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Monitoring groundcover: an online tool for Australian regions

Report prepared for the Australian Government Department of Agriculture and Water Resources

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Cover image

Sharp contrast in ground cover across a fence caused by differences in grazing management. Photo taken about 80 km north-east of Mildura by John Leys, April 2018.

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Acknowledgments

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Executive summary

Investments made through the Australian Government's National Landcare Program aim to improve the condition of Australia's natural resources. The agricultural components of these programs have mostly focused on improving the condition of the national soil asset by encouraging farmers to adopt land management practices that reduce the risk of soil loss through wind and water erosion, manage soil acidification, and improve the carbon content of their soil.

Is the Program having an impact on the condition of the soil resource? This has been a difficult question to answer despite the Program's significant investment in research to improve monitoring and reporting. Recent advancements in satellite remote sensing have led to the production of datasets depicting vegetation and soil cover for the Australian continent which can be used to monitor and report on wind and water erosion risk.

This report presents the results of a project to deliver public online access to a dataset of vegetation and soil cover produced monthly (2001-present) from the MODIS satellite with 500 metres spatial resolution. Specifically, the dataset estimates three cover types: photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV) and bare soil (BS). These three fractions are referred to as "fractional cover". The sum of PV and NPV equals to Total Vegetation Cover (TVC). In areas with sparse or no tree cover TVC is equivalent to the ground cover (i.e. the vegetation cover in contact with the soil surface). The online tool helps regional natural resource management organisations: 1) view and report on ground cover change for their organisations, 2) plot time-series of mean ground cover for an area, 3) understand the decile ranking of the ground cover level for the month by comparing it to the same month in other years, and 4) understand how many percentage points the ground cover level is above or below the long term mean for each pixel and 4) understand if the ground cover level is normal. The tool can also be used by industries and policy makers to inform them of ground cover change, and will provide the basis for Department of Agriculture and Water Resources' reporting on improvements in resource condition at the national level.

The Australian reporting tool (https://map.geo-rapp.org/#australia) is part of a global online tool for accessing vegetation fractional cover with a spatial resolution of 500 metres. The tool, named Rangeland and Pasture Productivity Map (RaPP Map), provides ready access and the ability to query very large datasets for users without remote sensing or GIS experience. RaPP Map complements other Australian initiatives such as VegMachine© (vegmachine.net) and FarmMap4D Spatial Hub (farmmap4d.com.au), which deliver higher spatial resolution (30 metre) but lower temporal resolution (3 monthly seasonal compilations) of ground cover data to end users.

The MODIS fractional cover datasets have been used by the New South Wales Office of Environment and Heritage DustWatch program since 2012 to monitor and report on ground cover change for inland organisations in south eastern Australia at risk of wind erosion. Future developments proposed include: training for natural resource management organisations in the use of the tool, improvements in the tool to facilitate target setting, replacing MODIS-derived products with higher spatial resolution Landsat and Sentinel products, and exploration of whether the effects of antecedent (sum of rainfall over previous months) rainfall on vegetation cover levels can assist in the separation between rainfall and anthropogenic (land management) effects on vegetation cover.

The report includes an Appendix with a step-by-step guide to using the current (September 2018) version of the tool to visualise and interrogate vegetation cover and related environmental data.

1 Introduction

Investments made through the National Landcare Program aim to improve the condition of Australia's natural resources. The agricultural components of the program, particularly since 2008-09, have focused on improving soil resource condition by encouraging the adoption of land management practices that reduce the risk of soil loss through wind and water erosion, manage soil acidification and improve the carbon content of soil. These soil factors are driver variables which have a major influence on other soil factors such as nutrient and water availability and storage, and hence on agricultural productivity and profitability.

In addition to private benefits of improving soil carbon storage, managing soil acidification and reducing soil lost through wind and water erosion, soils in good condition provide public benefits in the short and long term to the broader community, in the form of ecosystem services. These services include improved air and water quality and protected biodiversity. The associated land management practices that increase soil water holding capacity or improve the volume of soil (and hence access to water and nutrients) available for rooting also help improve the resilience of agriculture to climate change. Cork et al. (2012) provides a review of the relationships between soil condition, land management practices and ecosystem services in the Australian agricultural environment.

The main policy tools used to deliver the National Landcare Program's agriculture outcomes are extension and technology development. The underlying program logic or theory of change assumes that landholders will consider adopting management practices with positive private benefits if they are able to learn about these practices, and preferably to see these demonstrated in a cost-effective context. The logic also assumes that over time, successful project investments will be able to demonstrate improvements in condition beyond the project boundaries (for example in similar landscapes on similar land uses elsewhere in a region). It is acknowledged that there are many contributors and contributing factors in the land management extension process. Demonstrating direct links between individual projects and change is not expected.

NLP project funds and the resources available for extension of project results are very modest relative to the scale of Australia's wind and water erosion problems. Regular (at least annual) reporting on the status of ground cover for NLP project areas is highly desirable, although it is important to recognise that improvements in ground cover may be slow, especially during drought. Information from the tool presented here (RaPP Map) will enable regional organisations to publish monthly maps and reports on the status and trends in ground cover in their region. These maps, together with commentary on possible reasons for localities with similar rainfall and soils having different ground cover trajectories, will help to demonstrate at a regional level that land management can have an impact on ground cover outcomes. This information will provide a useful resource for discussions on the range of practices needing to change to increase agriculture's resilience to drought. The 18 year ground cover and rainfall record also provides a useful benchmark against which current performance can be monitored.

Until recently, with the exception of New South Wales' regions participating in the DustWatch program, few tools have been available to help organisations monitor and demonstrate change in soil resource condition at the regional level. This report describes a new online tool developed to help organisations monitor and report on the status of ground cover as an indicator of the extent of wind and water erosion risk, and to set and report on progress towards targets for improved ground cover management. Water erosion is restricted to hillslope erosion in this report (i.e. sheet and rill erosion but not gully and streambank erosion) (McKenzie et al 2017).

The report’s Appendix is an introductory guide to the version of the online tool available in September 2018. Further developments are planned, and will be undertaken in conjunction with regional training workshops being provided through the National Landcare Program.

1.1 The impact of wind erosion and hillslope erosion

Around 204 million hectares of Australia’s agricultural land (principally the grazed rangelands (93 percent) and some adjacent drier cropping lands (7 percent, see Figure 1) have a moderate to high risk of wind erosion and subsequent removal of topsoil and nutrients (carbon, nitrogen and phosphorus) which are needed to underpin agricultural production (Leys et al. 2017). The rangelands provide around 330 million hectares of mainly native pasture for the grazing industry, which in 2015-16 contributed an estimated $5.6 billion (10 percent) to the gross value of agricultural production. In addition, Australia’s 17.7 million hectares (80 percent) of cropping lands outside the rangelands regions, which in 2015-16 contributed an estimated $12.1 billion to the gross value of agricultural production, cannot afford to lose soil volume, or run down carbon or nutrient content (ABARES analysis based on ABS 7503.0 Value of Agricultural Commodities produced (2015-16)).

Wind erosion can have significant off site impacts. The broader community is affected by wind erosion which causes dust emissions that travel downwind. When dust concentration is high, such as in a dust storm, air quality is reduced in urban areas which may be thousands of kilometres away from the land the dust blew from (O'Loingsigh, et al. 2017). There are also substantial cleanup costs, respiratory health impacts and interruptions to economic activity such as closing of airports and building sites. One major dust storm cost the New South Wales’ economy $299 million (Tozer and Leys 2013).

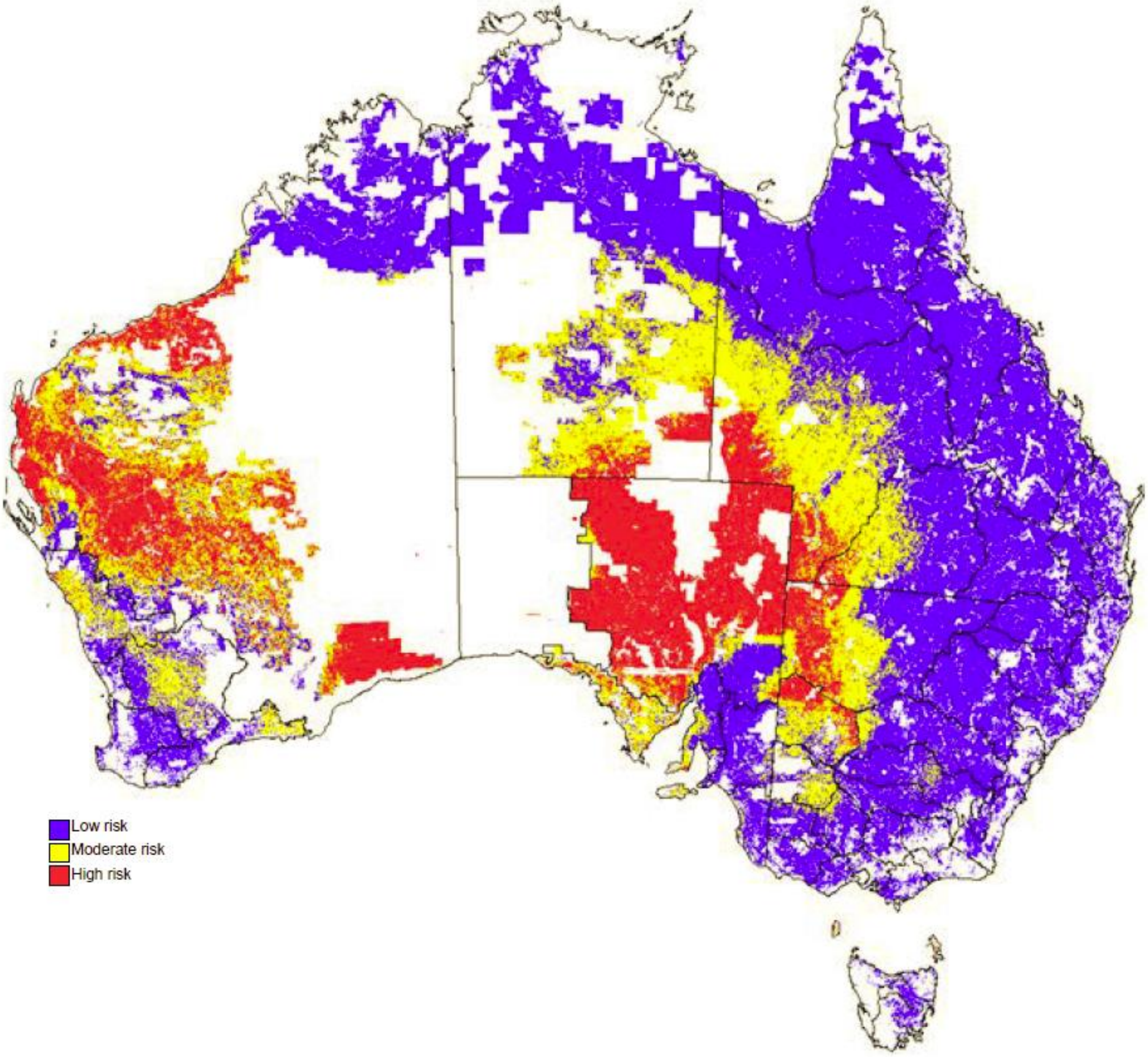

Figure 1: Risk ranking for wind erosion in Australia's agricultural areas.
Boundaries for states and territories and natural resource management regions are shown, white = non-agricultural land. From Leys et al. (2017).

A number of rangelands and cropping regions are also at risk of hillslope erosion by water which results in soil loss and elevated concentrations of nutrients and sediment in downstream waters, with subsequent impacts on water quality for aquatic and some marine environments, stock water and human uses.

This loss of soil, nutrients and potential land productivity is occurring at a rate which may only be perceptible over decades, but is much greater than rates of soil formation, and also results in a net rundown of the soil resource (McKenzie et al. 2017). The area of agricultural land at risk of hillslope erosion has yet to be quantified, but the problem is widespread (Figure 2).

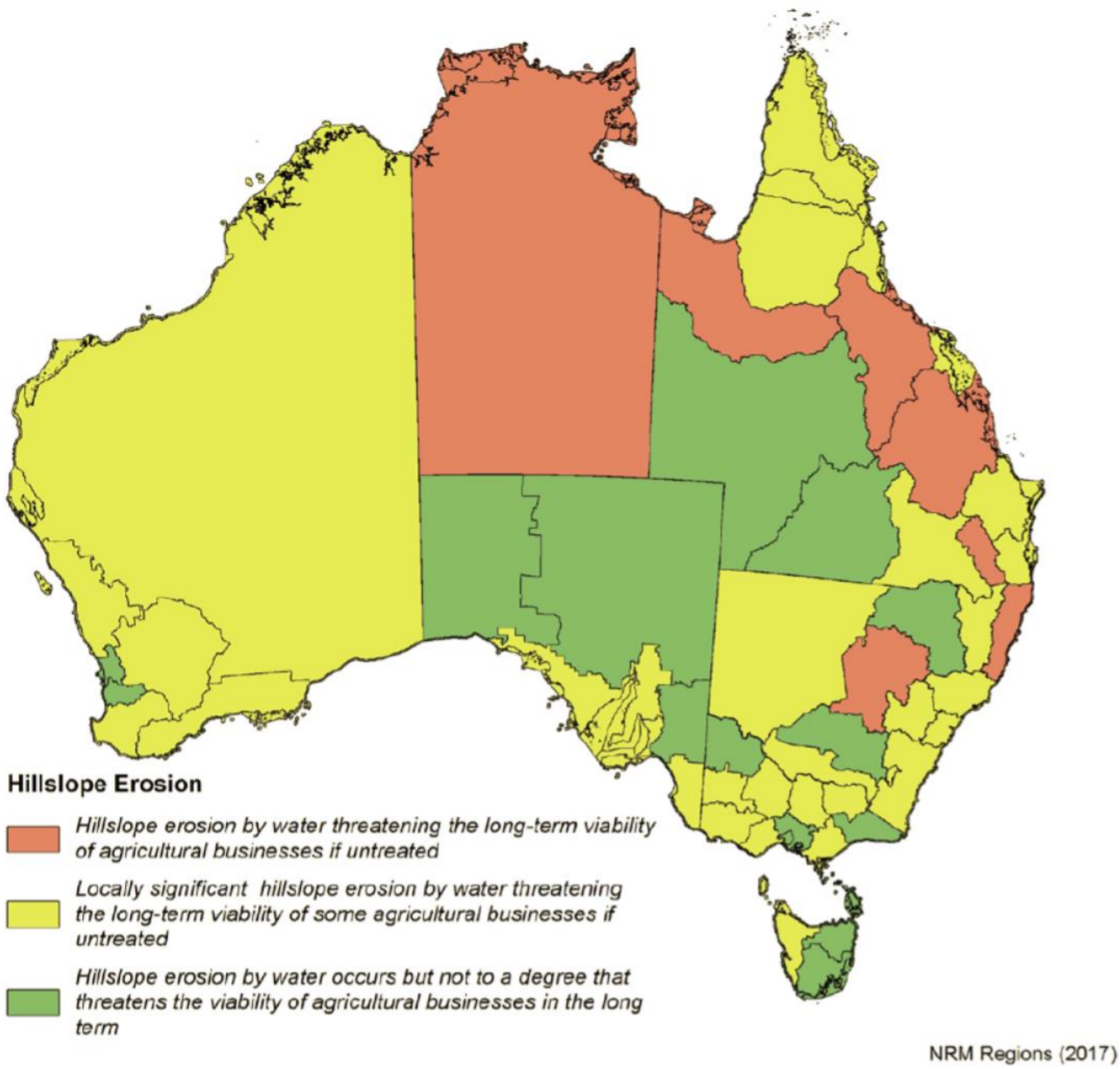

Figure 2: The significance of hillslope erosion for Australia's natural resource management regions. Note that while having low rankings, the risk of hillslope erosion is accelerating in Queensland's Southern Gulf and Cape York regions due to land use intensification. From: McKenzie et al. (2017).

