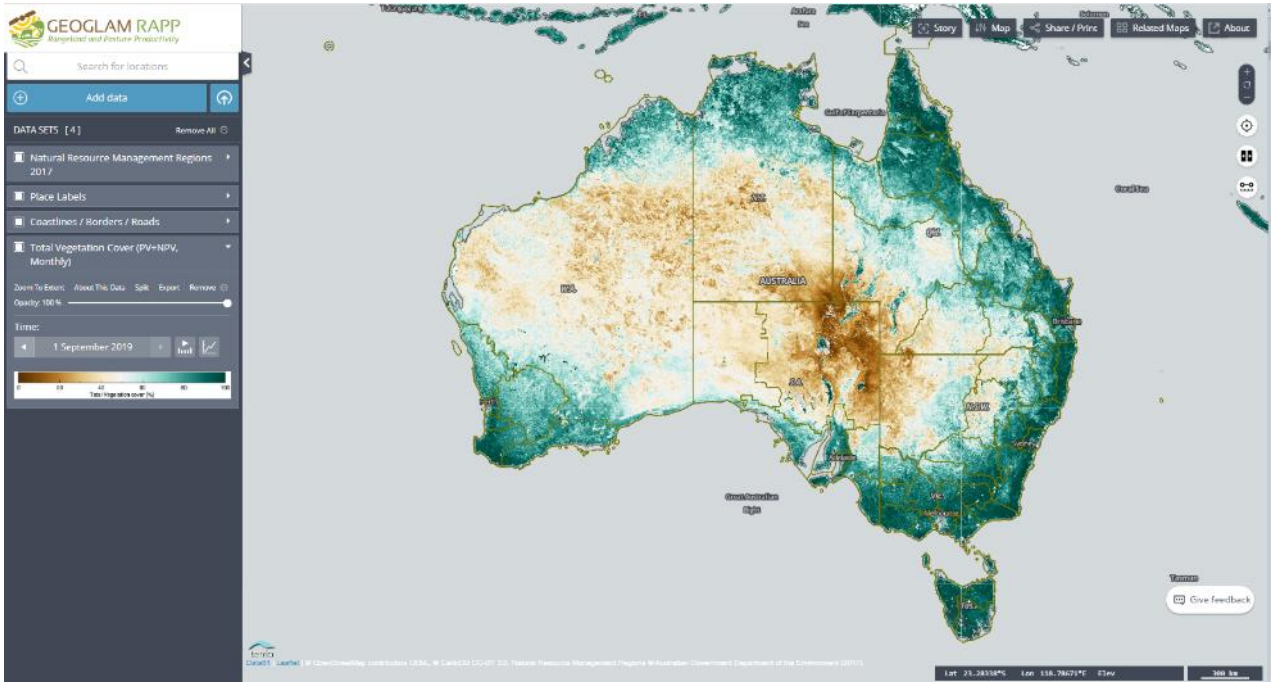
DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Setting targets for National Landcare Program monitoring and reporting vegetation cover for Australia



Cover photo: Total vegetation cover map screenshot from RAPP Map tool for September 2019.

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1. Executive summary

1.1 Overview

The Regional Land Partnerships (RLP) component of the National Landcare Program (NLP) is a 5-year $450 million investment of the Australian Government. One of its priorities is to improve soil condition to benefit our environment, farms and communities in partnership with land managers.

The key challenge is to help land managers make changes and report the outcomes of the program.

This project has delivered:

- a method to monitor the risk of soil erosion by wind and water, anywhere in Australia, by anyone with an internet connection
- accessible information on vegetation cover to inform decisions about tillage and stocking rates, which are critical to achieving NLP outcomes
- guidance on setting and reporting against vegetation cover targets as part of the RLP Evaluation Plan for regional natural resource managers and the Australian Government Department of Agriculture
- a series of workshops for regional natural resource staff to apply and improve the methods and tools.

The method described in this report has been developed with the end users. The method uses vegetation cover detected using satellite imagery for frequent national and regional reporting. Vegetation cover protects the soil, making it a good indicator of the risk of soil erosion by wind and water. In addition to reducing soil erosion, vegetation cover increases water infiltration into soil, reduces evaporation, drives soil carbon sequestration, maintains or improves soil condition, and enhances biodiversity and agricultural production.

Monthly national vegetation cover data with a spatial resolution of 500 metres is delivered by CSIRO with support from the Australian Government Department of Agriculture, the NLP and New South Wales Department of Planning, Industry and Environment – Environment, Energy and Science (DPIE–EES) using the Rangelands and Pasture Productivity (RAPP) Map online tool. This data complements seasonal vegetation cover data at 30-metre resolution delivered every 3 months.

The participation and contribution from regional natural resource managers was critical to the project's outcomes. Natural resource managers work directly with farmers and pastoralists to implement the RLP component of the NLP.

This project has focused on NLP outcomes, but the concepts and tools have wider application. For example, they could be used to:

- prioritise projects and on-ground works to sustain soil and vegetation condition
- monitor and report on other outcomes linked to vegetation cover, such as the protection of cultural and archaeological sites
- predict drought by using vegetation cover trends
- assess the impact of drought policy, such as whether recipients of assistance can demonstrate improved total vegetation cover over time.

This project was a collaboration between DPIE–EES, the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), CSIRO and the Australian Government Department of Agriculture.

1.2 Recommendations

This project involved wide consultation with regional natural resource management organisations and the Australian Government Department of Agriculture staff. Feedback from workshops and meetings revealed that users need more targeted support. The results of the project and thinking around this are also relevant to other programs.

To realise and value-add to the significant investment made to date, the project team recommends:

1. Provide ongoing support for users

   Feedback from workshop participants highlighted the value of ongoing user support for setting, monitoring and reporting vegetation cover targets. Support required includes continued contact, targeted training, and published example use cases.
2. Fill the gaps

   Research and development can fill missing links to improve monitoring of vegetation cover and soil condition including:
   - finer resolution vegetation cover data to improve farm-scale use
   - a national method to determine threshold cover levels required to protect the soil from erosion for different rainfall, soil types, slopes and landscapes
   - mapping of total vegetation cover to show if cover is low due to climate or land management
   - warning systems to predict when vegetation cover will drop below target levels to enable time to adapt land management practices to minimise soil loss
   - use of vegetation cover data to inform biomass reports for herd management decisions, natural capital accounting, and soil health trends.
3. Maintain and improve the online tool

   Users want assurance that the RAPP Map online tool is supported for at least the duration of the NLP. This tool enables users to set, monitor and report on vegetation cover targets at the regional and national level. Funding to CSIRO will enable maintenance and priority improvements to the RAPP Map tool.

A fuller description of these recommendations is provided in Section 6.2.

2. Introduction

2.1 Project scope

Vegetation cover has been selected as an indicator of soil condition for the National Landcare Program Regional Land Partnerships (NLP RLP) program. This project aimed to develop methods for setting and reporting on levels of vegetation cover.

The Australian Government invests in improved soil management by encouraging land management practices that:

- address soil acidification in areas where it has been increased by past land management practices
- decrease erosion
- increase soil carbon.

Vegetation cover is a major driver of soil condition because it reduces soil erosion and evaporation, and increases soil water infiltration and soil carbon sequestration. This enhances agricultural production by maintaining or improving soil to support vegetation for food and fibre production.

Farmers and pastoralists actively manage vegetation cover on a daily basis. Decisions about tillage and stocking rates all impact vegetation cover. Making information about vegetation cover available to natural resource management (NRM) organisations that directly engage with farmers and pastoralists on how to access and use the information is critical to achieving NLP outcomes.

The second phase of the Australian Government National Landcare Program (NLP) began in 2018–19. It continues on from the 2014–15 to 2017–18 phase one program and "is a key part of the Australian Government's commitment to protect and conserve Australia's water, soil, plants, animals and ecosystems, as well as support the productive and sustainable use of these valuable resources" (Australian Government, 2017a). The second phase aims to show the return on investment in project areas (Australian Government, 2017c). The Australian National Audit Office proposes to review early implementation of the Regional Land Partnerships Program in 2019–20 (Australian National Audit Office, 2019). It is anticipated that funding for the adoption of improved management practices will result in improved vegetation cover levels. It is also assumed that, over time, successful investments will demonstrate improvements in regional soil condition beyond the project boundaries. Therefore, monitoring and reporting at the site of investment and the regional scale should help answer the question: Is the program having an impact on the condition of the soil resource?

In this report we use total vegetation cover (TVC), which is the sum of green or photosynthetic vegetation (PV) and non-green or non-photosynthetic vegetation (NPV) cover. TVC is derived from fractional cover products estimated from satellite data. Fractional cover comprises three cover types: PV, NPV and bare ground (BG) (Guerschman et al. 2015).

TVC includes ground cover. Muir et al. (2011) define ground cover as: "… non-woody vegetation (forbs, grasses and herbs), litter, cryptogamic crusts and rock in contact with the soil surface." As noted by Guerschman et al. (2018): "In treeless vegetation types such as grasslands, TVC and ground cover are equivalent. As a rule of thumb, the TVC can be assumed to be a good estimator of ground cover when tree cover is lower than 20 percent."

Reporting on progress towards intended natural resource management outcomes has previously been limited by the absence of consistently validated data, lack of agreement on performance indicators, and quality and measurability of targets in regional plans (Auditor-

General 2008). The DustWatch project team, part of the New South Wales (NSW) Department of Planning, Industry and Environment – Environment, Energy and Science (DPIE–EES), has been working with NRM groups for over a decade and has observed that most groups find setting targets difficult. Government and NRM groups in Queensland, particularly along the Great Barrier Reef, lead the way in vegetation cover target setting, reporting and improvement (Australian Government and Queensland Government, 2016). Some of the other states lack access to required resources or expertise.

Capacity building was identified by Park et al. (2013) and Pannell et al. (2013) as necessary for good target setting. Pannell et al. (2013) outlined several factors that support evaluation of environmental reporting, these include:

- simplicity
- training and support of users
- trusting relationships with users
- transparency
- flexibility
- compatibility with the needs and contexts of users
- supportive institutional arrangements
- the use of a theoretically correct metric.

Fractional cover (defined in Guerschman et al. 2015) is identified by the NLP and the Australian Government Department of Agriculture in the annual Portfolio Budget Statements as a key performance measure for monitoring and reporting on the status of the natural resource base (Department of Agriculture and Water Resources, 2019). This project focused on gaining the insights and needs as well as building the capacity of natural resource managers and Australian Government staff using fractional cover for reporting in the RLP component of the second phase of NLP.

Extensive consultation was held with those who will set vegetation cover targets, i.e., the NLP management units, and those who will evaluate the NLP outcomes, i.e., the Australian Government Department of Agriculture. For this report we substitute NLP management units with NRM regions to be consistent with the first phase of NLP and the fact that most regions identify as NRM regions.

We collaborated with three ‘test’ NRM organisations to develop a workshop. We then held a series of eight, 5-hour workshops and meetings with 44 NLP management units plus staff from nine other organisations, including the Australian Government Department of Agriculture. Two additional meetings were held with the Australian Government Department of Agriculture to gain further insights. From these workshops and meetings, we gained understanding, shared proposals and information, and discussed views on the needs and approaches to target setting and reporting. Details of the workshops including attendees and their feedback on tools and reports are included in Appendix 1.

The main aim of the workshops and meetings was to develop a method that would enable users to set their own targets (from site to national scale) and use the results to report on the soil condition both at investment sites and at the regional and national scale.

To undertake national, regional or site reporting, we believe that four things are required:

1. access to data (current and baseline or reference)
2. targets that are transparent, logical and appropriate
3. a method for reporting
4. ongoing support and evaluation.

To meet the first two aims, a free tool, the Rangeland and Pasture Productivity Map (RAPP Map), has been developed by CSIRO and DPIE–EES over the last 3 years. With funding from the Australian Government Department of Agriculture, the tool provides monthly time series data at 500-metre resolution of fractional cover. The RAPP Map complements other free tools like VegMachine (Beutel et al. 2019) and subscription services like FarmMap4D Spatial Hub, which deliver higher spatial resolution (30 metre) and lower temporal resolution (3-monthly seasonal compilations) national fractional cover data and tools to end users.

To increase the capacity to report on the effectiveness of NRM nationally, regionally and at investment sites, two projects were established in 2018 by the Australian Government Department of Agriculture:

- ground cover training and target setting (GTTS) – managed by DPIE–EES to train users to set targets using tools that use fractional ground cover data (this project)
- improving the RAPP Map Monitoring Tool for Australia – managed by CSIRO to improve the RAPP Map tool for users based on feedback from the GTTS project.

The GTTS project aimed to increase NRM regional staff, farming and pastoral communities' capacity to:

- understand the role of ground cover in landscape protection
- establish baseline ground cover levels from remote sensing data
- use the baseline data to establish locally relevant targets
- use freely available ground cover data to monitor and report progress against outcomes in the second phase of the NLP Evaluation Plan.

Several issues were also identified in the GTTS project that need further work, such as:

- improving the quality of ancillary input data, e.g. land use
- target setting for non-agricultural land
- improving functionality of other existing tools beyond the RAPP Map
- reporting on the capacity of NRM organisations to implement projects and guidelines to improve target setting
- ensuring that fractional cover data and satellite data from new sensors continues to be processed into fractional cover and used.

2.2 Ground cover as an indicator of soil health

Ground cover is a component of total vegetation cover. Ground cover has been chosen as an natural resource indicator (Leys et al. 2009) as it:

- is a strong driver of soil erosion with well-established threshold cover levels for wind (Leys 1999) and water erosion (Lang 1979)
- is closely linked to carbon storage and emission (Chappell et al. 2019)
- increases soil water infiltration and soil water holding capacity, thereby storing water in soil and reducing runoff
- is loosely linked to biodiversity, with bare areas having low diversity (McCosker et al. 2009)
- improves agricultural productivity, with production lower when cover is low (Larney et al. 1995).

The thresholds to control wind (Leys 1999) and water erosion (Lang 1979) are 50% and 70% respectively. These thresholds were developed from wind tunnel and runoff plots with areas of 4 square metres and 100 square metres respectively. Thus, they represent cover protection levels for small areas.

Ground cover stabilises the land and this provides many ecosystem services like clean air and water (Cork et al. 2012). In a changing climate maintaining ground cover will be more difficult (Leys et al. 2009).

In this study we used satellite-derived vegetation products. Trevithick et al. (2014) provides a description of the three vertical vegetation structural strata that contribute to the satellite estimates of cover:

(i) the ground layer, which includes non-woody green and non-green vegetation and woody and non-woody litter

(ii) the midstorey woody vegetation stratum, which includes green and non-green vegetation less than 2 metres in height

(iii) the overstorey vegetation stratum, which includes green and non-green vegetation greater than 2 metres in height.

Woody cover is persistent in the landscape. It changes at a slower rate than herbaceous plants (e.g. forbs) and grasses that retain higher cover in dry periods; i.e., trees and shrubs provide ground cover even during extended dry periods while grasses and forbs decline at a faster rate. Figure 1 represents a conceptual model of how grassland cover changes with land management over time after rainfall ceases (or is very much below average for years).

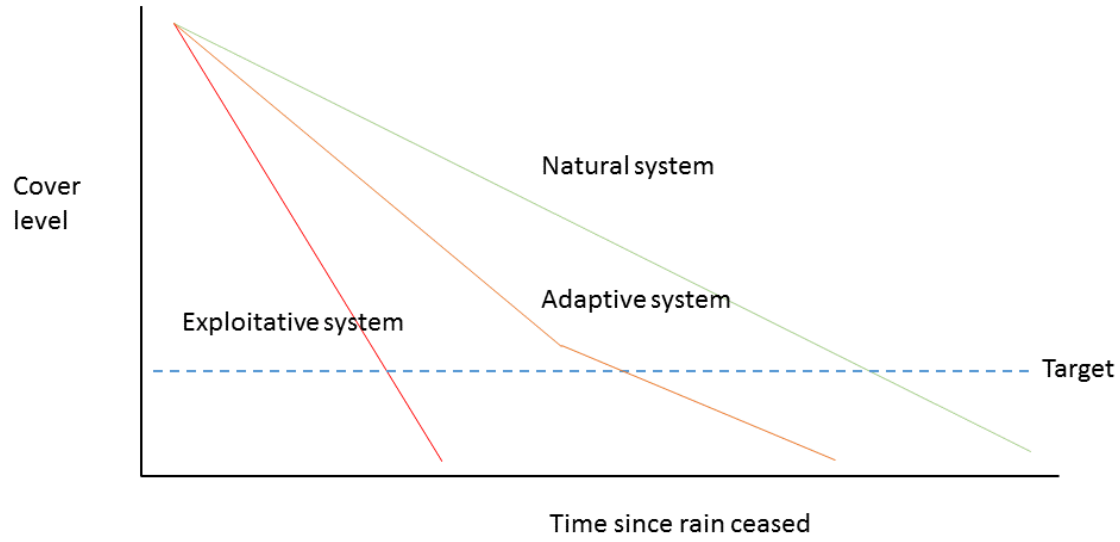

Figure 1 Conceptual model of vegetation cover change with management since last effective rainfall for grasslands.

Note: The blue dotted line indicates the ground cover target or desired level of ground cover, the green line represents the natural 'no domestic stock' site, the orange line represents the adaptive stocking system where domestic stock are removed before the cover target is reached, and the red line represents an exploitive system where stock numbers are kept until stock lose condition.

The horizontal 'target' line in Figure 1 represents the level of cover desired. Conceptually, grasses and forbs decay and are grazed by native and pest animals and the cover slowly deceases until it drops below a cover target (green line denoted 'natural system'). On agricultural land, cover falls more rapidly than the natural system because grasses and forbs are consumed by domestic stock and pest animals. Conceptually there are two curves: 1) the adaptive grazing system (orange line), where grazing occurs until the cover approaches the cover target. At this point stocking rates are adjusted, and the rate of cover decline slows, but continues to fall. The cover may drop below the cover target if it does not rain, but management actions are taken to conserve cover. 2) the exploitative system (red line) where stocking rates are not adjusted. Destocking only occurs when the stock lose condition, rather than when cover is getting low or below the target.

What we can draw from the conceptual model is that the climate alone can drive ground cover below the cover target; however, agricultural practices accelerate the cover decline at different rates. The aim of NLP is to encourage land management practices that maintain ground cover to minimise soil erosion losses.

One of the advantages of maintaining vegetation cover for longer is that it increases the chance of rainfall infiltrating the soil surface. Figure 2 shows an example of the effect of vegetation cover on a rangeland paddock after a thunder storm. The foreground has high cover and no water sitting on soil because more plants make more root channels and increase soil carbon, and these attributes increase infiltration. The background has low cover with ponded water on the surface.

Figure 2 Total vegetation cover impact on soil water infiltration after a rain storm. The foreground shows no water on the surface of a stock reserve with high ground cover. The background shows rainfall sitting on the surface of a grazed paddock with low ground cover.

3. Target setting

3.1 Background

Target setting is not simple. During the 2000s, there was criticism that regional plans lacked clear measurable targets and that return for public investment in improving natural resources management could not be demonstrated (Auditor General, 2008). Attempts were made to improve target setting and measurement of outcomes (Barson et al. 2012) in the Caring for Our Country Business Plans (Australian Government, 2008, Australian Government, 2010); however, reporting was still inconsistent and not undertaken by all natural resource management (NRM) organisations.

Park et al. (2013) evaluated "the quality of resource condition targets established in catchment strategies in Victoria and NSW from 1997 to the present by assessing the degree to which targets are specific, measurable and timebound". They concluded that "… governments need to insist on sound target setting (as part of a strong planning and decision-making process) as a prerequisite for public environmental funding. Resource condition targets meeting the criteria of being SMART [specific, measurable, attainable, relevant and time-bound] should be a minimum requirement." They identified three reasons for poor target setting:

1. a lack of appropriate standards and guidelines from governments to enable high-quality target setting
2. a lack of realism about the budgetary and technical feasibility of ambitious environmental targets amongst those involved in natural resource management
3. a lack of adequate focus on outcomes by natural resource management groups and governments.

Following the insights of Park et al. (2013), we developed a method for setting ground cover targets that:

- incorporates and learns from existing targets such as the Reef Water Quality Protection plan (Queensland Government, 2018)
- was co-developed with agencies that manage National Landcare Program Regional Land Partnerships (NLP RLP) projects, are interested in NRM, and are actively reporting against NRM targets
- is accessible to users with a range of skills, experience, and resources
- produces realistic and achievable targets
- relates directly to outcome 5 in the RLP Evaluation Plan "the condition of the soil, biodiversity and vegetation is improved".
- uses the metric specified in the RLP Evaluation Plan, i.e., the trend in fractional cover as derived from satellite imagery
- can be applied to data from different sources
- scales from point to continental
- is location specific, thus considering the soils, climate and management of the area.

Regional ground cover targets can be set and reported against using the free online Rangelands and Pasture Productivity (RAPP) Map tool. The RAPP Map tool removes technical impediments by making ground cover data, target setting and reporting available to a wider user group. These methods also work with other fractional cover data and tools like VegMachine.

The RAPP Map tool:

- is freely accessible
- does not require propriety software
- makes fractional cover data available to view, explore, compare and download
- produces derived data and time series, thus removing the need for the user to complete complex computations
- creates monthly reports and data files for NRM regions and local government areas (LGAs) for download and viewing
- enables the user to add their own contextual data.

For more information about the RAPP Map tool see Section 5.

3.2 Types of target

Natural resource management plans feature three broad types of target (Park et al. 2013):

1. Aspirational – long-term goal or vision for the desired condition of natural resources. For example, “the condition of the soil, biodiversity and vegetation is improved”
2. Resource condition – this relates to the condition of the natural resource in the medium term. For example, increase the native vegetation cover to 30% of the catchment by 2030, as cited in Park et al. (2013)
3. Management action – building blocks for resource condition targets; short-term management or community capacity targets. For example, by 2016, regenerate 550 kilometres of degraded native riparian vegetation, as cited in Park et al. (2013).

3.2.1 SMART targets

SMART resource condition targets need to be:

- Specific – is the target the right type and clearly defined?
- Measurable – what target is being measured and have the right metrics been recorded?
- Achievable – is the target practical, is it possible to achieve in the time available, and is the project sufficiently resourced to measure the indicators?
- Realistic – is the target within the time scale and bounds of the expected outcomes?
- Time-bound – is there a clear end-point in time? This must be specified. For example, the target needs to be met by 2030 (Park et al. 2013), and data needs to be available for the time period and spatial scale so that reporting can occur at the required times.

3.2.2 Outcome and improvement targets

Resource condition targets can relate to an:

1. Outcome – achieving an environmental threshold or objective.
2. Improvement – change from a baseline or control.

Outcome target

Outcome targets may be more closely linked to aspirational targets but may not be achievable with limited time or resources. For example:

- To reduce wind erosion at Mildura, north-west Victoria, to negligible levels (equivalent to less than 60 hours per year of blowing dust) requires more than 85% of the area within

25 kilometres of Mildura to have more than 50% total vegetation cover during all wind events (Leys et al. 2018).

- To reduce deaths caused by fine-particle emissions in large populations, the National Environmental Protection (Ambient Air Quality) Measure, set a goal that the maximum daily average concentration of particles 2.5 micrometres and smaller is below 20 micrograms per cubic metre of air by 2025.

Improvement target

Improvement targets aim to do better than before. An improvement target may not stop all the soil erosion or achieve a specified ecological or agricultural production threshold, but it aims to reduce erosion below previous levels. Improvement targets may allow assessment of progress towards an outcome.

In the workshops (see Section 2.1) we identified two ways of assessing improvement:

- improvement from baseline
- improvement from control.

3.3 Using appropriate metrics

Understanding the metrics for targets is critical. When choosing appropriate metrics for reporting it is important to consider the size of the reporting area, the variation over space and time of the vegetation cover and the impact of averaging or summarising.

Terms used to set and report against vegetation cover targets include:

- Average or mean – regional or temporal averages are often used to summarise total vegetation cover (TVC). Averages can be useful for small areas. However, averages can be misleading and hide variation especially over large areas or time spans. We suggest spatial TVC averages are appropriate for areas less than 1 square kilometre depending on the complexity of the landscape. Creating a target based on the average TVC (or average area protected) from a time series is also problematic because the target will fail half of the time. This is because the average has roughly half the values above and half below it. Averages can also be skewed by outlier values.
- Median – the value of the midpoint of the distribution.
- Cover threshold – the amount of TVC required to reduce erosion; a minimum of 50% for wind erosion and 70% for water (hillslope) erosion. Cover thresholds apply to a small area or pixel and not large areas because of the effect of averaging (see Section 3.4).
- Area protected – the area protected assesses the number (or proportion) of pixels within an area that are achieving a cover threshold. The soil is assumed to be protected from substantial erosion events in pixels where the TVC is equal to or above the cover threshold. Achieving these thresholds of TVC will reduce, but not entirely stop soil erosion.
- Baseline – data from a reference period (see Section 3.6).
- Treatment – area or location where different land management practices or interventions have been applied.
- Control – an area or location of a similar land type (land use, climate, vegetation type, soil type, available soil moisture) where the treatment or intervention has not been applied. Selection of a control site relies on availability of reliable data on land type. Selection of control areas would be greatly improved with nationally consistent land type mapping. Unfortunately, this is only available in some states and regions.

Reporting period – when the reporting will occur. For example, monthly and annually between 2019–2022.

To highlight the impact of the metric type, we provide two target examples which use averages:

1. minimum 70% late dry season ground cover on grazing lands by 2020
2. 50% ground cover for 80% of the time for wind erosion control.

For target 1, having an average of 70% ground cover on grazing lands over an NRM region of 424,000 square kilometres in coastal Queensland will not control the erosion. For example, in 2016 this target was met but 19% (80,560 square kilometres) of the region was still prone to soil erosion as these areas had less than 70% ground cover (Australian Government and Queensland Government, 2016). This target was originally developed using an average metric (Australian Government and Queensland Government, 2013), but the area achieving 70% ground cover has also been reported.

For target 2, applying a 50% average for the region, is likely to overlook substantial high-risk areas within the region. For example, the agricultural areas in the Desert Channels NRM region had an average total cover of 54% in August 2019, this left 37% or about 16 million hectares of the region with less than 50% cover at risk of wind erosion (Figure 3).

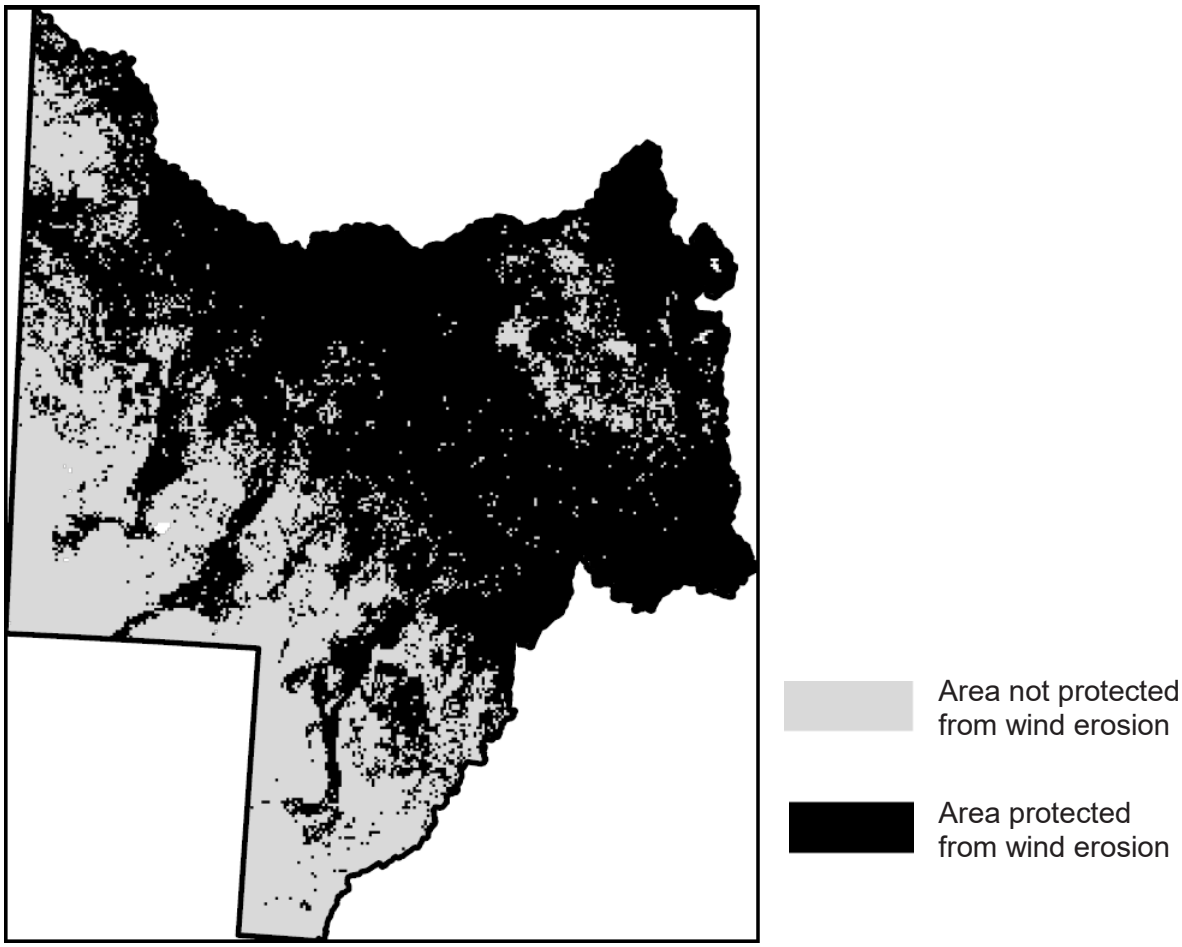

Figure 3 Wind erosion protected area map for the Desert Channels Natural Resource Management Region in Queensland.

