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Summary

Nationally consistent and regularly updated ground cover information is critical for assessment of environmental targets related to soil erosion and land management in Australia.

The Ground Cover Monitoring for Australia project aims to develop and implement a nationally agreed, reliable and cost-effective basis for measuring and mapping ground cover using satellite imagery, and produce regular updates of ground cover conditions across Australia. The project will assist the monitoring and reporting of ground cover change at national, state and regional scales.

The project commenced with a workshop in November 2009 that scoped key tasks to deliver nationally validated remotely sensed fractional ground cover data (Stewart et al. 2011). This report documents progress in the delivery of those identified tasks to June 2011. Major outputs include:

- agreed national standards for the field measurement of fractional ground cover to support remote sensing products (Muir et al. 2011)
- a database containing data from 81 funded sites identified by location and with fractional ground cover measured according to the national standards (Rickards et al. 2012)
- a Moderate Resolution Imaging Spectroradiometer (MODIS)-derived vegetation fractional cover data archive (Guerschman et al. 2009) and associated metrics (Randall & Smart 2011).

The database and fractional cover data and metrics are available as Terrestrial Ecosystem Research Network (TERN) AusCover products through the National Computational Infrastructure website (2012a).

The project is funded by the Department of Agriculture, Fisheries and Forestry (DAFF), coordinated by the department’s Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) in partnership with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and state agencies. The project is funded to June 2013. Through TERN, data products from the project are accessible online. Additional site data will be collected under TERN AusPlots (rangelands).

Refer to the Caring for Our Country website (DSEWPC & DAFF 2012) for updates on products from the Ground Cover Monitoring for Australia project.
1 Introduction

Ground cover data has been identified as critical for assessment of environmental targets related to soil erosion and land management by natural resource management agencies (McKenzie & Dixon 2006). For Australia to manage its current natural soil resources, develop policies to help land managers adjust to a changing climate and demonstrate the effectiveness of current land management policies and investments, a clearly defined process is required for monitoring and reporting on ground cover at regional, state and national scales (Leys et al. 2009).

Ground cover can be monitored using remote sensing. From a remote sensing perspective, ground cover is the fractional cover of the non-woody vegetation and litter near the soil surface. Fractional cover comprises living (photosynthetic) vegetation, senescent or dead (non-photosynthetic) vegetation and bare soil or rock.

The Ground Cover Monitoring for Australia project commenced with a workshop in November 2009 to scope tasks to deliver nationally validated remotely sensed fractional cover (Stewart et al. 2011). Workshop participants agreed on a national approach to ground cover mapping to automate a remotely sensed (MODIS-based) fractional cover method (Guerschman et al. 2009) operationally for the nation. Participants also agreed to establish a national network of sensor-independent ground reference sites to validate this product. This report documents progress in the delivery of identified tasks to June 2011.

Progress in 2010–11

Project achievements in 2010–11 include:

1. publishing workshop proceedings on ‘Ground cover monitoring for Australia—Establishing a nationally coordinated approach to ground cover mapping’ (Stewart et al. 2011)
2. training in all states and the Northern Territory on site selection, field measurement and data entry for validation of remotely sensed fractional cover (July 2010–May 2011)
3. developing a national sampling strategy and recommendations for selecting ground cover control sites at an expert workshop on 17 and 18 August 2010 (Malthus et al. in prep.; sampling protocol in Appendix A)
4. publishing nationally applicable ‘Field measurement of fractional ground cover: A technical handbook supporting ground cover monitoring for Australia’ (Muir et al. 2011)
5. creating a database of existing and new sites across Australia with fractional ground cover measured and recorded to agreed standards (Rickards et al. 2012; Map 2)
6. collecting data for validation of remotely sensed fractional cover from April 2011, with a network of sites predominantly in extensively grazed rangelands (Figure 1)
7. updating MODIS-derived vegetation fractional cover data archive (Version 2.1) to June 2011, available online at the National Computational Infrastructure website (NCI 2012b)
8. validating and assessing accuracy of MODIS-derived vegetation fractional cover data archive (Version 2.1) using available site data—briefing provided to the National Committee on Land Use and Management Information and the National Committee on Soil and Terrain in April 2011 (Appendix B; Guerschman et al. 2012)
9. providing users with data metrics such as mean, minimum, maximum and frequency of processing errors (flag classes) for the MODIS fractional cover archive (Version 2.1) with a user guide (Randall & Smart 2011) and metadata available online at the National Computational Infrastructure website (NCI 2012c)

10. creating a Landsat-derived fractional cover product for scenes related to training sites in South Australia and Western Australia. These products are enabling assessment of variability and accuracy of Landsat and MODIS-derived fractional cover products using site data

11. compiling this annual report on the Ground Cover Monitoring for Australia project.