Substantial National Landcare Program funding has been provided to regional NRM organisations to facilitate the wider adoption of practices to reduce soil loss through wind and water erosion. The key to controlling soil erosion is the maintenance of protective cover on the soil surface, the ground cover. Ground cover comprises the vegetation, leaf litter, biological crusts and stone in contact with the soil surface. If ground cover is not maintained, wind and hillslope erosion can occur, reducing soil depth and fertility, and its moisture holding capacity and aggregate stability. Previous research has identified that ground cover levels greater than 50 percent are needed to reduce soil losses through wind erosion (Leys 1991), and that 70 percent ground cover is needed to protect against soil loss via hillslope erosion (Lang 1979).

At a national workshop (Leys et al. 2009), participants discussed what would be required to establish a cost effective program to monitor soil erosion at national, state and regional scales. It was agreed that one element would be the monitoring of fractional ground cover. Recent developments in remote sensing have enabled three ground cover types to be identified:

photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV) and bare soil (BS). Together they are known as fractional cover. The inclusion of NPV or dry vegetation into the assessment is a major advance. Previously only PV vegetation, identified from normalised difference vegetation index (NDVI) was reported (Lu et al. 2003) causing a major underestimation of ground cover and overestimation of erosion rates. The sum of PV and NPV is total vegetation cover (TVC), and provides the data needed to monitor and report on changes in ground cover.

In treeless vegetation types such as grasslands, TVC and ground cover are equivalent. At the other extreme, in dense forests with closed canopies, ground cover cannot be observed by optical remote sensing from sensors such as MODIS or Landsat. In mixed tree-grass systems such as savannas, woodlands and shrublands, the trees obscure the understory layer (the ground cover) and therefore the total vegetation cover may be equal or higher than ground cover. 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.

This project has contributed to CSIRO’s development of a global online dataset and tool for seasonally updated, 500 metre resolution, MODIS-derived vegetation cover, the Rangeland and Pasture Productivity Map (RaPP Map https://map.geo-rapp.org/), and produced a customised version for Australian reporting https://map.geo-rapp.org/#australia) which is updated monthly.

This Australian reporting site delivers public online access to the monthly MODIS fractional cover data (2001-present). The main product displayed is the total vegetation cover (TVC). A simple tool is available to help regional NRM organisations: 1) view and report on ground cover change for their regions, 2) plot time-series of mean ground cover for an area, and 3) understand the ranking of the TVC for the month for each pixel by comparing it to all other months as a decile, and 4) understand how many percentage points the TVC is above or below the long term mean for each pixel. The tool can also be used by industries and policy makers to inform them on ground cover change.

2 Remote sensing of vegetation cover

2.1 Data products

Remote sensing has been used by researchers for tracking changes in TVC (i.e. PV plus NPV) for Australian rangelands since the 1980s. Recent developments in remote sensing (Guerschman et al. 2009; 2015; Guerschman and Hill 2018) resolve the fractions of TVC into PV, NPV and BS, enabling the separation and reporting of green, dead and bare components of cover. The reporting of the dead fraction has led to a major improvement in erosion modelling and monitoring. Previously only green cover was used (Lu et al 2003) which underestimated the amount of ground cover protecting the soil from erosion especially on semi-arid rangelands.

Fractional cover refers to the fraction of an area (usually a pixel for the purposes of remote sensing) that is covered by a specific cover type such as green vegetation (PV), dead vegetation (NPV) (i.e. stubble, senescent herbage, leaf litter) and bare soil/rock (BS) (Stewart et al. 2009). The term integrates all layers of vegetation, including the understorey (grasses, forbs, rocks, cryptogams) and, if present, the midstorey (shrubs) and overstorey (trees) (Figure 3).

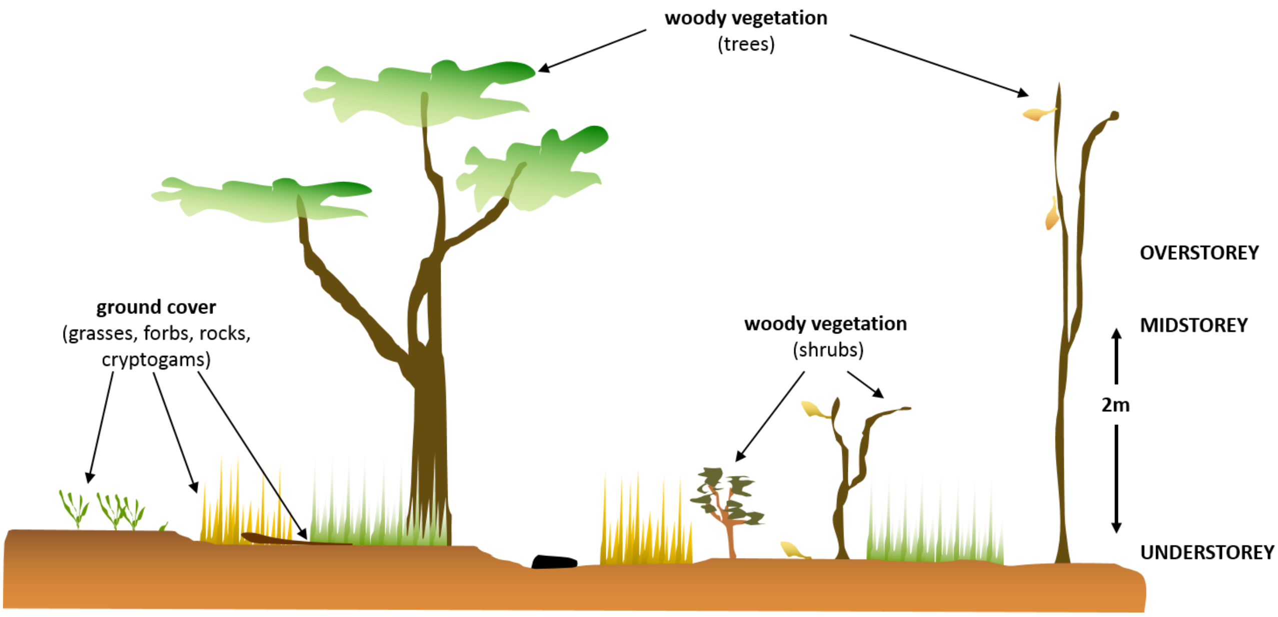

Figure 3: Vegetation cover classes
Adapted from Muir et al. (2011).

Land degradation is actually generally a slow process therefore it's the cumulative impact of both rapid and prolonged effects that cause land degradation. Perennial woody vegetation such as trees and shrubs generally change over periods of months, years or decades; except when major disturbance events occur such as fire, cyclones or land clearing. The non-woody ground cover is generally more dynamic and can change over much shorter time periods (e.g. weeks to months), in response to rainfall events and land management practices such as grazing and cropping. It can therefore be a useful indicator of land management, particularly if it is understood in the context of local or regional climate patterns and landscape variability (i.e. soil types and landform pattern).

Distinguishing which is the driver of the monthly change in TVC; land management or climate, is a challenge and cannot be achieved empirically with RaPP Map. What can be achieved with RaPP Map is a narrative. Explanations of why areas have low cover and visualisations of cover that show management boundary effects can be developed.

TVC is closely linked to the soil erosion potential. The higher the TVC levels, generally the lower the risk of losing soil by wind or water erosion. This is the message that has been promoted through soil conservation extension (Leys et al. 2009) (Figure 4). However, in pastoral areas it is difficult to initiate land management practice change, more so than in cropping areas. In rangelands there are significant barriers in terms of unmanaged total grazing pressure from native and feral animals. Consequently, landholder behaviour change is a decadal task. The availability of accessible monitoring tools, such as RaPP Map can help make the link between land management and erosion more obvious.

Figure 4: Grazing management effects on cover levels
Photo: John Leys

The range of satellite derived fractional cover products developed by CSIRO and by the Queensland Department of Science, Information Technology and Innovation (QDSITI, now the Department of Environment and Science) are shown in Table 1. These complementary products have different spatial and temporal resolutions, time spans and coverage.

The general guideline for each product use is:

Landsat fractional cover is good for farm and paddock scale investigations and evaluation reporting that require long time series. The seasonal (every 3 months) make it good for evaluation of site-based investments.

Sentinel fractional cover is good for looking at the detail of the spatial distribution of cover on a paddock or farm because of the high spatial resolution of 10m. It is available seasonally but on from 2016.

MODIS fractional cover is good for regional and landscape scale evaluation and reporting that requires high temporal resolution over the last 18 years. It is also good for tactical decision making because data are available each 8 days and monthly for the nation.

Table 1 Summary of the characteristics of fractional cover and derived products available for Australia

	Landsat Fractional Cover	Sentinel Fractional Cover	MODIS Fractional Cover
Spatial resolution	30 metres	10 metres	500 metres
Temporal repetition	Satellite overpass every ~8 to 16 day Product available seasonal composite (3 months)	Satellite overpass every ~5 to 10 day Product available seasonal composite (3 months)	Satellite overpass twice daily Product available: 1: 8-day composite 2: monthly composite
Time span	1990-present	2016-present	2001-present (*)
Coverage	Australia	Australia (only Qld, NT, NSW and Tas)	Global
Latency (frequency and timing of updates)	Within a month of the end of the season	Within a month of the end of the 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
Derived products	Ground Cover (cover under trees) (#) Total ground cover (green + non-green ground cover) Seasonal deciles		Total cover (PV and NPV fractions) Ground Cover (cover under trees) (#) Monthly anomalies Monthly deciles
Access to data	http://auscover.org.au/purl/landsat-seasonal-fractional-cover	http://data.auscover.org.au/xwiki/bin/view/Product+pages/Sentinel-2+Seasonal+Fractional+Cover	http://www.auscover.org.au/purl/modis-fractional-cover-csiro and http://dap.nci.org.au/thredds/remoteCatalogService?catalog=http://dapds00.nci.org.au/thredds/catalog/u39/public/prep/modis-fc/v310/catalog.xml
References	Scarth et al. 2010		Guerschman et al. 2009, 2015; Guerschman and Hill 2018

(*): in the last MODIS reflectance data update (collection 6) data for the year 2000 have some problems in band 7, the fractional cover product for 2000 will be produced when the issue is resolved. (#) As per methods in Trevithick et al. (2014).

Figure 5 shows examples of the Landsat and the MODIS fractional cover products, demonstrating their differences in spatial resolution.

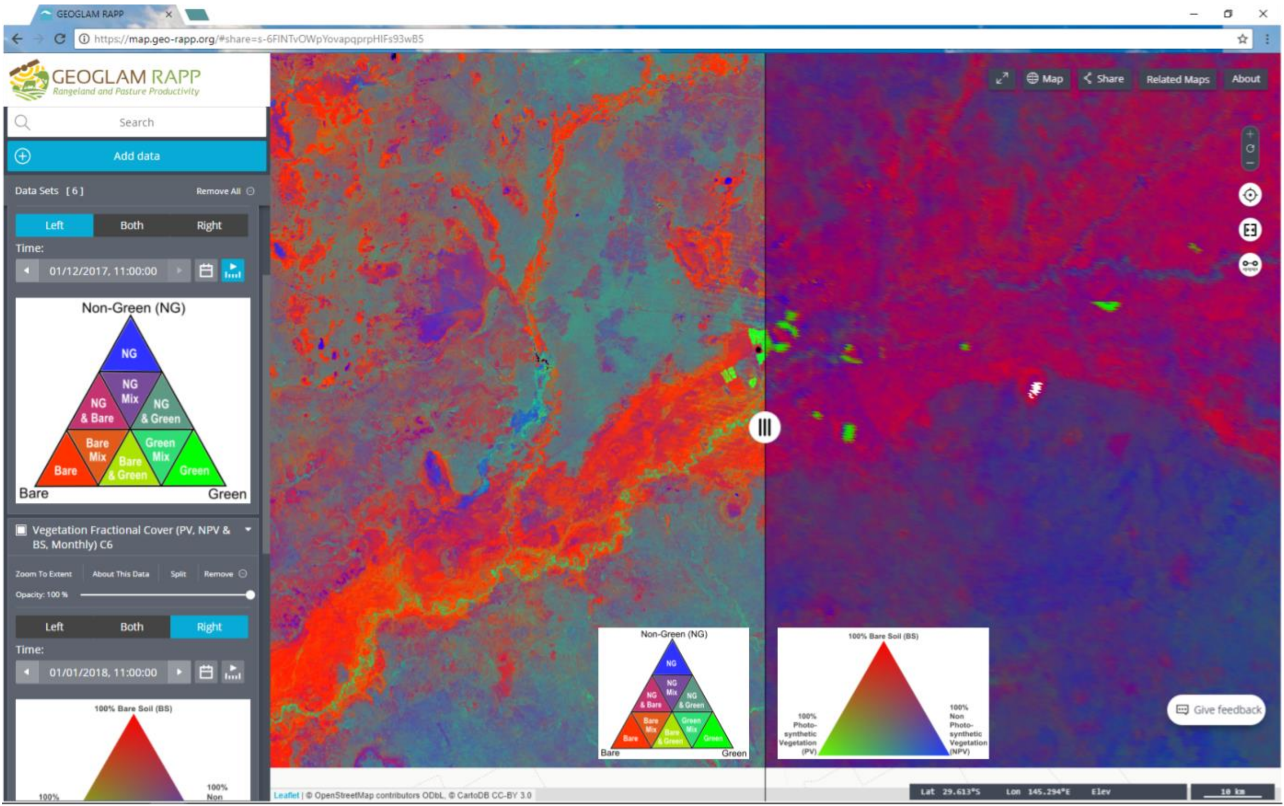

Figure 5: Screen capture of the seasonal Landsat and MODIS fractional cover
The images correspond to the seasonal Landsat fractional cover for the summer of 2018 (left) and the monthly MODIS fractional cover for January 2018 (right). The figure is centred in -32.15, 145.8, near the city of Bourke in NSW. Note that the two products have a slightly different colour enhancement, and the two legends have been superimposed on each side of the figure. The figure shows a single scene with the central line indicating the slider function in the tool that allows dynamic overlaying of the two products in the viewer. Link to the RAPP Map tool with the view as in this figure in https://map.geo-rapp.org/#share=s-vTCxIL3We6GKDJnl05V43ljOcSS

The Landsat and the MODIS-derived fractional cover products have been developed and tested using around 1700 field measurements (Guerschman et al 2015) collected using the "SLATS transect" method (Muir et al 2011). The MODIS Fractional Cover product has recently been recalibrated and enhanced using the most up to date version of the SLATS transects dataset (3022 sites, provided by the Queensland Department of Environment and Science/Joint Remote Sensing Program on August 13th 2017, see Figure 6), and data from the MODIS collection 6 (Schaaf and Wang 2015). This update resulted in an improvement in the separation between NPV and BS and a decrease in the uncertainty of the fractional cover estimates. The results of this update have been documented by Guerschman and Hill (2018).