Note: The Desert Channels Region is 449,070 square kilometres. Sixty-three per cent of this area is protected from wind erosion (black), and 37% is not protected (grey).

From these two target examples, it is apparent that for reporting on large areas, the area protected, i.e., the area achieving 50% for wind erosion and 70% for water erosion, is a better metric than average total cover.

A more detailed example of how metrics impact on reporting is given in Appendix 2.

3.4 Setting a cover threshold

A cover threshold is the amount of TVC required to control soil erosion. The cover threshold is critical as it indicates whether each pixel is protected from soil erosion.

Different cover thresholds are required to reduce wind or water erosion. Cover thresholds that reduce water erosion (specifically hillslope erosion) vary in different places.

In general, TVC is recommended to be:

- 50% to control soil loss by wind erosion (Leys 1999)
- 70% or greater to control soil loss by water erosion (Lang 1979). Higher cover thresholds are required on steep slopes (>12%, or 7 degrees), erodible soil types and high rainfall areas. Higher cover thresholds were supported by workshop participants from high rainfall regions.

These cover thresholds were derived from wind tunnel and runoff plots with small areas of 4 and 100 square metres respectively. Thus, these cover thresholds apply to small areas or pixels and cannot be extrapolated to large areas.

We acknowledge that for water erosion estimating the ground cover under trees is a more accurate way of estimating the level of erosion protection. The method of Trevithick et al. (2014) excludes the midstorey and overstorey woody vegetation from the ground cover estimate and has been applied to Landsat data and tested against field data in Queensland. Currently this method has not been tested against the MODIS 500-metre products and so was not used in this project. Also, for wind erosion control, the TVC is a better indicator of erosion control than ground cover.

Ideally a threshold cover should be determined for each pixel. The cover threshold would consider the land characteristics of rainfall, soil type and erodibility, slope and slope length as suggested by Lang and McDonald (2005). Unfortunately, these input data are not yet nationally consistent. Investment in these inputs would significantly improve setting and reporting against cover thresholds and improve modelling of sediment loss from water erosion by informing the Universal Soil Loss Equation. However, this is beyond the scope of this project.

The current method applies a consistent cover threshold to each pixel within the reporting region. Users will receive reports based on several different cover thresholds for their reporting region and will need to choose which is most appropriate, as explained in Section 4.2.2. Each report includes the following vegetation cover thresholds for reporting:

- >50% – for wind erosion
- for water erosion
    - >70%
    - >80%
    - >90%
    - >95%.

3.5 Choosing a data source

As at 2019, fractional cover is available from three different satellites sensors; Landsat, MODIS and Sentinel 2 (Table 1). While fractional cover from any of these sensors could be used to calculate and report against TVC targets, there are advantages for using the different products depending on the application.

To decide which product to use, consider which:

- resolution matches the size and spatial variation of the reporting area
- frequency and currency are needed to assess the decision or intervention
- available reporting tools.

Based on these considerations:

- MODIS-derived fractional cover is recommended for large areas (>100 hectares), regional and national scale, as it has enabled monthly reporting since 2001 (18 years), and can be analysed using the RAPP Map online tool. Currently RAPP Map is the only tool that can report the area above a cover target.
- Landsat-derived fractional cover is recommended for paddock scale (1–1000 hectares) reporting, has enabled seasonal reporting since 1990 (almost 30 years), can be analysed using the VegMachine online tool.
- Sentinel 2-derived fractional cover is recommended for paddock or sub-paddock scale (0.01–10 hectares) **viewing** in Northern Territory, Queensland, New South Wales, Victoria and Tasmania. It has enabled seasonal viewing since 2016, but cannot be used for target setting because the time series is too short, e.g. 3 years, and data is not available nationally for download via VegMachine.

Work is being done by CSIRO and others to generate a blended multi-sensor fractional cover product.

Table 1 Summary of fractional cover data for Australia derived from Landsat, Sentinel 2 and MODIS satellites

Feature	Landsat	Sentinel 2	MODIS
Spatial resolution	30 metres	10 metres	500 metres
Temporal repetition	Every 8 to 16 days Product available: • seasonal composite every 3 months	Every 5 to 10 days Product available: • seasonal composite every 3 months	Twice daily Products available: • 8-day composite • monthly composite
Time span	1990 to present	2016 to present	2001 to present
Coverage	Australia	Australia (only Qld, NT, NSW and Tas)	Global
Update	Within a month of end of season	Within a month of end of season	8-day: A week after the end of the 8-day period Monthly: A week after the last 8-day period of the month
Tool to access data	https://vegmachine.net/	Not available	https://map.geo-rapp.org/#australia
Best suited for	Long time series, paddock scale (100 metre by 100 metre), strategic reporting	Recent data, sub-paddock scale (30 metres by 30 metres), strategic reporting	Medium-term time scale, large paddock/property (1500 metres by 1500 metres), tactical decisions and strategic reporting

3.6 Setting a baseline

The ‘Baseline’ is the data used to set the ‘Baseline target’. The baseline should not include the period of the intervention, the ‘Post intervention’ data in Figure 4. The baseline period should, where possible, encompass the range of expected climatic conditions likely to occur during the intervention. The baseline data needs to be captured using the same method as the reporting period. Finally, the ‘Post target’ to assess the impact of the intervention is calculated from the baseline (not all the dates in the time series) and should be the same as the baseline target.

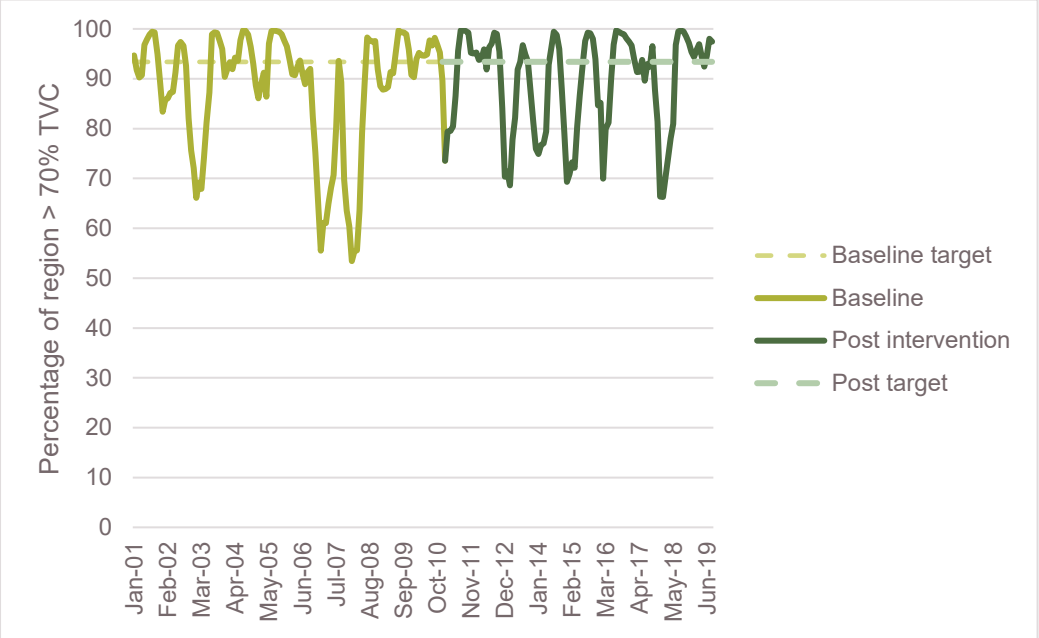

Figure 4 Baseline and post intervention data, and baseline target for the agricultural areas of the Northern Agricultural Natural Resource Management Region in Western Australia.

4. Reporting

4.1 Background

From June 2018 to June 2023 the Australian Government is investing in partnerships with "governments, industry, communities and individuals to protect and conserve Australia's water, soil, plants, animals and ecosystems, as well as support the productive and sustainable use of these valuable resources" (Australian Government, 2018b). The National Landcare Program Regional Land Partnerships (NLP RLP) program is jointly administered by the Australian Government:

- Department of the Environment and Energy, and
- Department of Agriculture

and is delivered in partnership with 50 natural resource management (NRM) organisations.

The NRM organisations (Figure 5) and Australian Government Department of Agriculture will undertake the reporting on vegetation cover targets. Farmers and pastoralists can also monitor their properties.

This project brought together those who will be undertaking the reporting to work out the best way to report on vegetation cover targets for properties/project areas, regions and nationally. We expect this reporting will also provide opportunities for farmers to understand the level of vegetation cover on their property and trends for the region if regional reports are published on NRM websites or in local media.

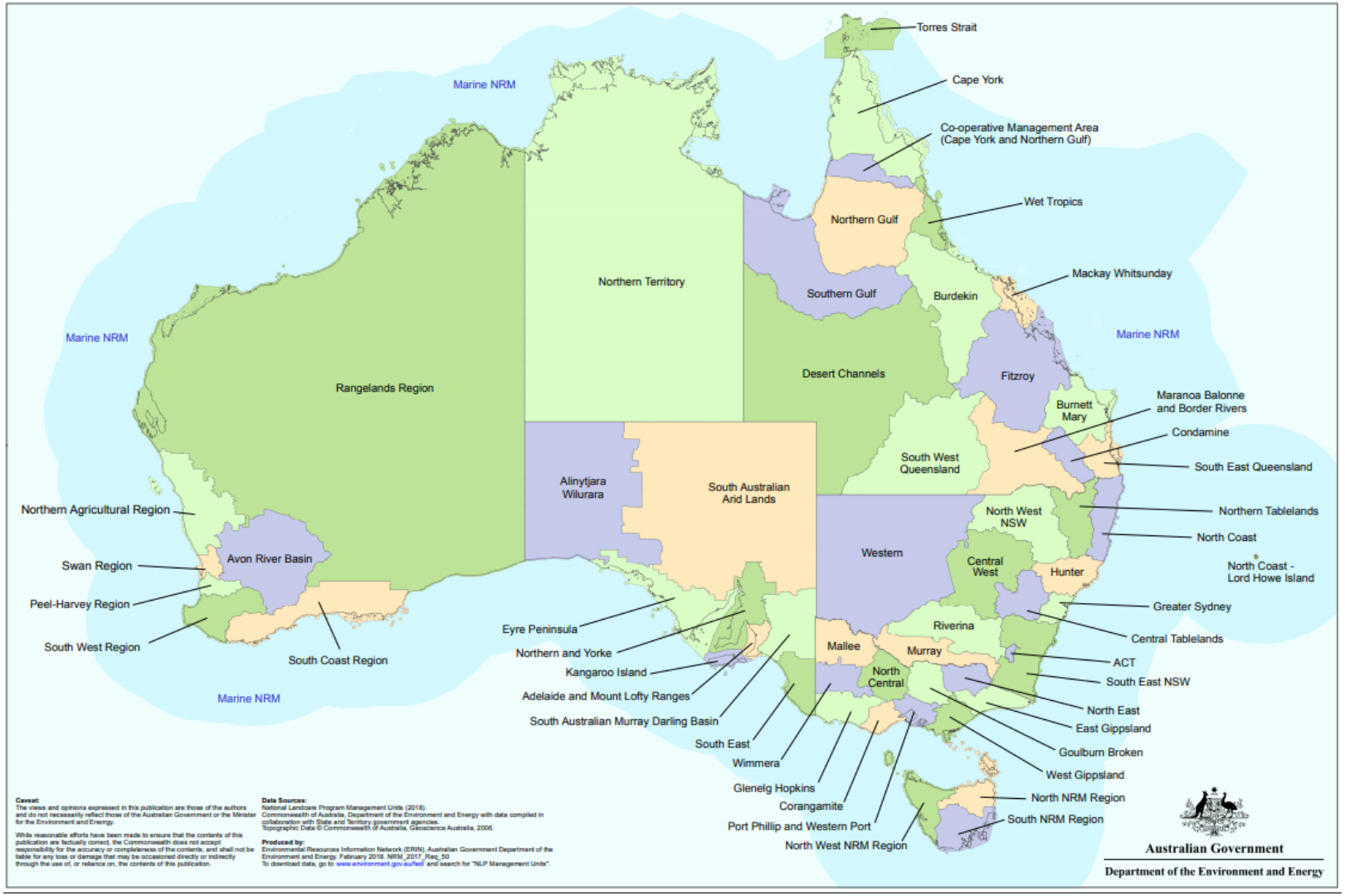

Figure 5 Natural resource management (NRM) regions for Australia. Source: www.nrm.gov.au

4.1.1 Purpose of reporting

The Regional Land Partnerships (RLP) Evaluation Plan Outcome 5 states that over the next 10 to 20 years "the condition of the soil, biodiversity and vegetation is improved". Progress against Outcome 5 will be assessed using fractional cover determined from remote sensing (Australian Government, 2017a).

This project provides a method for using fractional cover as an indicator of change in the condition of soil, biodiversity and vegetation. The fundamental aim of evaluating fractional cover is to assess whether changes in land management meet the assumption that "improving and protecting the condition of the soil, biodiversity and vegetation will lead to long term agricultural productivity" (Australian Government, 2017a).

Total vegetation cover (TVC) reporting indicates the area of soil erosion protection and trend of TVC for:

- national agricultural areas
- NRM regions
- properties /project areas.

National and regional reporting captures broad trends in TVC and climatic conditions. However, landscape management occurs at the paddock spatial scale. In previous reports and during the workshops, natural resource managers were concerned that regional reporting may not pick up changes in small areas like properties/project areas where RLP investment will be made within the short time periods of their projects (Guerschman et al. 2018). As changes are likely to be seen first at the properties or project areas where investment is made, and later across the landscape as innovations are adopted by the wider community, this project co-developed a multi-scale approach using two reporting methods:

1. comparison of area with a baseline TVC target
2. comparison of TVC time series of properties or project areas against a control area.

National, regional, properties and project areas can all report against an improvement from a TVC baseline target. Properties and project areas can also report against a control area to control for the influence of climate.

Steps to complete each of these methods are described later in this section. The methods described here can be used on any polygon; e.g. group of properties in a project area.

Monthly and annual reporting for the RLP is proposed for NRM regions. This is modelled on the approach used by DustWatch as it assists with tactical decisions. Annual reports are appropriate for the NLP time frames: short-term (up to 3 years), medium-term (3–5 years), and long-term (5–20 years) outcomes.

Regular reporting on fractional cover will also assist with priority setting, and strategic and tactical decision making. If reports are published locally, they may also assist those not directly involved with the NLP in making on-ground decisions.

4.1.2 Setting targets

The NLP RLP program improvement target has the following characteristics:

- type of target: resource condition – improvement from baseline
- baseline period: January 2001 to December 2018
- metric reported against: area protected
- thresholds: 50% and 70% (higher thresholds required for high-risk hillslope zones).

The baseline period used for the NLP RLP program is the time before the RLP investments were distributed. We chose the period January 2001 to December 2018 because fractional cover information for Australia is available on a monthly basis (12 times a year) from the Moderate Resolution Imaging Spectroradiometer (MODIS). Seasonal (four times a year) fractional cover data from Landsat is also available for a 30-year time frame (1990 to present), but monthly data is more useful to our application, especially for tactical decision making. While this 18-year baseline is considerably shorter than the standard 30 years used for climatic anomalies (Bureau of Meteorology, 2019), it captures the climate extremes of two wet periods (2001 and 2011) and three droughts (2002, 2009 and 2018).

The improvement target assumes that “improving and protecting the condition of the soil, biodiversity and vegetation will lead to long-term agricultural productivity” (Australian Government, 2017a). Most soil degradation is caused by erosion during droughts, or when the breaking rains come at the end of a drought when the least protective vegetation cover remains.

This improvement target aims for better vegetation cover during dry times, thus increasing the area protected from erosion. Soil erosion may still occur; but the aim is to reduce soil loss during the most susceptible period. Therefore, the improvement target for a defined region during its investment period would be to:

maintain the area protected from soil erosion by keeping the TVC above the 10th percentile of the area exposed to erosion during the baseline (January 2001 to December 2018).

The metric reported is the area protected for a threshold TVC, generally 50% or 70%. An example for the Desert Channels NRM region is shown in Figure 6.

This translates into the real erosion protection target that:

greater than 30% of the Desert Channels NRM region is protected from wind erosion for all months from January 2019 to June 2022.

No workshop participant disagreed with this form of target. Participants liked the transparency of the target and the logic behind it.

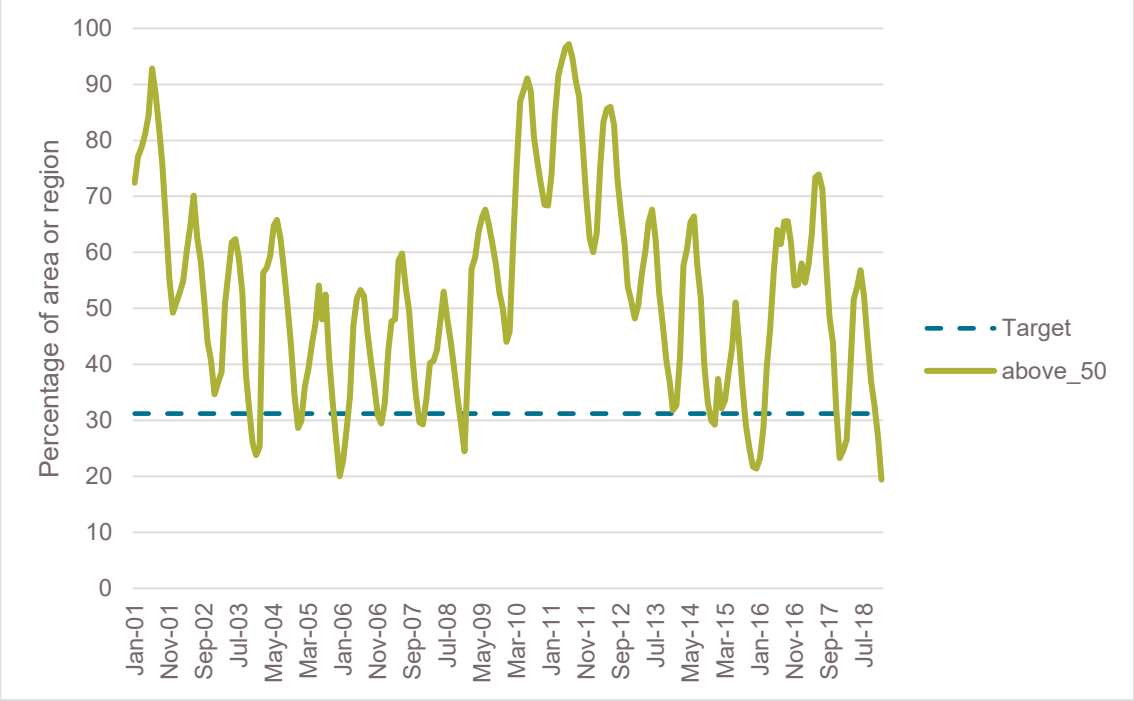

Figure 6 Baseline data and target for the Desert Channels Natural Resource Management Region in Queensland.

Note: Percentage area protected from wind erosion, i.e. >50% total vegetation cover. The target considers the baseline period for all months between January 2001 and December 2018.

4.1.3 Reporting by land use and forest cover classes

Land use and tree cover influence, total vegetation cover, soil erosion risk, the way land is managed and the applicability of reporting using remotely sensed fractional cover.

The project created a 13-class land use and forest cover classification to report areas with different land use/forest cover combinations (Figure 7 and Appendix 3). This is the Catchment Scale Land Use and Forests of Australia (2018) –13 classes, which:

- improves reporting and target setting by showing the effect of tree cover and land use
- is based on publicly available, spatially explicit national scale inputs
- shows ground cover areas, i.e. non-forest
- groups major agricultural land uses where similar management may be used
- incorporates feedback from users
- is available for use within the Rangelands and Pasture Productivity (RAPP) Map online tool.

The classification is described in more detail in Appendix 3.

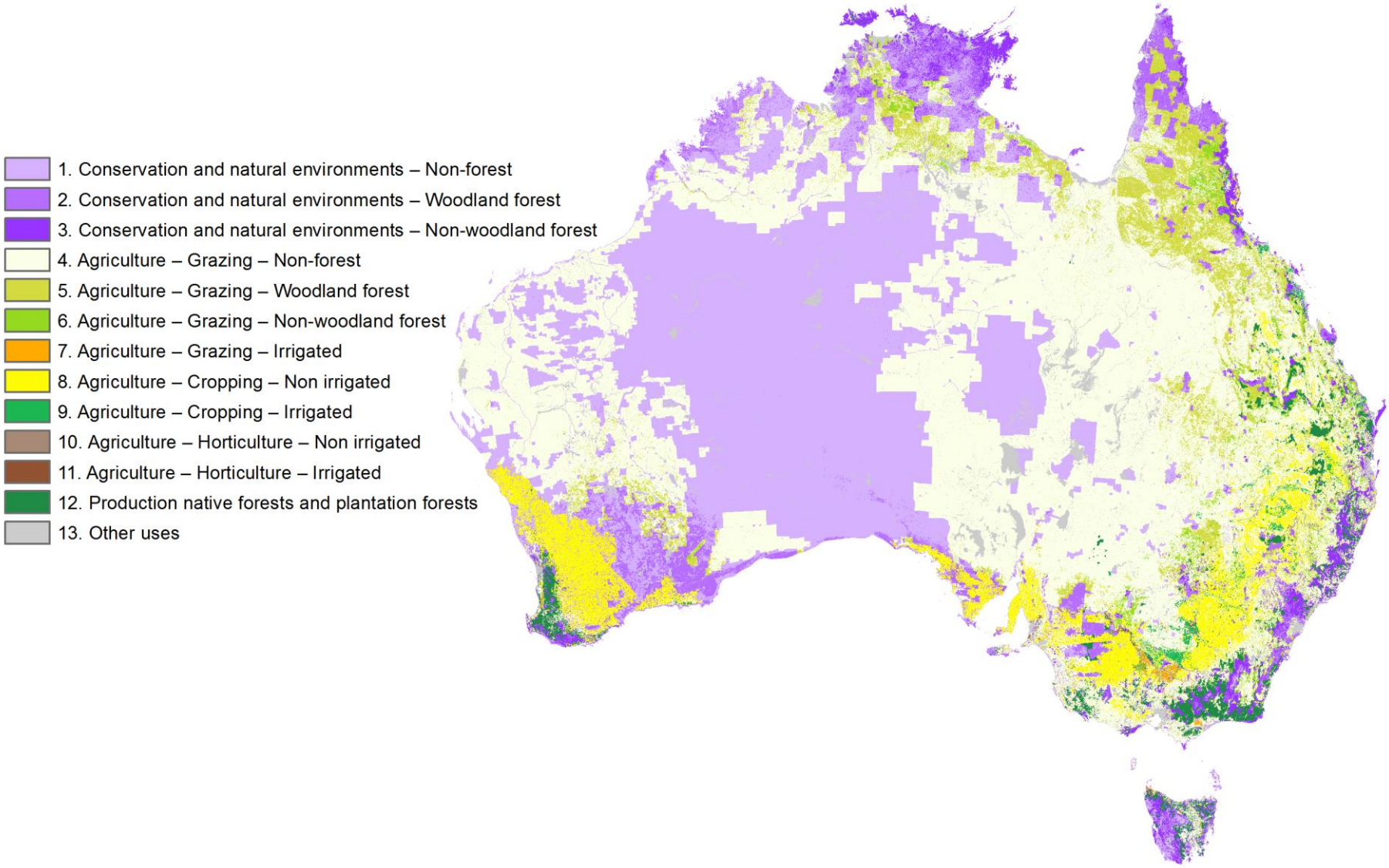

Figure 7 Map of catchment-scale land use and forests of Australia (2018) showing 13 summary classes for vegetation cover reporting.

4.2 Annual national report

This section proposes an annual TVC report to provide progress against the RLP Evaluation Plan Outcome 5: “the condition of the soil, biodiversity and vegetation is improved”.

In the context of this report, ‘improved’ means not having the area exposed to soil erosion greater than the target. We report against this target in three ways:

1. national snapshot – progress against national target for agricultural areas
2. regional evaluation – how total vegetation cover in each region compares to regional targets
3. investment area summary – how investment areas are progressing relative to selected control sites.

We recommend annual summaries be prepared for the period July to June. This is consistent with RLP reporting, the financial year, Australian Bureau of Statistics agricultural census and surveys, and enables us to capture the winter and summer cropping cycles.

4.2.1 Snapshot report

The national snapshot provides a single indicator of ‘pass’ or ‘fail’ against the national RLP improvement target. For Australia the target is:

That greater than 56% of Australia is protected from wind erosion and 30% is protected from water erosion based on the 2001 to 2018 baseline for all months from January 2019 to June 2022.

The snapshot report is supported by descriptive narrative and provides a quick overview of progress against the target:

- has the national target been met (Figure 8)
- reporting period rainfall (Figure 9a)
- cover level achieved in the month with the lowest cover (Figure 10a)
- areas of above and below average cover – total vegetation cover anomaly map (Figure 10b)
- areas protected from wind and water erosion (Figure 10c)
- number of months below the national target for wind and water erosion protection (Figure 11).

An example of national reporting for 2018–19 against the improvement target is shown below.

National vegetation cover report card for agricultural areas 2018–19

For Australian agricultural land, that greater than 61% of Australian agricultural land is protected from wind erosion and 30% is protected from water erosion based on the 2001 to 2018 baseline for all months from January 2019 to June 2022.

Figure 8 shows that the national targets for the area of agricultural land protected from wind and water erosion both failed in 2018–19.

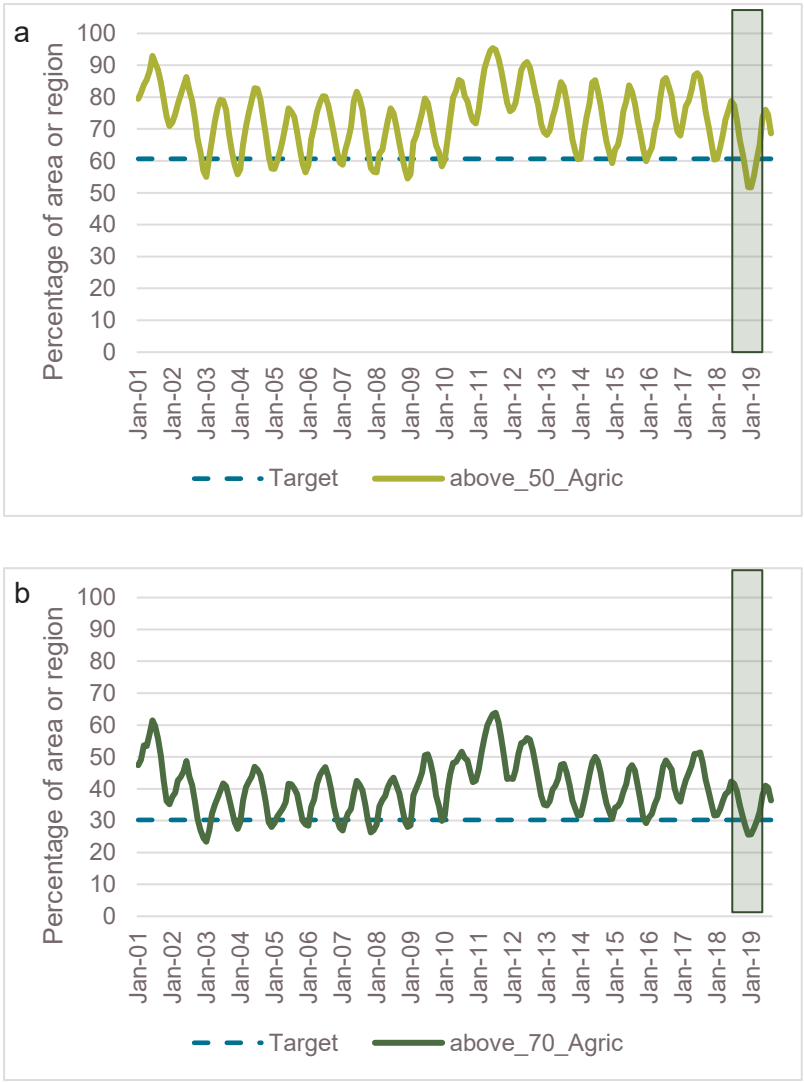

Figure 8 National trends in agricultural land area protected from erosion. Area protected from a) wind erosion, and b) water erosion with respective Regional Land Partnerships targets (blue dotted line) and year of reporting (shaded box).

Context for annual report for agricultural land

The 2018–19 year was very dry, with about half of Australia recording below average rainfall Figure 9a. Most agricultural land has had below average rainfall for the last three years Figure 9b. This lack of rainfall has had an impact on the ability to grow new non-woody cover and has made it difficult for land managers to maintain TVC.

National TVC for agricultural areas for 2018–19 were lowest in January (Figure 10). In January 2019, large areas across Australia had low TVC exposing the soil to wind erosion (represented by dark- and light-brown in Figure 10a). These areas of low TVC extend from the semi-arid centre of Australia into the usually higher rainfall coastal regions.

The severity of the low vegetation cover is demonstrated by the TVC anomaly. The impact of the below-average rainfall season is that, in January 2019, large areas show below 20% of the average TVC for January (shown as red in Figure 10b). The TVC anomaly clearly shows that the entire sheep/wheat belt from South Australia through Victoria and New South Wates, and the grazing lands of central Queensland and eastern Northern Territory, have far below average TVC. If the low TVC was caused by land management, we would expect to see sharp boundaries between farms or paddocks. As we don't, we suggest that the climate is the driver for this below average cover in the 2018–19 reporting period.

