 2023. The highest number of sites with either a decline or improvement in health from 2020 to 2023 was assigned to the overall water source. For sites with no comparative data, where only one sampling had been done for either 2020 or 2023, it was assumed that no change has occurred in the water source.

Results

Changes in GDE health

Changes in groundwater ecosystem health were determined by comparing baseline condition (pre-2020) to that measured in 2023. Results showed that groundwater ecosystem health across the NSW basin in 2023 ranged from poor to good. The areas in poor health were generally surrounded by intensive agriculture.

Changes in Namoi alluvial groundwater ecosystem health between 2020 and 2023 could not be determined as only one baseline bore could be resampled in 2023 (Figure 19a). Within the Lower Gwydir (Figure 18b), Lachlan (Figure 19b) and Murrumbidgee (Figure 20a) alluvial water sources, an equal number of sites showed improvement or decline in health from the 2020 baseline resulting in no change in condition being assigned for those alluvial areas.

The Macquarie alluvial area showed improvement across the lower Macquarie area compared to the 2020 baseline (below). Baseline condition was not captured for the upper Macquarie area in 2020, so no change could be assigned (Figure 19a).

In 2023, the Murray alluvial water sources had more sites across the lower alluvial area in poorer health compared to the baseline, therefore the water source was in declining health. Sites were added to the upper alluvial area in 2023 and could not be compared to a baseline for this reporting period (Figure 20b).