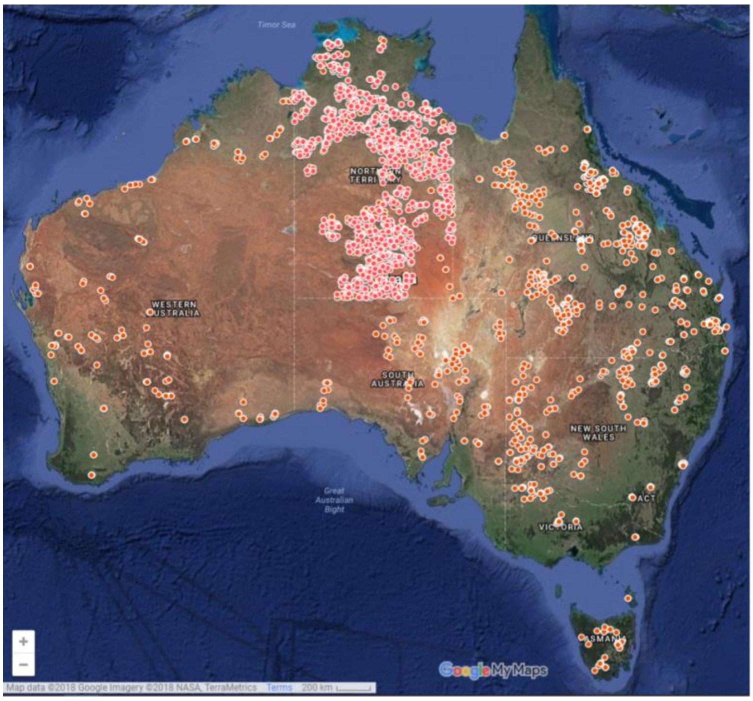

Figure 6: Map of Australia showing the locations of the calibration and validation sites for the MODIS fractional cover product.
Adapted from Guerschman and Hill (2018).

The MODIS fractional cover dataset has been chosen to establish a national/regional monitoring capability. This dataset has two key features which make it particularly suitable for reporting at regional scale the TVC change: 1) a high temporal frequency with two daily overpasses providing 60 scenes per month which ensure a mostly cloud-free monthly composite, and 2) a short latency so that the data are available shortly after the overpass. For composites, data are available shortly after the end of the compositing period. The disadvantage of the MODIS data is its pixel size of 500 metres. In landscapes such as intensively managed farm land in Victoria and Tasmania, where TVC changes over smaller distances, cover components are mixed, and the likelihood of measuring higher and lower TCV levels decreases. This issue will be addressed in the next year, when new imagery products with both high spatial and temporal resolution are introduced to replace the MODIS data.

2.2 Web services and access

Fractional cover data has traditionally been delivered to experienced users of spatial data via ftp or other similar portals. This is very useful when these users want to download data for analyses such as calculating areal summaries, looking at trends, combining with other data sources such as climate and so on.

The RaPP Map tool for Australia (https://map.geo-rapp.org/#australia, Figure 7) has been designed to simplify the reviewing and reporting of regional, state and national TVC change.

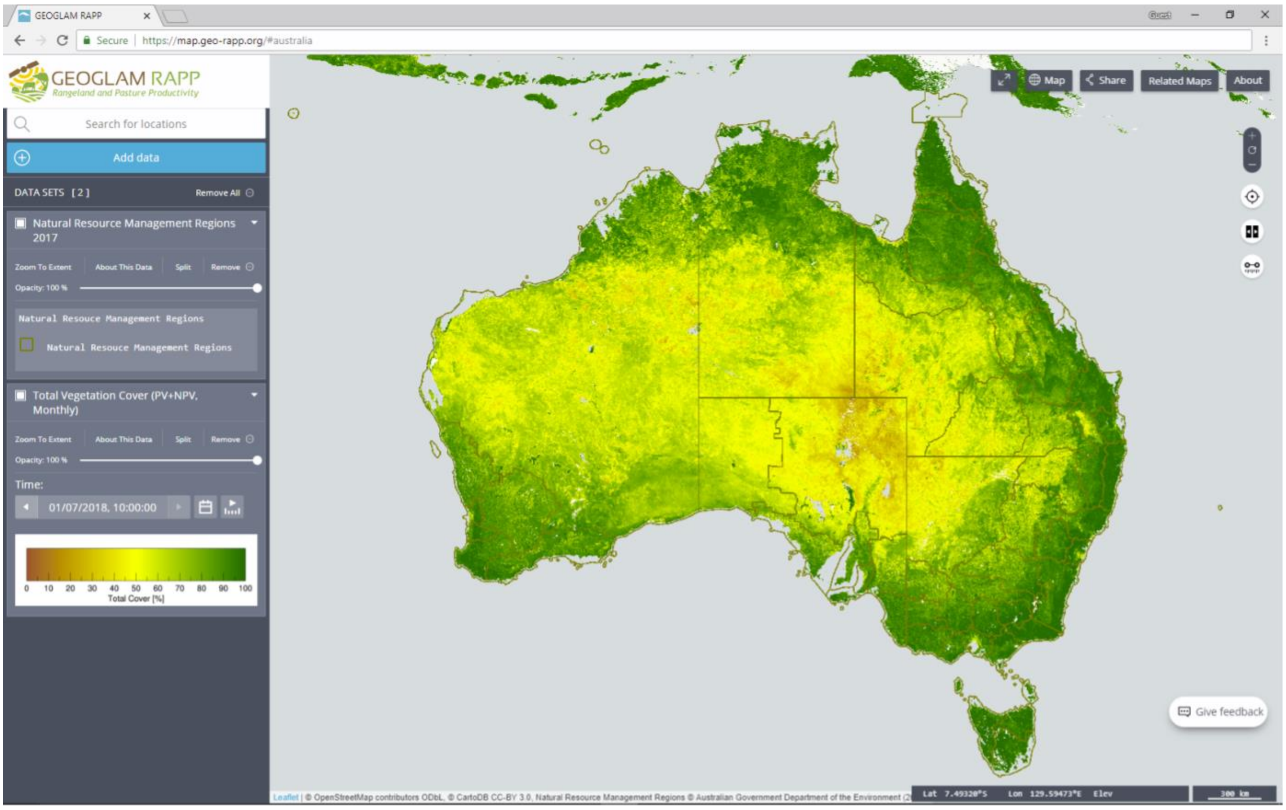

Figure 7: Screen capture of the RaPP Map

The RaPP Map tool (Table 2) contains:

1. Time-series layers for the MODIS and Landsat fractional cover datasets and several derived data products such as anomalies and deciles (see Glossary for definitions). The MODIS layers provide coarse spatial resolution (500 metre pixels) information updated every eight days and monthly. The Landsat layers provide high spatial resolution (30 metre pixels) information updated seasonally (every three months). Landsat is good for property scale analysis over long time periods at seasonal time steps. MODIS data are good for monthly regional scale analysis, reporting and tactical decision making.

2. Climate data to assist with interpretation of cover trends. The global CHIRPS dataset is currently displayed (Funk et al 2015). CHIRPS will be replaced by Bureau of Meteorology data when licensing arrangements are finalised.

3. Land use and land cover information to assist with interpretation of the remotely sensed images.

4. Digital boundaries for commonly used reporting areas. Additional boundaries can be added by the user (using shapefiles or kml formats) or can be requested by the user and added to the tool.

Many of the available layers, particularly the land use/land cover and the boundaries can be displayed in the RaPP Map and used for extracting statistics from the time-series of TVC data, as explained in Section 2.3. Users can also add data layers, from the web if these are available as a Web Map Service (WMS) or by adding vector layers stored locally in the user's computer. These layers can be visually inspected, and also used to extract time-series data from the fractional cover dataset (see below). Appendix A provides a step-by-step guide for using the current (September 2018) version of the tool for Australia.

Table 2 List of available layers in RaPP Map for Australia as of September 2018

Layer type	Layer name	Custodian
Remote sensing time-series	MODIS Fractional Cover: Monthly: • Fractional Cover (PV, NPV and BS) • Total Vegetation Cover (PV+NPV) • Total Vegetation Cover anomalies • Total Vegetation Cover deciles 8-day: • Fractional Cover (PV, NPV and BS) • Total Vegetation Cover (PV+NPV)	CSIRO
	Landsat/Sentinel Fractional Cover: Seasonal: • Fractional cover (Landsat) (green, non-green, bare) • Fractional cover (Sentinel 2) (green, non-green, bare) • Ground Cover ("cover under trees", Landsat) (green, non-green, bare) • Persistent Green Cover (Landsat)	Joint Remote Sensing Research Program (JRSRP)
Climate	Rainfall Totals - CHIRPS Rainfall Anomalies, monthly	Climate Hazards Group, UC Santa Barbara
Land Use and Land Cover	Catchment Scale Land Use of Australia – update 2017 Land use of Australia 2010-11 (national scale) Extent of all forms of vegetation across Australia	Australian Bureau of Agricultural and Resource Economics and Sciences
	Ramsar Wetlands of Australia Interim Biogeographic Regionalisation for Australia (IBRA) version 7.0 Regions Interim Biogeographic Regionalisation for Australia (IBRA) version 7.0 Subregions Collaborative Australian Protected Areas Database (CAPAD) Observed major vegetation subgroups, from Australia's NVIS database	Australian Government Department of the Environment
	Physiographic Regions of Australia Generalised map of soil orders for Australia (ASRIS).	CSIRO
	Vegetation height and structure	Joint Remote Sensing Research Program (JRSRP)
Boundaries	Australian Rangelands Natural Resource Management Regions 2017	Australian Government Department of the Environment and Energy
	Local Government Areas 2016 Census Mesh Blocks 2011 Suburbs (SSC) 2016 Census Statistical area level (SA1, SA2, SA3 and SA4)	Australian Bureau of Statistics
	River Regions	Australian Government Bureau of Meteorology

2.3 Using RaPP Map for ground cover reporting

The RaPP Map tool can be used to:

1. visualise the type of ground cover (whether green, dead vegetation or bare) in a region,
2. visualise total ground cover (green plus dead), anomaly and decile ranking for any month from January 2001 to current month as maps (Figure 8), and
3. look at trends in the mean TVC (green plus dead) for any area of interest.
4. visualise paddock and property level variability in cover levels across seasons over 30 years using the Landsat fractional cover data

The results are displayed on the screen as a chart, and the user can also download the data as a .csv file. Figure 8 shows the TVC for July 2018 and a time-series of the mean TVC for the Western NRM region in NSW. The outputs can be displayed on the screen and downloaded into a spreadsheet for further analyses. At the time of publishing, the tool is undergoing development to enable users to set targets for ground cover improvement for regions or parts of regions to reduce the risk of soil lost through wind or hillslope erosion. For more information on target setting, see the Discussion.

A further explanation on the steps to obtain the various outputs are provided in Appendix A.

The RaPP Map user tool has been developed by CSIRO's Data61 National Map team. The handling of time-series is supported by CSIRO, AusCover (www.auscover.org.au) and the National Computational Infrastructure (NCI). The system developed for this project by the NCI (named 'GSKY'), to serve the MODIS layers as maps (Web Mapping Service, WMS) and queries of data over time (Web Processing Service, WPS) (see Larraondo et al 2017a and 2017b), has recently been adopted by Geoscience Australia's Digital Earth Australia initiative to provide advanced data services.

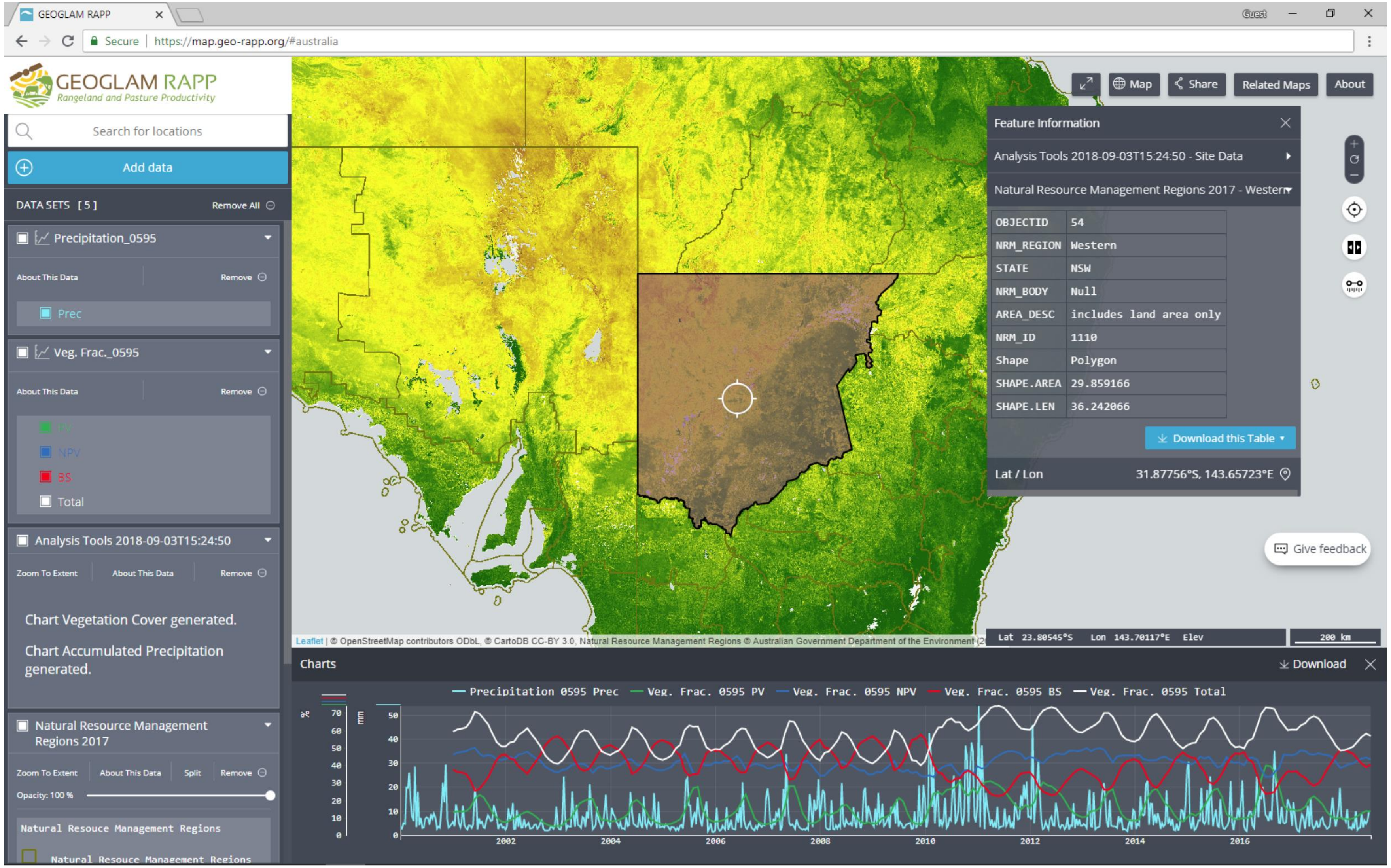

Figure 8: Screen capture of an output for the fractional cover and rainfall data in the Western NRM region of NSW.
The lines in the bottom chart show the median value for the region of photosynthetic vegetation (PV – green line), non-photosynthetic vegetation (NPV – blue line), total vegetation (PV+NPV – white line) and bare soil (BS – red line) respectively. The light blue line shows average rainfall in the region. The data in the chart can be downloaded for further analysis using the download button