The water erosion risk was highest during December 2018. December showed the lowest area of agriculture area protected from water erosion (70% TVC threshold) during 2018–19. Twenty-six percent of Australia's agricultural area was protected from water erosion (represented by black area in Figure 10c). This is below the target of 30%.

The wind erosion risk was highest during January 2019. January showed the lowest area of agriculture protected from wind erosion (50% TVC threshold) during 2018–19. Fifty-two percent of Australia's agricultural area was protected from wind erosion (represented by black area in Figure 10d). This is below the target of 61%.

Statistics for annual report

- Australia experienced four months below the target for both the agricultural area protected from wind (Figure 11a) and water erosion (Figure 11b), showing that 2018–19 is the equal worst year with 2002–03 for wind erosion risk and the worst year for water erosion risk since 2001–02 (Table 2).
- The high number of months below targets relates to the ongoing below average rainfall (Figure 9a and b).
- Vegetation cover was much lower than the average for the entire agricultural area of Australia, except for farming areas in south-west Western Australia (Figure 10b).

Table 2 Performance against national total vegetation cover targets for erosion protection in agricultural areas, 2018–19

National target – wind erosion (% area protected)	Months below target – wind erosion	Number of years with more months below target – wind erosion	National target – water erosion (% area protected)	Months below target – water erosion	Number of years with more months below target – water erosion
61%	4	0 equal worst with 2002–03	30%	4	0 worst since 2001–02

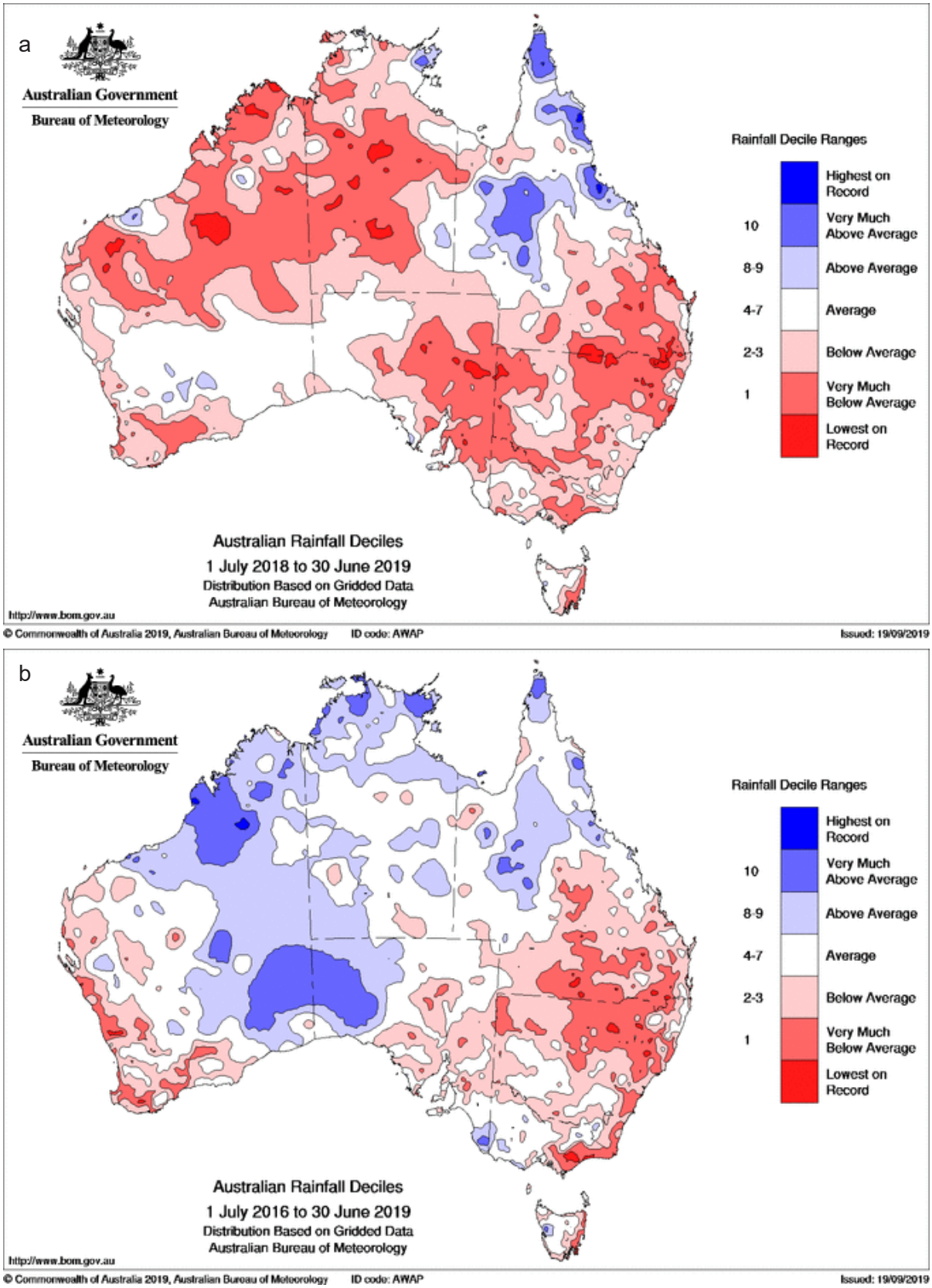

Figure 9 Rainfall data organised into deciles for a) July 2018 to June 2019, and b) July 2016 to June 2019.

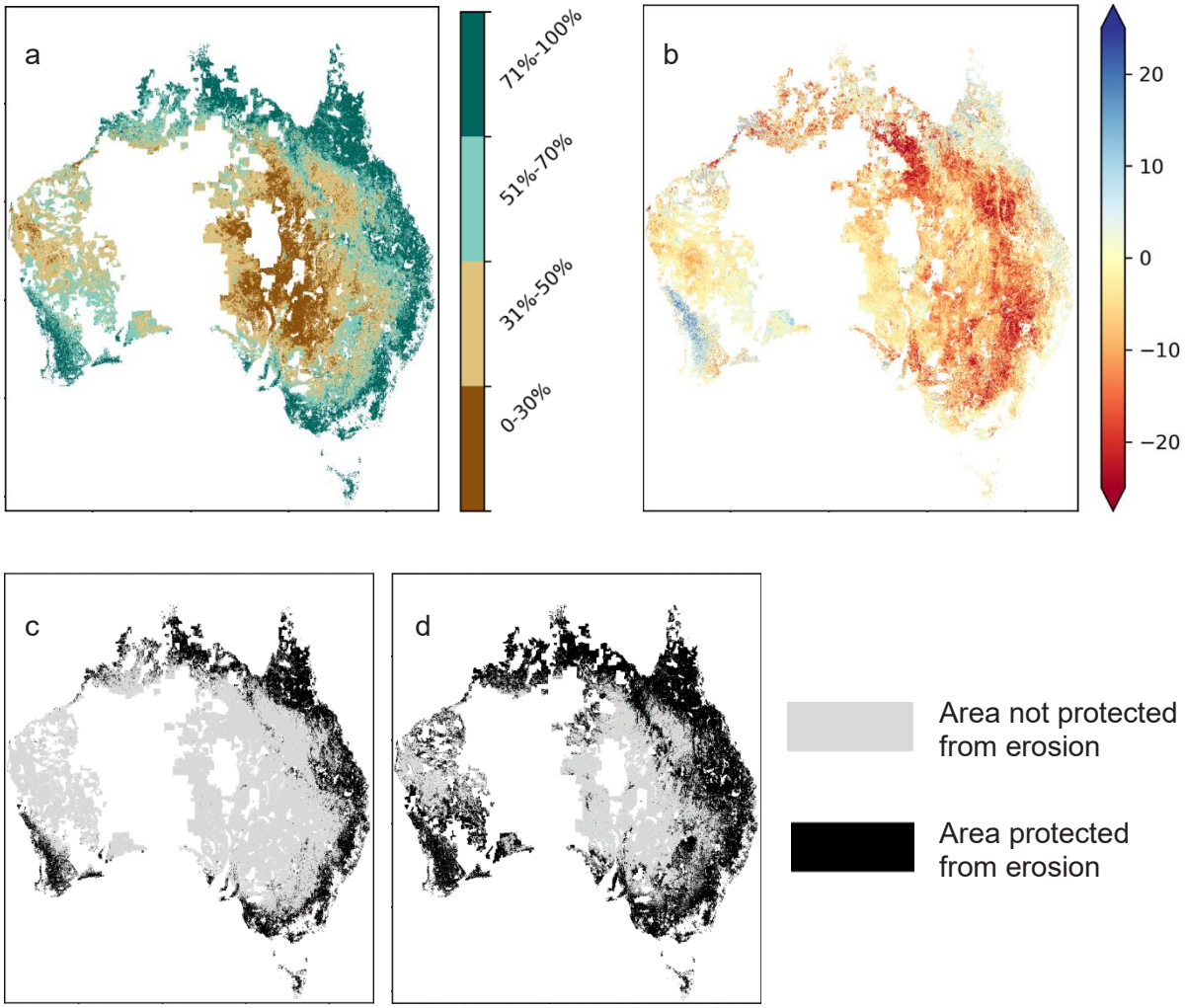

Figure 10 Agricultural areas of Australia showing a) total vegetation cover – January 2019, b) total vegetation cover anomaly – January 2019, c) area protected from water erosion – December 2018, d) area protected from wind erosion – January 2019.

Note: Monthly total vegetation cover anomaly shows how that month's total vegetation cover compares to all the other same months in the time series (i.e. January 2019 compared to January 2001–2019).

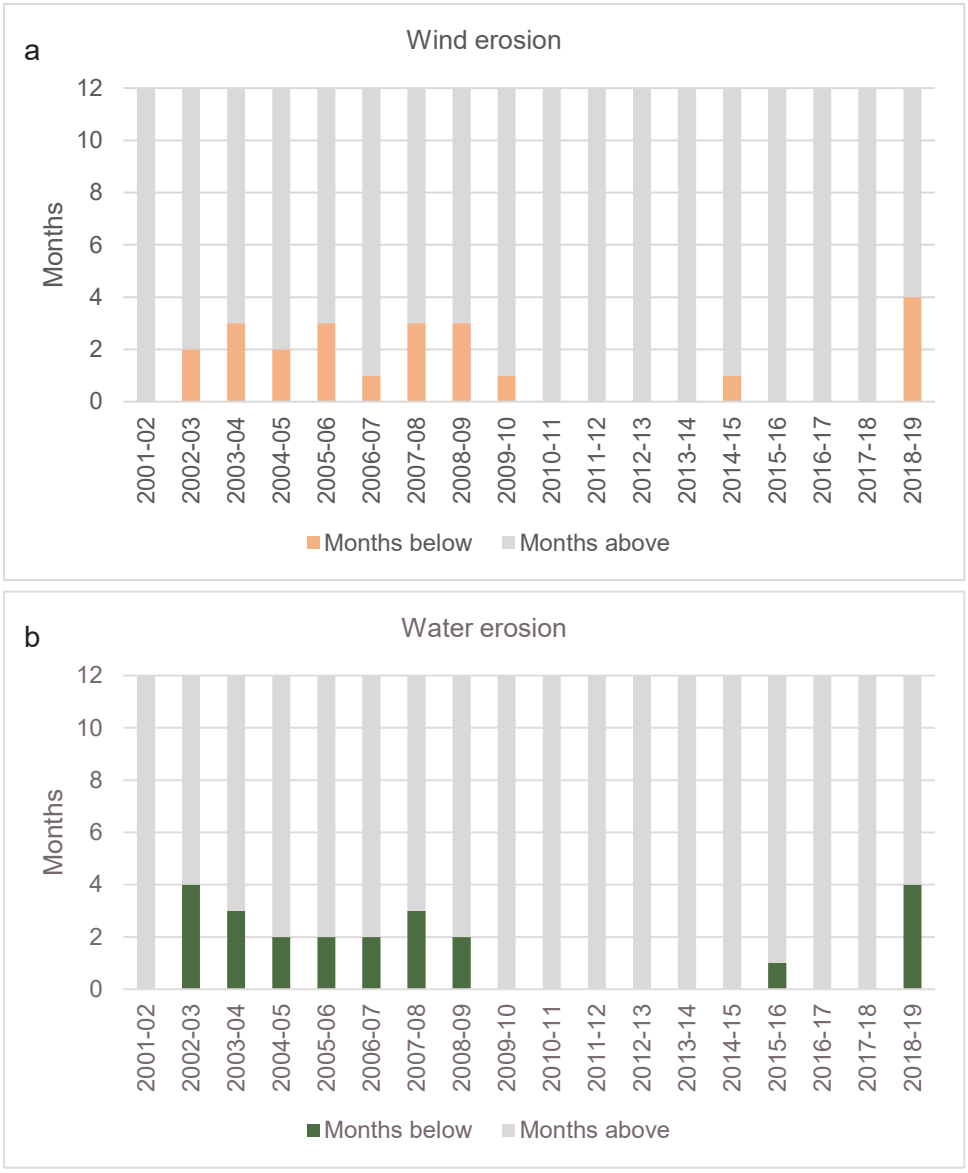

Figure 11 Total months above and below the national Regional Land Partnerships target for protection of Australia's agricultural land from a) wind erosion, and b) water erosion.

4.2.2 Regional evaluation

The second level of national reporting is to evaluate the nation at a regional scale. Identifying which regions are not meeting their targets helps the Australian Government consider the interactions between climate and land management, evaluate the impact of large-scale investments, and prioritise future investments.

The concept for regional reporting is to understand whether the target was not met and how frequently the target was not met using monthly data. How often the target is not met helps understand the severity of pressure on the soil resource.

Natural Resource Management (NRM) Regions 2017 (Australian Government, 2017b) have been used for reporting. The names and boundaries of these 56 NRM regions are equivalent to the NLP management units (Australian Government, 2018a) except for the Marine, Alinytjara Wilurara and Torres Strait regions, which do not have agriculture and are therefore not included in national reporting for agricultural land.

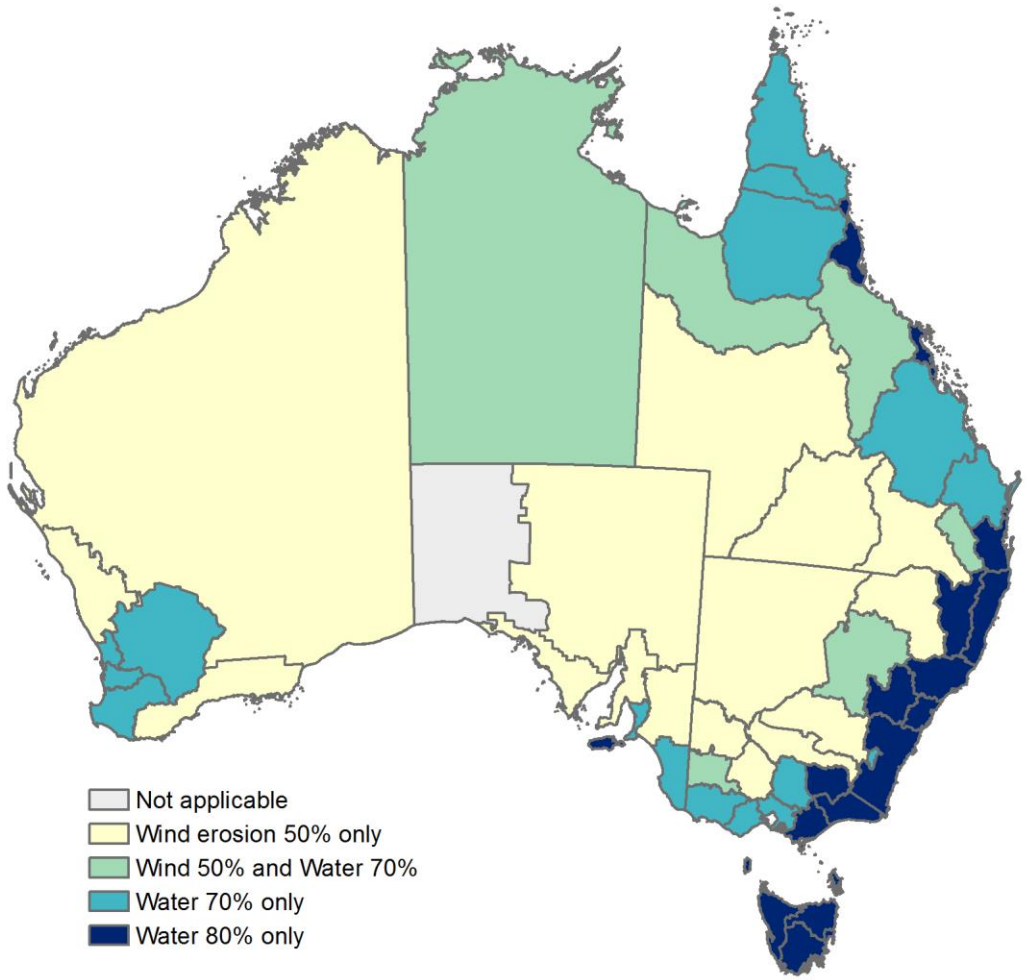

Figure 12 Total vegetation cover thresholds for agricultural land in each natural resource management region for wind and water erosion.

Note: Percentages are thresholds of >50%, >70% or >80% total vegetation cover

Fifty-four NRM regions have RLP improvement target/s for wind and/or water erosion.

The total vegetation cover threshold required to protect the soil from erosion in each region depends on the dominant erosion risk. For regions at risk of wind erosion the RLP improvement target uses a cover threshold of 50%. For regions at risk of water erosion the RLP improvement target uses a cover threshold of 70% or 80%.

Sixteen regions have a wind erosion target only, six regions have both wind and water erosion targets, 16 regions have a water erosion target based on the 70% cover threshold, and 16 regions have a water erosion target based on the 80% cover threshold (Figure 12 and Table 3). In summary, 22 regions has been assigned a wind erosion target and 38 regions have been assigned a water erosion target.

Table 3 Number of natural resource management regions with Regional Land Partnerships improvement targets for erosion at each total vegetation cover (TVC) threshold

		Number of regions with a water erosion improvement target at each TVC threshold			
	TVC threshold	**N/A**	**70%**	**80%**	**Total**
Number of regions with a wind erosion improvement target at each TVC threshold	**N/A**	2	16	16	**34**
	50%	16	6		**22**
Subtotal			22	16	
Total		**18**		**38**	**56**

The method to determine the erosion risk and assign total vegetation cover thresholds for the RLP improvement targets is described in Figure 13.

This method is based on several steps:

1. Whether the region contains agriculture. The RLP program focusses on agricultural areas and therefore regions without agriculture have not been explored in this report.
2. Whether a wind erosion target is required. In low rainfall areas with low total vegetation cover, wind erosion is the dominant erosion risk. The risk of wind erosion is increased when TVC is below 50%. The time series of area protected from wind erosion for a region indicates how often, and how much of the region drops below the 50% TVC threshold. Where the range of the time series is less than 10% there has been very little change in the area protected from wind erosion during the 19-year period indicating that a wind erosion target is unlikely to be effective as a management tool.
3. Whether a water erosion target is required and what TVC threshold should be used.
    a. Whether the region has sufficient rainfall. In regions with low rainfall soil erosion will be dominated by wind and therefore water erosion targets may not be needed or achievable. Water erosion targets have been applied where more than half of a region receives more than 700-millimetre annual average rainfall (based on Leys et al. 2018; Appendix 5).
    b. Whether the region is an identified water erosion risk priority. Water erosion targets have also been applied to NRM regions identified as a risk priority for hillslope erosion by McKenzie et al. (2017).
    c. Whether 70% TVC is informative. The risk of water erosion is increased when TVC is below 70%. Higher thresholds should be assigned for areas that require more vegetation cover to protect areas of high rainfall, steep slopes and erodible soil types. The time series for a region indicates how often, and how much of the region drops below the 70% TVC threshold. The 70% TVC threshold is suitable where the range of the time series of area protected with 70% TVC is greater than 10% (Figure 8b ranges from 64% to 23%). Where the range of the time series of the area protected with 70% TVC is less than 10%, then the 80% TVC threshold has been used to calculate the RLP target (Figure 15). Eighty percent TVC was the highest threshold used for the RLP NRM regional targets, however higher thresholds may be appropriate in some other situations and therefore can be viewed in the online RAPP Map tool for some regions (see Section 3.4).

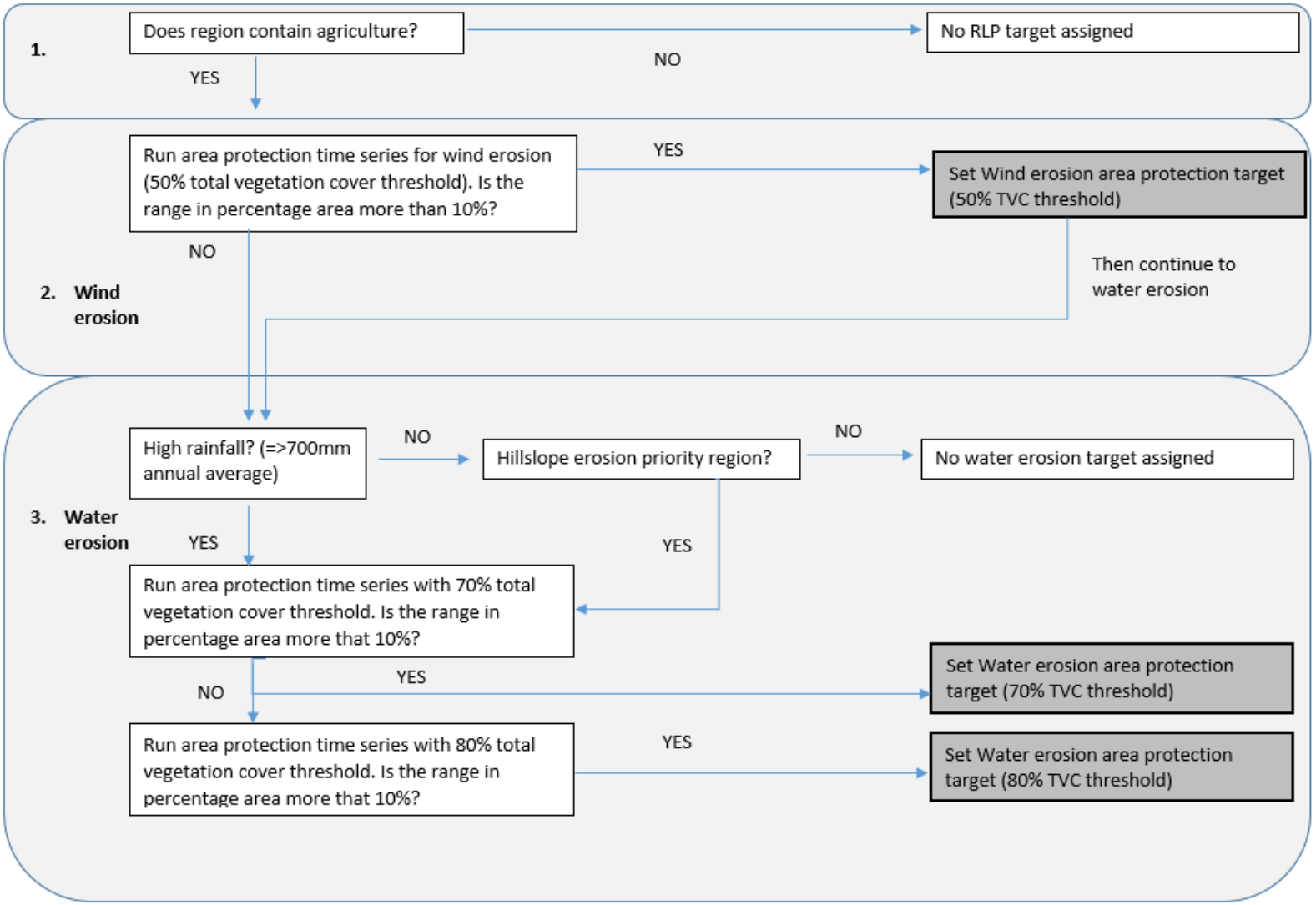

Figure 13 Method to assign total vegetation cover (TVC) thresholds for soil erosion protection.

Notes: mm = millimetres; RLP = Regional Land Partnerships.

The time series of area protected from wind erosion for the South Coast NRM Region (Figure 14) ranges from 100% of the region protected down to 93%. This time series shows less than a 10% range indicating that, in this region, wind erosion is not the dominant erosion risk, water erosion is.

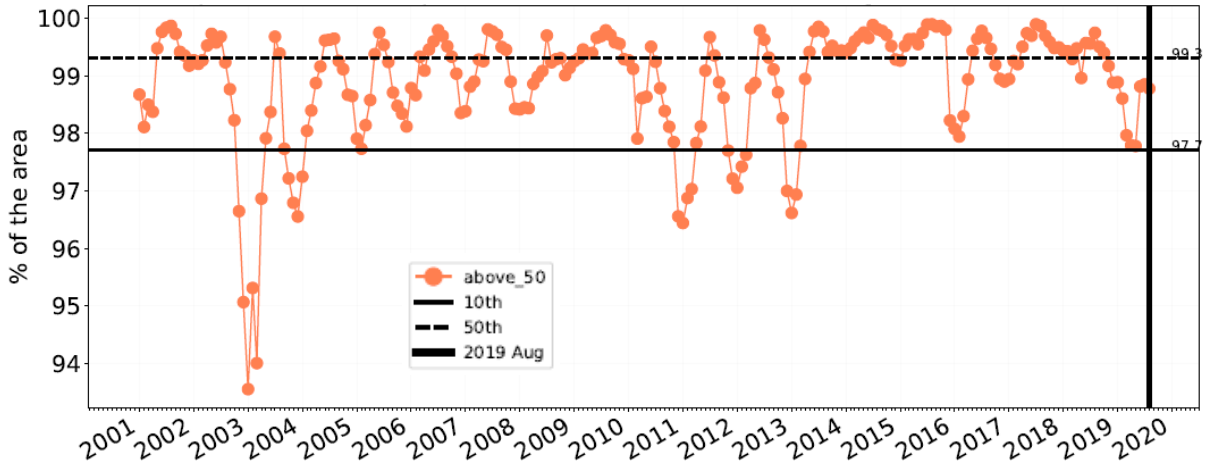

Figure 14 Percentage area protected from wind erosion in the South Coast Natural Resource Management Region in Western Australia.

Table 4 lists the total vegetation cover threshold and target for area protected for the 38 NRM regions which met the criteria for a water erosion target (Figure 13).

The full list of RLP targets for the relevant cover thresholds, calculated for the agricultural areas within each NRM region, along with the months below target for July 2018 to June 2019 and the percentage range of area protected are shown in Appendix 4.

Table 4 Agricultural land water erosion cover thresholds and area protection targets for 38 natural resource management (NRM) regions

NRM region	Water erosion cover threshold	Water erosion area protection target – agricultural land (% area protected)
ACT	>70%	97.1
Adelaide and Mount Lofty Ranges	>70%	85.6
Avon River Basin	>70%	23.2
Burdekin	>70%	63.2
Burnett Mary	>70%	97.0
Cape York	>70%	95.4
Central Tablelands	>80%	87.3
Central West@	>70%	36.6
Condamine @	>70%	58.6
Co-operative Management Area	>70%	83.1
Corangamite #	>70%	93.7
East Gippsland	>80%	93.0
Fitzroy#	>70%	73.6
Glenelg Hopkins #	>70%	96.0

NRM region	Water erosion cover threshold	Water erosion area protection target – agricultural land (% area protected)
Goulburn Broken #	>70%	91.2
Greater Sydney	>80%	92.5
Hunter	>80%	87.7
Kangaroo Island #	>80%	82.1
Mackay Whitsunday	>80%	82.5
North Coast	>80%	96.3
North East	>80%	83.8
North NMR Region	>80%	90.7
North West NMR Region	>80%	88.7
Northern Gulf	>70%	81.4
Northern Tablelands	>80%	91.2
Northern Territory	>70%	27.5
Peel–Harvey Region	>70%	89.4
Port Phillip and Western Port	>70%	89.8
South East #	>70%	84.9
South East NSW	>80%	85.7
South East Queensland	>80%	90.6
South Region	>80%	86.9
South West Region #	>70%	79.9
Southern Gulf @	>70%	21.2
Swan Region	>70%	90.6
West Gippsland	>80%	91.9
Wet Tropics	>80%	95.1
Wimmera @	>70%	50.0

Notes: # = regions with ≤700 millimetres (mm) annual average rainfall that are reported as water erosion dominated regions because the time series of percentage area protected from wind erosion (>50% total vegetation cover) shows less than 10% variation; @ = regions that were the highest priority for hillslope erosion as mapped by McKenzie et al. (2017) for the Regional Land Partnerships but not identified as a water erosion risk by the other criteria.