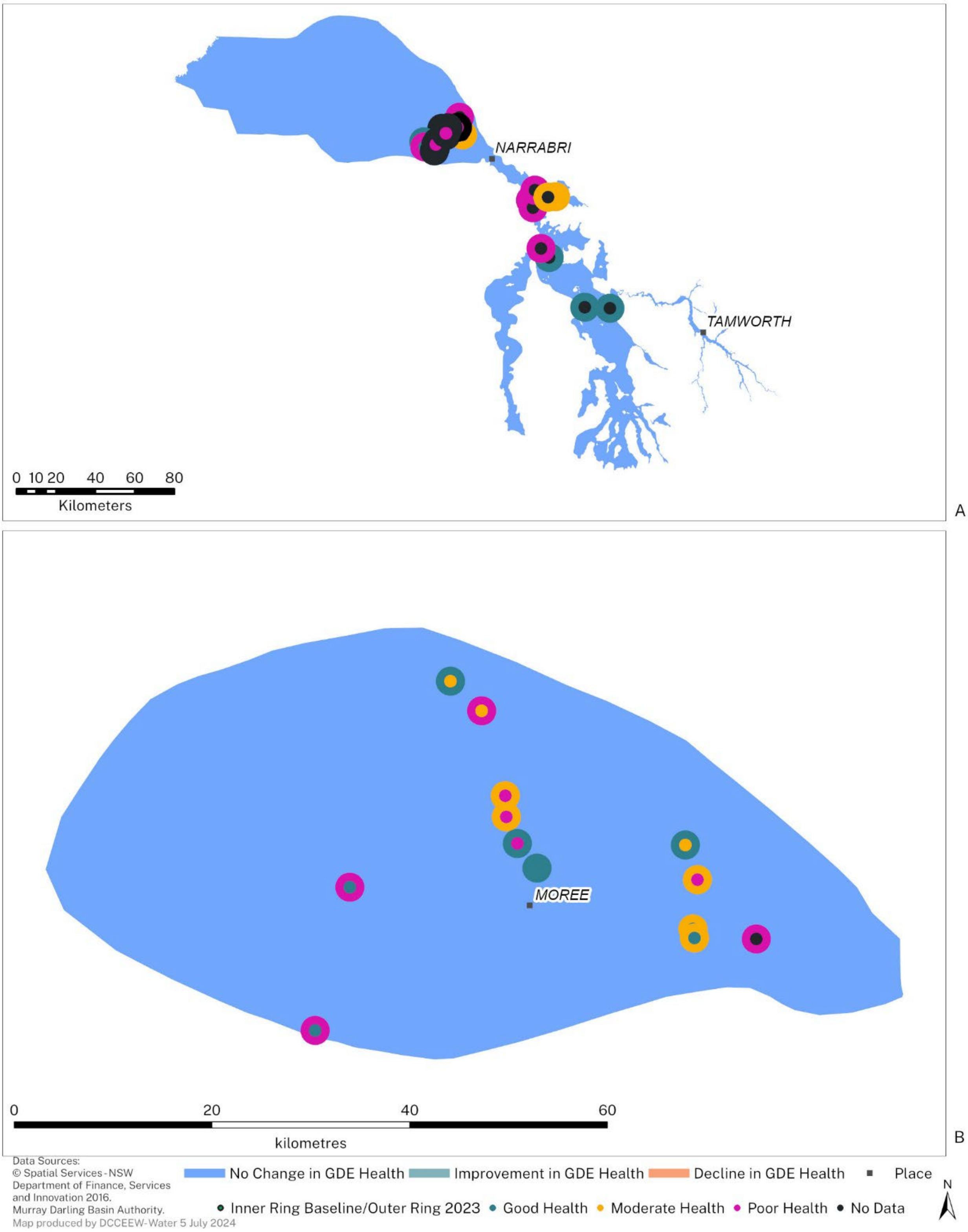

Figure 18. Groundwater ecosystem health in the Namoi Alluvium (a) and Lower Gwydir Alluvium (b) Water Sources. Circles represent the health at bores sampled for baseline and 2023 with the change in ecosystem health represented across the entire water source.

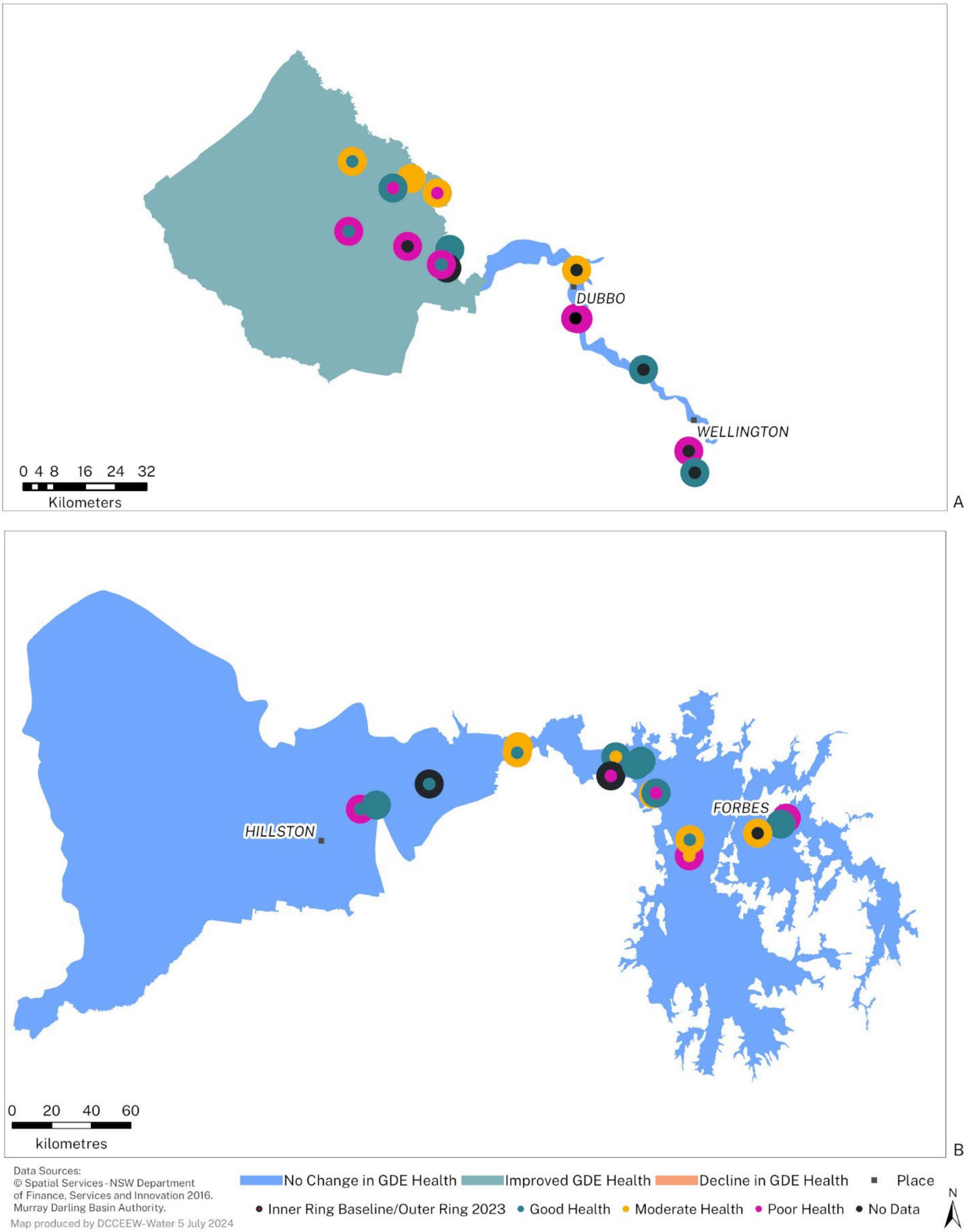

Figure 19. Groundwater ecosystem health in the (a) Macquarie Alluvium and (b) Lachlan Alluvium Water Sources. Circles represent the health at bores sampled for baseline and 2023 with the change in ecosystem health represented across the entire water source.