3 Discussion

3.1 Improving natural resource condition

National Landcare Program funding provided through the Agriculture stream is aimed at improving the condition of Australia's natural resources (soil and vegetation) on land used for agriculture. Since 2008-09 the focus has been on improving the management of acid soils, building and retaining soil carbon and reducing the soil carbon, nutrients and soil volume lost through wind and water erosion. These soil factors are driver variables affecting nutrient and water availability which underpin agricultural productivity, profitability and resilience to climate change, and influence the quality of ecosystem services (air and water quality, protected biodiversity) enjoyed by the community.

Demonstration of improved resource condition outcomes and the associated benefits to farmers and the community is needed to reduce the decline in investment in natural resources management. In the last 10 years the Agriculture stream of the NLP has invested around $12 million in developing methods for monitoring and reporting changes in soil carbon and soil pH (e.g. Grealish et al. 2011), and monitoring wind erosion (e.g. Leys et al. 2010, McTainsh et al. 2010, Chappell et al. 2018) and water erosion (e.g. Bui et al. 2010). However, soil carbon and soil acidification processes are slow and difficult to detect over periods of less than five years, whilst wind and water erosion tends to occur episodically. Further, the large areas and highly heterogeneous environments used for agriculture across the Australian continent, make design of sampling strategies to monitor changes in soil condition extremely difficult.

3.2 Data and data sets

At a national workshop (Leys et al. 2009), participants discussed what would be required to establish a cost effective program to monitor soil erosion at national, state and regional scales. It was agreed that one element would be the monitoring of fractional ground cover. The New South Wales DustWatch program (https://www.environment.nsw.gov.au/topics/land-and-soil/soil-degradation/wind-erosion/community-dustwatch, which since 2012 has combined continuous monitoring of dust with MODIS derived ground cover data, has been very successful in monitoring wind erosion for south eastern Australia. DustWatch was expanded using NLP funding to include Western Australia and the arid regions of South Australia, but the service could not be maintained, and no data were available for northern Australia.

Data from the DustWatch program is reported monthly (https://www.environment.nsw.gov.au/Topics/Land-and-soil/Soil-degradation/Wind-erosion/Community-DustWatch/DustWatch-publications) for nine NRMS across South Australia, Victoria and New South Wales. Murray, Riverina and Western Local Land Service (LLS) regions have been experimenting with different methods on how to monitor and report on regional progress in improving ground cover. This work has helped these organisations:

- understand the dynamic nature of ground cover and the relative impacts of climate and land management
- how land use affects trends in ground cover
- identify locations at risk of wind erosion (e.g. areas with less than 50 percent cover) and assess their suitability for investment
- establish regional or subregional targets for wind erosion and ground cover improvement (Western LLS)
- report on the impact of investment on ground cover in cropping areas (Western LLS)

The development of a fractional cover dataset using MODIS satellite information (Guerschman et al. 2009) has enabled separate reporting of the brown and/or dead vegetation and bare ground components of cover for all of Australia each month. This has been very important for improving the accuracy of monitoring and modelling erosion in Australia which has significant areas of seasonally dry and dead vegetation that protects soil from wind and water erosion. This approach has also been adapted to Landsat data (Guerschman et al. 2015) and more recently to Sentinel 2 data to produce comparable fractional cover products. These products are used to support a range of extension and reporting programs in support of land management and policy initiatives for the management of the Great Barrier Reef (Department of Science, Information Technology and Innovation 2017).

National Landcare Program funds were used to expand the number of vegetation data points available to calibrate and validate remotely sensed fractional cover data for Australia (Muir et al. 2011) to better support ground cover monitoring. This has been further supported by ongoing data collection by the state and territory governments, following the same, consistent methodology. With the continued collection of field calibration data, the products are being continually improved in their accuracy. Increasing confidence in the data led to the decision to provide further NLP funds to make the data and associated tools readily accessible to natural resources managers, policy and industry groups.

The MODIS dataset, because it is available for all of Australia, every month, is ideal for regional reporting. Regional reporting complements investment site/property reporting that can be achieved with higher spatial resolution fraction cover products (Table 1). Extension literature reports that farmers learn from farmers (Šūmane et al. 2018), as a result, the impact of the NLP investment will be seen beyond the investment site. By reporting, not just at the investment site, but at the regional scale, the true impact of changed management should be seen. However we acknowledge that this is a long decadal process, as shown in Figure 10 and that other social and economic factors may impede progress.

3.3 Setting ground cover targets

Using the fractional cover datasets a few NRMs have discussed how they might set targets, with the outcome of improving the area protected from erosion. In Figure 9 the plot shows the monthly time-series of the area protected for wind erosion in the Western LLS. The idea discussed was to set a target where the aim was to try and manage the landscape so as to not repeat the very low areas of protection that have been previously measured. In Figure 9 this meant not having about 30 percent of region protected from wind erosion. A target of 40 percent of the region protected could be used (blue line in Figure 8). One possible reporting method is to publish the time-series plot and compare the current month to the target. At the time of writing only Queensland NRMs in the Great Barrier Reef have ground cover targets.

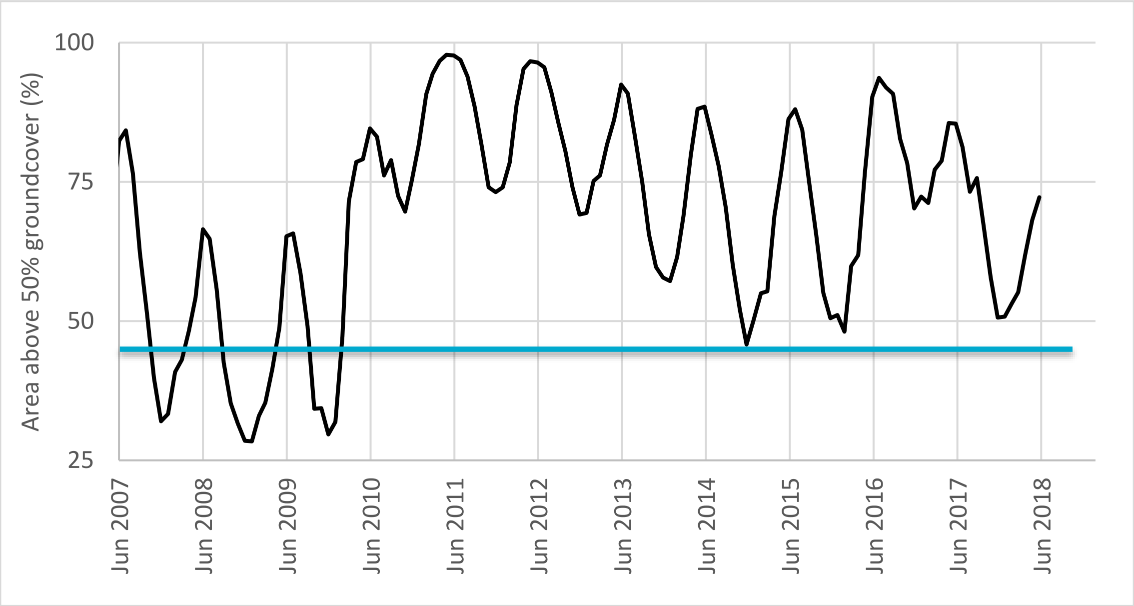

Figure 9: Area of Western LLS region that is protected from wind erosion (>50 percent TVC) and proposed target of having > 40 percent of the region protected from wind erosion.

In Queensland reef catchments the target for ground cover reporting is for 90 percent of the grazing lands to have greater than 70 percent of cover in the late dry season (Department of Science, Information Technology and Innovation 2017).

The Western LLS also measured the presence of best management practices at 260 cropping sites over 14 years. The idea was that these practices were linked to lower wind erosion and increased ground cover, which were also measured at the sites. The result in Figure 10 shows a 50 percentage point increase (15 percent to 65 percent in the number of sites adopting better management practices) over the project period.

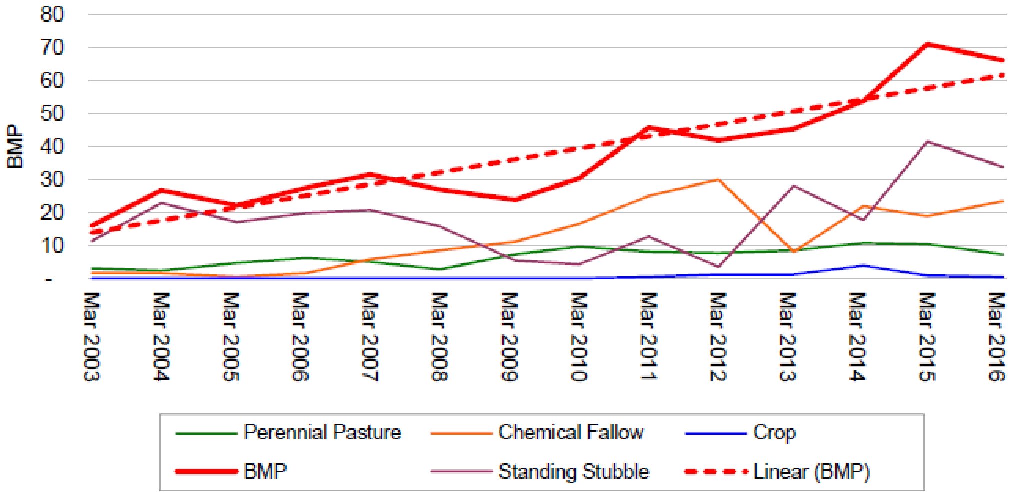

Figure 10: Trend in Best Management Practices and each practice type in the south west of the Western Local Land Services (LLS) Region.
From: Leys et al. (2016)

The RaPP Map tool provides ready access and the ability to query very large datasets (the global MODIS fractional cover dataset is 1.6 Terabytes, and the Australian Landsat seasonal fractional cover is 8.8 Terabytes) to users without remote sensing or GIS experience.

The RaPP Map tool complements other Australian initiatives including VegMachine© (vegmachine.net) and FarmMap4D Spatial Hub (farmmap4d.com.au) which currently deliver higher spatial resolution seasonal (3 monthly) compilations of ground cover data to end users. VegMachine© provides access to Landsat and Sentinel fractional cover data products. Users can select a region of interest and retrieve time-series data, or compare cover mean TVC values for two regions over time. FarmMap4D Spatial Hub is a commercial service aimed at property level management, and is available by subscription (AUD 300 per year for the standard service). It uses the same web services as VegMachine© to show time-series data from the Landsat fractional cover product, and provides property managers with a tool to assess, monitor and manage property infrastructure. These tools build on services such as AussieGRASS (www.longpaddock.qld.gov.au/aussiegrass/) and FORAGE (www.longpaddock.qld.gov.au/forage/) developed by the Queensland Department of Environment and Science/Joint Remote Sensing Program to provide landholders with Landsat based seasonal information on the status of ground cover in their pastures. It is worth noting that all the tools mentioned here rely on the same infrastructure (TERN AusCover) for the Landsat data products.

The MODIS fractional cover data will provide the basis for the Department of Agriculture and Water Resources' reporting on improvements in soil and vegetation condition at the national level, and to identify whether National Landcare Program project funding is having an impact on soil management and condition at regional level. We acknowledge that this is not going to be a simple process, for discerning if the change is ground cover is driven by land management practices or climate remains a challenge. To date one attempt has been made to separate the effect of grazing and rainfall at regional scale using remote sensing imagery (Bastin et al. 2012). They used Landsat data and report how they "calculate a minimum ground cover image across all years to identify locations of most persistent ground cover in years of lowest rainfall." And "This difference estimates ground-cover change between successive below-mean rainfall years, which provides a seasonally interpreted measure of management effects.” In this way they identify if management is improving for successive dry periods. The limitation of this method is that you only can report on improvement after each dry period.

4 Future developments

This section outlines the proposed developments and improvements to the tools and services described in this report.

4.1 Training for NRM organisations

The National Landcare Program is proposing to provide training in the use of the RaPP Map tool to regions funded through the Program to reduce soil loss through wind or water erosion. Workshops will be run with regional staff to familiarise them with the tool and the nature of ground cover change in their region. The workshops will also guide NRM organisations through a process, so they can set their own regionally relevant targets.

Establishing ground cover targets is part of the monitoring, evaluation and reporting process. Targets enhance NRM outcomes by helping people measure if projects are achieving their goals, including the extent to which local projects are encouraging ground cover management improvements at the district and regional level. While the data used might vary, e.g. Landsat for paddock scale monitoring versus RaPP Map for regions, the method of setting the target should be similar. While the concept of target setting is simple, the practice is not so simple, as targets should be SMART —Specific, Measurable, Attainable, Relevant and Timely.

The RaPP Map tool will be upgraded to provide access to data that can be used to set regionally specific targets that can be used for on-going monitoring. At this time, we can envisage three types of targets, but organisations might suggest more. Three target types include:

a. Area average

b. Area achieving erosion control

c. Temporal or seasonal targets

The training will use the concept of are we doing better than we have done in the past, that is comparison to a benchmark.