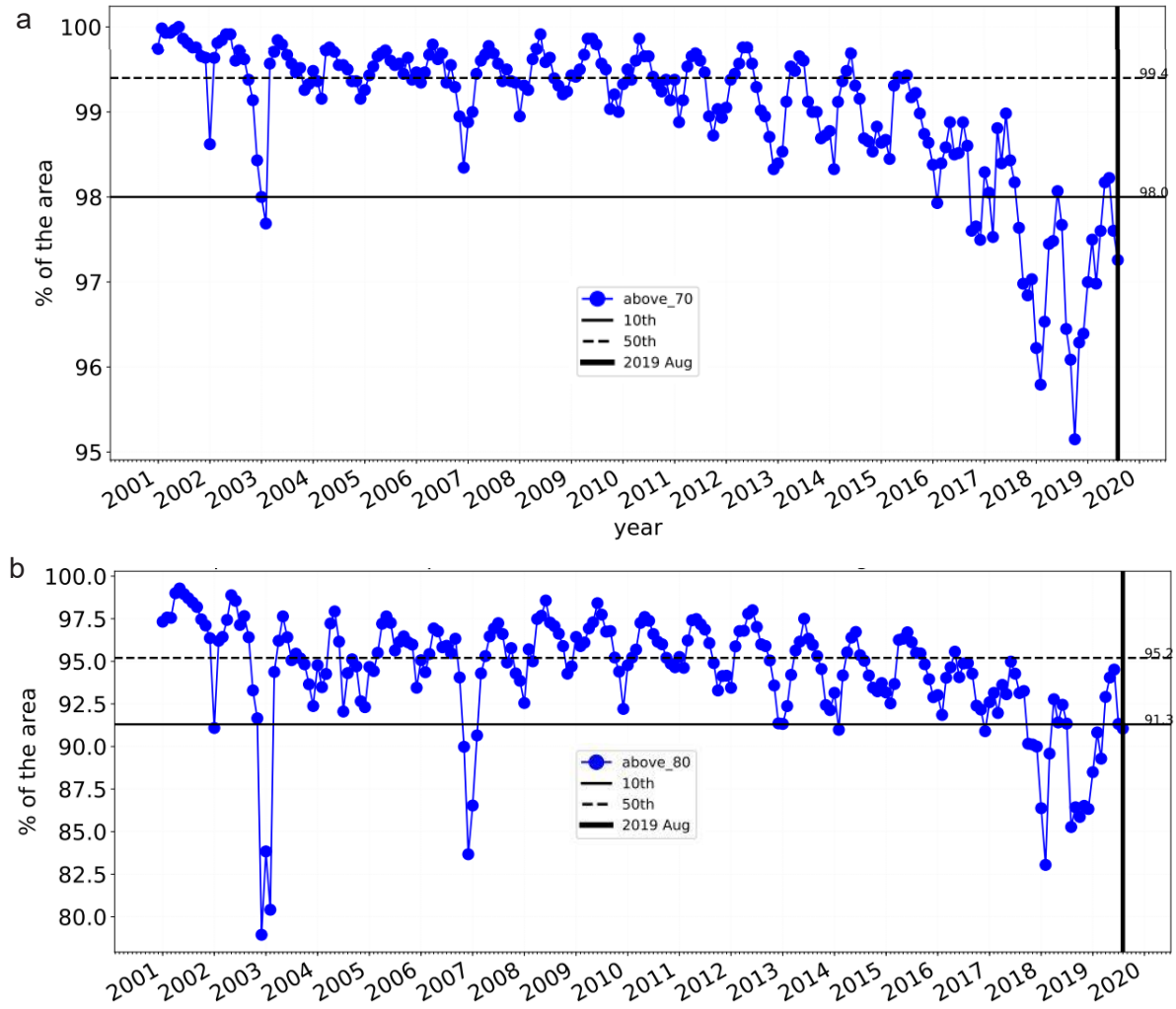

Figure 15 Percentage of agricultural land protected from water erosion in the Greater Sydney Natural Resource Management Region in New South Wales. a) >70% total vegetation cover (TVC) and b) >80% TVC.

Note: The Regional Land Partnerships improvement target for the region is set using the 10th percentile for percentage of area above the TVC threshold (>70% or >80% TVC for water erosion).

National vegetation cover report card for 2018–19: regional evaluation

Number of natural resource management regions not meeting targets of area of agricultural land protected from erosion

Much of eastern Australia reported below their regional targets to protect agricultural land from wind erosion for more than four months in 2018–19 (Table 5).

Figure 16a shows RLP wind erosion targets for all NRM regions. The map shows that most of Australia has a target to protect <65% of agricultural land in each region from wind erosion. As rainfall increases, the target area increases, with the Burdekin having the highest target of 95.5% protection from wind erosion. Figure 16b shows RLP water erosion targets for all NRM regions. Water erosion area protection targets for most of the wetter parts of Australia range from 95%, with a cover threshold of 80% for the wet tropics, to 28% with a cover threshold of 70% for the Northern Territory.

Figure 16c and d, show the number of months each NRM region was below the area protection target for wind and water erosion respectively. As rainfall increases, the wind erosion target increases with the Burdekin having the highest target of 95.5% protected. The

North West and Central West Local Land Services (LLSs) in New South Wales had the lowest protection for wind erosion or greatest pressure on the soil resource. For water erosion, mainly eastern New South Wales and Victoria were below their targets for more than four months. The Northern Tablelands and Hunter LLSs had the greatest water erosion pressure on the soil resource. The percentage of NRM regions meeting, failing and not having a target for wind and water erosion protection are shown in Figure 17.

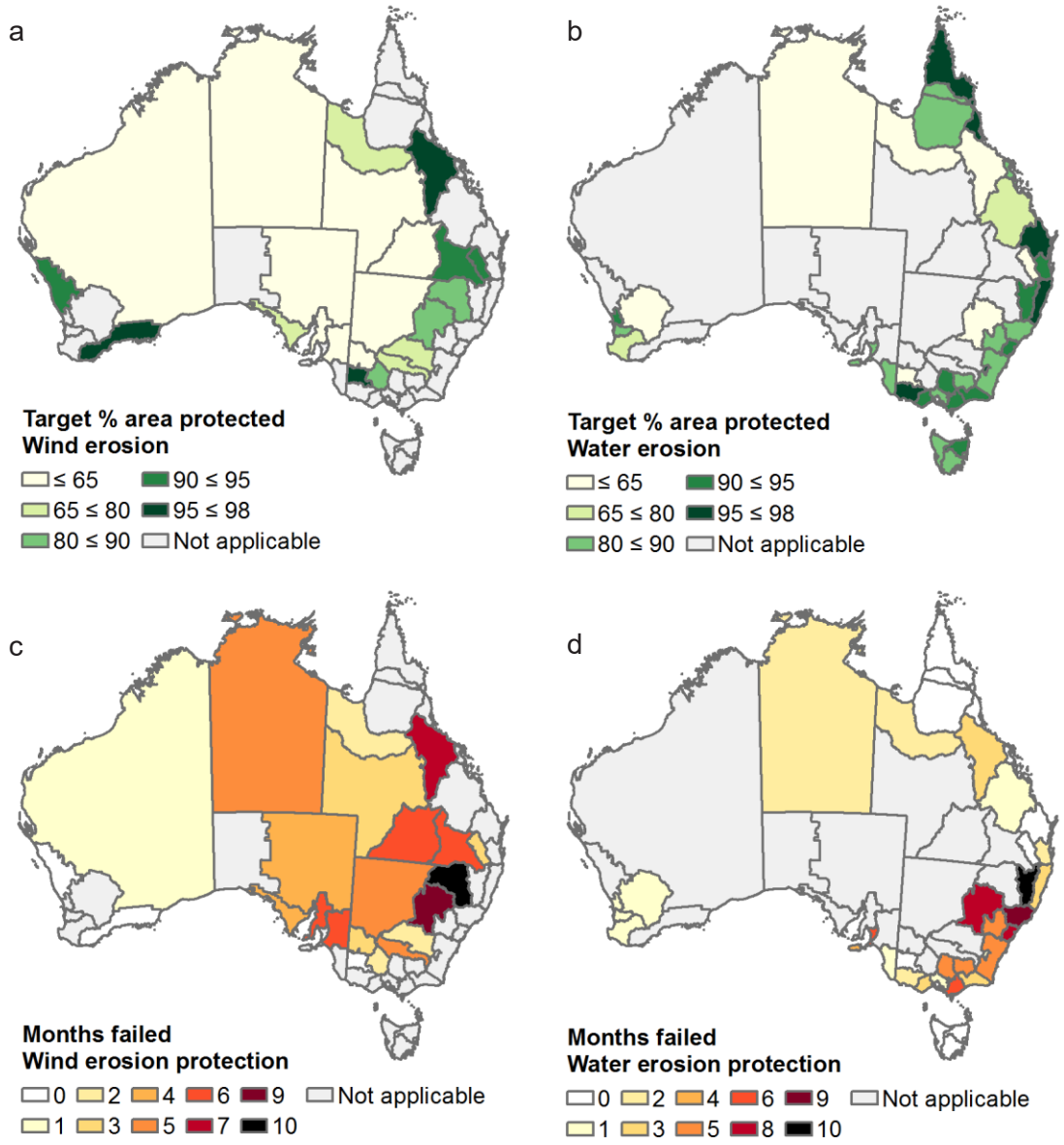

Figure 16 Regional Land Partnerships erosion targets for agricultural areas by natural resource management regions a) Wind and b) water erosion targets (as a percentage range), c) wind and d) water erosion protection (number of months target failed to be met) in 2018–19.

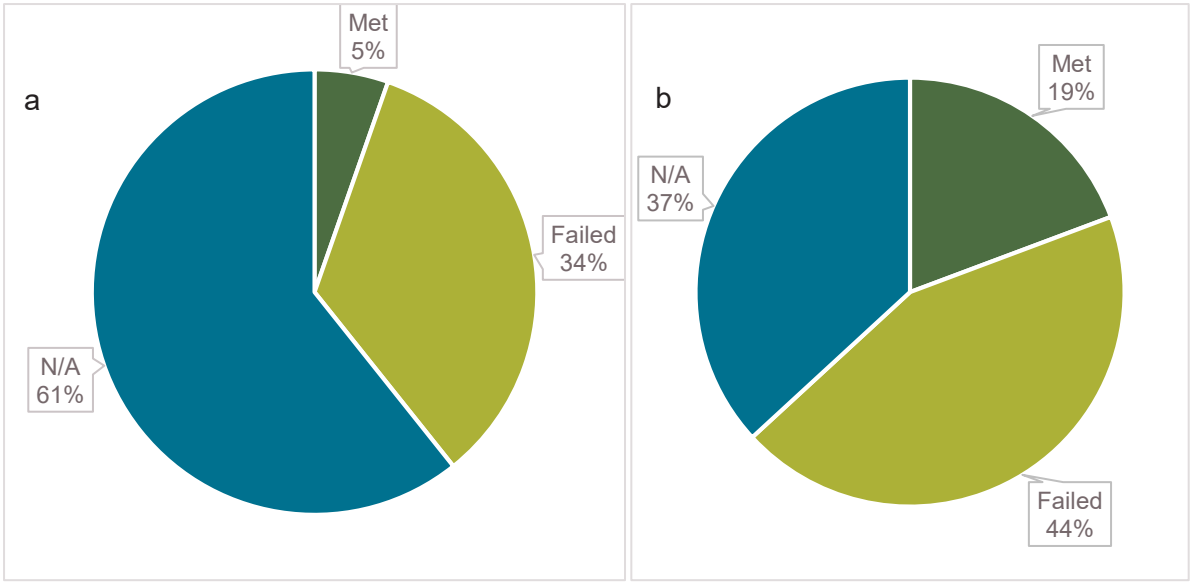

Figure 17 Natural resource management (NRM) regions meeting their cover targets to protect agricultural land from a) wind, and b) water erosion in 2018–19.

Note: The results show that 5% of NRM regions met their target and 34% failed in protecting agricultural land from wind erosion, whereas 19% met their target and 44% failed in protecting agricultural land from water erosion.

Context for regional report

The 2018–19 year was very dry, with about half of Australia recording below average rainfall. Most agricultural land has had below average rainfall for the last 3 years. This presents major challenges to farmers and pastoralists to maintain non-woody vegetation.

Statistics for the report showed that:

- in 2018–19, 4 months were below the target for the area protected from wind (Figure 8a) and water (Figure 8b) erosion, representing the equal worst year with 2008–09 for wind erosion, and the second worst year for water erosion (2002–03 had 5 months below target; Table 2)
- the high number of months relates to ongoing below average rainfall (Figure 9)
- vegetation cover is much lower than the average for the entire agricultural area of Australia, except for farming areas in south-west Western Australia (Figure 10).

Table 5 Performance against regional targets for agricultural land protected from soil erosion, 2018–19

NRM region	Wind erosion area protection target – agricultural land (% area protected)	Months <target	Water erosion area protection target – agricultural land (% area protected)	Months <target
ACT	N/A	N/A	97.1	1
Adelaide and Mount Lofty Ranges	N/A	N/A	85.9	6
Avon River Basin	N/A	N/A	23.2	1
Burdekin	95.5	7	63.2	3
Burnett Mary	N/A	N/A	97.0	0
Cape York	N/A	N/A	95.4	0
Central Tablelands	N/A	N/A	87.3	5
Central West	87.4	9	36.3	8
Condamine	90.8	3	58.6	0
Co-operative Management Area	N/A	N/A	83.1	0
Corangamite	N/A	N/A	93.7	3
Desert Channels	27.8	3	N/A	N/A
East Gippsland	N/A	N/A	93.0	3
Eyre Peninsula	71.9	4	N/A	N/A
Fitzroy	N/A	N/A	73.6	1
Glenelg Hopkins	N/A	N/A	96.0	2
Goulburn Broken	N/A	N/A	91.2	5
Greater Sydney	N/A	N/A	92.5	8
Hunter	N/A	N/A	87.7	9
Kangaroo Island	N/A	N/A	82.1	4
Mackay Whitsunday	N/A	N/A	82.5	0
Mallee	40.9	3	N/A	N/A
Maranoa Balonne and Border Rivers	91.1	6	N/A	N/A
Murray	80.0	5	N/A	N/A
North Central	89.4	2	N/A	N/A
North Coast	N/A	N/A	96.3	3
North East	N/A	N/A	83.8	5
North NRM Region	N/A	N/A	90.7	0
North West NRM Region	N/A	N/A	88.7	0
North West NSW	83.3	10	N/A	N/A
Northern Agricultural Region	94.2	0	N/A	N/A

NRM region	Wind erosion area protection target – agricultural land (% area protected)	Months <target	Water erosion area protection target – agricultural land (% area protected)	Months <target
Northern and Yorke	51.5	6	N/A	N/A
Northern Gulf	N/A	N/A	81.4	0
Northern Tablelands	N/A	N/A	91.2	10
Northern Territory	56.5	5	27.5	2
Peel–Harvey Region	N/A	N/A	89.4	1
Port Phillip and Western Port	N/A	N/A	89.8	1
Rangelands Region	46.0	1	N/A	N/A
Riverina	65.1	2	N/A	N/A
South Australian Arid Lands	5.3	4	N/A	N/A
South Australian Murray Darling Basin	58.8	6	N/A	N/A
South Coast Region	97.3	0	N/A	N/A
South East	N/A	N/A	84.9	1
South East NSW	N/A	N/A	85.7	5
South East Queensland	N/A	N/A	90.6	2
South NRM Region	N/A	N/A	86.9	0
South West Queensland	50.3	6	N/A	N/A
South West Region	N/A	N/A	79.7	1
Southern Gulf	70.0	2	21.2	2
Swan Region	N/A	N/A	90.6	1
West Gippsland	N/A	N/A	91.9	6
Western	32.0	5	N/A	N/A
Wet Tropics	N/A	N/A	95.1	0
Wimmera	95.4	0	50.0	0

Notes: N/A indicates the target is not applicable to that natural resource management (NRM) region. Refer to Appendix 4 for the total vegetation cover thresholds for each target.

4.3 Regional reports

The NLP program has 56 NRM regions (Figure 5). This section outlines what could go in a NRM regional report. This is not a definitive list, but a guide to what could be included. Some of the material is similar to that in the regional evaluation of the annual national report (Section 4.2.2).

The aim of a regional report is to:

- report against an RLP improvement target (see Section 4.1.2)
- report severity of the pressure on the soil resource, such as the number of months the target was not achieved
- explain the context for the monthly result, for example, the impact of climate or different land uses and management practices on TVC.

These reports can also be used for:

- prioritising work
- drought warning
- monitoring improvements in land management.

We suggest two formats for regional reports:

- annual – which would be similar to the national snapshot report (see Section 4.2.1), except done for a region.
- monthly – an example of which is given in Section 4.3.1.

4.3.1 Monthly regional report example

Central West Local Land Services regional total vegetation cover report card for August 2019

Overview

The Central West Local Land Services (LLS) region, in New South Wales, is dominated (90% of the region) by agriculture. Cropping covers 43%, grazing of non-forest lands covers 36% and irrigation covers 3% of the region (Figure 18). The annual rainfall is 400 to 600 millimetres, but is highly variable from month to month. In August 2019, the region experienced one of its driest periods on record and has not had effective rain since March 2017 (Figure 19a). Since April 2019, it has had much lower than average rainfall in 2019 (Figure 19b).

It is a region with episodic wind erosion; however, in August 2019, nearly a third of the region was not protected from wind erosion (brown colours in Figure 20a).

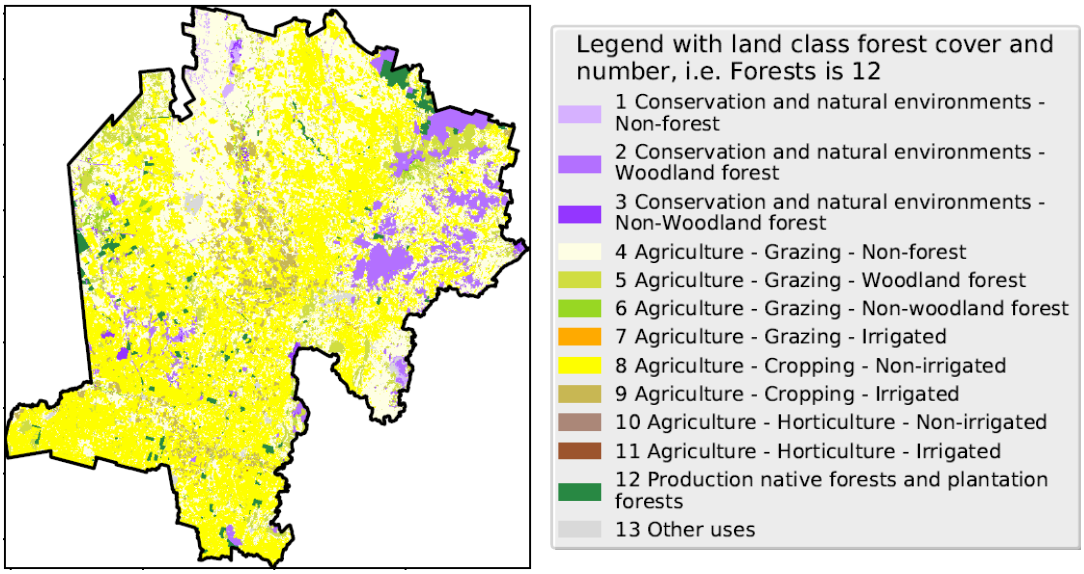

Figure 18 Land use/forest classes of Central West Local Land Services region.

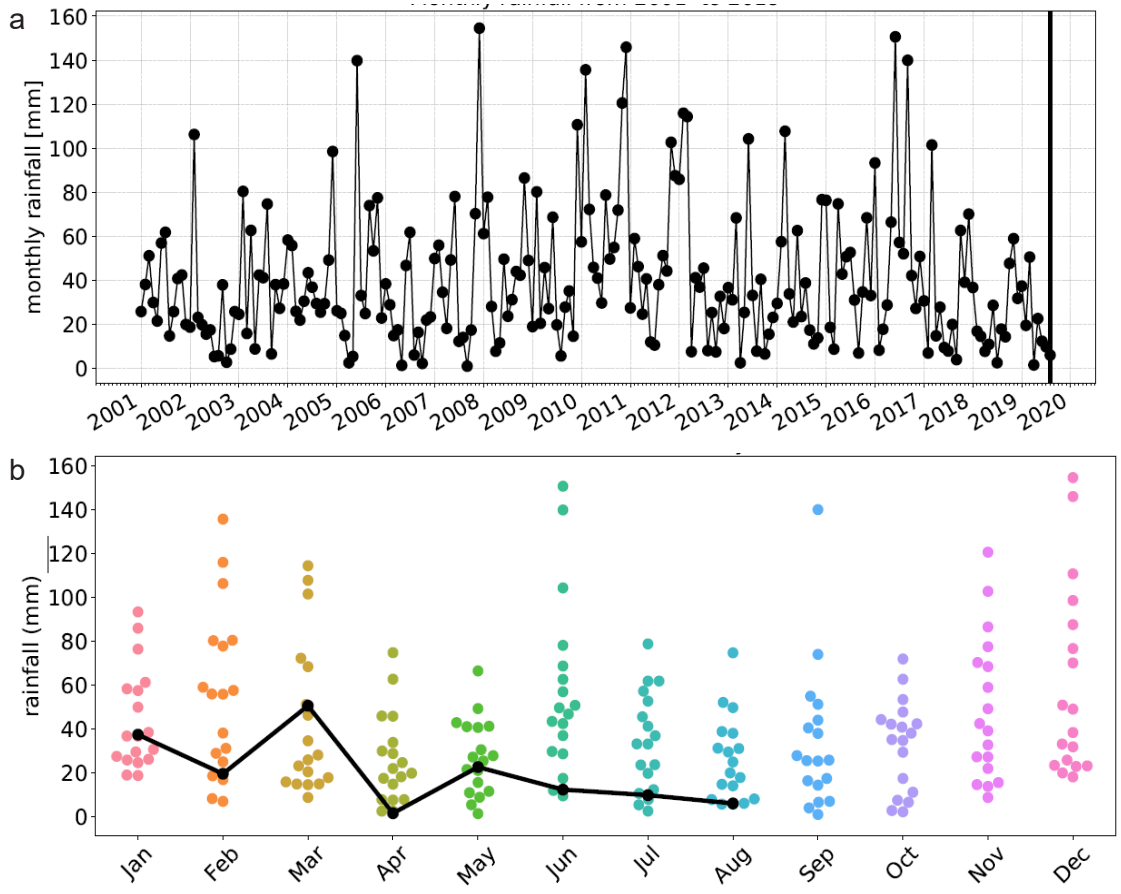

Figure 19 Rainfall for the Central West Local Land Services region, showing a) monthly time series and b) monthly data, from 2001 to August 2019 grouped by month. The black line in b) represents monthly data for 2019.

In August 2019 the region had large areas with low TVC (Figure 20a). For example:

- 28% or 2,562,224 hectares of the NRM region was not protected from wind erosion (Figure 20a)
- 65.3% or 5,975,472 hectares of the NRM region was not protected from water erosion (Figure 20b)
- nearly all the region was in the lowest three deciles of TVC, with most in decile 1 (Figure 20c)
- most of the region TVC was 20% lower than the average of all previous Augusts since 2001 (Figure 20d and Figure 21b)
- in 2019, TVC for wind erosion protection was the lowest in August (65%) since 2001 (Figure 21a) and the lowest TVC for wind erosion protection in the 19-year record since June 2018 (Figure 21b)
- the second failure in a row of the growing season lead to lower winter TVC levels (Figure 21)
- all targets were not met across a range of land use/forest classes (Table 6), which is exceptional as failure of the target usually only happens in the summer months (Figure 21b).

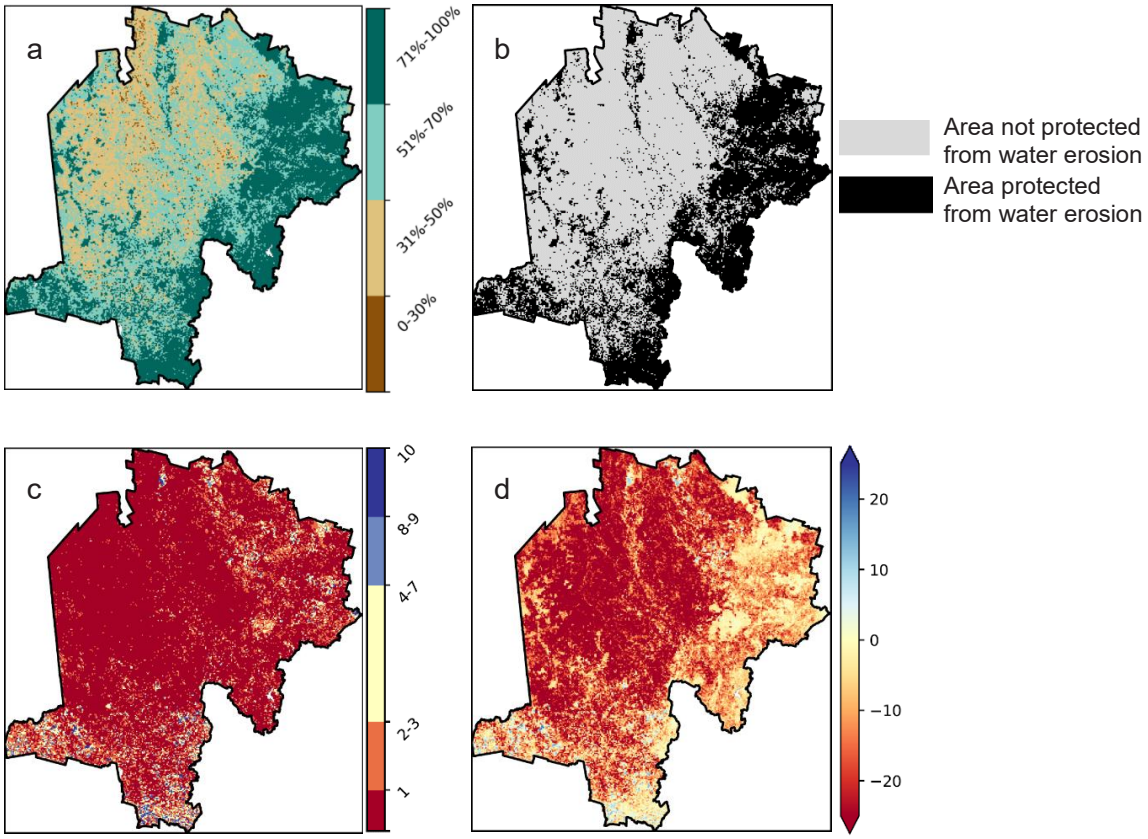

Figure 20 Maps of the Central West Local Land Services region for August 2019 showing a) total vegetation cover (TVC) – areas with <50% TVC (brown colours) are at risk of wind erosion, b) area protected from water erosion (black), c) TVC decile map, d) TVC anomaly map.

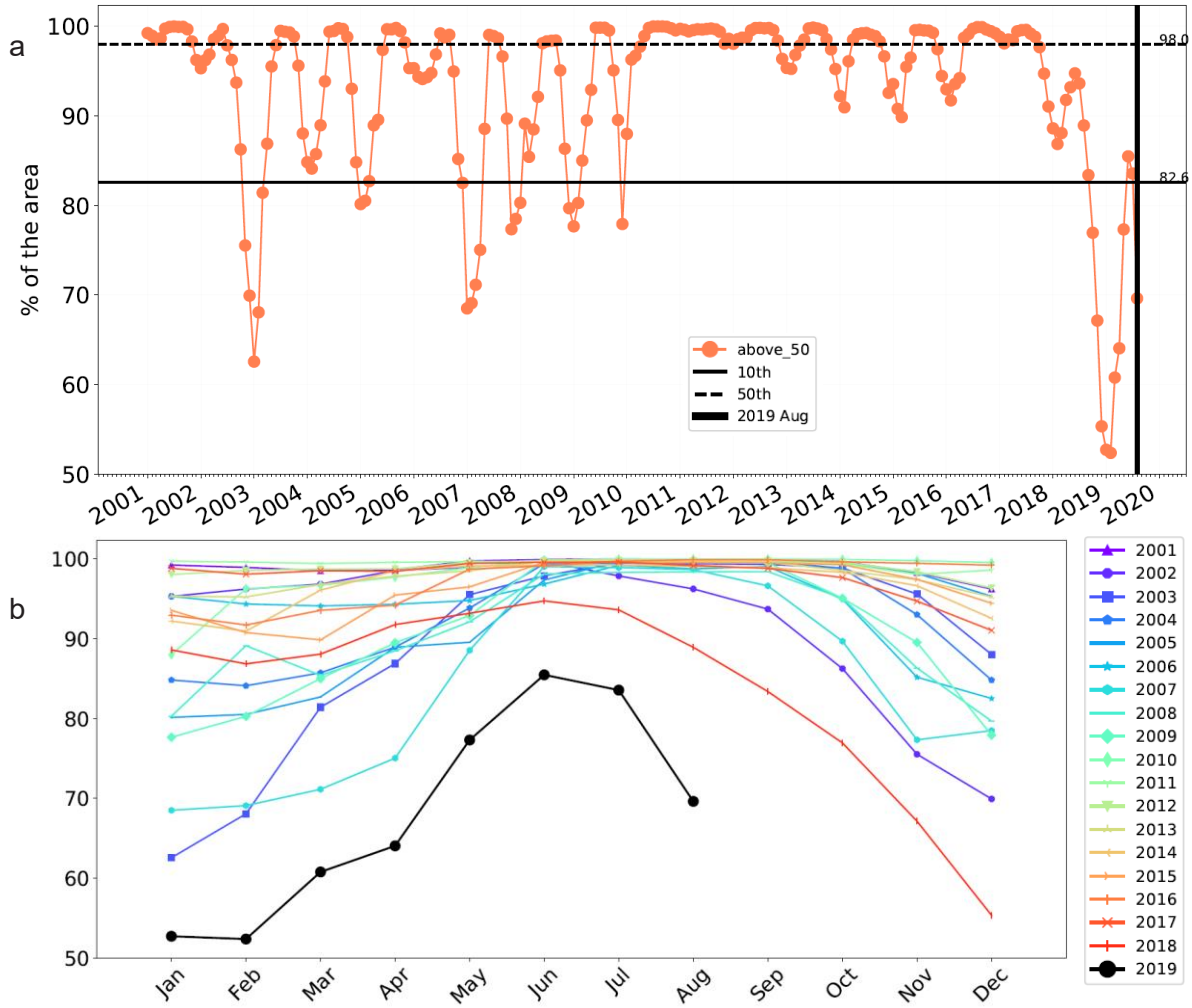

Figure 21 Time series of percentage area of agricultural land protected from wind erosion in the Central West Local Land Services region a) displayed chronologically by month, and b) displayed annually by month.