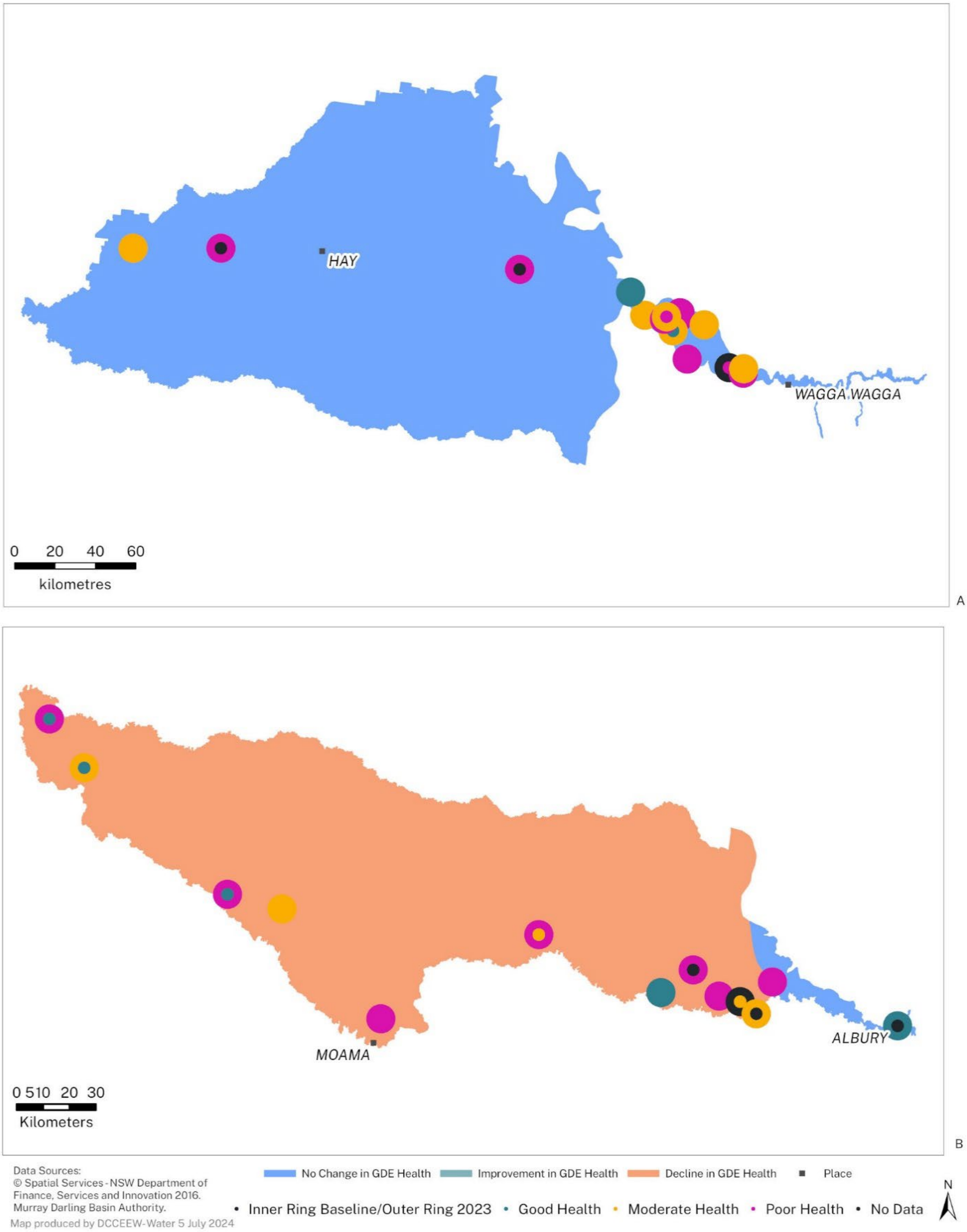

Figure 20. Groundwater ecosystem health in the (a) Murrumbidgee Alluvium and (b) Murray Alluvium Water Sources. Circles represent the health at bores sampled for baseline and 2023 with the change in ecosystem health represented across the entire water source.

The effect of salinity levels on groundwater microbial communities

The groundwater health index data obtained in the southern basin catchments was examined to identify the influence of salinity on groundwater microbial communities in agricultural landscapes (Nelson et al. 2024). The study results indicated widespread groundwater salinisation within the southern NSW Murray Darling Basin, with electrical conductivity ranging from 63 to 51,257 µS cm^{-1}. The highest electrical conductivity values were recorded in the Murray catchment. However, mean electrical conductivity values did not differ significantly among catchments (P > 0.05).