For example, if a hypothetical region has 100 percent bare in one half and 100 percent cover in the other half during November the data can be used in three different types of targets. For target a) above the answer is an average cover of 50 percent cover. However, the consequences for soil erosion in this example is that half the region is not protected from wind erosion. For target b) above the target might be - 80 percent of the region is achieving pixels with greater than 50 percent cover for the month with lowest cover. For target c) above the target might be 90 percent of the region has > 70 percent cover at the end of dry season in the north).

The above discussion shows that several types of targets can be used depending on the reporting or tactical decision-making need.

4.2 RaPP Map improvements

A number of features suggested by users will be improved or added to the RaPP Map tool. These include:

- Ensuring the data are routinely updated each month
- Incorporating the capacity to report areas above target (see next section) to enable users to retrieve reports for any area and any time period
- Better labelling of results returned from the analysis tools – replacing random numbers assigned to time-series so the user can more readily distinguish between polygons when results for more than one area are retrieved
- Removal of the maximum restriction of the size of the polygon (currently around 4.4 million km^2) for which data can be retrieved
- Replacing the global rainfall dataset with interpolated data from the Bureau of Meteorology (awaiting licensing agreement)
- Including additional data layers for the tool and in reporting, including fire occurrence, lateral cover (a horizontal projection of the lateral density of roughness across the land surface, Chappell et al. 2018), plus others that may be requested by users.

4.3 Improvements in satellite imagery

The MODIS sensors used for producing the vegetation fractional cover product are quickly approaching their end of life. Arrangements will be made to replace these -possibly with a combination of data from the Landsat and Sentinel 2 and 3 sensors. The aim is to provide users with a dataset with both high temporal and high spatial resolution to overcome the main individual drawbacks of the currently used Landsat and MODIS data product (e.g. Emelyanova et al. 2013, Hilker et al 2009).

4.4 Routine delivery of lateral cover data

Fractional cover is a measure of ground cover when looking down vertically from the satellite. Fractional cover has been correlated to wind erosion rates, with 50 percent TVC being sufficient to control wind erosion (Leys 1999). However, wind erosion is more closely correlated with lateral cover, because wind erosion can happen below tall canopies and between ground cover elements. Fractional cover does not capture the effects of surface roughness created by objects projected into the airstream. Chappell et al. (2018), present a measure of lateral cover which is derived from MODIS albedo data. Surface roughness can also be used to infer cover type, e.g. forest, annual grassland, perennial grassland. If a lateral cover dataset was made available, it would provide a better measure than fractional cover for setting targets and monitoring wind erosion risk.

4.5 Antecedent rainfall effects on vegetation cover

Research has been initiated on the effects of antecedent (sum of previous months) rainfall on TVC levels. One of the main environmental drivers of vegetation growth is rainfall. Years with higher rainfall lead to higher vegetation growth and vice-versa. It is also evident that the vegetation growth response is delayed from the rainfall event, and that in many cases there is a period of rainfall accumulation before a response is observed (Andela et al. 2013, Evans and Geerken 2004). There is anecdotal evidence that in rangeland systems vegetation cover responds (growing or decaying) to the rainfall accumulated over long periods (for example 2-3 years). There are many factors affecting this including the depth to the groundwater table, the particular terrain characteristics and the vegetation type. The idea was to explore, for every "pixel" in the rangelands, how much of the temporal variability in vegetation cover could be explained by the rainfall accumulated in the antecedent period, and also, the length of the period which maximises the predictive capacity of rainfall to explain TVC.

This idea is illustrated for a location in Cubba, NSW (-31.393, 145.461). Figure 11 shows the dynamics of TVC in that location. In March 2018 the TVC was lower than the mean for all Marchs on record. However, March 2018 was not the absolute lowest March as TVC in March 2003 and 2005 were lower than 2018.

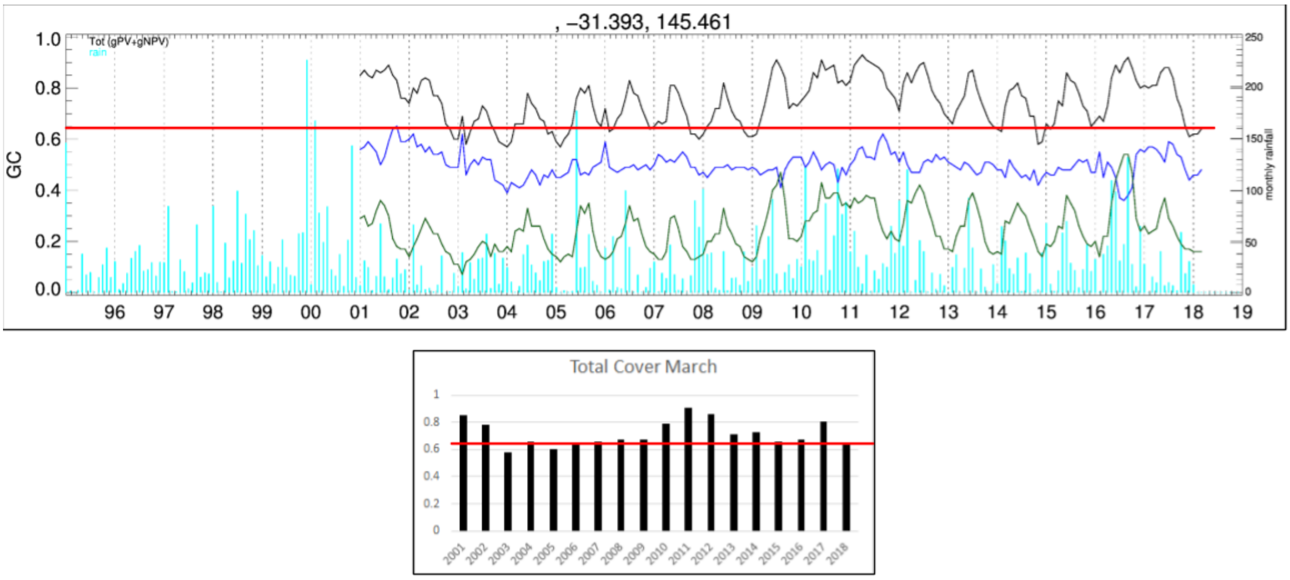

Figure 11: Vegetation cover in a MODIS pixel centred near Cubba, NSW
The exact location of the pixel is -31.393, 145.461. The top chart shows the monthly green vegetation cover (green line), non-green vegetation cover (blue line) total vegetation cover (black line) and the monthly rainfall (cyan bars). The bottom chart shows the total vegetation cover in March for each year. The red horizontal lines show the total vegetation cover in March 2018 for reference.

However, when the vegetation cover for all the months of March is plotted as a function of the accumulated rainfall in the preceding 26 months (2 years and 2 months), the value for March 2018 is much lower than would be expected from the linear relationship between the two variables (Figure 12).

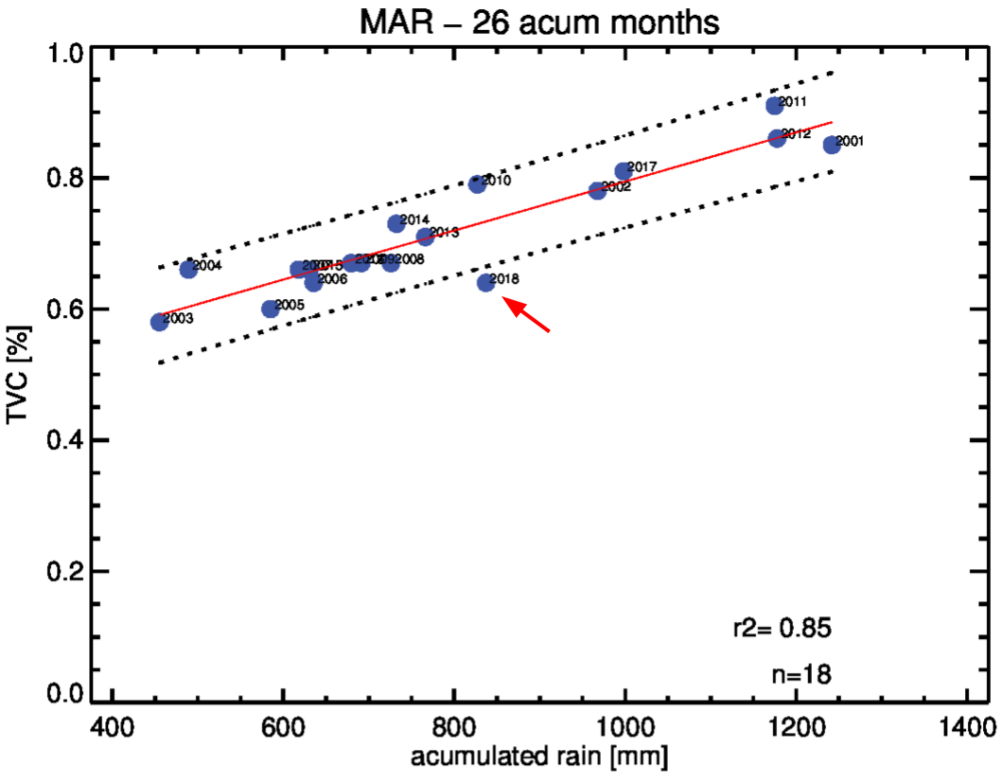

Figure 12: Relationship between Total vegetation cover in March and the accumulated rainfall in the 26 months before each March. The value for TVC in March 2018 is highlighted with a red arrow.
The red line is the line of best fit and the dotted lines show the 95 percent confidence interval for the prediction.

The cause of this anomaly cannot be inferred from Figure 12, but as the vegetation cover in March 2018 is much lower than would be expected given the amount of rainfall accumulated in the previous 26 months this suggests some disturbance has occurred in that pixel. Possible explanations are: fire, uncontrolled grazing pressure (e.g. feral goats) changed grazing intensity or management or some other human-induced change.

A system could be built to apply this approach to all pixels. Each month the observed vegetation cover would be compared to the expected cover based on the antecedent rainfall. When the observed value is much lower than the expected (like in the Cubba example), an ‘alarm’, or flag, for further exploration could be issued. This would serve as an early warning detection of negative anomalies potentially attributed to changes in grazing management or other human-related causes.

5 Conclusion

The MODIS fractional cover (2001-present) is a valuable resource which contributes to monitoring the risk of wind and water erosion. We have developed an online tool to facilitate access and use of these large remote sensing datasets. This simple tool can be used to help NRM organisations report on ground cover (represented here by TVC) change for their regions, and to provide information to industries and policy makers on ground cover change for reporting purposes. Users do not need specialist knowledge of GIS or remote sensing. With training and access to TVC data for the area above a threshold, say 70 percent, then targets can be set to monitor land management outcomes.

This tool can help to understand the dynamic nature of ground cover (represented here by TVC), if the levels are above or below the mean for the area when compared to the previous recorded months. It can help to identify locations at risk of wind and water erosion and establish regional or subregional targets for ground cover improvement.

Future developments include specific training for NRM organisations in the use of the tool and training in how to set ground cover targets. Further interaction with users will also provide opportunities to improve the tool. It is anticipated that a more comprehensive study of the dependency of ground cover on antecedent rainfall will provide land managers with a predictive tool to support timely land management decisions.

Abbreviations and acronyms

BS	Bare soil
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CSIRO	Commonwealth Scientific and Industrial Research Organisation
GEOGLAM	Group on Earth Observations Global Agricultural Monitoring initiative
GIS	Geographical Information System
KML	Keyhole Markup Language
LLS	Local Land Services
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalised Difference Vegetation Index
NLP	National Landcare Program
NPV	Non-photosynthetic vegetation
NRM	Natural Resource Management
PV	Photosynthetic vegetation
RAPP	Rangeland and Pasture Productivity
SLATS	Statewide Landcover and Trees Study
TVC	Total Vegetation Cover
WMS	Web Map Service
WPS	Web Processing Service

Glossary

Anomaly	The difference between total vegetation cover (PV+NPV) in a given month and the mean total vegetation cover for that month in all years available, expressed in units of cover.
Antecedent rainfall	For a given point in time, the sum of the rainfall over a preceding number of months.
Decile	The ranking (in nine value intervals) for the total vegetation cover in a given month in relation to the vegetation cover in that month for all years in the time-series.
Fractional cover	The percentage or fraction of an area (usually a pixel for the purpose of remote sensing) covered by the specific cover types of green or photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV) such as stubble, senescent herbage and leaf litter, and bare soil or rock. Areas that have been burnt resulting in ash or blackened soil are considered a bare soil cover type
Ground cover	Any plant cover, both photosynthetic and non-photosynthetic, near the soil surface including vegetative litter (modified from Murphy & Lodge 2002). Using remote sensing, ground cover is derived from fractional cover by excluding woody vegetation. Stones in contact with the soil are not included in estimates of remotely sensed ground cover as they cannot be reliably distinguished from the underlying soil.
Rangelands	In Australia, encompasses tropical woodlands and savannas in the far north; vast treeless grassy plains (downs country) across the mid-north; hummock grasslands (spinifex), mulga woodlands and shrublands through the mid-latitudes; and saltbush and bluebush shrublands that fringe the agricultural areas and Great Australian Bight in the south. Seasonal rainfall changes from summer-dominant (monsoonal) in the north to winter-dominant in the south. Soils are characteristically infertile. Distinctly characterised by great climate variability and the dominating influence of short growing seasons (Bastin et al. 2008).
Remote sensing	The process of obtaining information on vegetation attributes from a distance. Remote sensing records the reflected surface electromagnetic radiation of the vegetation cover and bare soil

Soil erosion	The displacement of the upper layer of soil caused by the dynamic activity of erosive agents, particularly water and wind
Total vegetation cover	The percentage or fraction of an area covered by any vegetation (both photosynthetic (PV) and non-photosynthetic (NPV)) including all vegetation layers: understorey, mid-storey and overstorey (see Figure 3). It is equivalent to the sum of the PV and NPV components of fractional cover.

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Appendix A User Manual for RaPP Map

A.1 What is included in this tutorial?

The online Rangeland and Pasture Productivity Map (RaPP Map) can be used to assess total vegetation cover and ground cover in areas with tree cover lower than 20 percent.

This manual will show how to use some of the functions available in RaPP Map as at September 2018.

This tutorial works with the following data:

- vegetation fractional cover: Total Vegetation Cover (PV+NPV, Monthly).
  - Total vegetation cover is the sum of the green or photosynthetic vegetation (PV) and brown or non- photosynthetic vegetation (NPV) and includes trees.
  - Total vegetation cover can be interpreted as ground cover in areas with tree cover lower than 20 percent.
- Natural Resource Management regions 2017. These administrative boundaries are found in the Australia tab, Boundaries folder.

To get more help while using the software click About and Help and FAQ in the top right of the screen or go to https://map.geo-rapp.org/help/help.html. Help will be updated as the RaPP Map tool is developed.