Table 6 Regional Land Partnerships target and percentage of area protected from wind erosion for different land use types in the Central West Local Land Services region, August 2019

Land use type	Wind erosion area protection target (%)	% area protected August 2019
All land uses combined	84	72
Conservation and natural environments	97	95
Agriculture #	82	70
Grazing	90	72
Grazing non–forest	87	67
Cropping	74	67
Irrigation	82	73

Note: # = where agriculture includes irrigated and non-irrigated grazing, cropping and horticultural land uses.

4.4 Property/project area reports

Project area reporting helps to establish whether interventions or changes in management practices funded by RLP are having the desired outcome. It also provides information and case studies for use by local NRM staff and Australian Government agencies to share knowledge for training and to demonstrate progress.

Five high-priority soil indicators were chosen for the RLP program (McKenzie et al. 2017). Three are slow changing: soil nutrient imbalances, soil acidity and carbon levels, and two change more rapidly: wind and water erosion. Leys et al. (2009) outlined how to improve monitoring of wind and water erosion, and reported that dust and vegetation cover are good indicators because dust is readily visible and measurable, and vegetation cover can be detected remotely and reported nationally every month.

Another reason for property or project area reporting is that RLP investments are made at that scale and not the landscape or land-use scale. Therefore, changes in cover status caused by RLP investments may not be detectable at larger spatial scales.

TVC or ground cover can used for property- and project-scale reporting. For property/project areas a polygon comparison method developed by the VegMachine team is appropriate. VegMachine reports the median ground cover within the polygons based on 30-metre pixels and a 30-year seasonal record.

The method compares two polygons: the investment polygon and the control. This method can also be used with the RAPP Map tool using its Analysis Tools function; however, we recommend the VegMachine tool because it has higher spatial resolution (30 metres) which is better suited to small investment areas (properties/project areas) and paddocks.

There are a number of things to think about when doing this type of analysis:

- try and compare like land types (i.e. similar soils and slopes) in the two polygons
- keep areas less than about 25 square kilometres as larger areas can have a wide range of ground cover levels which when using the median metric will obscure bare areas
- keep the two areas close together to maintain a similar climate
- remember the analysis can only be updated seasonally (every three months).

Figure 22 shows two paddocks and how the cover changes over time. Polygon 1, the control, starts with higher ground cover than polygon 2. Investment begins in the year 2000 in polygon 2. From this time on, polygon 2 starts to have higher ground cover. From about 2012, the confidence bands do not overlap (Figure 23), giving us confidence that the cover levels are different and that the investment has improved the median cover in polygon 2.

It is also possible to determine the improvement target for these polygons using downloaded data from the VegMachine site. Simply download the data, sort it from the highest to lowest value, and calculate the 10th percentile (i.e. using the Excel formula =PERCENTILE([data range], 0.1)). The result is shown in Figure 24 for the example in Figure 22. This analysis shows that polygon 1 has an RLP improvement target of 30% and polygon 2 a target of 45%. Since 2010, polygon 1 has been below target 3 times and polygon 2 only twice, this further confirms that the investment by RLP is improving the ground cover.

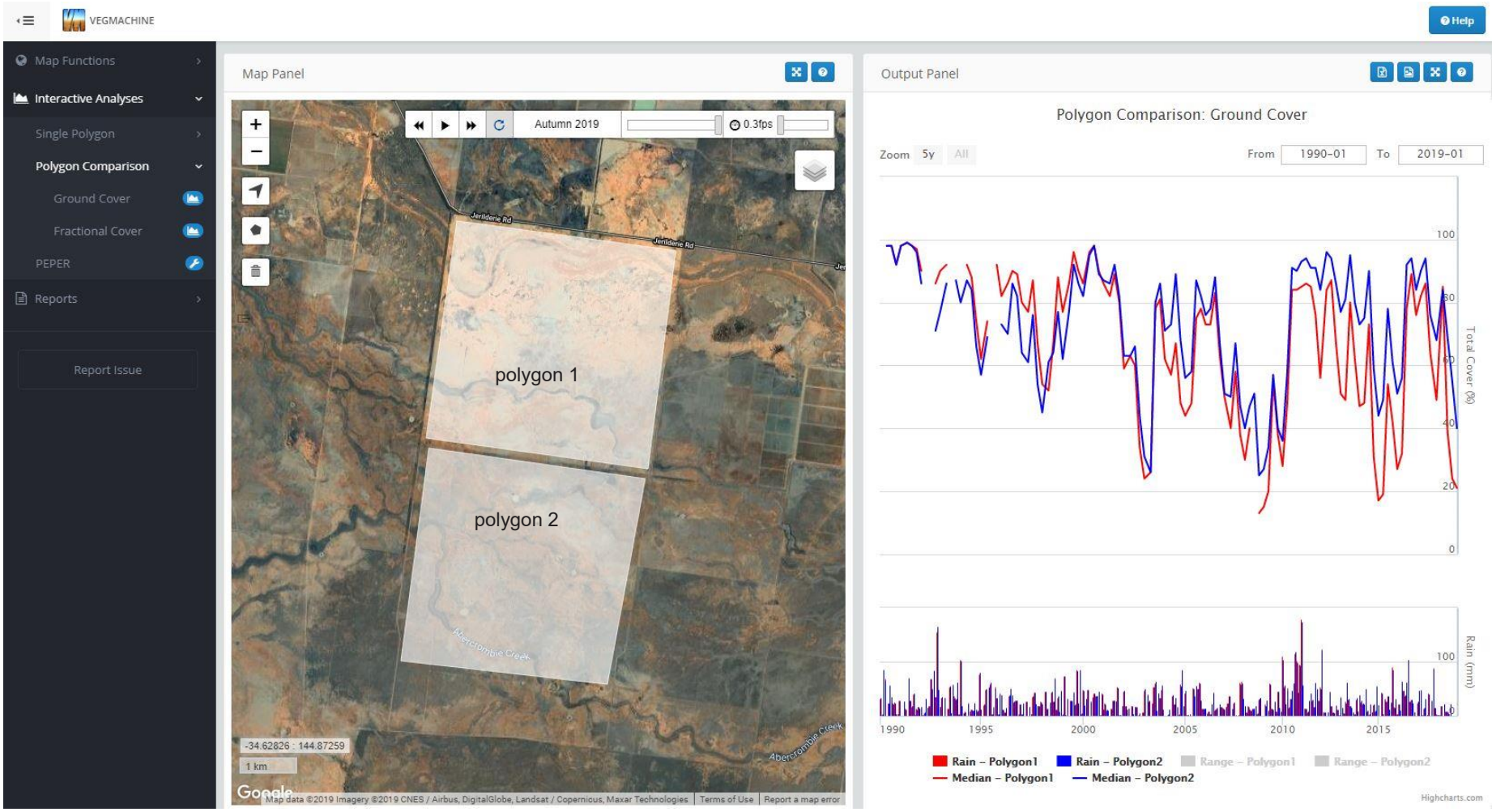

Figure 22 VegMachine ground cover reporting for two adjacent paddocks.

Notes: The left panel shows the extent of the paddocks selected for reporting. The top of the right panel shows the median cover for the control polygon 1 (red) and polygon 2 (blue), from 1990 to March 2019. The bottom of the right panel shows the rainfall for each polygon.

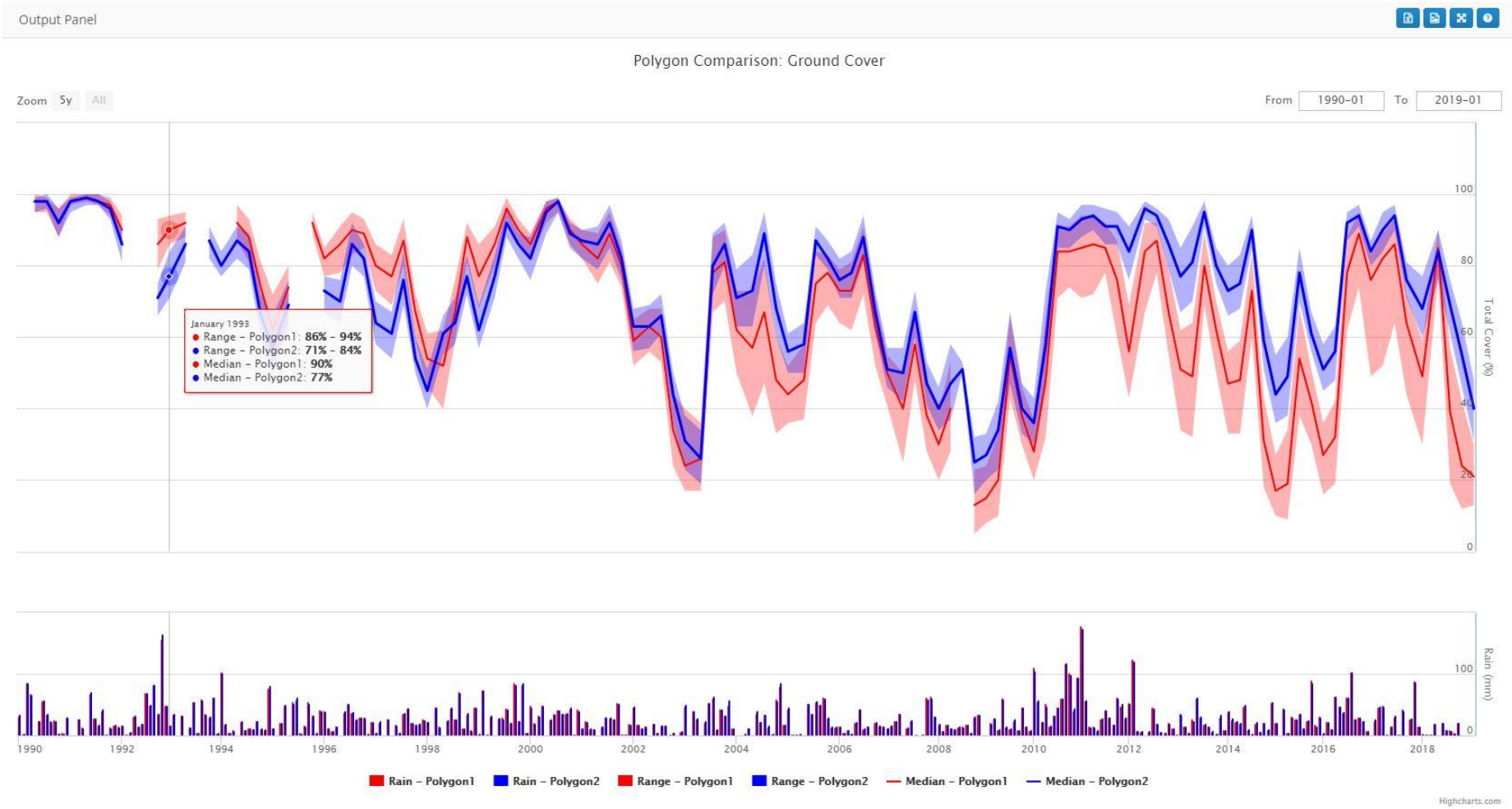

Figure 23 VegMachine ground cover reporting output for two adjacent paddocks showing confidence bands.

Notes: The control, polygon 1, is shown as red, and the intervention, polygon 2, is shown as blue. The chart shows 20 to 80% confidence bands for the time series for both polygons. Moving the vertical line to January 1993 on the graph displays the ranges and median for each polygon. Note that polygon 1 starts with higher median cover than polygon 2, but after 2000 median cover is lower in polygon 1. Since the paddocks are adjacent this suggests the changes may be due to management rather than climate.

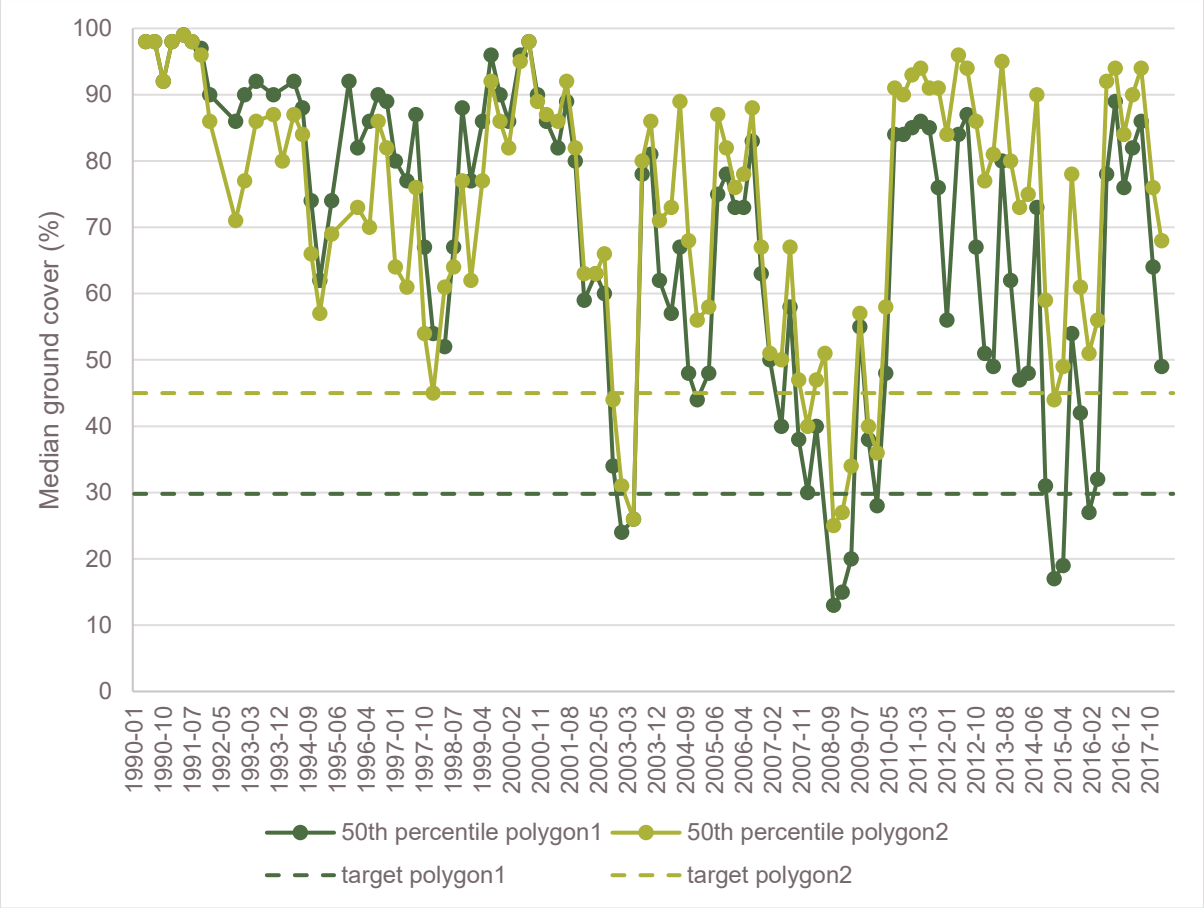

Figure 24 Comparison of improvement in ground cover for two paddocks and Regional Land Partnerships targets for each paddock.

Note: Solid lines show the median ground cover for polygon 1 and 2. The dashed lines show the 10th percentile targets. Polygon 1 (control – dark green) has a lower target of 30% median ground cover and polygon 2 (intervention – light green) has a higher target of 45% median ground cover.

4.5 When to apply target methodology and which scale of data to use

Sections 4.2 to 4.4 cover scales from national to paddock. This section suggests guidelines to help the user understand what data to use.

Fractional cover is available from three satellites. A summary of the resolution and timeliness of this data is given in Table 1. Each satellite can be used to calculate targets; however, there are advantages for using different satellites for certain applications.

There are basically two types of fractional cover data:

- high spatial resolution (30 and 10 metre pixels) available seasonal (3-monthly composite) time steps
- moderate spatial resolution (500 metre pixels) available every 8 days or monthly.

So, depending on the spatial detail required, or the frequency of reporting, different data sources are available.

Landsat-derived fractional cover is ideal for paddock- or project-scale reporting, as it has data for over 30 years and reporting about 1 month after the last image is taken at the end of each season.

In summary:

- Use Landsat-derived fractional cover for comparison over decades with small-scale sites (1 hectare) where you don't need data every month as the data is available about one month after the end of each season. Note you can also compare large areas with this Landsat based data.
- Use MODIS-derived fractional cover for large-scale sites (100 hectares) and where you want to make strategic or tactical decisions every month as the data is available 14 days after the end of each month.

5. Rangelands and Pasture Productivity Map tool – basic user guide

The Rangelands and Pasture Productivity (RAPP) Map has online help and videos available to users. The online help will continue to be updated. These instructions were accurate as of 11 November 2019. Subsequent changes and more detailed help can be found in the RAPP Map tool under About > Help and Frequently asked questions.

The tool was evaluated by workshop participants and reflects their suggested improvements. Things like accessibility (e.g. colour blind friendly), better labelling of output files from time series queries, mean and area above a threshold cover time series queries, being able to download total vegetation cover (TVC) data for use in GIS, individual reports for each land use and forest cover (LUFC) type, ability to submit your own polygon and get a report. At the time of writing, all these were available except the last two which were in test and expected to be implemented by the end of 2019.

5.1 Background

Interpreting spatial and time series ground cover data via RAPP Map or VegMachine can greatly assist with decision-making on stocking and cultivation management which impacts TVC. Decisions can be strategic or tactical.

In this section we explore how ground cover tools can be used to:

1. Monitor monthly cover patterns – how much, where is high and low?
2. Understand whether the monthly cover is ‘normal’ using anomaly and decile data
3. Understand time series fractional cover data.

5.2 Monitoring monthly total vegetation cover patterns

The RAPP Map and VegMachine tools can be used to investigate where in the landscape the TVC is low. For the Mallee Catchment Management Authority (CMA) in Victoria the Millewa district in the north-west corner of the region, south-west of Mildura, has the lowest TVC within the region in January 2019 (Figure 25). Thus, the RAPP Map provides a regional perspective. However, there is variability in TVC within the Millewa district as seen by the different 500-metre pixel colours in Figure 25. This variability is at the paddock level.

VegMachine, with its smaller 30-metre pixels, shows the TVC variation better due to the higher spatial resolution (Figure 26). The TVC variation for the individual paddocks can been seen, i.e. different brown colours. Even within paddock there are east–west lines of lighter tone (1 to 20% TVC), which are sand dunes.

The right-hand plot in Figure 26 shows all three cover fractions (red = bare ground, green = green or photosynthetic (PV) cover, blue = non-green or non-photosynthetic (NPV) cover, black = total cover (green + non-green) for the black-boxed polygon in Figure 25 and Figure 26. Each year the TVC increases in winter and decreases in summer following the Mediterranean rainfall pattern of the region. Looking at total cover (black line), we can see that since 2017, the cover has fallen each winter. This is because of the lack of green growth in winter in 2018 and 2019, represented by the green line.

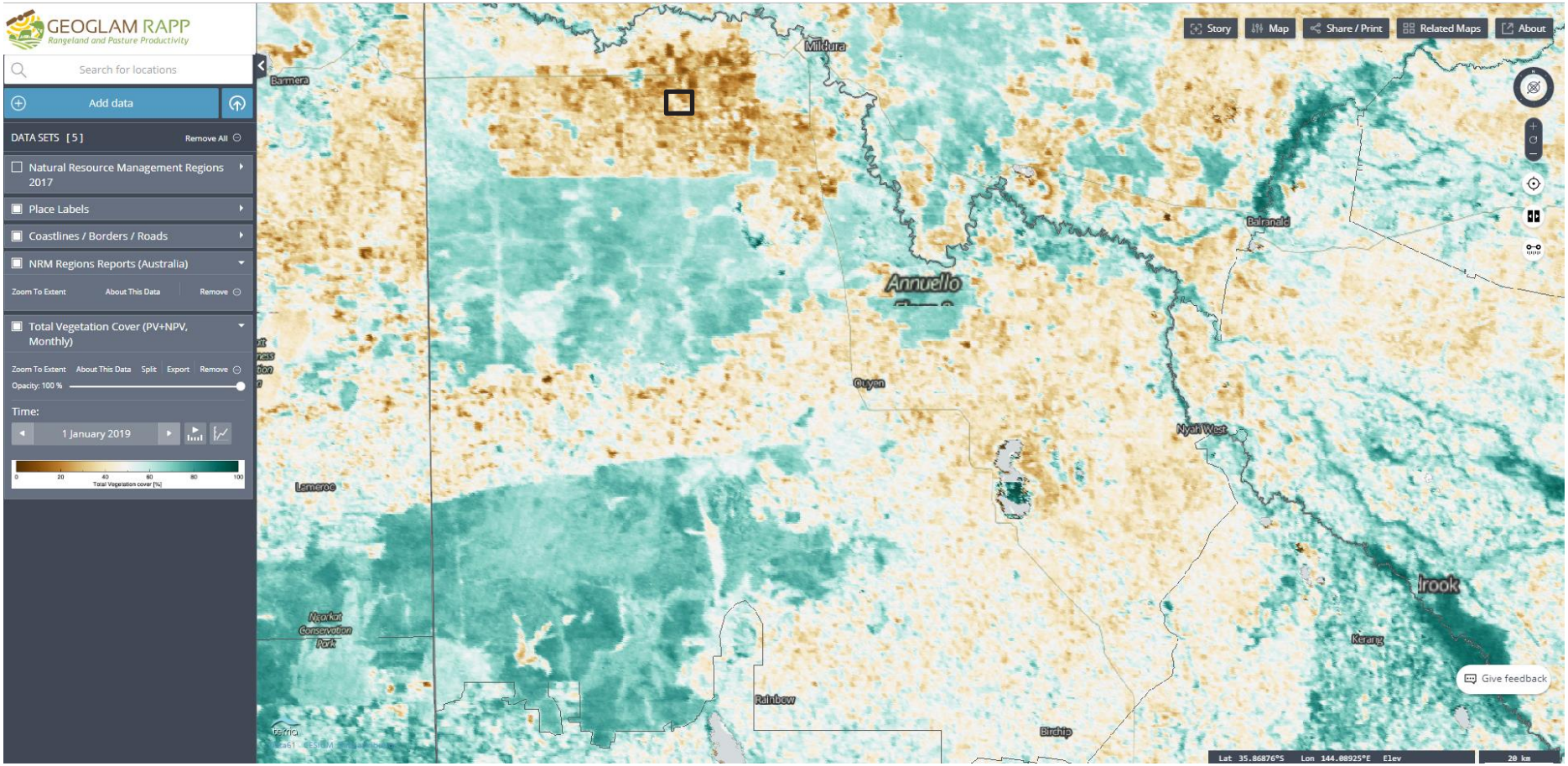

Figure 25 RAPP Map screen shot of total vegetation cover in the Mallee Catchment Management Authority region for January 2019.

Notes: The black square delineates a farm-level polygon within the Millewa district in north-west Victoria. Vegetation cover for this polygon is shown in Figure 26.

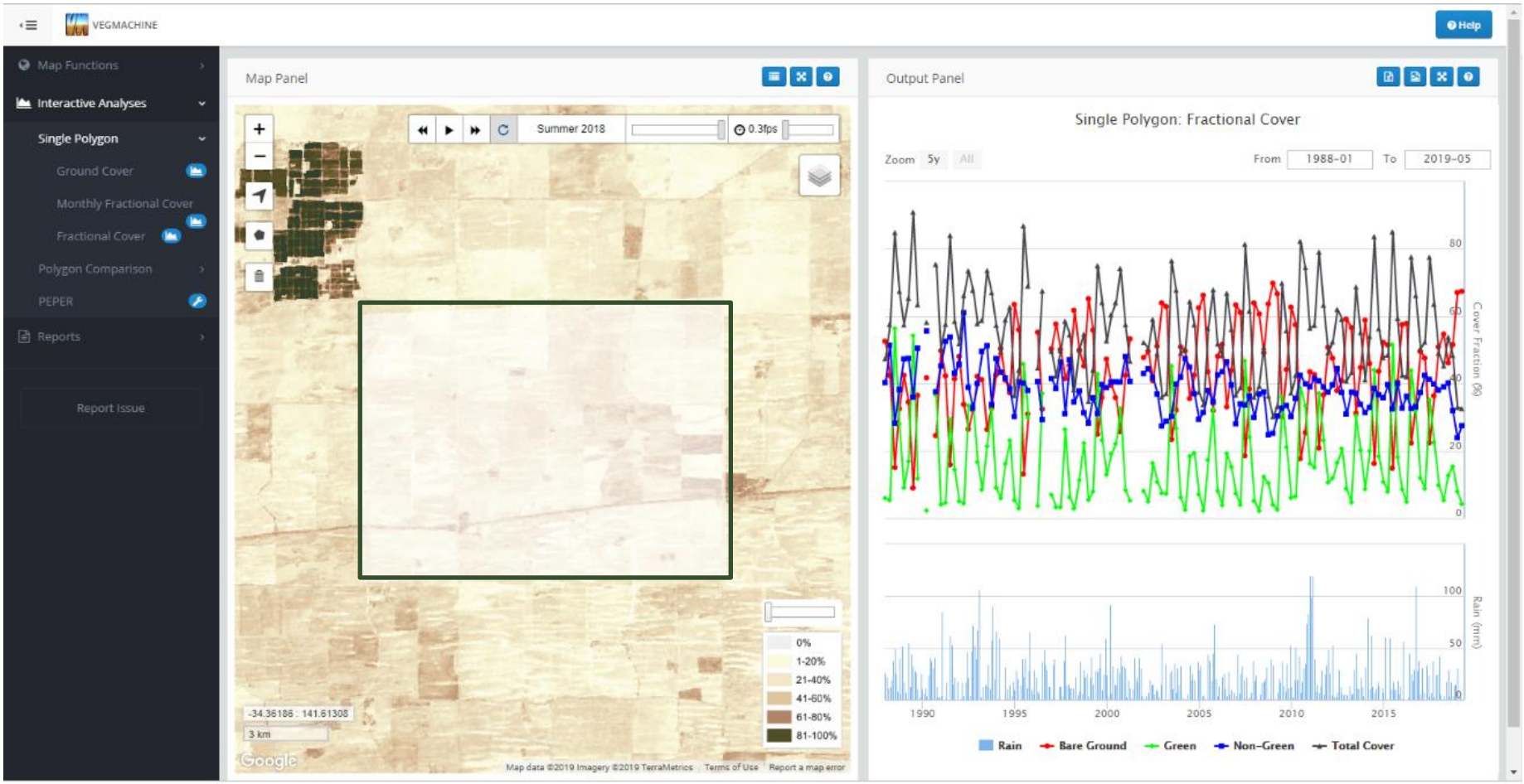

Figure 26 VegMachine screen shot of the vegetation cover for a farm-level polygon within the Mallee Catchment Management Authority region.

Notes: VegMachine displays the vegetation cover for the small black square in Figure 25 using Landsat imagery at 30 metre resolution in January 2019 (left-hand side) with six total vegetation cover classes (brown colours). The time series for each cover fraction and the rainfall are shown at the right.

5.3 Is the cover this month unusual?

Having a time series of many years enables us to place a monthly map within the record of previous months.

The October 2019 TVC map for Australia in Figure 27 shows low cover areas (i.e. <30% cover, represented by orange) in central and north-western Australia, and white to orange over most of the country. But is this cover usual for October 2019? To investigate this question, RAPP Map has two products: decile and anomaly maps.

The TVC decile map (Figure 28) shows the decile ranking of each TVC pixel for October 2019 when compared to the same months over a time series (e.g. all other Octobers). The map clearly shows that much of Australia is in the bottom decile of TVC. The most notable exception being the uplands and channels of the Desert Channels NRM region which are in the top decile (blue in colour) in Figure 28.

The TVC anomaly map (Figure 29) shows how far away from the mean TVC each pixel is when compared to the same months over a time series (e.g. all other Junes). Areas that are <15% lower than the mean for June 2019 are shown in red colours. Thus, Figure 29 shows that the Western, Central West and North West Local Land Services in NSW plus the north and east of Longreach in the Desert Channels NRM region, and the northern areas of Northern Territory and Western Australia, are at least 15% below the mean June cover level. Similarly, areas like the Desert Channels NRM region that are well above the mean (>15%) are shown in green.