The composition of microbial communities differed significantly between sites with low (<3000 µS cm^{-1}) and high (>3000 µS cm^{-1}) electrical conductivity. Microbial activity, richness and abundances were all greater at low than high-electrical conductivity sites (Figure 21).

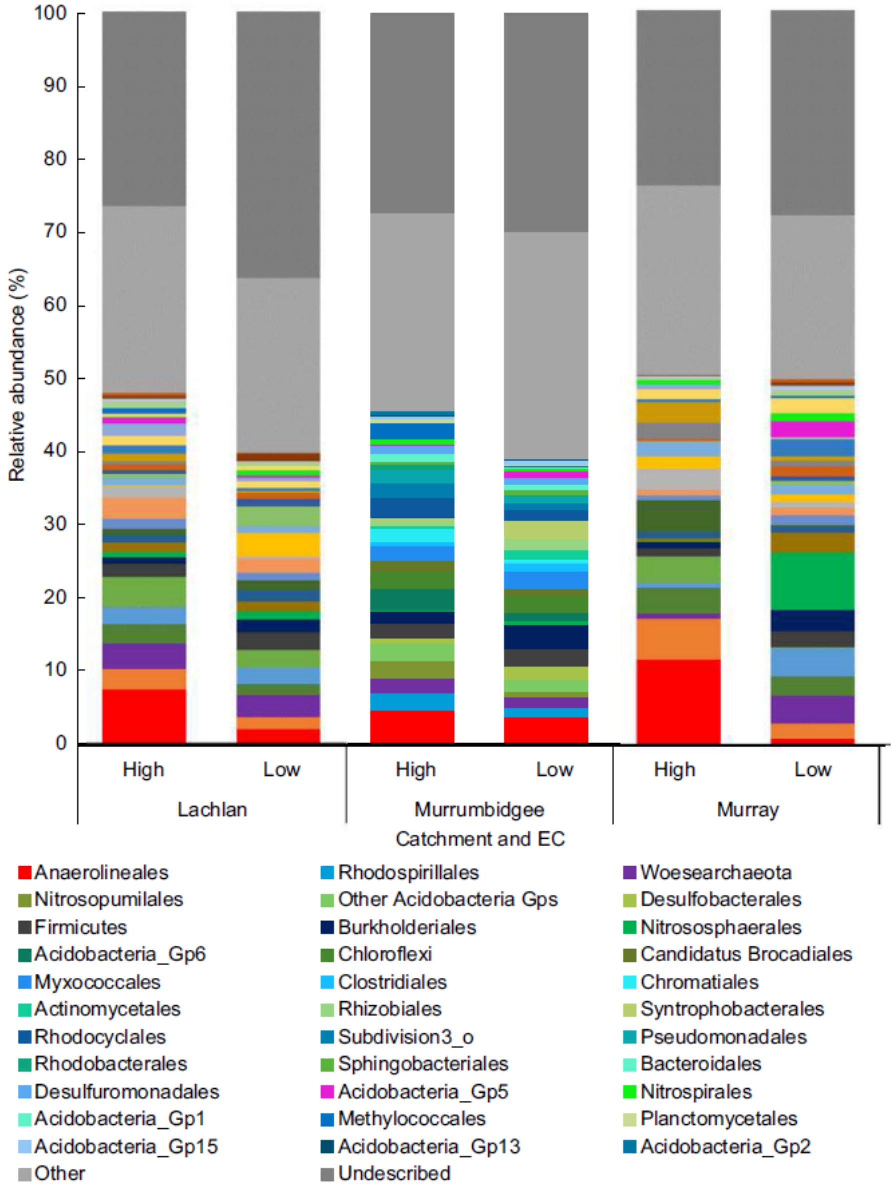

Figure 21. Graphical comparison of microbial relative abundance per catchment and EC group (low or high). 'Other' refers to orders that each contribute <2% of the total abundance. 'Undescribed' refers to the proportion of prokaryotes that were taxonomically unassigned at order level (From Nelson et al 2024).

Conclusions

The project has established a useful water quality database for 90 sites across the basin. The database can be used for future assessments, meeting a variety of management and community applications. This project is also the first comprehensive analysis of groundwater biota and systematic use of eDNA in aquifers across NSW. This is particularly important for future inclusion to the National GDE atlas and to provide data and information to supplement the assessment work undertaken by the Commonwealth Department of Climate Change, Energy, the Environment and Water and the Independent Expert Scientific Committee for coal-seam gas and mining in Australia. This work also supplements and uses the methods published under the Metagenomic research project for the Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development.