This manual will focus on comparison and exploration of cover trends, rather than reporting on cover or setting ground cover targets

You will learn how to:

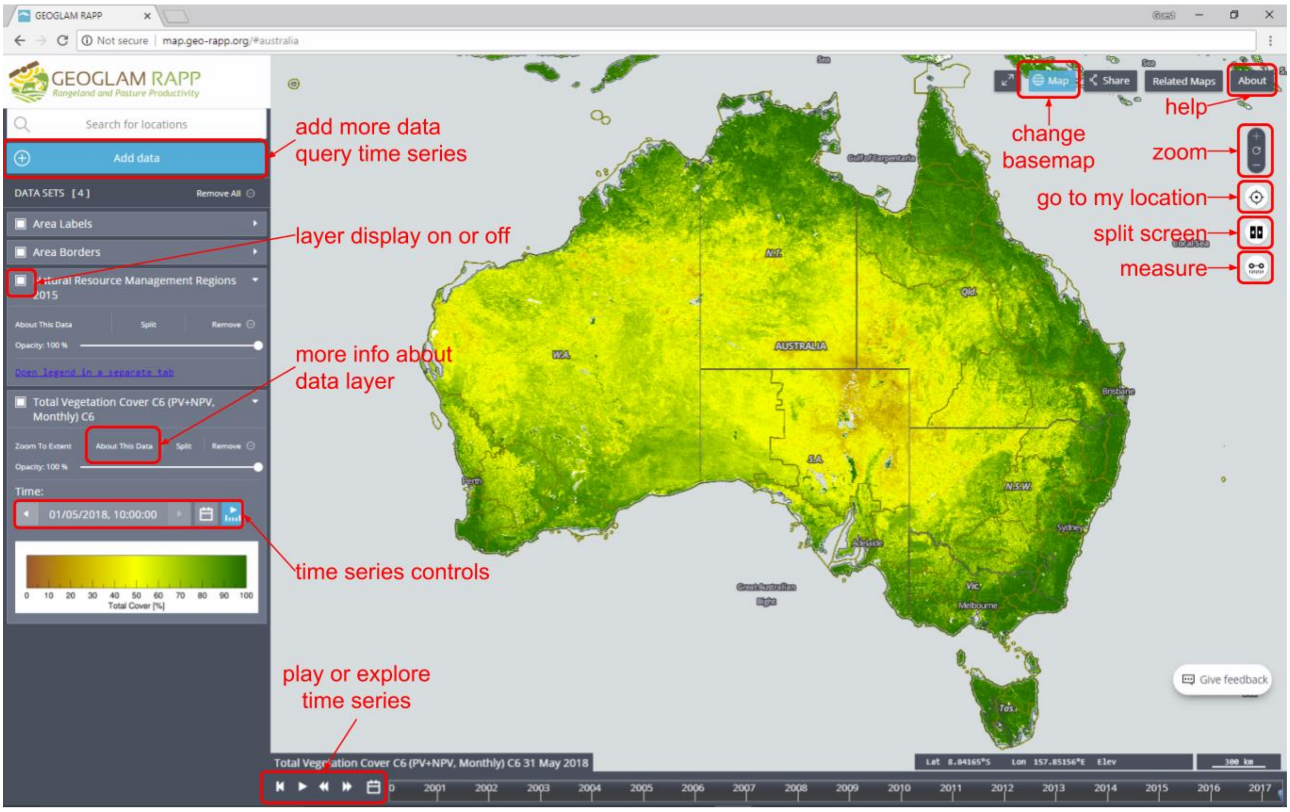
- Open RaPP Map # Australia
- Find tools on the interface
- Add and remove existing data from the map viewer.
- Select an image from the calendar
- Compare two images using a split screen slider
- View a time-series for a region
- Troubleshoot common problems

A.2 Getting started

1. Open the tool

Go to https://map.geo-rapp.org/#australia

Accept the disclaimer by clicking Continue. The screen will show as at Figure A1.



Apx Figure A1 Tools on the RaPP Map Interface.

Note: The image shows the RaPP Map interface displaying Total Vegetation Cover (PV+NPV) Monthly and 2017 Natural Resource Management Regions. This is the default view and the map is the latest monthly TVC available. Tools available for use are labelled.

A.3 Add and remove existing data layers to the map viewer

1. Click Add data
2. The Add data window shown at Figure A2 will appear. This window includes five tabs:

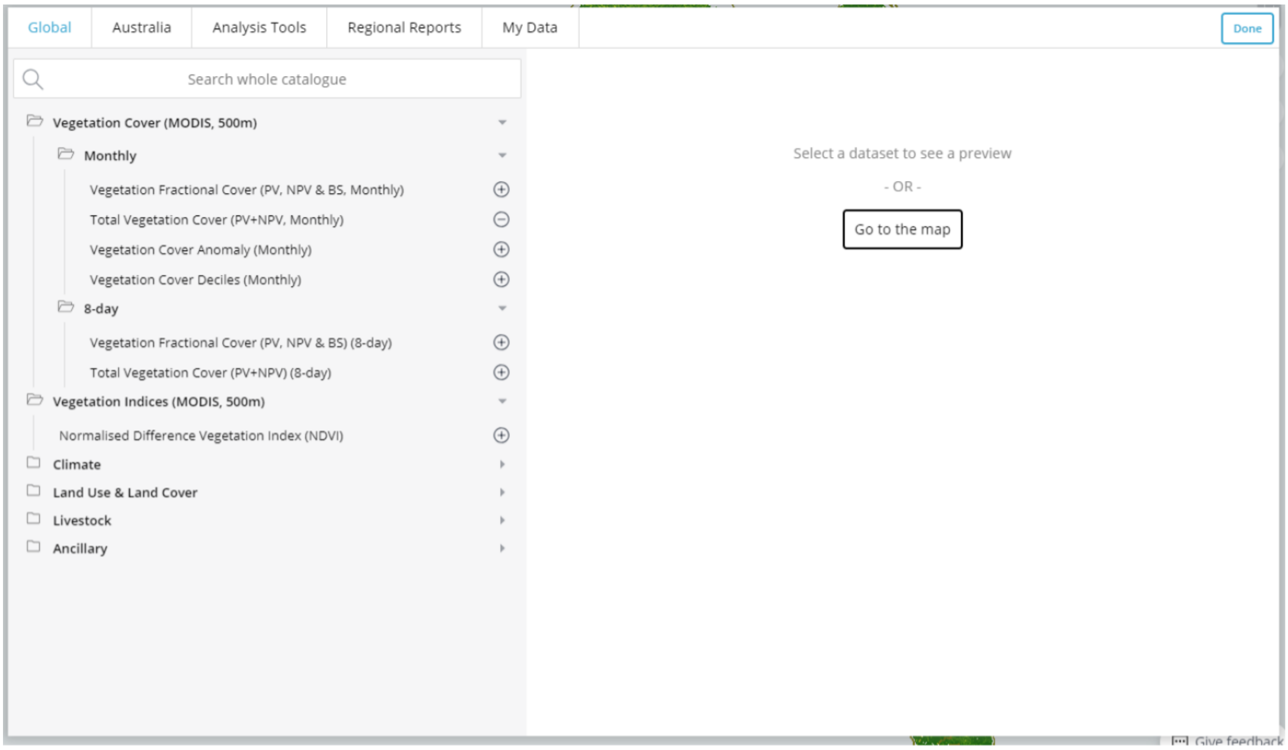
   Global: Data available for the world

   Australia: Data available for Australia (MODIS data from the Global tab are repeated here)

   Analysis tools: Allows you to produce a graph of the vegetation fractional cover for a point or polygon

   Regional reports: Prepared reports of vegetation cover over time for each Australian NRM and LGA Region.

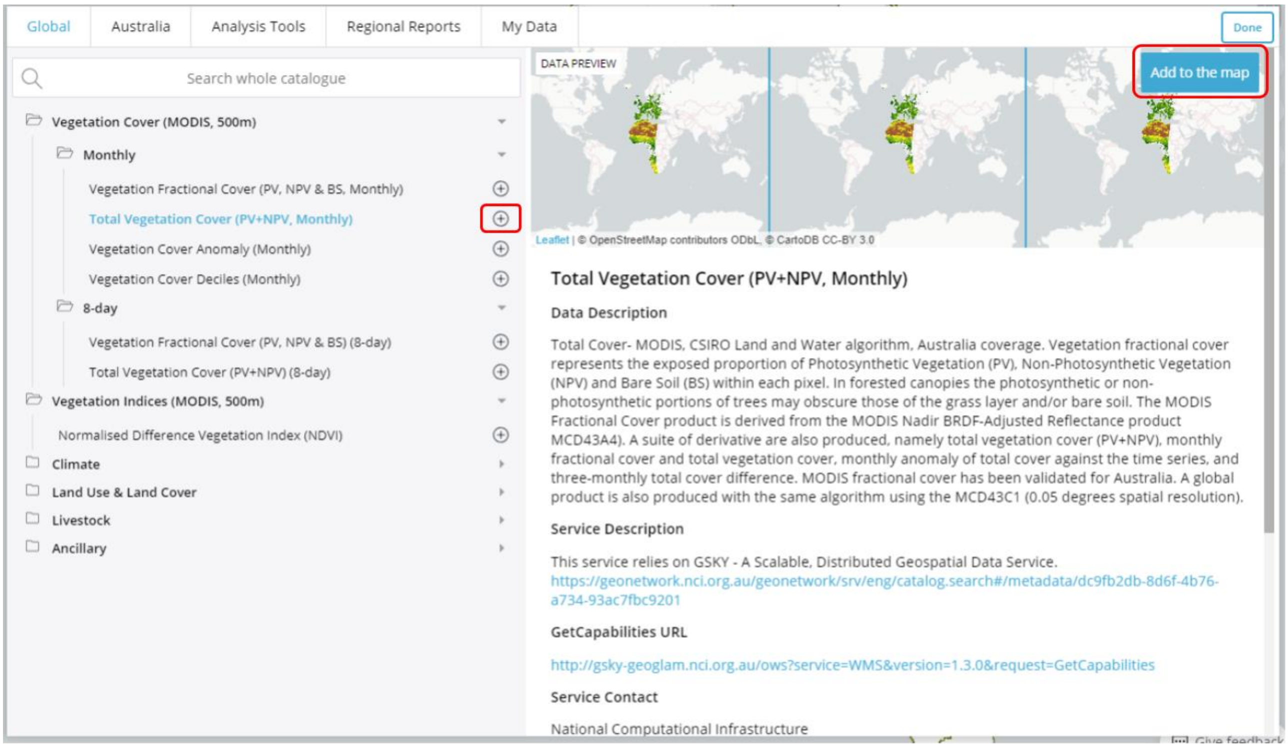
   My Data: Add own data, either local (from user's computer) or Web data



Apx Figure A2 Add data window, global tab.

Note: The image shows the Add data window with Total Vegetation Cover (PV+NPV) Monthly selected from the Global tab. ⊕ symbols indicate data layers which can be added to the map. ⊖ symbols indicate data layers which are already displayed on the map and can be removed. Clicking Done in the top right will close the window.

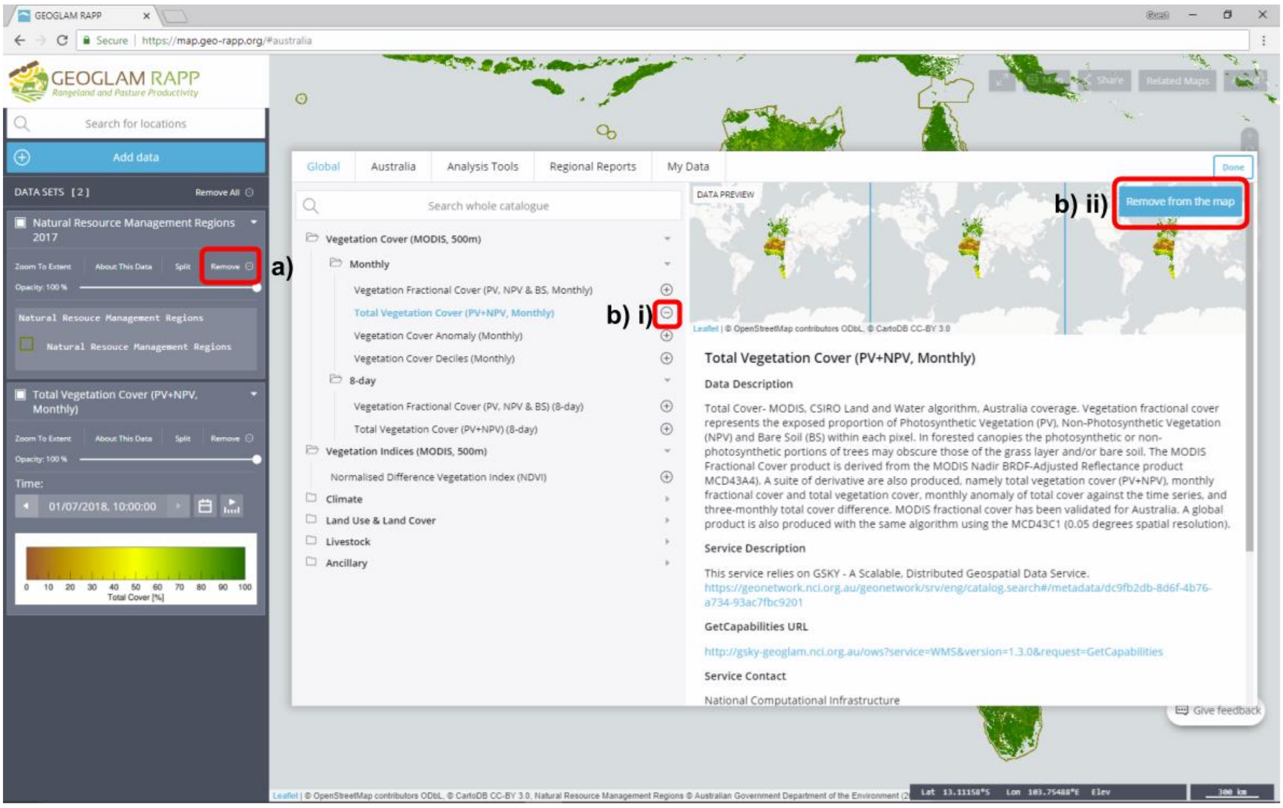
3. Expand the folders to view data layers which are grouped by theme. For example climate and boundaries.
4. Add a data layer to the map from the Add data window by either:
   a. Click the ⊕ button beside the layer of interest (see Figure A3), or
   b. Click the layer name to view the metadata for the layer and click Add to the map in the top right of the window.



Apx Figure A3 Options to add a data layer to the map view.

Note: The image shows the Add data window with Total Vegetation Cover (PV+NPV) Monthly selected from the Global tab.

5. Remove a single data layer or multiple layers from the map (see Figure A4) by either:
   c. Click the Remove ⊖ button beside the layer in the left hand interface panel, or
   d. Open the Add data window then:
      e. click the ⊖ button beside the layer (or layers) that you don't wish to display, and then Done in the top right of the window, or
      f. Click the layer names to view the metadata for the layer and click Remove from the map then Done in the top right of the window.
6. For this exercise ensure that Total Vegetation Cover (PV+NPV, Monthly) and Natural Resource Management regions are shown on the map and the legends for these layers can be seen on the left hand side of the interface panel.