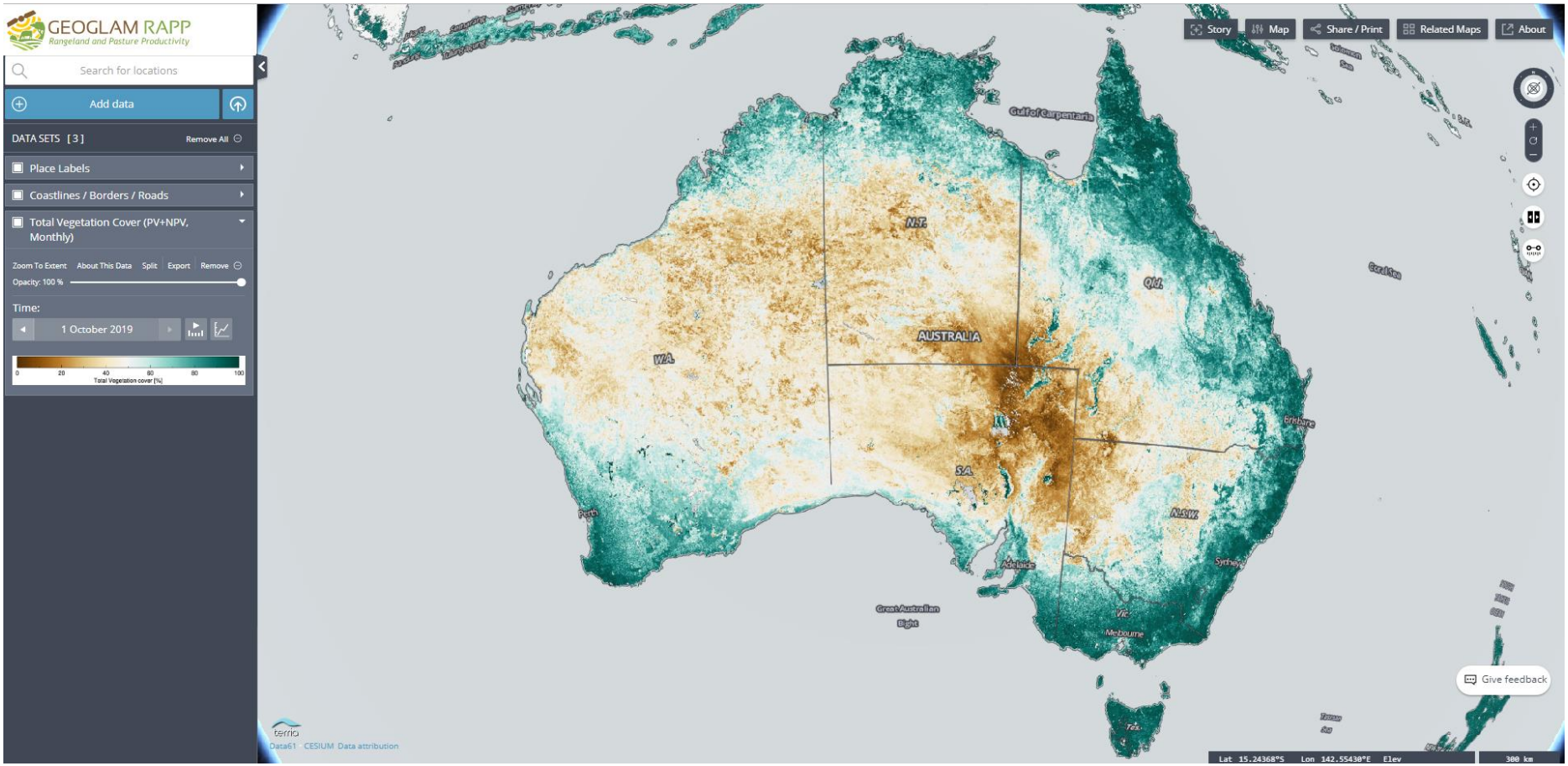

Figure 27 RAPP Map total vegetation cover map for Australia, October 2019.

Notes: The map legend on the left-hand side shows low total vegetation cover (TVC) is represented by dark brown and high TVC by dark green.

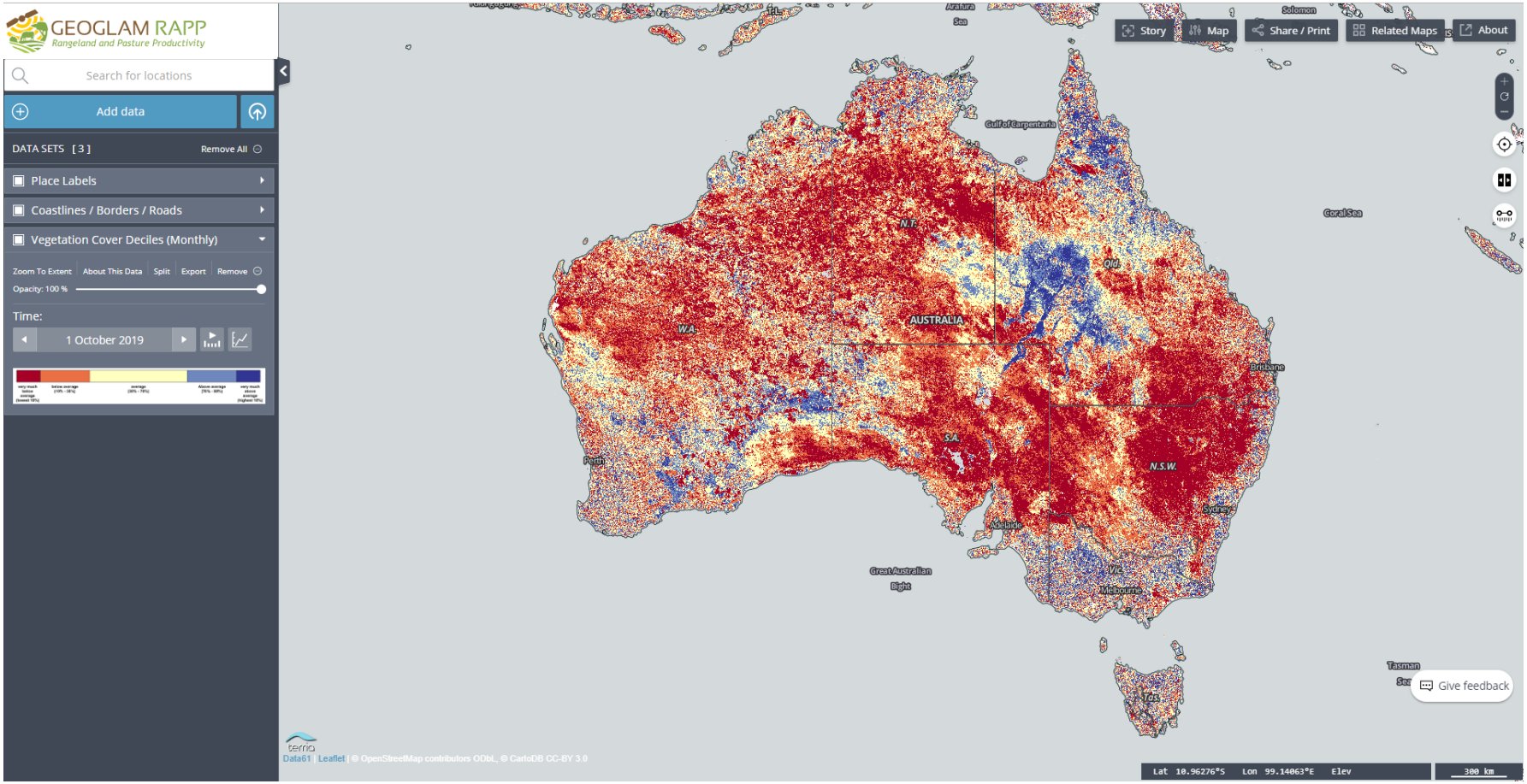

Figure 28 RAPP Map total vegetation cover decile map of Australia, October 2019.

Notes: The total vegetation cover (TVC) decile map shows where the pixel ranks when compared to the same month through the time series, e.g. all previous Octobers. Compared to Figure 27, Figure 28 shows large parts of the continent are in the lowest decile of records in October 2019. It also shows the Channel Country in south-west Queensland was in the top decile rankings indicating very much above average TVC.

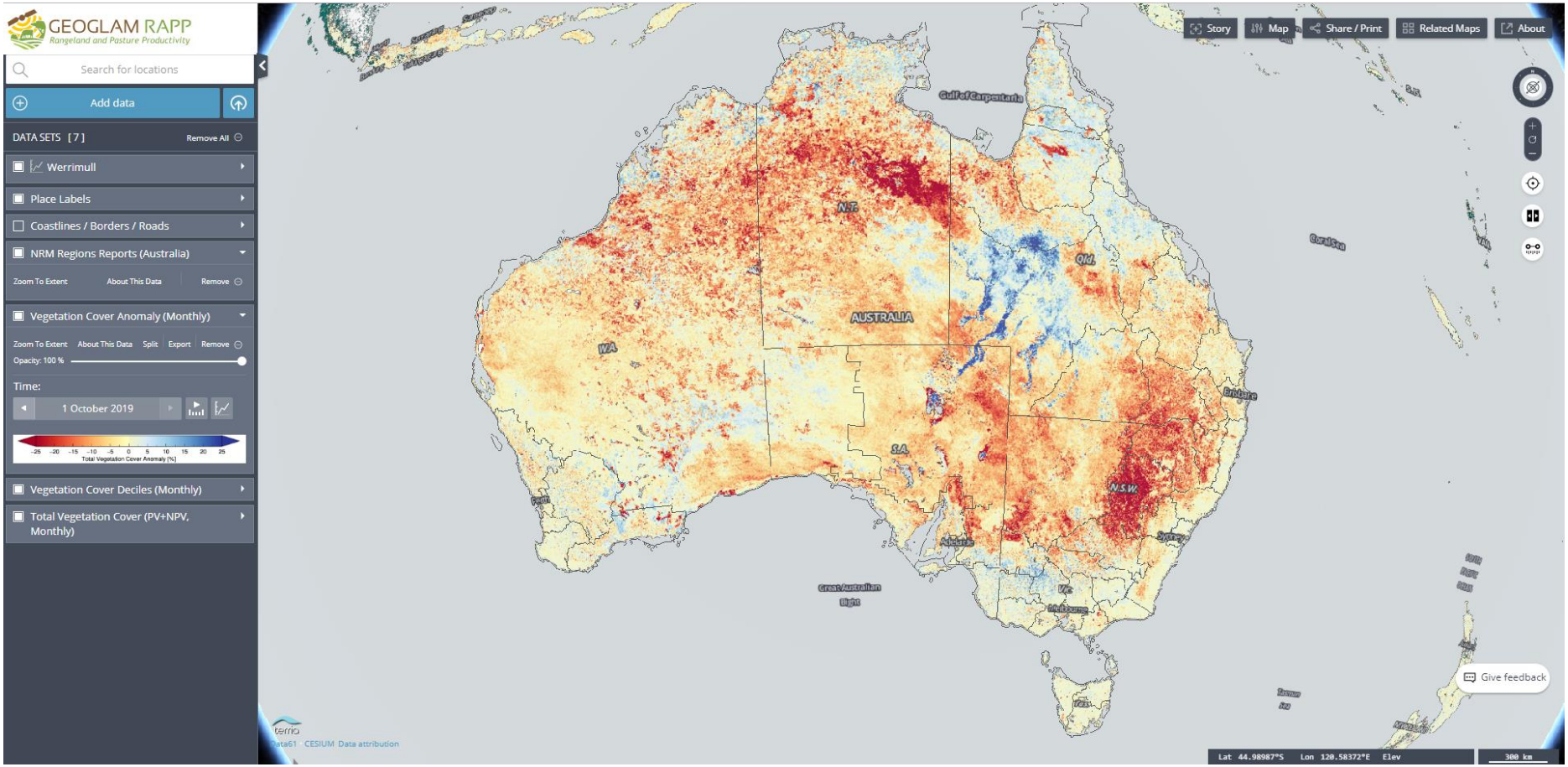

Figure 29 RAPP Map total vegetation cover anomaly map of Australia, October 2019.

5.4 Understanding time series data

RAPP Map and VegMachine both have time series tools that provide the fractions of green (PV), non-green (NPV), bare ground and TVC.

A time series of the fractional cover can be useful to understand trends in TVC and why it is increasing and decreasing each year, as seen for a polygon of the Werrimull area in north-west Victoria (Figure 30). In this figure, you can clearly see the Mediterranean rainfall response with increase in green cover each winter. The average TVC varies from about 75% in winter to 25% in summer. The green cover was low in the winters of 2002, 2004, 2006, 2008, 2012 and 2018; however, in 2018 and 2019, there was a double failure to grow pasture and crop, i.e. the peak of the green cover is not as high as normal years. The result is a steady decline in TVC (white line) since the winter of 2017.

An additional feature of RAPP Map is the ability to report the area protected from erosion (Figure 31). This overcomes the averaging problem that can mask large areas of bare ground. In the Figure 31 we see the area protected from wind erosion (>50% TVC) varies from 90% in winter to about 10% in summer. This analysis shows why this region is so susceptible to wind erosion during summer. It also highlights the value of using the area protected from erosion rather than just the median or average of a polygon's TVC.

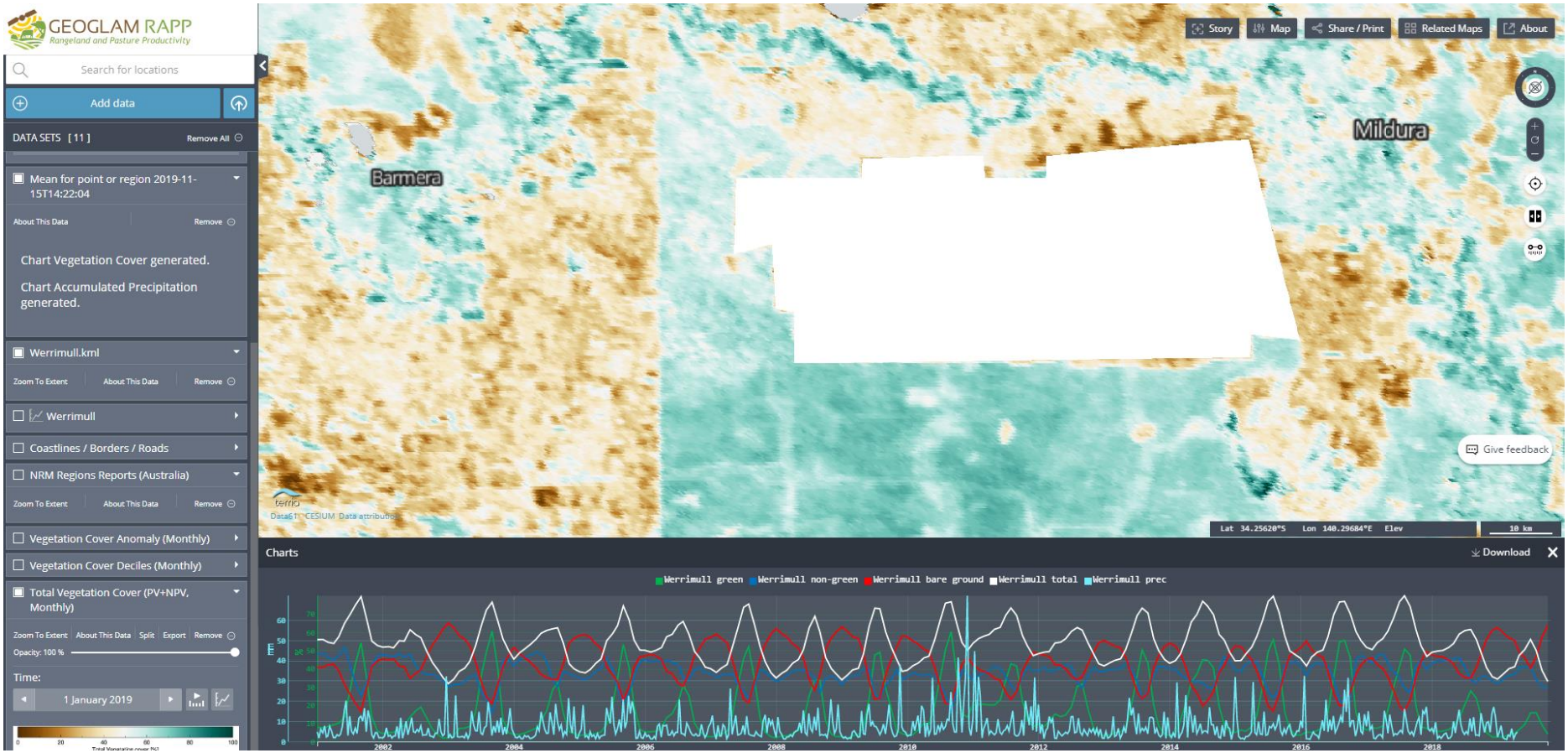

Figure 30 RAPP Map time series output of total vegetation cover, green (photosynthetic (PV)), non-green (non-photosynthetic (NPV)) and bare ground (BG) for the Werrimull area, north-west Victoria.

Notes: Total vegetation cover = white line, green or photosynthetic vegetation (PV) = green line, non-green or non-photosynthetic vegetation (NPV) = blue line, and bare ground (BG = red line) for the Werrimull area (shown as a white polygon).

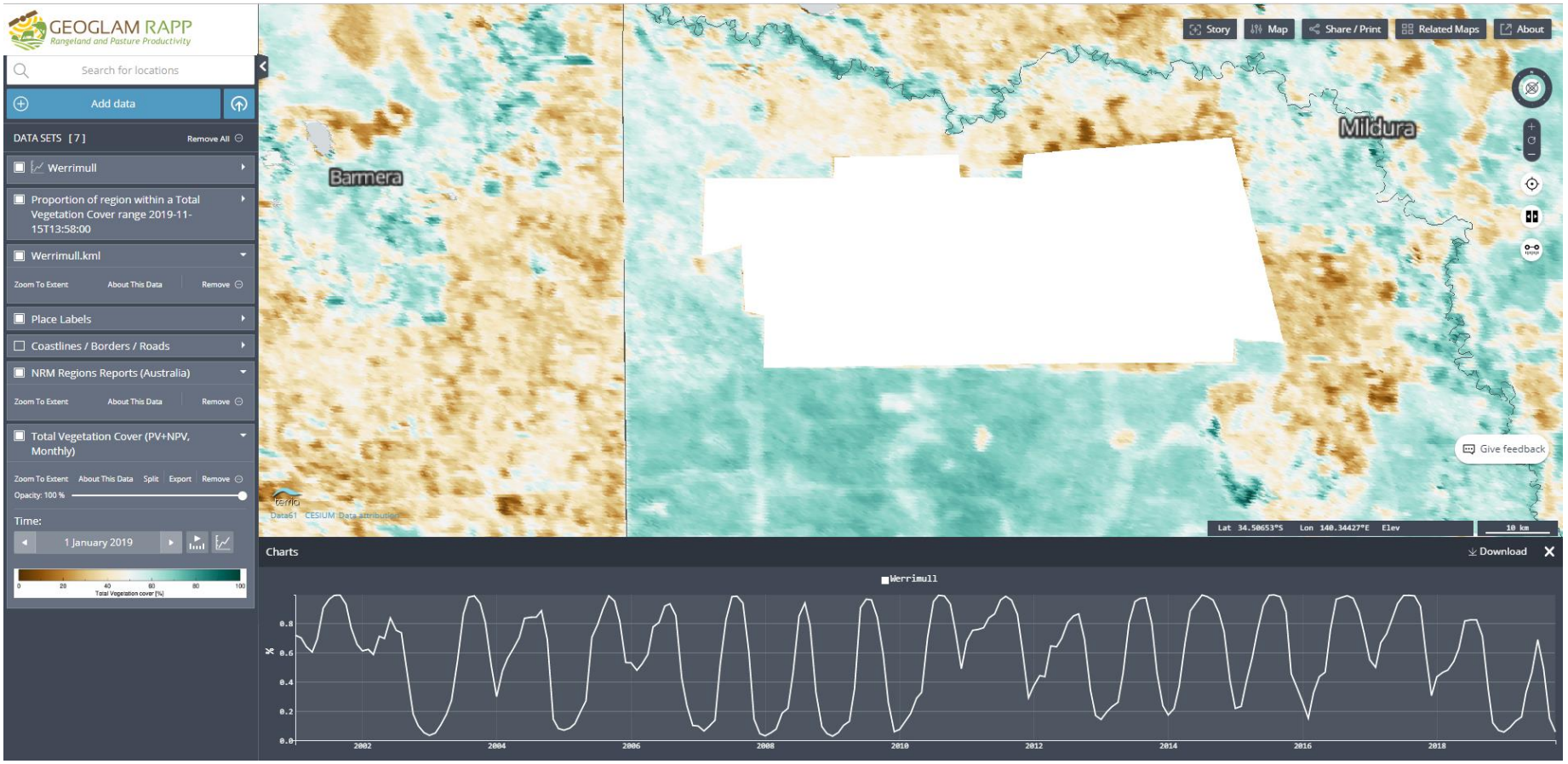

Figure 31 RAPP Map time series of the percentage of the Werrimull area, north-west Victoria, with total vegetation cover >50%.

Notes: The Werrimull area is shown as a white polygon on the map. The percentage of the Werrimull area with more than 50% total vegetation cover (TVC) is shown as a while line in the time series chart.

5.5 Setting targets

The concepts around setting targets have already been discussed in Section 3 and the results shown in Section 4.

In brief, the method for setting a target is:

1. set the baseline time period (e.g. for RLP the baseline is all months January 2001 to December 2018)
2. generate the time series of area protected (the count of pixels above the cover threshold at each time interval) for the baseline time period
3. calculate the 10th percentile rank of the pixels above the cover threshold from the time series (e.g. months if using MODIS)
4. the 10th percentile from the baseline time period is the RLP target
5. subsequent months after the baseline period (or subsequent to the intervention) can then be compared to the target.

The target setting method is illustrated in Figure 32.

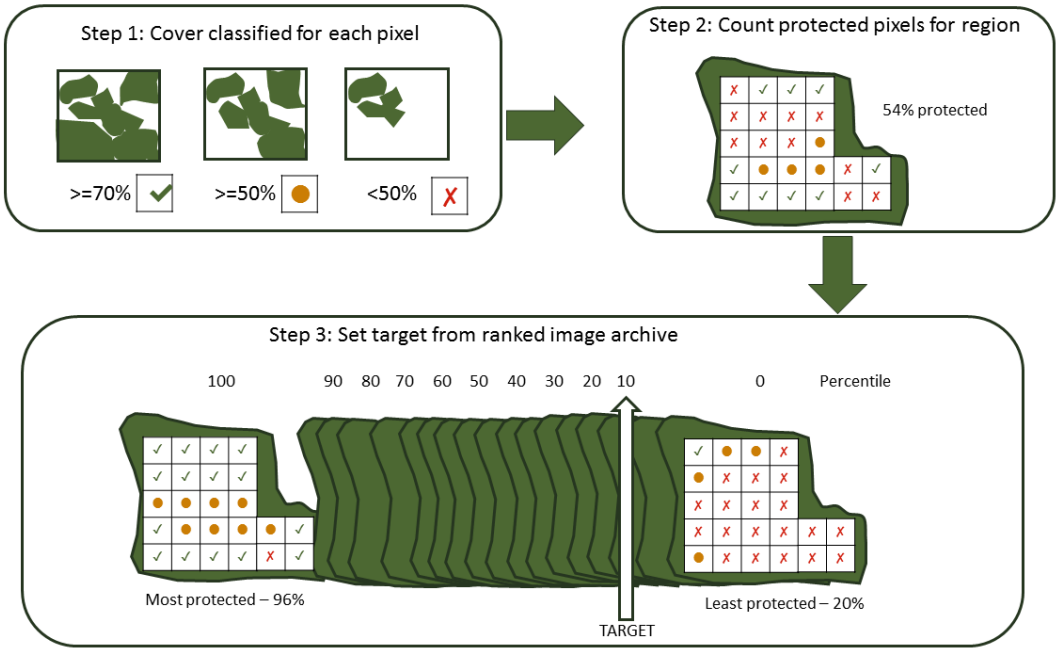

Figure 32 Method to calculate target of 10th percentile of area protected from soil erosion using a time series as completed using total vegetation cover from MODIS in the RAPP Map tool.

Notes: Step 1: assign each pixel as above the various cover thresholds. Step 2 calculate the area protected, e.g. >50% TVC for each time step. Step 3: rank the time steps from highest to lowest area protected, and calculate the 10th percentile.

This section describes how to complete the two recommended methods for setting and reporting against targets using TVC data and the online tools. The two methods are:

Method 1: comparison against the improvement target

Method 2: comparison against a control area (polygon comparison for small regions or investment areas).

5.5.1 Method 1: Comparison against the improvement target

The RAPP Map tool creates a report and a data file for the user each month. Within the report there are time series plots with the RLP improvement target pre-calculated. Currently two extent reports are created:

- full NRM region and all land use/forest classes within
- full local government area (LGA) and all land use/forest classes within.

These reports can be accessed via the RAPP Map tool or directly via these links:

- NRM regional reports – https://eo-data.csiro.au/remotesensing/reports/nrm/
- LGA regional reports – https://eo-data.csiro.au/remotesensing/reports/lga/

To open the reports within RAPP Map:

1. Open the RAPP Map system in Google Chrome or Firefox (The tool works in Internet Explorer but may have reduced functionality).
2. Click 'Continue' to close introduction messages.
3. To find the report for your NRM region click:
   a. Add data (blue box at the top of the left-hand pane)
   b. A new screen opens. Click on Regional Reports (middle tab)
   c. click the '+' symbol to the right of the NRM Regions Reports (Australia) or LGA Reports (Australia), this will load the NRM region or LGA polygons to the main screen map.
4. Click on the NRM region or LGA polygon of interest and a new 'Feature Information' screen will open. This screen has links to:
   a. the entire report as a PDF
   b. reports for previous months for this region
   c. a CSV file with the data used for this report.
5. To access the PDF report, click on the blue 'this link' text next to 'You can download the entire report as a PDF in this link'.
6. When the report opens you can save the report to your local drive.
7. Scroll down through the report, the maps, statistics and time series with the 10th percentile target (solid horizontal line) is given for all cover thresholds (50, 70, 80, 90, 95%). An example is shown in Figure 33.

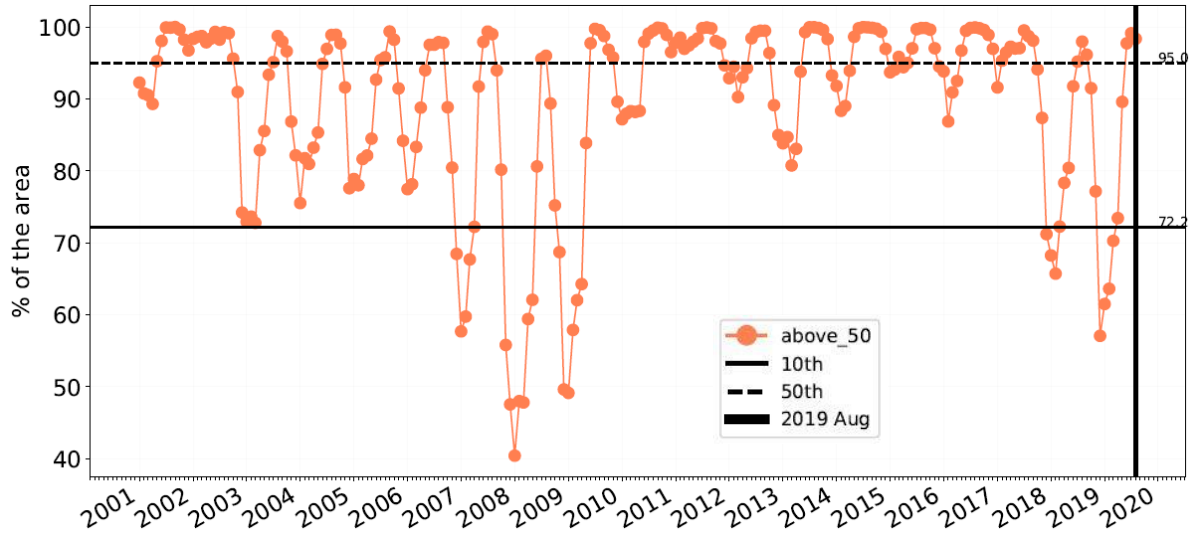

Figure 33 Example time series for the percentage area with total vegetation cover >50% showing the 10th and 50th percentiles.

Note: Orange line shows time series of percentage of area with TVC greater than 50%. 10th percentile is shown as a horizontal solid black line at 72% of the area. 50th percentile is shown as a dashed black line at 94% of the area. The reporting data is August 2019 as shown by the vertical black line on the right of the time series.

To recreate the 10th percentile target, download the CSV file from the Feature Information page. In Excel sort the column of interest from highest to lowest value and calculate the 10th percentile using the Excel function '=PERCENTILE([data range], 0.1)'. Headings for the CSV file are explained in the heading information text file.

Example time series from the downloaded CSV file of area protected from wind erosion, (i.e. >50% TVC) and water erosion (>70% TVC) for the Desert Channels NRM region with the 10th percentile target marked are shown in Figure 34a and b.