Basin Plan reporting conclusions

Declines in groundwater ecosystem health across the NSW Murray Darling Basin was likely due to influences of La Niña weather events. During floods, some bores were completely inundated which likely changed the water chemistry and ecological responses experienced under normal conditions. The water levels within some bores showed evidenced of recharge (DPE 2023).

Consecutive La Niña events were experienced during the 2022 to 2024 reporting period across NSW, resulting in record rainfall and inundation events across the Murray Darling Basin. Due to these unprecedented events, it is unknown if environmental water contributed to changes in groundwater ecosystem health.

Groundwater extraction especially over 2022 and 2023 water years was low due to the climatic conditions. Therefore, the outcomes were not likely influenced by the current Sustainable Diversion Limits set by the Basin Plan. These limits are likely to have more influence during drier periods.

Next steps

This project will be continued into the next reporting period and extended into the Darling Alluvium. To determine if the groundwater ecosystem health changed from baseline conditions established prior to 2020.

Impacts of groundwater extraction on groundwater dependent ecosystems

Project Team

Grant Hose (Macquarie University), Kathryn Korbel (Macquarie University), Tess Nelson (Macquarie University), Loren Pollitt (Macquarie University), Kitty McKnight (Macquarie University), Jodie Dabovic, Martin Anderson (University of NSW), Helen Rutlidge (University of NSW), Mahmood Sadat-Noori (Southern Cross University), Quanyi Ye (University of NSW).

Project collaborators

Macquarie University, University of NSW.

Project aims

Researchers from Macquarie University, University of NSW and the department undertook a month-long groundwater pump test in September 2022 in a shallow alluvial aquifer at Maules Creek, near Narrabri, NSW in the Namoi Alluvium Groundwater Sharing Plan Area.

This is part of an Australian Research Council and NSW Environmental Trust funded project. Our aim was to determine the impact of prolonged groundwater pumping on groundwater chemistry and the ecology.

The specific aim(s) of the project are provided below.

Key project questions

- Does prolonged groundwater pumping of shallow alluvial aquifers have an impact on groundwater chemistry and ecology (stygofauna, microbes and groundwater dependent vegetation) in water sharing plan areas?

Link to water management activities

- Will current drawdown rates within the alluvial aquifers in water sharing plans have an impact on groundwater chemistry and groundwater dependent ecosystems?

Methods

The study area was located at Elfin Crossing on Maules Creek (Figure 22) as the site has a network of monitoring bores running perpendicular to the creek, accessing the shallow alluvial aquifer system. The existing infrastructure of bores was suitable to evaluate the impacts of drawdown both spatially and temporally. The alluvial aquifer system at Elfin Crossing is known to contain an ecological community of stygofauna consisting of taxa typical of groundwater communities. These include crustaceans, tardigrades, flatworms, and other invertebrates that enable a comparison of how different taxonomic groups respond to drawdown (McKnight, 2024). The site is also surrounded by groundwater dependent vegetation species of river red gum and river oak.

Figure 22. Location of the Maules Creek site. Map Credit: Kitty McKnight (Macquarie University)

The extraction bore was set up with a high flow pump (pumped at approximately 22 L/s) and ran continuously for 28 days in September 2022. There was an expected maximum drawdown of around 7 m, tapering off to the creek level 40 m away from the extraction bore (Figure 23 and Figure 24). There are multiple monitoring wells within the zone of influence and beyond, which served as reference sites. Some bores are known to access water from the nearby Maules Creek, while others access regional groundwaters. We expected that over the course of the test, pumping would draw water from the nearby creek into the shallow aquifer.

Figure 23. Pump test site at Elfin Crossing, Maules Creek. Image credit: Tess Nelson (Macquarie University)

Projects undertaken during the pump test

1. What is the impact of prolonged pumping/drawdown on microbial communities & water quality?

Twelve bores (4 control, and 8 impacted- 2 of which will dry) plus river water, were sampled on 11 occasions during the pump test and 3 occasions post pump test to capture the recovery period of 3 months. Field parameters, water quality, eDNA samples were collected.

2. Can we use plant DNA as a line of evidence for a change in water source?

This project sampled 12 bores (4 control, and 8 impacted- 2 of which will dry) plus river water for plant materials using eDNA. These plant materials could have been from trees located around the site and from aquatic plants in the river. Samples were filtered and frozen for DNA extraction. A vegetation survey was conducted to identify what plants were likely to be detected.