Apx Figure A4 Options to remove data layers from the map view.

Note: The image shows options for removing data from the map view. a) shows the remove button in the left hand interface, b) i) shows the remove button in the List of Data layers from the Add data window and b) ii) shows the Remove from Map button which displays when viewing metadata for a layer in the Add data window.

A.4 Select an image from the calendar

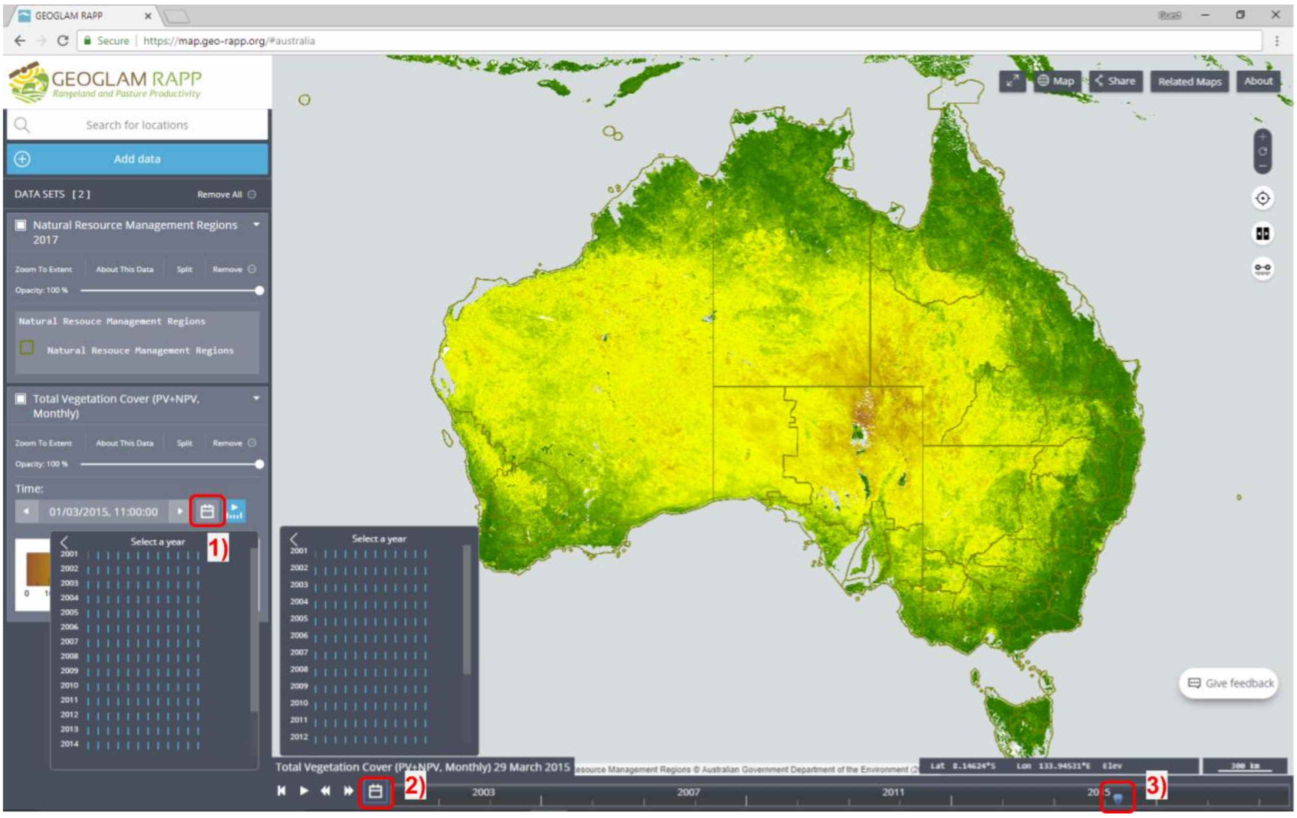
The RaPP Map contains a time-series of images derived from satellites. For example Total Vegetation Cover (PV+NPV, Monthly) contains monthly images from February 2001 until the latest month of data. This time-series will be updated as more imagery becomes available.

To choose an image to view in the map you can choose one of three options (Figure A5), either:

1. Click the calendar icon in the left hand interface panel,
   a. The select a year window shows the number of images available in each year as blue lines. Scroll down using the mouse or right hand scroll bar to see more recent images.
   b. Select your year of interest by clicking anywhere in that row
   c. Select an image by clicking the image date from the list (Figure A6)
   d. Your selected image will show in the map view
2. Use the calendar icon at the bottom of the screen, (follow the steps at 1) or
3. Use the slider on the bottom of the screen

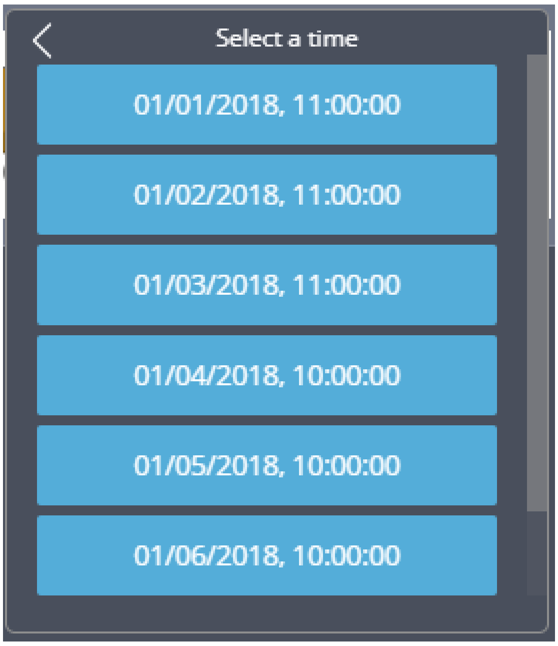
A.4.1 Where can I see the date of the imagery in the map view?

The date of the imagery for each layer is shown in the left hand interface panel next to the calendar view. The date of the imagery of the active layer is also shown above the slider at the bottom of the screen (Figure A5).



Apx Figure A5 Options for selecting an image from the calendar.

Note: The image shows the locations of the calendar icons and sliders for selecting an image from the time-series. 1) calendar icon in the left hand interface panel open to select an imagery year 2) calendar icon at the bottom of the map open to select a imagery year for the data layer currently active in the map window 3) the slider bar.



Apx Figure A6 Available images for 2018 shown in the Select a time window.

A.5 Compare two images using a split screen slider

A.5.1 What does the split screen slider do?

You can compare two images using the split screen slider. The split screen tool slider allows you to have a different image on the right and left of the RaPP Map view and slide the divider left and right to see locations covered by one image and then the other.

You can use the split screen to compare different dates of imagery and or different imagery products. In this example we will compare imagery for two different dates.

A.5.2 How to use the split screen slider

1. Activate the split screen slider by either:
    a. Click the *Split* button in the left hand interface panel for any of the data layers open in the map view. This will duplicate the imagery on both left and right of the split. This option is better for comparing imagery for different dates from the same data layer.
    b. Click the *Toggle splitter* control on the right hand side of the map view (Figure A1. and Figure A7). This will turn the splitter on, but not duplicate the active data layer. This option is better for comparing images from different data layers.
2. Assign images to left, right or both sides of the splitter
    a. Once split screen is active the options Left, Right and Both will be shown for every data layer in the left hand interface panel (Figure A8). Use these buttons to assign a layer to left and right of the splitter.
3. Compare images
    a. Use the mouse to grab the splitter icon and drag left and right to switch between the two chosen images

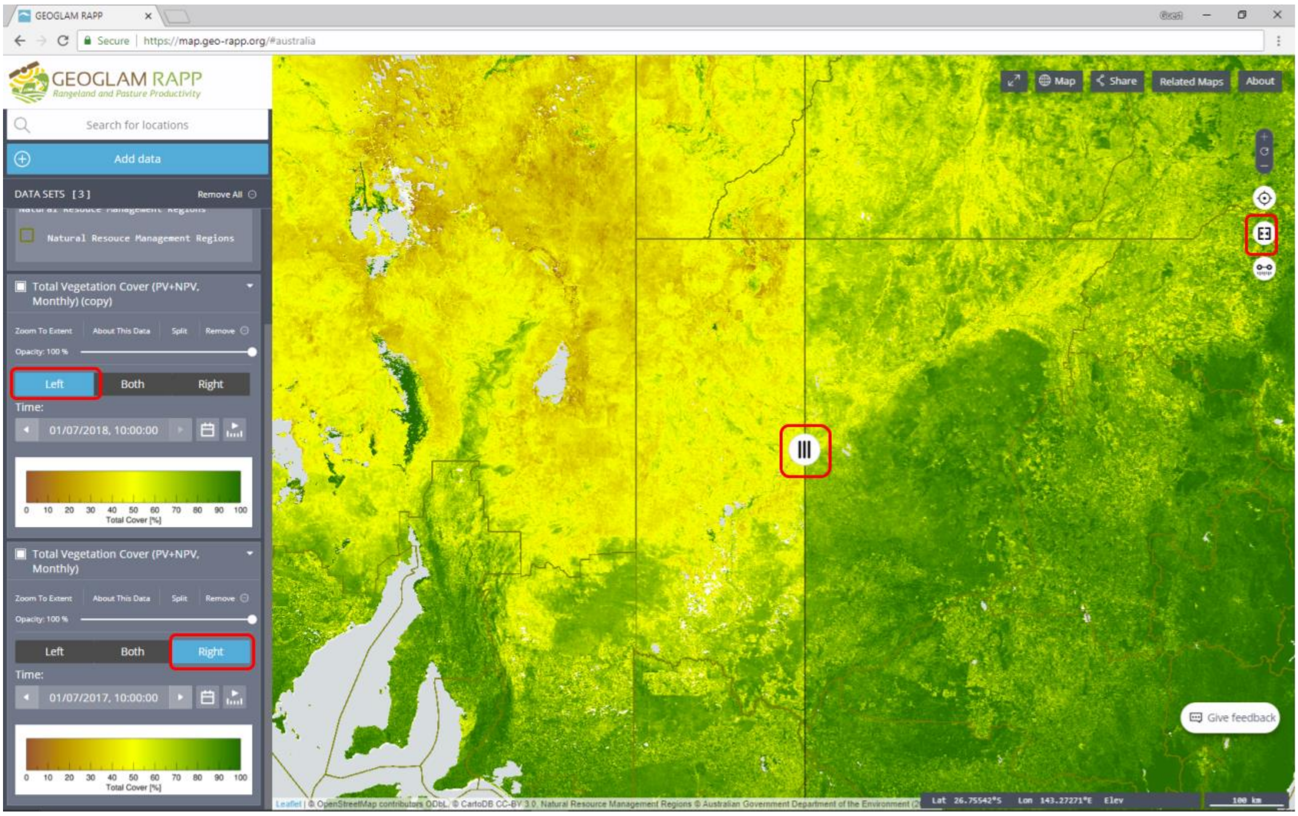
A.5.3 How to turn off the split screen slider

Remove the split screen slider by clicking the *Toggle splitter* control again (Figure A7).

Apx Figure A7 Toggle splitter control.

To compare two different total vegetation layer dates

1. Click “Split” on the Total Vegetation Cover layer. The layer is duplicated and one is shown on the left and the other on the right (Figure A8)
2. Select different dates in each layer
3. Drag the toggle splitter (in the middle of the screen) left or right to expose the Total Vegetation Cover in each date.



Apx Figure A8 Toggle split option, showing total vegetation cover in July 2017 (left) and in July 2018 (right).

A.6 View a time-series for a region

A time-series of mean vegetation cover and rainfall for a region shows variation in vegetation cover between months and across years. This can provide a picture of the vegetation responding to temperature, rainfall and land management.

Average cover is different to area achieving total cover for wind and water erosion protection. As such this tool is intended for comparison and exploration of cover trends, rather than reporting on cover or setting ground cover targets

You can view a time-series for:

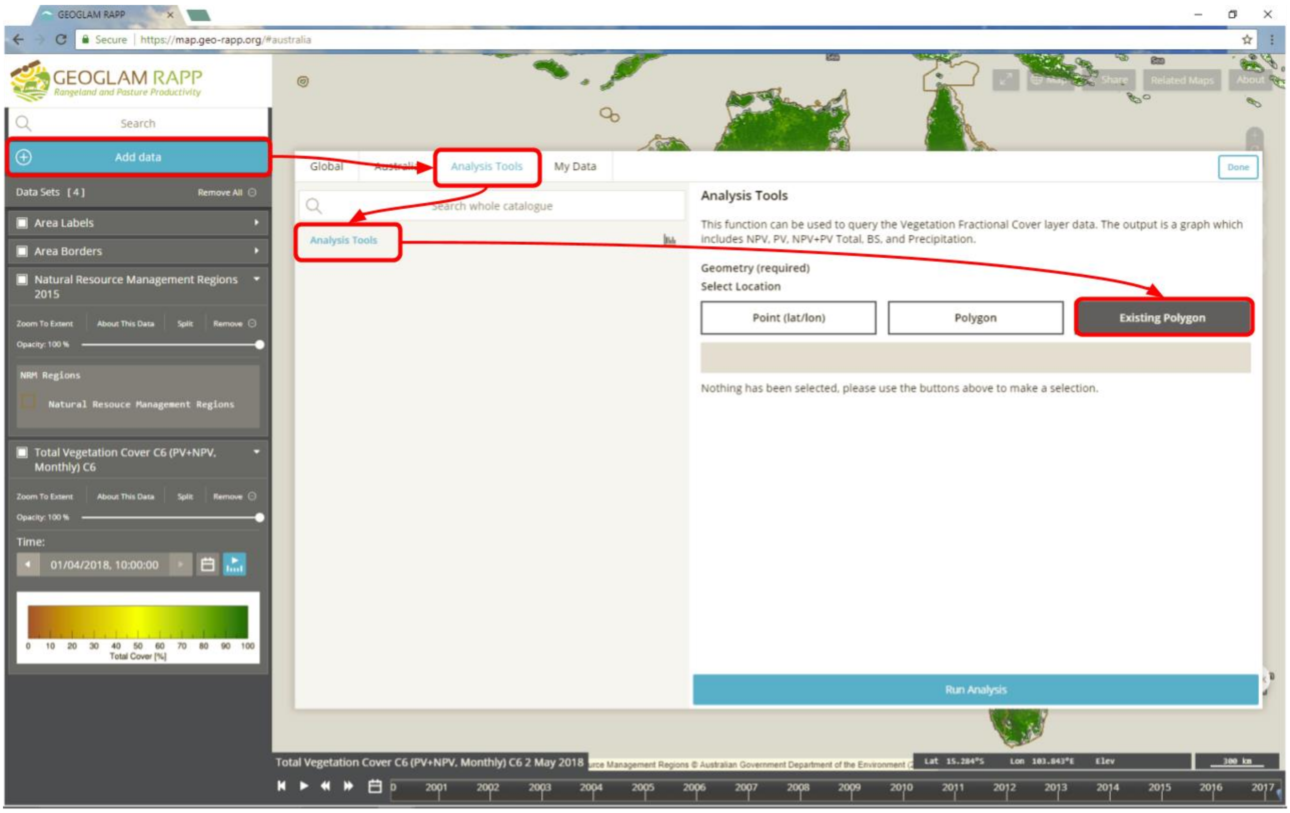
- A point: a point will represent a single pixel of the imagery. At the moment this option is only available for MODIS pixels, then the size of the pixel will be 500 metres. A time-series from a pixel may be useful for portion of a farm or property.
- An existing polygon: boundaries for several regions are included in RaPP Map such as Natural Resource Management Regions, Local Government Areas, and Statistical Regions
- Your own polygon: you can draw a polygon on the map or upload a polygon and use for extracting a time-series. To draw your own polygon, click Add Data -> Analysis Tools Tab -> Analysis Tools -> polygon. Then draw the polygon by clicking points on the map. The last point must be clicked on the first point to close the polygon. Click Done -> Run analysis

These instructions will show changes in **mean** total vegetation cover and rainfall for a polygon, for an existing polygon (a Natural Resource Management (NRM) Region).