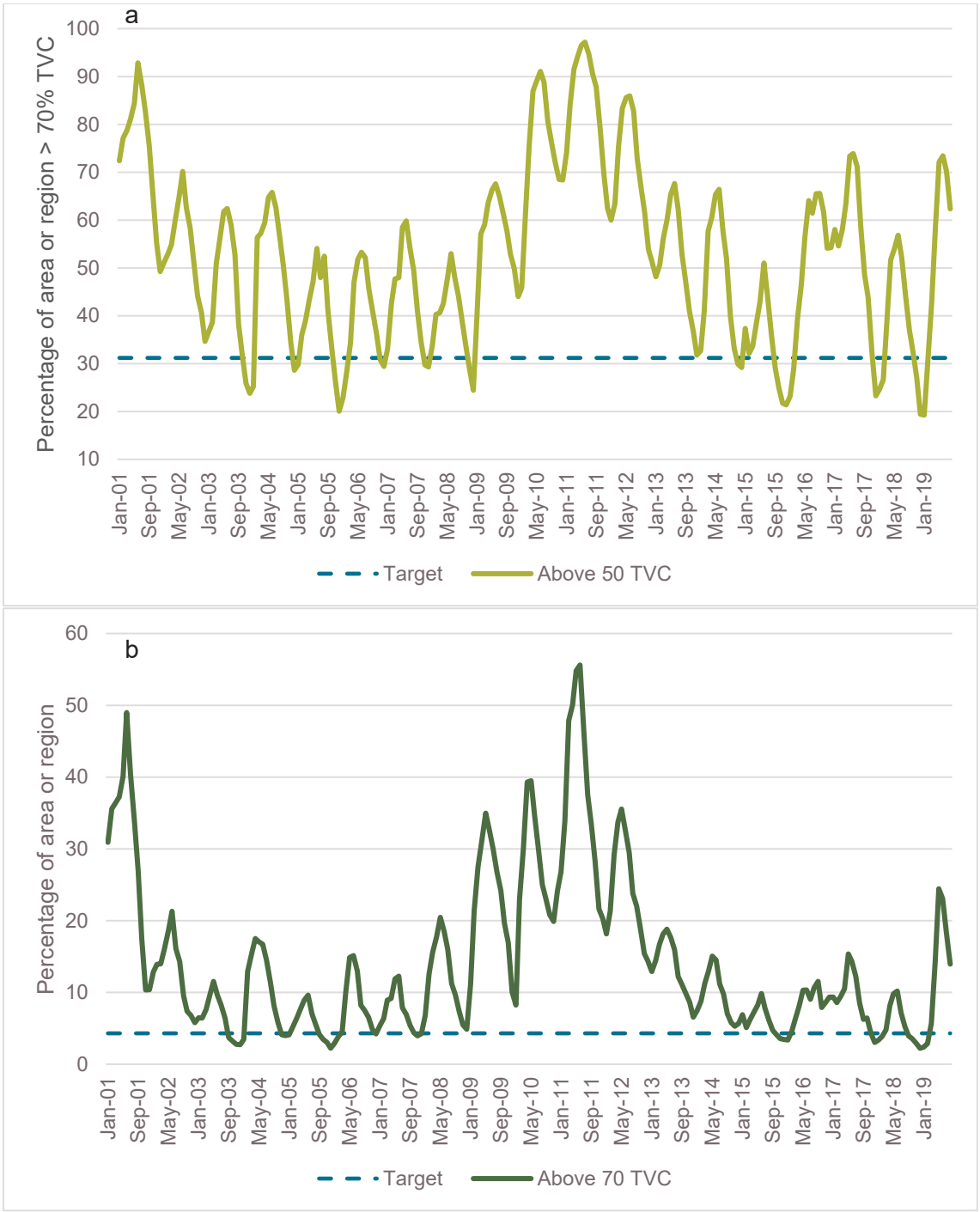

Figure 34 Baseline data and targets for the Desert Channels Natural Resource Management Region in Queensland for: a) area protected from wind erosion (>50% total vegetation cover (TVC)), and b) area protected from water erosion (>70% TVC).

Note: The target is the 10th percentile based on all months from January 2001 to December 2018.

5.5.2 Method 2: Comparison with a control area (polygon comparison)

Comparison with a control area (or polygon comparison) is intended to track progress against outcomes by comparing performance of the investment action at a site or paddock against a business-as-usual site or paddock.

To use this method, a control site with similar climate and land type is required. Land type mapping, such as vegetation type available for Queensland, is very useful to select a control site. In the absence of land type data, local knowledge of the landscape will suffice.

Large areas are less suitable for this method because a suitable control site with similar land type diversity may not exist. The method also compares the average cover for the region rather than the area protected. Average or median cover is a less useful metric for large areas.

This method can be done in RAPP Map using MODIS data, but is more easily done in VegMachine for smaller areas using Landsat data. The application of monthly Landsat data (or Sentinel 2 data in the future) is likely to be the best approach due to investment sites tending to be small.

Steps to report against the control area:

1. identify the investment area – draw or import and label polygon
2. select and identify the control – consider land use, climate, soil and vegetation type, and draw or import and label the control polygon
3. define the baseline and intervention periods
4. run the time series for both polygons – VegMachine can run two batched polygons concurrently from Landsat data (depending on polygon size), polygons will need to be run consecutively in RAPP Map
5. compare results from the investment site and control from the baseline and intervention period, this can be done visually using the charts generated within the tools, however the data will need to be downloaded to do any statistical analysis.

The output from VegMachine is shown for two paddocks in the Hay area of New South Wales in Figure 23. The improvement targets for both paddocks of 30% for polygon 1 and 45% for polygon 2 are shown in Figure 24.

6. Conclusions and recommendations

6.1 Conclusions

This project has focused on the reporting requirements of the Regional Land Partnerships (RLP) Evaluation Plan, Outcome 5 “the condition of the soil, biodiversity and vegetation is improved”.

Through a series of meetings and workshops with 44 natural resource management regions (NRMs) and nine other agencies, mainly regional development and a primary industry organisation, the project has:

- co-developed and agreed on methods for developing total vegetation cover (TVC) targets that can be used at multiple spatial scales (from the pixel to nationally) and with any time series vegetation cover data
- co-developed with CSIRO the Rangelands and Pasture Productivity (RAPP) Map tool to enable NRM managers to access satellite-derived data to both develop targets and report against those targets
- developed and delivered eight training workshops for NRM managers to learn about vegetation cover, how to set vegetation cover targets and report against them with data and reports from the RAPP Map and VegMachine tools
- incorporated feedback from workshop participants into improving useability of the RAPP Map tool, delivery of reports and setting targets
- co-developed a reporting method with the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and the Australian Government Department of Agriculture staff to report against vegetation cover targets at a national scale.

Previous studies have highlighted limitations in setting targets for natural resource management outcomes (Auditor General 2008; Pannell et al. 2013; Park et al. 2013). Based on feedback from training participants and Australian Government representatives, we believe that this project has:

- developed appropriate standards and guidelines to enable high-quality target setting of vegetation cover
- devised a target methodology that is both technically feasible for users and realistic in its ambition
- strongly linked vegetation cover targets to RLP outcomes.

This project has focused on RLP outcomes, but the concepts and tools have wider application including:

- prioritising projects and on-ground works to sustain soil and vegetation condition, e.g. identifying areas of persistent low cover to assess causes and possible interventions
- monitoring and reporting of other outcomes linked to vegetation cover, e.g. cultural protection of archaeological assets afforded by vegetation cover
- drought prediction, e.g. using pattern analysis of ground cover trends to predict the likelihood of going below the TVC target
- assessing the impact of drought policy, e.g. whether recipients of assistance demonstrate improved TVC over time.

6.2 Recommendations

This project has widely consulted with representatives from regional NRMs and the Australian Government Department of Agriculture. The consultation has revealed that further support is required to improve adoption of target setting for evaluation of governmental programs and individual land manager sites. It has also revealed that this project is relevant to programs beyond RLP. As such we recommend three future projects:

1. decision-support for land management organisations, policy makers and land managers
2. understanding and valuing ground cover and soil health
3. operations, maintenance and improvement to RAPP Map reporting.

6.2.1 Decision-support for land management organisations, policy- and land-holders

Ground cover is an incredibly useful indicator as it has both production and environmental uses. Feedback from participants of the workshops and meetings held with other organisations revealed an appetite for more training, consolidation of reporting and delivery of products developed in this study. Improvements such as reporting over smaller areas, more objective methods of identification of control sites for investment site comparison, and application of the data to other questions like ‘where to invest to increase cover’ were raised.

Further development and consolidation would enhance decision-making due to availability of fit-for-purpose information to land management organisations, policy- and land-holders. Improved reporting would also be possible using standardised methods across a range of initiatives.

New stakeholders (e.g. the Australian Government drought team) have also been identified as they are seeking innovative monitoring and assessment tools linked to remote sensing that provide accurate and timely information on the condition of vegetation and soils.

A project team consisting of CSIRO, Australian National University, ABARES and erosion modellers from state agencies working with land management organisations, policy- and land-holders is seen as the way forward.

6.2.2 Understanding and valuing ground cover and soil health

Several questions were raised during meetings with stakeholders that were beyond the scope of this project and will require new science and research. In particular, conversations about the availability of biomass estimates to better estimate stock carrying capacity, better attribution of ground cover to natural climate variability versus anthropogenic factors, and incorporating ground cover and soil/vegetation condition into natural capital accounting.

This research could help separate the effects of climate from land management and provide a system of alerts for when total vegetation cover might be about to go below targets. These products would also enhance natural capital accounting.

A project team consisting of CSIRO, Australian National University, ABARES, Geoscience Australia, Department of the Environment and Energy, Queensland Joint Remote Sensing Research Program and System of Economic and Environmental Accounting, people from land management organisations, policy- and land-holders is seen as one way forward.

6.2.3 Operations, maintenance and improvements to RAPP Map reporting

The RAPP Map system forms the basis for national reporting on ground cover levels used by ABARES and is being adopted by the RLP as one of the tools for ground cover target setting and monitoring for RLP projects. Outcomes from projects 1 and 2 outlined in Section 6.2 can be delivered via the RAPP Map tool. For continued use and uptake of opportunities, the system needs to be maintained operationally and adapted or enhanced to support end-users.

The current RAPP Map team (CSIRO, Data61) would deliver these services in collaboration with stakeholders of project 1 and 2.

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8. References

ABARES 2018a, Catchment scale land use of Australia - Update December 2018, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, CC BY 4.0, https://doi.org/10.25814/5c7728700fd2a

ABARES 2018b, Forests of Australia (2018), Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, CC BY 4.0, https://doi.org/10.25814/5c59170ec780d

ABARES 2016, The Australian Land Use and Management Classification Version 8, Prepared by the Australian Collaborative Land Use and Management Program partners, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1027181/0

Auditor-General 2008, Regional Delivery Model for the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality, ANAO Audit Report No.21 2007–08, Australian National Audit Office, Canberra, www.anao.gov.au/work/performance-audit/regional-delivery-model-natural-heritage-trust-and-national-action-plan

Australian Government 2008, Caring for our Country Business Plan 2009–2010, Department of the Environment, Water, Heritage and the Arts and the Department of Agriculture, Fisheries and Forestry, Australian Government, Canberra, http://nrmonline.nrm.gov.au/catalog/mql:2263

Australian Government 2010, Caring for our Country Business Plan 2010–2011, Department of the Environment, Water, Heritage and the Arts and the Department of Agriculture, Fisheries and Forestry, Australian Government, Canberra, http://nrmonline.nrm.gov.au/catalog/mql:2261

Australian Government 2017a, National Landcare Programme, Commonwealth of Australia, Canberra, www.nrm.gov.au/

Australian Government 2017b, Natural Resource Management (NRM) Regions (2017), Department of the Environment and Energy, Australian Government, Canberra, CC BY 3.0, https://data.gov.au/data/dataset/natural-resource-management-nrm-regions-2017

Australian Government 2017c, Regional Land Partnerships MERI framework, Commonwealth of Australia, Canberra, www.nrm.gov.au/publications/regional-land-partnerships-meri-framework

Australian Government 2018a, National Landcare Program Management Units 2018, Department of the Environment and Energy, Australian Government, Canberra, CC BY 3.0, www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7BE93A9599-3C1E-40EB-A408-DF2C7712F486%7D

Australian Government 2018b, National Landcare Program Phase Two, Commonwealth of Australia, Canberra, www.nrm.gov.au/national-landcare-program

Australian Government, Queensland Government 2013, Reef Water Quality Protection Plan 2013, Reef Water Quality Protection Plan Secretariat, Brisbane, www.reefplan.qld.gov.au/__data/assets/pdf_file/0016/46123/reef-plan-2013.pdf

Australian Government, Queensland Government 2014, Ground cover results: Great Barrier Reef Report Card 2014, in *Great Barrier Reef Report Card 2014 Results*, Australian Government and Queensland Government, Brisbane, pp. 27–62, www.reefplan.qld.gov.au/__data/assets/pdf_file/0025/46078/gbr-2014report-card-detailed-results.pdf

Australian Government, Queensland Government 2015, Ground cover results: Great Barrier Reef Report Card 2015, In: *Great Barrier Reef Report Card 2015 Results*, Australian Government and Queensland Government, Brisbane,

www.reefplan.qld.gov.au/__data/assets/pdf_file/0018/46080/gbr-2015report-card-detailed-results.pdf

Australian Government, Queensland Government 2016, Ground cover results: Great Barrier Reef Report Card 2016, Reef Water Quality Protection Plan, Australian Government and Queensland Government, Brisbane, www.reefplan.qld.gov.au/__data/assets/pdf_file/0018/46161/report-card-2016-ground-cover-results.pdf

Australian National Audit Office 2019, Regional Land Partnerships – Potential audit: 2019–20, Commonwealth of Australia, Canberra, www.anao.gov.au/work/performance-audit/regional-land-partnerships

Barson M, Mewett J, Paplinska J 2012, Land management practice trends in Australia's broadacre cropping industries, Department of Agriculture Fisheries and Forestry, Canberra, http://nrmonline.nrm.gov.au/catalog/mql:2866

Beutel TS, Trevithick R, Scarth P, Tindall D 2019, VegMachine.net. online land cover analysis for the Australian rangelands, *The Rangeland Journal* 41: 355–362, https://doi.org/10.1071/RJ19013

Bureau of Meteorology 2019, Climate Glossary, Bureau of Meteorology, www.bom.gov.au/climate/glossary/anomaly.shtml

Chappell A, Webb NP, Leys JF, Waters CM, Orgill S, Eyres MJ 2019, Minimising soil organic carbon erosion by wind is critical for land degradation neutrality, *Environmental Science & Policy* 93: 43–52, https://doi.org/10.1016/j.envsci.2018.12.020

Cork S, Eadie L, Mele P, Price R, Yule D 2012, The relationship between land management practices and soil condition and the quality of ecosystem services in Australia, Canberra, www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/natural-resources/ecosystem-services/chp6_10.pdf

Department of Agriculture and Water Resources 2019, Budget 2019–20. Portfolio Budget Statements 2019–20, Australian Government Department of Agriculture and Water Resources, Canberra, www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/about/budget/2019-20/2019-20-pbs-combined.pdf

Guerschman JP, Leys JF, Larraondo PR, Henrikson M, Paget M, Hill M, Barson M 2018, Monitoring ground cover: an online tool for Australian regions, Report prepared for the Australian Government Department of Agriculture and Water Resources, CSIRO, Australia, https://doi.org/10.25919/5bf84026e556d

Guerschman JP, Scarth PF, McVicar TR, Renzullo LJ, Malthus TJ, Stewart JB, Rickards JE, Trevithick R 2015, Assessing the effects of site heterogeneity and soil properties when unmixing photosynthetic vegetation, non-photosynthetic vegetation and bare soil fractions from Landsat and MODIS data, *Remote Sensing of Environment* 161: 12–26, https://doi.org/10.1016/j.rse.2015.01.021

Lang RD 1979, The effect of ground cover on surface runoff from experimental plots, *The Journal of the Soil Conservation Service of NSW* 35: 108–114

Lang RD, McDonald W 2005, Maintaining groundcover to reduce erosion and sustain production, Agfact P2.1.14, NSW Government Department of Primary Industries, www.dpi.nsw.gov.au/__data/assets/pdf_file/0018/162306/groundcover-for-pastures.pdf

Larney FJ, Izaurralde RC, Janzen HH, Olson BM, Solberg ED, Lindwall CW, Nyborg M 1995, Soil erosion – crop productivity relationships for six Alberta soils, *Journal of Soil and Water Conservation* 50: 87–91

Leys J, Smith J, MacRae C, Rickards J, Yang X, Randall L, Hairsine P, Dixon J, McTainsh G 2009, Improving the capacity to monitor wind and water erosion: a review, Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, http://nrmonline.nrm.gov.au/catalog/mql:2243

Leys J, Strong C, Heidenreich S, Koen K 2018, Where she blows! A ten year dust climatology of western New South Wales Australia, *Geosciences* 8: 232–247, https://doi.org/10.3390/geosciences8070232

Leys JF 1999, Wind erosion on agricultural land, In: *Aeolian Environments, Sediments and Landforms*, Goudie AS, Livingston I, Stokes S (eds). John Wiley and Sons, England, pp. 143–166

McCosker J, Rolfe J, Fensham R 2009, Can bare ground cover server as a surrogate for plant biodiversity in grazed tropical woodlands? *The Rangeland Journal* 31: 103–109, https://doi.org/10.1071/RJ08041

McKenzie NJ, Hairsine PB, Gregory LJ, Austin J, Baldock J, Webb M, Mewett J, Cresswell HP, Welti N, Thomas M 2017, Priorities for improving soil condition across Australia's agricultural landscapes, Report prepared for the Australian Government Department of Agriculture and Water Resources, CSIRO, Australia, https://doi.org/10.4225/08/59e4f3adc09ac

Montreal Process Implementation Group for Australia and National Forest Inventory Steering Committee 2018, Australia's State of the Forests Report 2018, ABARES, Canberra, www.agriculture.gov.au/abares/forestsaustralia/sofr/sofr-2018

Muir J, Schmidt M, Tindall D, Trevithick R, Scarth P, Stewart JB 2011, Field measurement of fractional ground cover: A technical handbook supporting ground cover monitoring for Australia, Prepared by the Queensland Department of Environment and Resource Management for the Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1027474/0

Pannell DJ, Roberts AM, Park G, Alexander J 2013, Designing a practical and rigorous framework for comprehensive evaluation and prioritisation of environmental projects, *Wildlife Research* 40: 126–133, https://doi.org/10.1071/WR12072

Park G, Roberts A, Alexander J, McNamara L, Pannell D 2013, The quality of resource condition targets in regional natural resource management in Australia, *Australasian Journal of Environmental Management* 20: 285–301, https://doi.org/10.1080/14486563.2013.764591

Queensland Government 2018, Reef 2050 Water Quality Improvement Plan 2017–2022, State of Queensland, Brisbane, www.reefplan.qld.gov.au/__data/assets/pdf_file/0017/46115/reef-2050-water-quality-improvement-plan-2017-22.pdf

Trevithick R, Scarth P, Tindall D, Denham R, Flood N 2014, Cover Under Trees: RP64G Synthesis Report, Queensland Government Department of Science, Information Technology, Innovation and the Arts, Brisbane, www.publications.qld.gov.au/dataset/ground-cover-fire-grazing

9. Acronyms and glossary

9.1 Acronyms

Acronym	Definition
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
BG	bare ground
CMA	catchment management authority
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSV file	comma separated values file
DPIE	Department of Planning, Industry and Environment (NSW)
EES	Environment, Energy and Science
GTTS	Ground cover training and target setting (project)
LGA	local government area
LLS	Local Land Services (NSW)
MODIS	Moderate Resolution Imaging Spectroradiometer
NLP	National Landcare Program
NPV	non-photosynthetic vegetation
NRM	Natural Resource Management
NSW	New South Wales
PDF	portable data format
PM	particulate matter
PV	photosynthetic vegetation
RALF	Regional Agricultural Landcare Facilitator
RAPP	Rangelands and Pasture Productivity
RLP	Regional Land Partnerships (program)
SMART	specific, measurable, achievable realistic and time-bound
TVC	total vegetation cover

9.2 Glossary

Term	Definition
Anomaly	The anomaly shows how far away a value is from the mean. In this report the anomaly usually refers to the monthly TVC for each pixel compared to the mean TVC for the same months from the time series (e.g. all other Junes).
Fractional cover	The percentage or fraction of an area (usually a pixel for the purpose of remote sensing) covered by specific types of photosynthetic vegetation such as growing plants, non-photosynthetic vegetation such as stubble, senescent herbage and leaf litter, and bare earth or rock (Guerschman et al. 2015).
Ground cover	Non-woody vegetation (forbs, grasses and herbs), litter, cryptogamic crusts and rock in contact with the soil surface (Muir et al. 2011).
Improvement target	To aim to improve compared to a baseline or control. In this report an improvement from baseline target aims to maintain the area with sufficient total vegetation cover to provide protection from soil erosion above the 10th percentile from the baseline time period.
Natural resource management regions	Equivalent to National Landcare Program (NLP) Management Units. As part of the second phase of the NLP the Australian Government's natural resource management (NRM) investments will be delivered within NLP Management Units. In NSW these management units are called Local Land Services and in Victoria Catchment Management Authorities. For a full list of regional NRM organisations see: http://www.nrm.gov.au/regional/regional-nrm-organisations
Total vegetation cover	The sum of photosynthetic vegetation and non-photosynthetic vegetation cover. TVC is derived from fractional cover products estimated from satellite data. TVC includes ground cover. In treeless vegetation types such as grasslands, TVC and ground cover are equivalent. TVC can be assumed to be a good estimator of ground cover when tree cover is lower than 20% (Guerschman et al. 2015)

10. Appendices

10.1 Appendix 1: Workshop feedback

10.1.1 Workshops

Ten workshops and two meetings were held between January and June 2019. Locations included: Adelaide, Melbourne, Perth, Sydney, Brisbane, Gunnedah and Canberra (three meetings). Two video workshops were held in Canberra with participants in the Northern Territory, Tasmania, Victoria, Queensland, New South Wales, and Western Australia using CSIRO infrastructure.

Eighty-nine workshop participants from 44 natural resource management organisations (NRMs) and nine other organisations, mainly agriculture or regional planning, attended.

Recordings of the workshops were made by CSIRO. The session on how to use VegMachine to create targets and report using Landsat fractional cover is incomplete as the VegMachine tool was not working online during the workshop. The recordings will be saved in the Australian Government Department of Agriculture record-keeping system.

The 11 July 2019 workshop was recorded in two parts:

1. Aims, introductions, understanding ground cover, target setting – background and options (1 hour 40 minutes)

Setting ground cover targets using the Rangelands and Pasture Productivity (RAPP) Map – demonstration of the online RAPP Map tool, conclusion and feedback (2 hours 23 minutes).

The video recordings were sent to several people who were unable to participate in the workshops.

10.1.2 Feedback from attendees

A major goal of the ground cover training was to collect feedback from participants to:

- ensure proposed target methods were acceptable and applicable
- ensure key messages were effectively communicated
- test and improve the RAPP Map tool
- refine regional report structure
- develop post-project support.

Feedback was collected during the workshops, and participants were encouraged to complete a feedback form at the end of each workshop. A response rate of 90% was achieved.

Overall the feedback was positive. Most participants had their expectations met or exceeded (Figure A.1). Participants are now aware that ground cover data is freely available, accessible, and relevant. The target methodology was accepted.

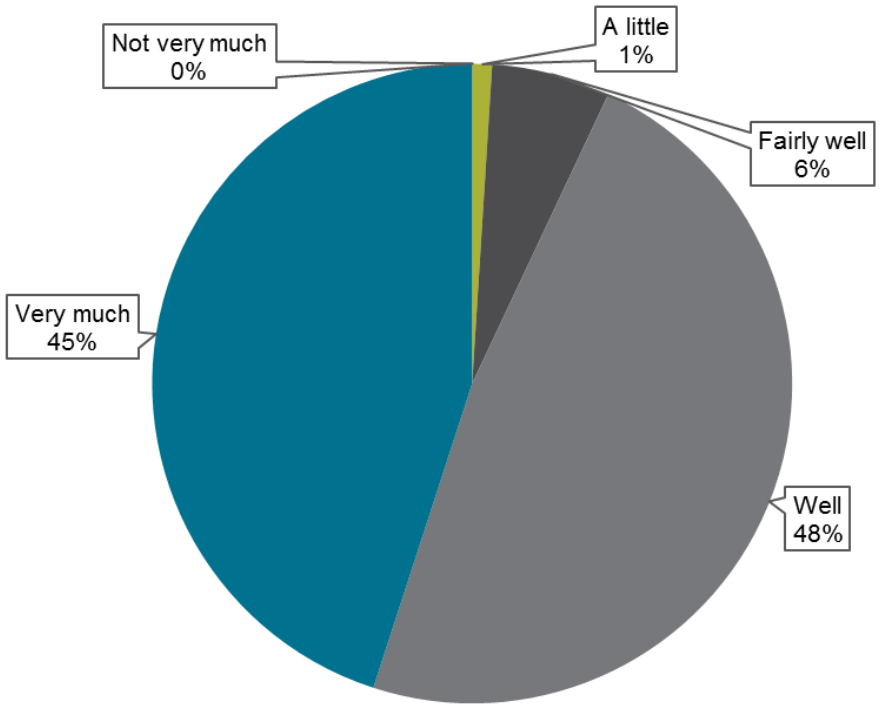

Figure A.1 Feedback on how well the workshop met the participants' expectations.

Participants found the workshops practical and informative. They reported that the knowledge they gained and networks they built provided them with a greater understanding of why and how to monitor and report on ground cover as an indicator of soil health for their region.

The online RAPP Map tool was well received, and a large number of improvements have been made as a direct result of feedback from the training.

The regional reports were well received. Example monthly reports about vegetation cover were provided and evaluated for each region. Feedback was noted and has been incorporated to improve the reports. Overall feedback from participants on the workshops, based on data in feedback forms, is represented in the word cloud in Figure A.2.

Figure A.2 Word cloud of feedback about the workshops.

Another indicator that the workshops were successful, is that some workshop attendees have run their own ground cover training and target setting training for staff in their units.

10.1.3 Which NRMs attended?

Forty-four NRMs attended the workshops. The number of participants varied from zero to three for each NRM (Figure A.3). As the workshop was promoted through the Regional Agricultural Landcare Facilitator (RALF) network, some regions may not have sent a representative if they did not have a RALF at the time or if soil erosion was not a priority in their region.

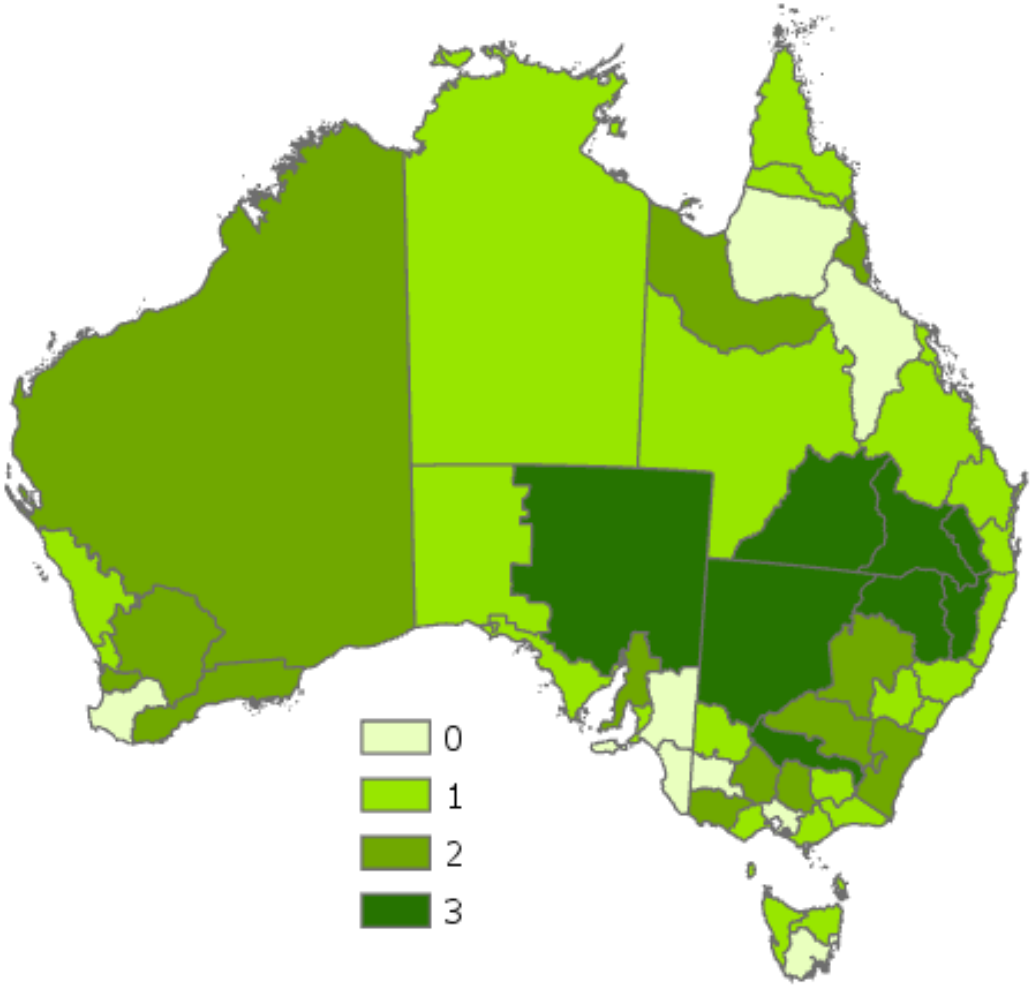

Figure A.3 Number of representatives (from zero to three) that attended workshops from each natural resource management region.

Participants at each workshop had a variety of roles, as shown in Figure A.4. They ranged from advanced GIS users to people with no spatial analysis or ground cover experience. The RAPP Map tool and approaches have therefore been tested with a wide range of people and ongoing support needs to cater for this diverse audience.

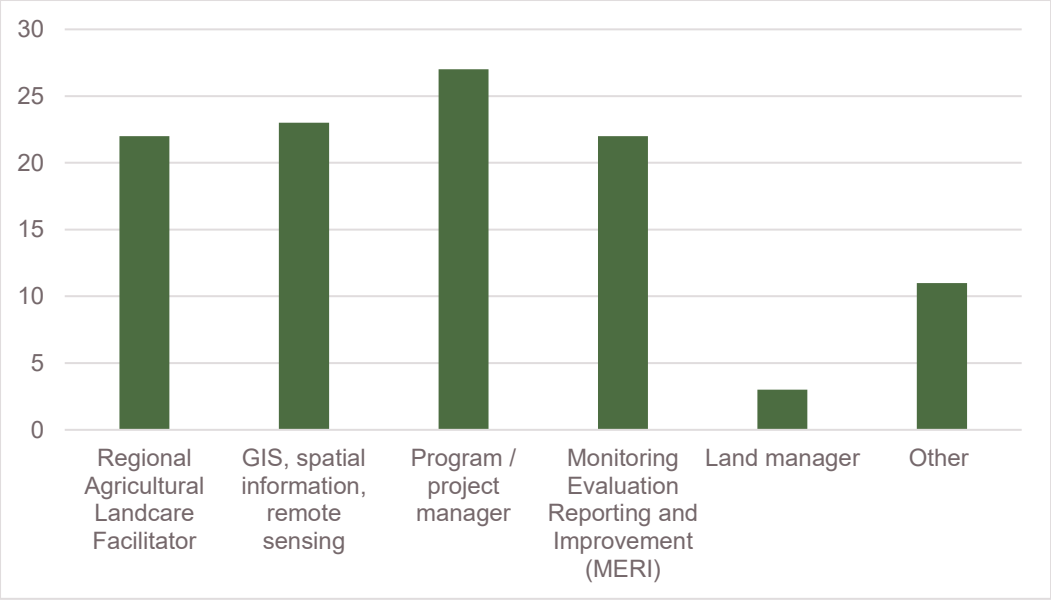

Figure A.4 Workshop participant roles.