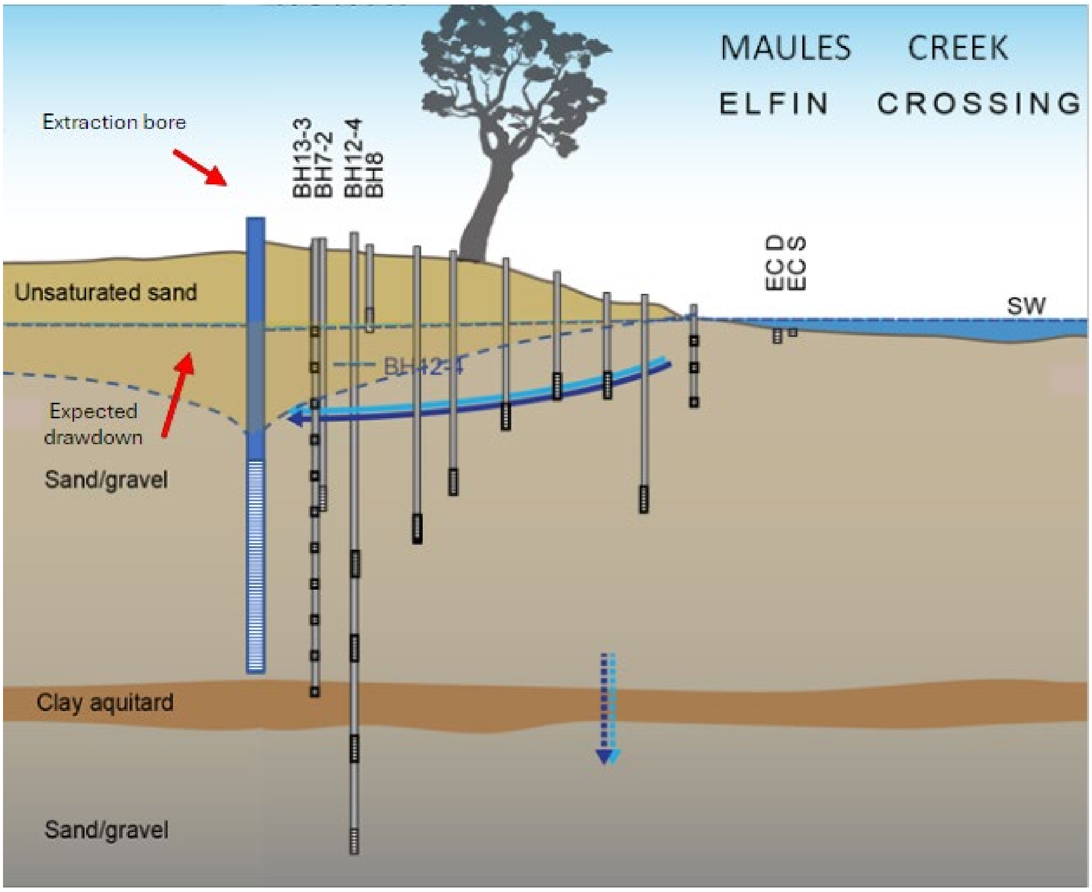

Figure 24 Conceptual model of effect of pumping generated for this project. Image Credit: Kath Korbel & Grant Hose (Macquarie University)

3. How do stygofauna communities respond to prolonged pumping & recovery?

The primary aim of this project (McKnight 2024) was to investigate the impacts of groundwater extraction on groundwater levels, chemistry, and biota. To investigate extraction impacts of groundwater bores, the nearby surface water was sampled before and after the groundwater extraction experiment, throughout a three-month recovery period. This recovery period was important in capturing how the system responded to the unexpected flood events that occurred during the study, though also added complexity to the groundwater extraction results.

The study was able to measure changes in groundwater levels and chemistry, and biotic communities, influenced by both the groundwater extraction and the flood events. Twelve bores (4 control, 8 impacted- 2 of which will dry) were sampled on 11 occasions during the pump test and 3 occasions during recovery. Stygofauna samples were collected, sieved and preserved in ethanol as follows:

- Day 0: all sites were pre-sampled collecting a 20 L purge sample and an additional 70L post purge sampled (90 L total)
- Days 2 – 30: 10-20 L purge sample at all sites were collected
- Day 30: a 20 L purge sample and an additional 70 L post purge sample (total 90 L) were collected at all sites
- Days 60, 90 and 120 (recovery sampling): 20 L purge sample and 70 L post purge samples were collected

- Extraction bore sampled every 24 hours using net

4. What are the impacts of prolonged pumping on microbial biofilm communities?

This project used 3 control and 4 impacted bores (7 bores total on 9 sampling occasions) to collect 63 bags of sediments in the pump test area. Sediment bags were prepared and placed into the bores approximately 1 month prior to the start of the pump test to enable microbial colonisation to occur. Water quality sampling and removal of one sediment bag occurred on days 0, 7, 14, 21, 28, 60 (1 month post pump test), 90 (2 months post pump test) and 120 (3 months post pump test). Each bag was removed using aseptic techniques (sterile gloves, cutting implement and labelled storage containers) and frozen immediately to stop further microbial changes. DNA was then extracted from each sediment bag for DNA sequencing and analysis.