1. Go to the *Add data window* – Figure A2.

2. Click the *Analysis Tools* tab and the *Analysis Tools* option

3. Choose *Existing polygon* – Figure A9. (Other options are *Point* (single pixel), a *Polygon* (user draws a polygon adding vertices by clicking on the map)



Apx Figure A9 Select fractional cover analysis for an existing polygon

4. The Select existing polygon window will open. Note that clicking *Cancel* will return to the Analysis tools tab to select a different option.

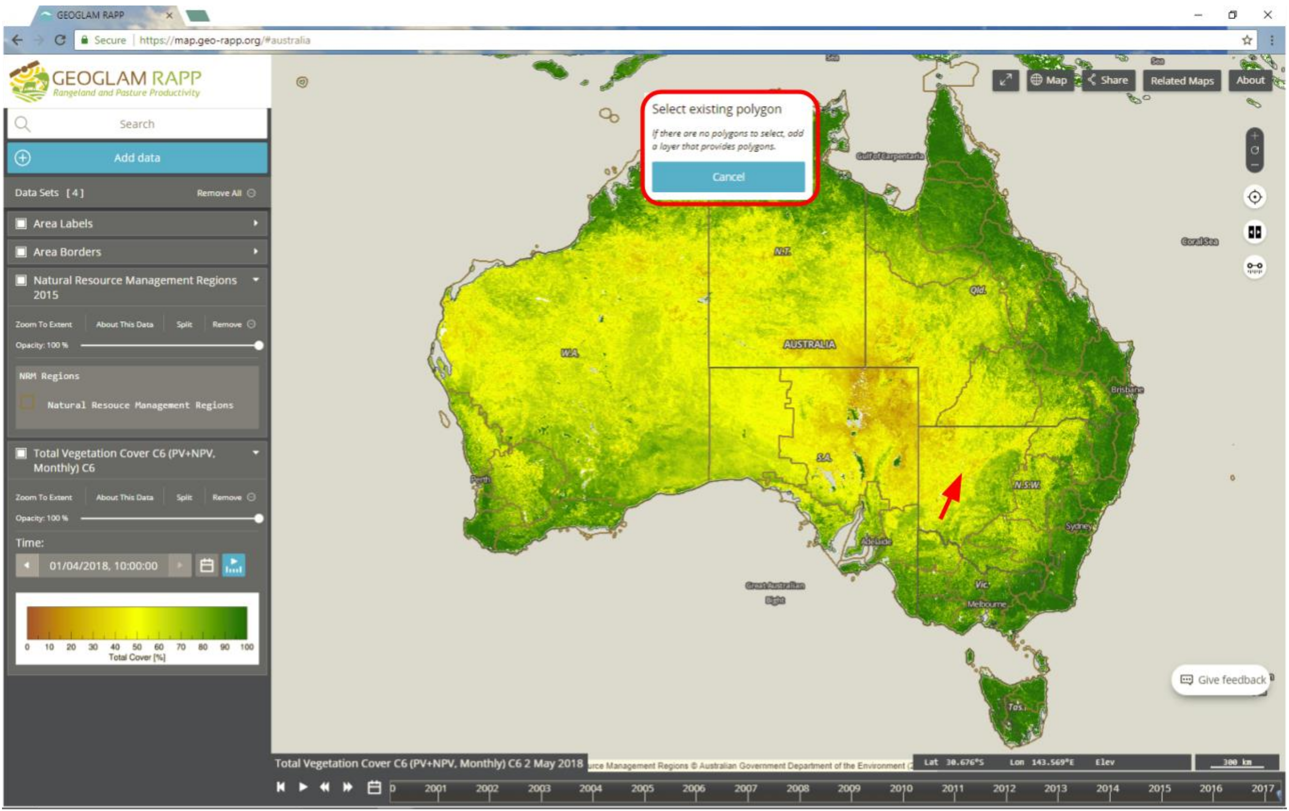
5. Ensure that the Natural Resource Management (NRM) Regions are displayed on the map

To turn on or off regions check the box on the left hand navigation panel (Figure A1).

6. Click on an NRM region

Select existing polygon by clicking with the mouse

In this case click on the Western New South Wales Natural Resource Management (NRM) region (see Figure A10).

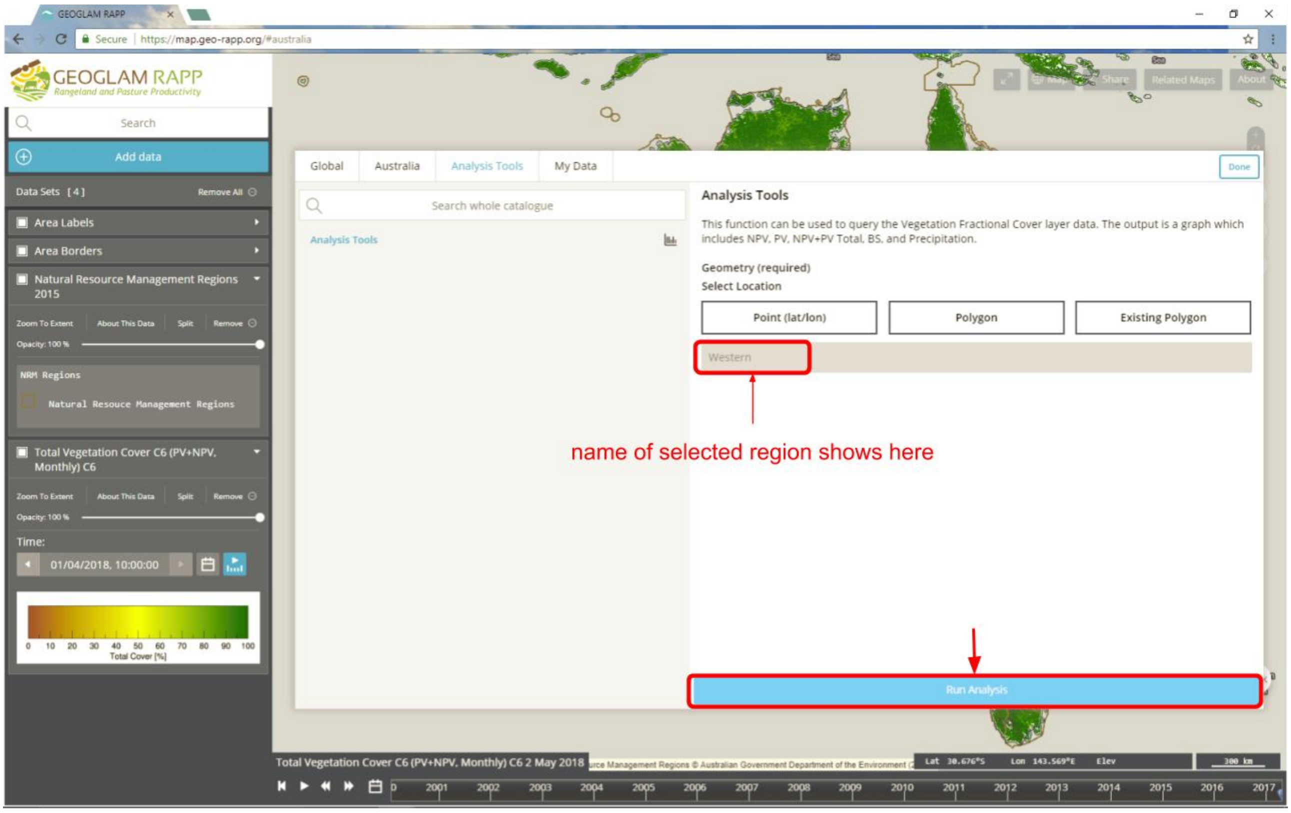


Apx Figure A10 Screen used to select an existing polygon to generate a time-series Select existing Western New South Wales region

7. You will return to the Analysis tools tab.

   a. Your selected region will show in light grey text below the select *location* options (Figure A11)

   b. Click Run analysis at the base of the page



Apx Figure A11 Run analysis

8. Wait for results to load. If the region is large the results may take several (20-30) seconds. Please be patient!
9. View the fractional cover and rainfall time-series chart at the bottom right of the screen see Figure A12.

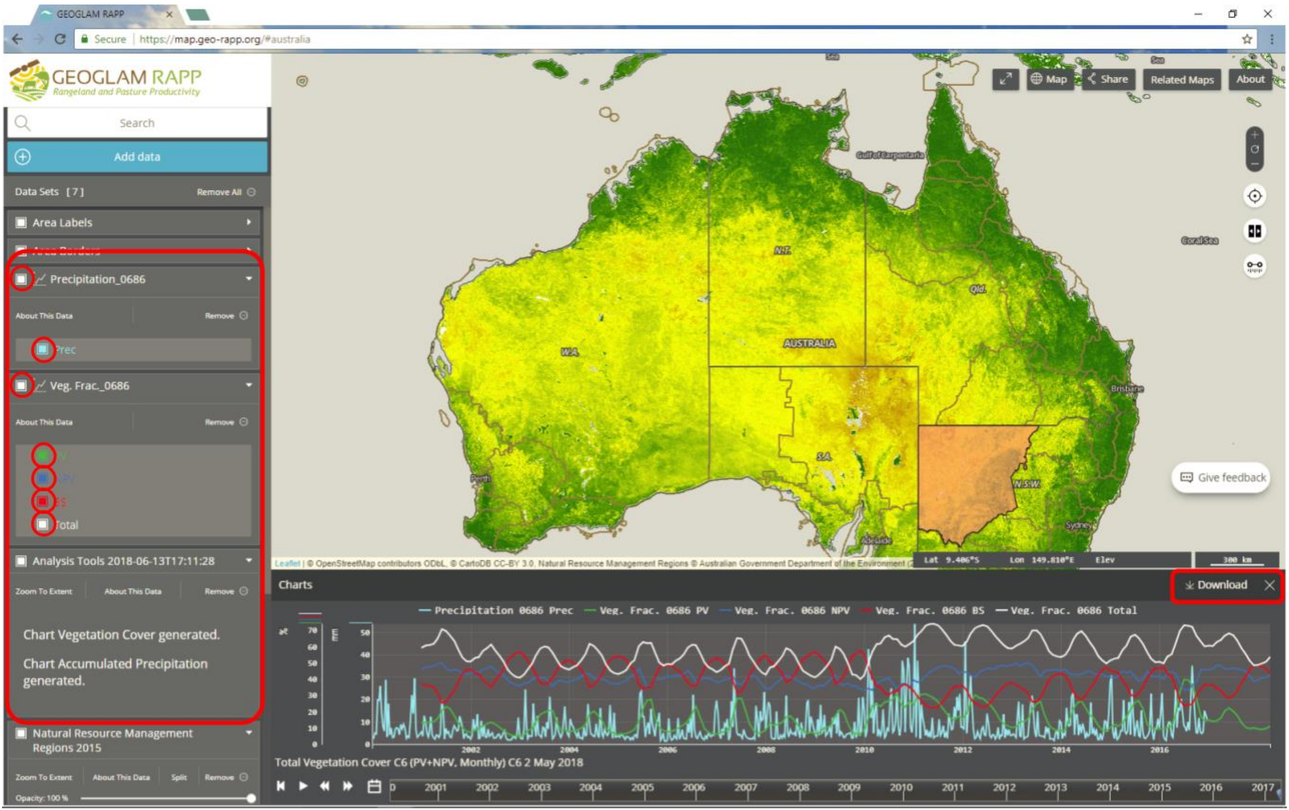
   The 5 time-series are labelled in the legend in the left panel

   Turn each time-series on and off using the left hand panel

   Download these time-series data to a csv file by clicking *Download* at the top right of the chart (Figure A12).
10. To create a time-series for another region

   Remove the existing time-series by clicking *Remove* in the left hand interface panel

   Repeat Steps 1-9



Apx Figure A12 Fractional cover time-series results

A.6.1 What does the time-series chart show?

Figure A12 shows time-series of vegetation cover and rainfall data for the Western NRM region of NSW (highlighted on the map). The time-series charts monthly rainfall and median monthly vegetation cover fractions. These values are calculated from an average (arithmetic mean) of all the pixels within the region (polygon). The colours lines on the chart are: light blue – rainfall (Precipitation), green – photosynthetic vegetation (PV), blue – non-photosynthetic vegetation (NPV), red – bare soil (BS), and white – total vegetation (PV+NPV).

A.6.2 What does the ground cover time-series tell me?

In the example shown there is a clear seasonal variation in total vegetation cover. The highest mean total cover in winter and the lowest cover is in summer. There is a decline in total vegetation cover from 2001 to 2002, a similar seasonal variation until 2010 when the total cover increases. The period of low mean cover was likely a result of the millennium drought and you can see the rainfall response from 2010 to 2012.

Looking at the green (PV) cover curve, there is a seasonal variation; however, in some winters, e.g. 2002, 2008 and 2009, there is low mean green cover. This suggests a failure of vegetation growth. The dominant cover type in the Western region is dead (NPV) cover, which is fairly uniform (mean of 30 to 50 percent) through the time-series. Bare Soil (BS) tends to be the inverse of green cover

A.7 Troubleshoot common problems

A.7.1 I don't see a map

Try changing the Basemap at the top right. 3D basemaps may not work with RaPP Map so try a 2D basemap.

A.7.2 Find more help

To get more help while using the software click *About* and *Help* and *FAQ* in the top right of the screen or go to https://map.geo-rapp.org/help/help.html. Help will be updated as the RaPP Map tool is developed.

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