10.1.4 What attendees want from the project

Overwhelmingly attendees wanted ongoing support in the form of video training, user guides and more ‘face to face’ training (Figure A.5). Video clips have been prepared and added to the help section in RAPP Map.

Training to undertake one case study per NRM would be a good step towards increasing the capacity of the attendees. This is currently beyond the scope of this project.

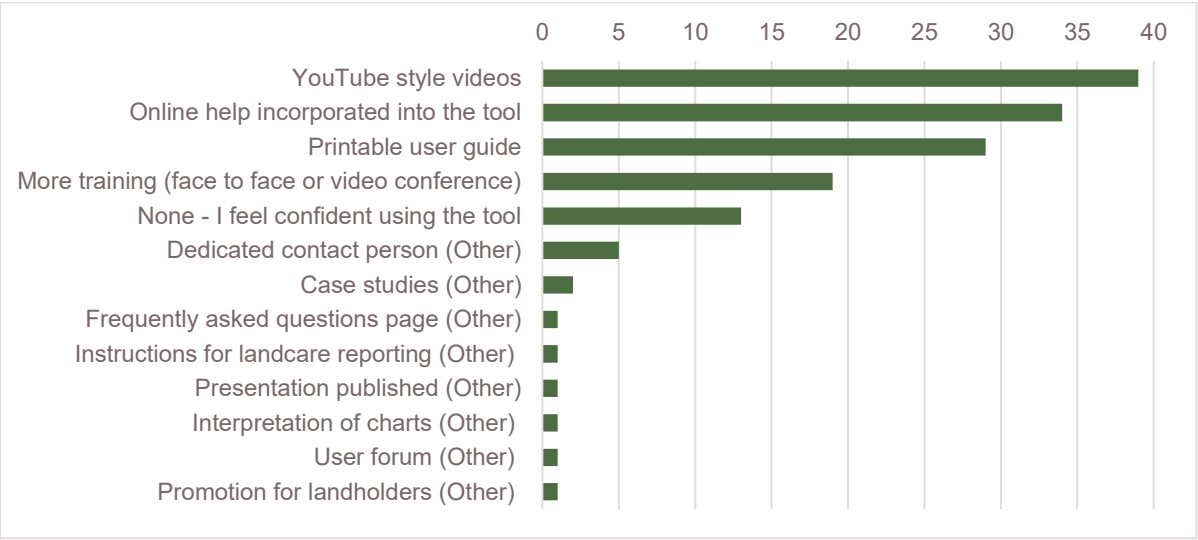

Figure A.5 Further support requested by attendees.

10.1.5 Modifications to reports

The feedback about the report has been addressed as follows:

- better definition of the land use and forestry data used to classify the landscape
- major modifications to the pre-processed PDF report and CSV (comma separated values) files of tabular data.

The land-use data used is Catchment scale land use of Australia – Update December 2018 (ABARES 2018a) and the forest data used is from Australia's State of the Forests Report 2018 (Montreal Process Implementation Group for Australia and National Forest Inventory Steering Committee 2018).

10.2 Appendix 2: Comparing Reef 2050 Water Quality Improvement Plan and National Landcare Program targets

For regional reporting, the Queensland Government has spent many years developing regional targets for the Great Barer Reef (Australian Government and Queensland Government, 2014, Australian Government and Queensland Government, 2015, Australian Government and Queensland Government, 2016).

In 2018, the Queensland Government released the 5-year Reef 2050 Water Quality Improvement Plan. It states that "The ground cover target focusses on late dry season ground cover levels across grazing lands, recognising that water quality risk is generally highest at the onset of the wet season. The target incorporates an area-based component (i.e. 90% of grazing lands will have achieved the ground cover target), while providing for natural variability in ground cover levels. Research supports a ground cover target of 70% to minimise erosion."

This area-based approach is in-line with the thinking developed in this project and forms the basis for the regional reports.

This section demonstrates the difference in the National Landcare Program Regional Land Partnerships (NLP RLP) total vegetation cover (TVC) improvement targets for five NRM regions in the Reef 2050 Water Quality Improvement Plan area (the Reef plan).

The Reef plan ground cover target of "90% of grazing lands will have achieved the ground cover target" is for the grazing lands and is fixed at 90% of the area. This target is likely an outcome target designed to improve water quality, which is one aim of the Reef 2050 Water Quality Improvement Plan. In contrast, the NLP regional reports will use improvement targets and report on a range of land use and forest classes.

The RLP improvement targets for grazing land with no forest for the six NRM regions in the Reef plan are:

- Cape York – 85%
- Wet Tropics – 99%
- Burdekin – 46%
- Mackay–Whitsunday – 98%
- Fitzroy – 66%
- Burnett Mary – 96%.

It should be noted that the comparison does not use the same parameters. The RLP target uses grazing land with no forest, which is different in extent to the 'grazing' land specified in the Reef plan, which we assume includes grazing areas with trees. Another difference is that

the Reef plan uses 'ground cover' as estimated by Trevithick et al. (2014) as opposed to TVC, which includes trees. This is less of an issue as grazing land with no forest is equal to ground cover.

The biggest difference is that the target is quite different for each NRM region ranging from 99% for the Wet Tropics to 46% for the Burdekin.

10.3 Appendix 3: Catchment scale land use and forests of Australia – 13 classes

This project created a 13-class land use and forest cover (LUFC) classification for NLP TVC reports, the Catchment Scale Land Use and Forests of Australia (2018) – 13 classes.

This classification is intended to be used with regional reporting of TVC to:

- Recognise the impact of land use and tree cover on TVC. Remotely sensed vegetation cover is more constant in areas with high tree cover and may mask seasonal or management effects when combined with other land uses.
- Improve reporting for NLP by focusing on agricultural landscapes managed for grazing and broadacre cropping.
- Explore how conservation and natural environments – non-forest areas could be used as control areas to compare with other non-forest LUFCs.

This classification has been derived by integrating:

- forest classes from Forests of Australia (2018) (ABARES, 2018b) (100 metre resolution), and
- land use from the Catchment scale land use of Australia – Update December 2018 (ABARES, 2018a) (50 metre resolution).

The dataset was created by resampling the Forests of Australian (2018) from a resolution of 100 by 100 metres to 50 by 50 metres to match the Catchment scale land use Australia (2018) and spatially combining the two layers to generate a new gridded dataset at 50 by 50 metres resolution in Albers Equal Area projection.

The resulting dataset is used within RAPP Map to generate regional TVC reports. A web-based mapping service (WMS) of the 13-class classification is available in the RAPP Map tool.

10.3.1 Forests of Australia (2018)

Forests of Australia (2018) is a continental spatial dataset of forest extent, by national forest categories, crown cover and types, assembled for Australia's State of the Forests Report 2018 (Montreal Process Implementation Group for Australia and National Forest Inventory Steering Committee 2018) published at a resolution of 100 by 100 metres.

Forests of Australia (2018) was developed from multiple forest, vegetation and land cover data inputs, including contributions from Australian, state and territory government agencies and external sources.

Three broad forest classes (Table A.1) have been derived from the Forests of Australia (2018) dataset forest category and cover attributes.

Table A.1 Forest classes derived from Forests of Australia (2018) dataset

Forest class	Crown cover		National forest category
	Range	Class	
Woodland forest	20–50%	Woodland forest	Native forest
Non-woodland forest	>50–80%	Open forest	Native forest
	>80%	Closed forest	Native forest
	n/a	Unknown	Commercial plantation
	≥20%	Unknown	Other forest
Non-forest	<20%	Not forest	Not forest

Information on crown cover for commercial plantations and other forest would help with more intuitive cover classes.

10.3.2 Catchment Scale Land Use of Australia (2018)

Catchment Scale Land Use of Australia (2018) is the national compilation of catchment scale land use data for Australia (CLUM), as at December 2018 compiled at a resolution of 50 by 50 metres from state and territory mapping programs through the Australian Collaborative Land Use and Management Program (ACLUMP). It replaces the 2017 CLUM update. This dataset was produced by combining land tenure and other types of land use information, fine-scale satellite data and information collected in the field. The date of mapping (2003 to 2018) and scale of mapping (1:5 000 to 1:250 000) vary, reflecting the source data, capture date and scale.

The Catchment Scale Land Use of Australia (2018) is mapped according to the Australian Land Use and Management (ALUM) Classification version 8 (ABARES 2016). The hierarchical ALUM Classification includes primary, secondary and tertiary classes broadly structured around potential degree of modification. The ALUM Classification version 8 is available as a vocabulary service.

Nine broad land use classes (Table A.2) have been derived from the ALUM Classification version 8 and applied to the Catchment scale land use of Australia (2018). Detailed land use class definitions and mapping guidelines are available from the ABARES website. Land uses are mapped according to a single prime use even though land may be used for multiple concurrent purposes. For example, the land use class marsh/wetland production is likely to be grazed during dry periods even though the prime use is water.

Table A.2 Land use classes derived from the Australian Land Use and Management Classification version 8

Land use class	Australian Land Use and Management Classification (v8) tertiary class codes
Conservation and natural environments	Nature conservation 1.0.0, 1.1.1, 1.1.2, 1.1.3, 1.1.4, 1.1.5, 1.1.6, 1.1.7, Managed resource protection 1.2.0, 1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.5 Other minimal use 1.3.0, 1.3.1, 1.3.2, 1.3.3, 1.3.4
Agriculture – grazing – non-irrigated	Grazing native vegetation 2.0.0, 2.1.0 Grazing modified pastures 3.0.0, 3.2.0, 3.2.1, 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5 Land in transition 3.6.0, 3.6.1, 3.6.2, 3.6.3, 3.6.4, 3.6.5
Agriculture – grazing – irrigated	Grazing irrigated modified pastures 4.2.0, 4.2.1, 4.2.2, 4.2.3, 4.2.4 Irrigated land in transition 4.0.0, 4.6.0, 4.6.1, 4.6.2, 4.6.3, 4.6.4, 4.6.5
Agriculture – cropping – non-irrigated	Cropping 3.3.0, 3.3.1, 3.3.2, 3.3.4, 3.3.5, 3.3.6, 3.3.7, 3.3.8
Agriculture – cropping – irrigated	Irrigated cropping 4.3.0, 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5, 4.3.6, 4.3.7. 4.3.8, 4.3.9
Agriculture – horticulture – non-irrigated	Perennial horticulture 3.4.0, 3.4.1, 3.4.2, 3.4.3, 3.4.4, 3.4.5, 3.4.6, 3.4.7, 3.4.8, 3.4.9, Seasonal horticulture 3.5.0, 3.5.1, 3.5.2, 3.5.3
Agriculture – horticulture – irrigated	Irrigated perennial horticulture 4.4.0, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.4.7, 4.4.8, 4.4.9, Irrigated seasonal horticulture 4.5.0, 4.5.1, 4.5.2, 4.5.3, 4.5.4
Production native forests and plantation forests	Production native forests 2.2.0, 2.2.1, 2.2.2, Plantation forests 3.1.0, 3.1.0, 3.1.1, 3.1.2, 3.1.3, 3.1.4, Irrigated plantation forests 4.1.0, 4.1.1, 4.1.2, 4.1.3, 4.1.4
Other uses	Agriculture – intensive horticulture and animal production Manufacturing and industrial Residential and farm infrastructure Services Utilities Transport and communication Mining Waste treatment and disposal Water

10.3.3 Dataset definitions

Agriculture

Land mostly used for agricultural industries including grazing of native and modified pastures, cropping and horticulture. Agriculture for the purpose of vegetation cover reporting includes classes:

- Agriculture – grazing – non-forest
- Agriculture – grazing – woodland forest
- Agriculture – grazing – non-woodland forest
- Agriculture – grazing – irrigated
- Agriculture – cropping – non-irrigated
- Agriculture – cropping – irrigated
- Agriculture – horticulture – non-irrigated
- Agriculture – horticulture – irrigated.

Agriculture – intensive horticulture and animal production, is excluded from agriculture reporting because soil erosion risk is difficult to infer from remotely sensed fractional cover for potted plants, shadehouses, livestock sheds and other intensive agricultural uses. 'Water' is also excluded even though in subclasses such as marsh/wetland production use includes grazed during dry periods.

Agriculture – grazing

Land where grazing by domestic stock of native and exotic pasture, or forage species is the prime use. Agricultural land in transition, where the land use is unknown or cannot reasonably be inferred from the surrounding land use, is also included. Intensive animal production such as production facilities, animal sheds and yards, emus, alpacas and beekeeping are excluded from this class.

Agriculture – cropping

Land where the prime use is broadacre crops like cereals (such as wheat, oats, barley); beverage and spice crops (such as tea and coffee); grass or other forage crops grown to be cut for stored animal fodder; oilseeds (includes canola, sunflower, soybean and peanuts); sugar cane; cotton; poppies grown for alkaloid (pharmaceutical) purposes; grain legumes/pulses (includes field beans, field peas, chickpeas, lentils and lupins).

Agriculture – horticulture

Land where crop plants are intensively cultivated, usually involving a relatively high degree of nutrient, weed and moisture control. Perennial horticulture (where the crop plants live for more than two years) includes tree fruits (such as apples, apricots, mangoes, bananas); olives; tree nuts (such as almonds, hazelnuts, macadamias); vine fruits (such as kiwifruit); shrub berries and fruits (such as pineapples, blackberries, red currants); perennial flowers and bulbs (represents cut flowers, flower products and bulbs); perennial vegetables and herbs (such as asparagus, rhubarb and fennel); citrus; grapes. Seasonal horticulture (where the crop plants live for less than two years) includes seasonal fruits (such as melons); seasonal flowers and bulbs (represents cut flowers, flower products and bulbs); seasonal vegetables and herbs. Intensive forms of horticultural plant production such as shadehouses, glasshouses and production nurseries are excluded from this class.

Agriculture – non-irrigated

Permanent irrigation infrastructure and active irrigation were not present at the time of mapping.

Agriculture – irrigated

Water may be applied to promote additional growth during dry periods, depending on the season, water availability and commodity prices. Permanent irrigation infrastructure or active irrigation was present at the time of mapping.

Conservation and natural environments

Includes land that has a relatively low level of human intervention. The land may be formally reserved by government for conservation purposes or conserved through other legal or administrative arrangements. Areas may have multiple uses, but nature conservation is the prime use. Some land may be unused as a result of a deliberate decision of government or landowner, or due to circumstance. This is ALUM primary class 1.

Forest

An area, incorporating all living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding two metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20%. This includes Australia's diverse native forests and plantations, regardless of age. It is also sufficiently broad to encompass areas of trees that are sometimes described as woodlands.

Non-forest

Areas which have been identified as not meeting the definition of forest. Some non-forest areas may be dominated by woody vegetation with mature stand height less than two metres, dense (greater than 20% crown cover) tall shrubs (greater than two metres high), multi-stemmed trees or treed areas of crown cover less than 20%.

Non-woodland forest

Areas of forest which do not meet the definition of woodland forest. This includes open and closed native forests, commercial plantations and other forests.

Other uses

Intensive uses and water are grouped as other uses. This class is not used for reporting of vegetation cover and bare soil as useful information may not be obtainable from remotely sensed fractional cover. Intensive uses include agriculture, intensive horticulture and animal production, manufacturing and industrial, residential and farm infrastructure, services, utilities, transport and communication, mining, waste treatment and disposal.

Production native forests and plantation forests

Production native forests is commercial production from native forests and related activities on public and private land, includes areas managed for wood production (sawlogs and pulpwood) and other forest production (including oil, wildflowers, firewood and fence posts). Plantation forests is land on which plantations of trees or shrubs (native or exotic species) have been established for hardwood and softwood production (sawlogs and pulpwood), or environmental and resource protection purposes.

Woodland forest

Native forest in which the tree crown cover ranges from 20% to 50%.

10.4 Appendix 4: Natural resource management National Landcare Program targets

Table A.3 shows, for each natural resource management (NRM) region, the target for the percentage of agricultural area protected from wind erosion (>50% total vegetation cover (TVC)), and/or water erosion (>70% TVC) and/or water erosion in high-risk areas (high rainfall, high slope, erodible soils; >80% TVC) calculated using the 10th percentile from January 2001 to December 2018. The number of months the TVC target was not achieved (months<target) for 2018–19, and range of percentage area protected between January 2001 and June 2019, are also shown.

Table A.3 Regional targets for agricultural area protected from soil erosion and 2018–19 status

NRM region	Parameter	% area >50% TVC	% area >70% TVC	% area >80% TVC
Australian Capital Territory	10th percentile (perc) target	99.9	97.1	72.1
	months<target	10.0	1.0	1.0
	range	2.7	43.0	77.5
Adelaide and Mount Lofty Ranges	10th perc target	99.0	85.9	70.7
	months<target	5.0	6.0	5.0
	range	5.4	20.7	40.7
Alinytjara Wilurara	10th perc target	N/A	N/A	N/A
	months<target	N/A	N/A	N/A
	range	N/A	N/A	N/A
Avon River Basin	10th perc target	97.0	23.2	4.8
	months<target	1.0	1.0	0.0
	range	4.6	78.9	39.1
Burdekin	10th perc target	95.5	63.2	32.8
	months<target	7.0	3.0	1.0
	range	12.0	54.8	79.2
Burnett Mary	10th perc target	100.0	97.0	81.4
	months<target	0.0	0.0	0.0
	range	0.3	15.1	41.3
Cape York	10th perc target	99.9	95.4	80.6
	months<target	0.0	0.0	0.0
	range	0.3	16.6	36.9
Central Tablelands	10th perc target	100.0	98.7	87.3
	months<target	9.0	6.0	5.0
	range	0.1	7.3	41.4

NRM region	Parameter	% area >50% TVC	% area >70% TVC	% area >80% TVC
Central West	10th perc target	87.4	36.3	17.0
	months<target	9.0	8.0	9.0
	range	37.8	79.6	86.8
Condamine	10th perc target	90.8	58.6	33.7
	months<target	3.0	0.0	0.0
	range	15.5	43.1	46.1
Co-operative Management Area	10th perc target	99.8	83.1	62.8
	months<target	1.0	0.0	0.0
	range	1.5	34.5	61.3
Corangamite	10th perc target	99.7	93.7	74.3
	months<target	2.0	3.0	2.0
	range	1.1	25.2	58.0
Desert Channels	10th perc target	27.8	2.6	0.2
	months<target	3.0	6.0	6.0
	range	80.1	55.4	26.7
East Gippsland	10th perc target	100.0	99.3	93.0
	months<target	2.0	4.0	3.0
	range	0.1	3.7	30.7
Eyre Peninsula	10th perc target	71.9	16.7	4.3
	months<target	4.0	1.0	0.0
	range	59.6	91.4	76.1
Fitzroy	10th perc target	98.9	73.6	42.7
	months<target	3.0	1.0	0.0
	range	3.6	48.0	74.1
Glenelg Hopkins	10th perc target	99.9	96.0	79.9
	months<target	2.0	2.0	3.0
	range	0.8	18.1	50.8
Goulburn Broken	10th perc target	99.7	91.2	68.7
	months<target	5.0	5.0	5.0
	range	2.0	18.7	50.9
Greater Sydney	10th perc target	99.9	98.1	92.5
	months<target	12.0	10.0	8.0
	range	0.5	4.6	18.7
Hunter	10th perc target	100.0	98.0	87.7
	months<target	7.0	10.0	9.0

NRM region	Parameter	% area >50% TVC	% area >70% TVC	% area >80% TVC
	range	0.2	8.6	30.3
Kangaroo Island	10th perc target	99.7	97.9	82.1
	months<target	2.0	3.0	4.0
	range	0.6	6.2	36.7
Mackay Whitsunday	10th perc target	99.8	96.8	82.5
	months<target	1.0	0.0	0.0
	range	0.4	8.0	32.2
Mallee	10th perc target	40.9	2.2	0.1
	months<target	3.0	3.0	3.0
	range	86.3	89.5	55.1
Maranoa Balonne and Border Rivers	10th perc target	91.1	27.8	7.2
	months<target	6.0	3.0	3.0
	range	24.1	86.3	84.0
Murray	10th perc target	80.0	27.3	13.3
	months<target	5.0	5.0	5.0
	range	48.3	85.9	86.4
North Central	10th perc target	89.4	42.0	19.3
	months<target	2.0	3.0	2.0
	range	31.7	71.3	85.7
North Coast	10th perc target	100.0	99.1	96.3
	months<target	1.0	0.0	3.0
	range	0.5	1.6	10.0
North East	10th perc target	99.9	97.1	83.8
	months<target	5.0	5.0	5.0
	range	0.6	9.2	34.3
North NRM Region	10th perc target	99.9	98.9	90.7
	months<target	0.0	0.0	0.0
	range	0.1	4.5	19.9
North West NRM Region	10th perc target	99.8	98.3	88.7
	months<target	1.0	1.0	0.0
	range	0.3	2.3	14.2
North West NSW	10th perc target	83.3	39.9	22.5
	months<target	10.0	12.0	11.0

NRM region	Parameter	% area >50% TVC	% area >70% TVC	% area >80% TVC
	range	40.3	63.5	48.0
Northern Agricultural Region	10th perc target	94.2	43.9	14.1
	months<target	0.0	0.0	0.0
	range	10.0	56.2	50.1
Northern and Yorke	10th perc target	51.5	15.3	4.8
	months<target	6.0	5.0	5.0
	range	65.5	88.1	77.5
Northern Gulf	10th perc target	99.1	81.4	52.8
	months<target	2.0	0.0	0.0
	range	2.6	36.4	69.8
Northern Tablelands	10th perc target	99.9	98.0	91.2
	months<target	12.0	10.0	10.0
	range	0.2	4.5	20.8
Northern Territory	10th perc target	56.5	27.5	14.2
	months<target	5.0	2.0	0.0
	range	53.0	54.5	44.6
Peel–Harvey Region	10th perc target	99.9	89.4	47.6
	months<target	4.0	1.0	1.0
	range	0.4	46.4	79.5
Port Phillip and Western Port	10th perc target	99.5	89.8	71.4
	months<target	5.0	1.0	1.0
	range	1.6	16.9	36.0
Rangelands Region	10th perc target	46.0	6.5	2.1
	months<target	1.0	1.0	0.0
	range	59.5	32.5	15.2
Riverina	10th perc target	65.1	37.0	23.7
	months<target	2.0	4.0	4.0
	range	52.1	70.2	75.7
South Australian Arid Lands	10th perc target	5.3	0.2	0.0
	months<target	4.0	4.0	4.0
	range	69.9	7.8	2.1

NRM region	Parameter	% area >50% TVC	% area >70% TVC	% area >80% TVC
South Australian Murray Darling Basin	10th perc target	58.8	14.2	5.9
	months<target	6.0	6.0	5.0
	range	54.8	72.9	45.2
South Coast Region	10th perc target	97.3	76.0	42.4
	months<target	0.0	6.0	2.0
	range	11.2	45.9	63.1
South East	10th perc target	99.0	84.9	60.1
	months<target	1.0	1.0	1.0
	range	6.0	37.2	66.4
South East NSW	10th perc target	100.0	98.0	85.7
	months<target	3.0	4.0	5.0
	range	0.1	6.3	33.6
South East Queensland	10th perc target	100.0	98.7	90.6
	months<target	3.0	2.0	2.0
	range	0.1	3.7	26.5
South NRM Region	10th perc target	99.8	97.7	86.9
	months<target	0.0	0.0	0.0
	range	0.4	7.0	31.8
South West Queensland	10th perc target	50.3	8.9	2.9
	months<target	6.0	7.0	6.0
	range	66.6	75.2	45.2
South West Region	10th perc target	99.4	79.7	43.3
	months<target	0.0	1.0	0.0
	range	2.3	47.9	70.9
Southern Gulf	10th perc target	70.0	21.2	5.8
	months<target	2.0	2.0	1.0
	range	46.6	86.2	78.0
Swan Region	10th perc target	99.7	90.6	47.3
	months<target	6.0	1.0	0.0
	range	0.7	15.1	62.8
Torres Strait	10th perc target	N/A	N/A	N/A
	months<target	N/A	N/A	N/A

NRM region	Parameter	% area >50% TVC	% area >70% TVC	% area >80% TVC
	range	N/A	N/A	N/A
West Gippsland	10th perc target	99.9	99.1	91.9
	months<target	5.0	7.0	6.0
	range	0.2	4.3	24.2
Western	10th perc target	32.0	3.3	0.2
	months<target	5.0	5.0	4.0
	range	75.6	61.5	32.4
Wet Tropics	10th perc target	100.0	99.4	95.1
	months<target	2.0	0.0	0.0
	range	0.1	2.1	10.6
Wimmera	10th perc target	95.4	50.0	24.7
	months<target	0.0	0.0	0.0
	range	20.7	72.1	81.7

10.5 Appendix 5: Relationship between rainfall and dust hours applied to TVC thresholds

The assessment that wind erosion dominates in regions with less than 700 millimetres (mm) annual average rainfall while water erosion dominates in regions with more than 700 mm is based on a relationship between rainfall and dust hours from NSW DustWatch sites (Leys et al. 2018). The equation describing the relationship between hours of dust and rainfall is:

$$ADH = -0.1049\ AR + 92.45$$

ADH is the average number of dust hours when particulate matter >10 micrometre concentration is >25 micrometres per cubic metre

AR is the annual July to June rainfall (millimetres) for the 10 years ending June 2017.

When there is less than 690 mm of rainfall over the financial year, there is an average of 20 hours of dust (Leys et. al. 2018). For simplicity, we rounded the rainfall up to 700 millimetres and mapped the areas with ≤700 mm (Figure A.6). Based on data availability at the time of analysis, these areas were determined using the average annual rainfall for the 10 years 1996–2005 from the Bureau of Meteorology.

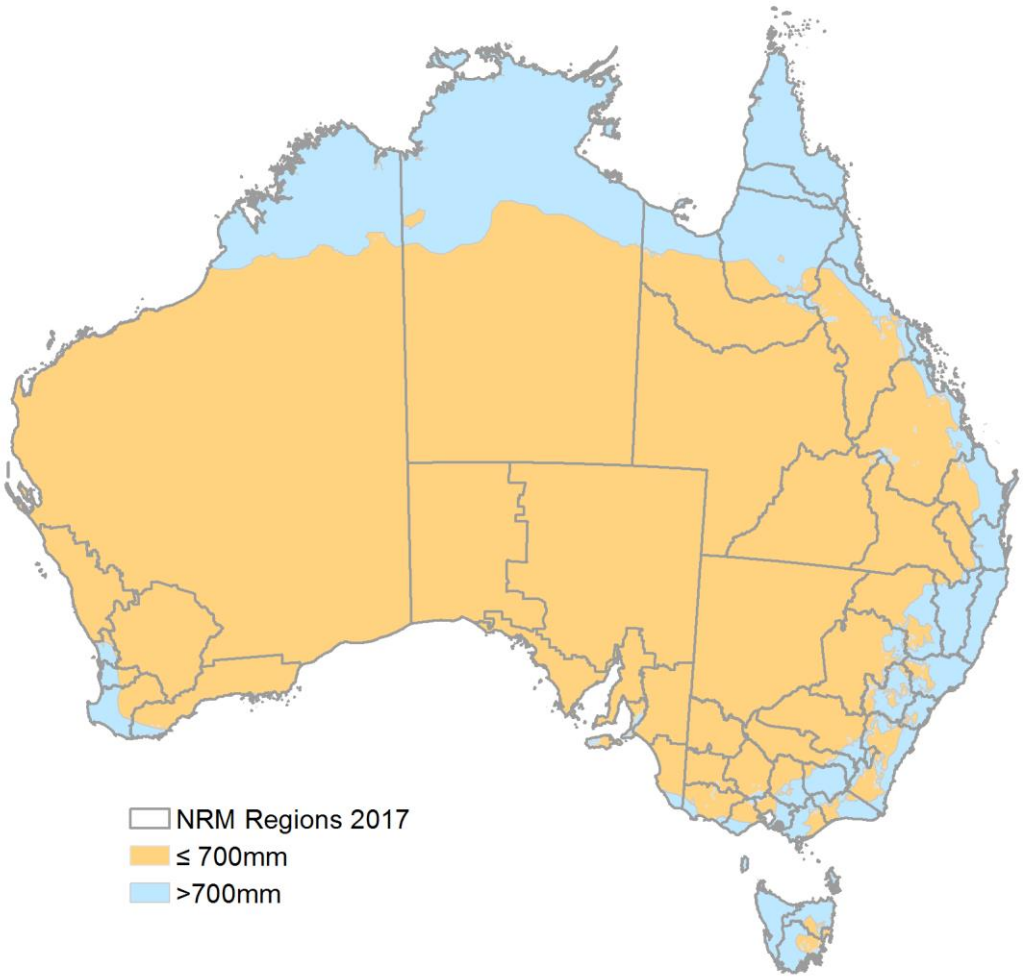

Figure A.6 Natural resource management regions and average annual rainfall map from 1996 to 2005. Wind erosion dominates in the ≤700 millimetres (mm) rainfall area and water erosion for >700mm.