5. Does drawdown cause changes in chemistry, carbon inputs and surface-groundwater connectivity?

Twelve bores (4 control, and 8 impacted- 2 of which will dry), plus pumping bore and river water were sampled throughout the pumping test (11 sampling occasions) and then 3 recovery sampling events. Field parameters, alkalinity, nutrients, carbon (dissolved and total), metals, redox, isotopes, tracers to monitor surface water influxes were sampled.

Results

Two hundred water quality, eDNA, and stygofauna samples were collected over the study period. Analysis of these samples is ongoing for projects 1, 2, 4 and 5 and no results are yet available. Once the analysis is completed, logger groundwater level data and multiple vegetation condition field surveys will provide information for drawdown impacts, recharge and recovery events and surface/groundwater connectivity information.

The complete results for Project 3 (How do stygofauna communities respond to prolonged pumping & recovery?) are available in McKnight (2024). The results presented in this thesis indicated that ecological communities within groundwaters responded to both drawdown and recharge events, and that these responses may have consequences for ecosystem food webs and functions. This project indicates that water level declines, due to extraction, can alter water quality and biological communities within groundwater. Some stygofauna crustacean species failed to recover during the sampling period following the extraction, including the larger Amphipoda and Syncarida, and smaller Ostracoda. This has been the first study investigating the impacts of extraction on groundwater biota and water quality in-situ in an alluvial aquifer.

Over the 28-day sampling period for the pumping bore (BH14), worms from the Nematoda phylum were the most abundant taxa recorded (>1500 individuals) followed by Harpacticoida (134) which are copepods. The least abundant taxa were Tardigrada, commonly known as water bears and Amphipoda, a type of crustacean of which only a single organism of each was found. Total abundance was highest on the 5th day of pumping (>410), although this was largely due to Nematoda abundance (>400). The highest richness observed over the sampling period was 8 taxa (recorded on the 6th, 7th, and 13th day of pumping). Total abundance and richness generally decreased over time. The total abundance of Crustacea was highest on the 1st day of pumping and followed the same pattern of decreasing abundance with increasing pump duration. No taxa were found at the end of the pump test, suggesting that continuous long-term ground water extraction is likely to cause local declines in stygofauna populations.

Conclusions

This project is ongoing so no final conclusions can be made at this stage. Some conclusions for stygofauna community's responses to prolonged pumping & recovery are available in McKnight (2024).

Next steps

This project will progress with a final PhD thesis and publications in peer reviewed journals. These will address the question 'does prolonged groundwater pumping of shallow alluvial aquifers have an impact on groundwater chemistry and ecology (stygofauna, microbes and groundwater dependent vegetation) in water sharing plan areas?' This work will help to answer the water management question 'will current drawdown rates within the alluvial aquifers in water sharing plans have an impact on groundwater chemistry and groundwater dependent ecosystems?'.

Establishing the links between groundwater ecosystem health, and groundwater dependent vegetation and wetland health

Project Team

Grant Hose (Macquarie University), Kathryn Korbel (Macquarie University), Jodie Dabovic.

Project collaborators

Macquarie University

Project aims

This project aims to provide a long-term dataset (7-8 years) to capture temporal changes in climate under La Niña through to the transition to El Niño. By establishing the linkages between groundwater ecosystem health and terrestrial/aquatic groundwater dependent ecosystem health at shorter temporal timescales, we can detect impacts on vegetation/wetland health at the start of the impact instead of after the decline in health has occurred. This in turn will better support adaptive management.

This study will apply the groundwater health index (Korbel & Hose 2011, 2017) as a measure of groundwater ecosystem health, tree canopy health (Bowen 2019), plant metabolic stressor indicators and wetland health indicators such as macroinvertebrates, vegetation health, water quality.

The specific aim(s) of the project are provided below.

Key project questions

- Can the health of groundwater dependent vegetation be linked to groundwater ecosystem health in the water sharing plan areas?

Link to water management activities

- Do current groundwater access rules in water sharing plans adequately protect the health of groundwater dependent ecosystems

Methods

The 2022 to 2024 stage of the project piloted the use of plant metabolic stressor indicators and collected field data. Field data was collected for groundwater ecosystem health and vegetation canopy data and plant material for water stress and isotopes for water source use. A pilot project for using carbohydrates (sugars) from leaves as an indicator of water stress consisted of 2 phases:

1. the development of methods to extract and analyse soluble and insoluble sugars as a measure for water stress
2. glasshouse experiment to investigate changes in sugar concentrations under varying water conditions.

Thirty-six sample sites were selected across the Namoi, Gwydir and Macquarie catchments based upon the results of the groundwater ecosystem health index program sampling sites with status from poor to good. The vegetation communities were assessed for health at each of these sites, The sites chosen were dependent on a monitoring bore being present.

At each site data, plant matter and groundwater samples were collected for analysis of:

- tree health which included tree stand condition, thermal and hemispherical photos, plant metabolic stressor samples, isotope analysis, eDNA analysis
- stygofauna community analysis
- microbial community analysis (using eDNA, total cell counts, cellulose degradation)
- water quality analysis
- stable isotopes
- recording of groundwater levels.

Sample analysis was undertaken for eDNA, stygofauna counts and ID, water quality, isotope, plant metabolic stressors. Data analysis has yet to be undertaken but will include univariate and multivariate statistical analysis to compare and explore linkages between each of the variables collected within and between catchments.

Results

This project will provide long term trend analysis as well as novel methods to monitor groundwater dependent vegetation condition/health and groundwater ecosystem health. So far field surveys were undertaken at 24 bores across the Macquarie and Namoi catchments biannually and at an additional 90 bores across the NSW Murray Darlin Basin as part of other ongoing projects. These field surveys collected samples for eDNA, stygofauna, water quality, isotopes and plant metabolic stressors. Vegetation condition data was collected for tree stand condition, along with canopy temperature at all these bores where vegetation was present for up to 6 trees per site.

Conclusions

The pilot study has only recently commenced, and results or conclusions are not available to be presented in this report.

Next steps

This project will progress with publications in peer reviewed journals. These will address the question 'can the health of groundwater dependent vegetation be linked to groundwater ecosystem health in the water sharing plan areas?'. This will help address the water management question 'do current groundwater access rules in water sharing plans adequately protect the health of groundwater dependent ecosystems?'.

Image credit: Jodie Dabovic NSW DCCEEW

Determining groundwater use by vegetation using environmental DNA

Project Team

Loren Pollitt (Macquarie University), Grant Hose (Macquarie University), Kathryn Korbel (MQU Macquarie University), Jodie Dabovic.

Project collaborators

Macquarie University.

Project aims

This project aims to develop and validate a cost-effective method to detect tree groundwater use using eDNA. This project will develop a method for collecting and analysing tree DNA in groundwater and determine the viability of using eDNA as a measure of tree groundwater use. This project is primarily being undertaken by a PhD student.

The specific aim(s) of the project are provided below.

Key project questions

- Can the eDNA of groundwater dependent vegetation be detected in groundwater in NSW water sharing plan areas?
- Can eDNA of groundwater dependent vegetation be used as a cost-effective method to determine groundwater use?

Link to water management activities

- Can eDNA be used to confirm the groundwater dependency of high priority groundwater dependent vegetation in water sharing plans?

Methods

The field component comprised of 2 tasks. Task 1 was to collect samples from trees within the groundwater flow path, outside the groundwater flow path and from bores with no trees present, with the aim of determining if tree DNA could be detected as environmental DNA from groundwater. Task 2 was a field verification component to verify the detection of eDNA in groundwater using sites with trees and no trees. Field sampling required the purging of bores and collecting groundwater samples using aseptic techniques. Groundwater samples were filtered using 0.2 μm filters and DNA extracted from the filters using the methods of Korbel et al (2018). DNA extracted from the groundwater will be analysed using primers specifically developed for the target Eucalypt species. Stable isotopes were also collected from the groundwater, surface water, soil moisture and tree xylem water to confirm water source use.

Results

The project is ongoing as part of a PhD thesis and thus no results can be presented in this document. The PhD is expected to be completed by June 30, 2025. However, this project also provides information and data for tree environmental DNA and water use at numerous sites within the Gwydir, Namoi, Macquarie and Murrumbidgee catchments which are novel data sets in NSW.

Conclusions

This project is ongoing, so no conclusions are not available to be presented in this report.

Next steps

This project will progress with finalisation of PhD thesis and publications in peer review journals. These will address the questions 'can the eDNA of groundwater dependent vegetation be detected in groundwater in NSW water sharing plan areas? and 'can eDNA of groundwater dependent vegetation be used as a cost-effective method to determine groundwater use?' This will help answer the water management question 'can eDNA be used to confirm the groundwater dependency of high priority groundwater dependent vegetation in water sharing plans?'

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