Report structure

This report is structured around five deliverable streams for 2010–11:

- investment plan
- network of ground cover sites
- MODIS-derived vegetation fractional cover
- reporting products
- monitoring fractional ground cover.

The report covers ongoing activities from 2010–11 and those commenced in 2011–12.
2 Investment plan

The Department of Agriculture Fisheries and Forestry (DAFF) will release an investment plan in 2012 to encourage investment in additional ground cover reference sites. The plan draws on the national sampling strategy developed by CSIRO following an expert workshop in August 2010.

The investment plan seeks to expand the number of ground cover reference sites to improve fractional vegetation cover products derived from remote sensing. It will be informed by the deliverables of the current Ground Cover Monitoring for Australia project in which DAFF is investing $2.8 million over 4 years to June 2013. These deliverables include over 500 reference sites, a national database, calibration, validation and improvement to the MODIS-derived vegetation fractional cover product developed by Guerschman and colleagues (2009), derived metrics and reporting products in a collaborative partnership coordinated by ABARES.
3 Network of ground cover sites

State agency partners began developing a network of ground cover reference sites in 2010–11. Data from over 500 sites will be collected during 2010–13, with the majority of sites located in the rangelands (Table 1). Sites were selected using the sampling protocol (Appendix A) derived from the sampling strategy (Malthus et al. in prep.).

Table 1 Number of sites where data is to be collected (2009–10 to 2012–13)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW</td>
<td>5</td>
<td>25</td>
<td>35</td>
<td>25</td>
<td>73</td>
<td>17</td>
<td>90</td>
</tr>
<tr>
<td>Vic.</td>
<td>5</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Qld</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>30</td>
<td>0</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>SA</td>
<td>5</td>
<td>35</td>
<td>35</td>
<td>25</td>
<td>83</td>
<td>17</td>
<td>100</td>
</tr>
<tr>
<td>WA</td>
<td>5</td>
<td>50</td>
<td>51</td>
<td>31</td>
<td>120</td>
<td>17</td>
<td>137</td>
</tr>
<tr>
<td>NT</td>
<td>5</td>
<td>35</td>
<td>36</td>
<td>26</td>
<td>87</td>
<td>15</td>
<td>102</td>
</tr>
<tr>
<td>Tas.</td>
<td>5</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30</strong></td>
<td><strong>155</strong></td>
<td><strong>187</strong></td>
<td><strong>137</strong></td>
<td><strong>393</strong></td>
<td><strong>116</strong></td>
<td><strong>509</strong></td>
</tr>
</tbody>
</table>

a Funding in 2009–10 was for training sites. b Proposed number of sites to be funded. c Approximately 90 per cent of sites will be located in rangelands. d Cropping sites are sites under cropping or pasture located outside rangelands.

Source: ABARES

Data is being collected from this network of sites following training in field measurement of fractional cover. The 30 sites funded in 2009–10 enabled the Queensland Department of Environment and Natural Resources (DERM) to coordinate training in the fractional cover method. Training was completed in all states (except Queensland) and the Northern Territory during 2010–11. To date, ABARES has received data from 29 of the 30 funded sites. Project partners have published a handbook to ensure consistent national adoption of the field methods (Muir et al. 2011).

This network builds on existing sites in Queensland and New South Wales (Table 3). Queensland DERM has been collecting fractional ground cover since 2002 and has 282 sites with 515 observations (up to October 2010). In 2009 the Lower Murray–Darling (LMD) Catchment Management Authority collected from 32 sites in New South Wales. CSIRO Land and Water collected fractional ground cover and spectral measurements at 14 sites in the Murrumbidgee catchment of New South Wales in February and October 2010.

As of June 2011 ABARES has received data from 81 sites: the 29 training sites and 52 of the 155 sites funded in 2010–11 (Map 1). Seasonal weather conditions have affected site access, causing delays in data collection. The site data is stored in a database for analysis and calibration and validation of the MODIS-derived vegetation fractional cover product.
Training

From July 2010 to May 2011 Queensland DERM provided standardised training in the measurement of fractional ground cover (Figure 1 and Table 2). Training has informed the development of a national handbook (Muir et al. 2011). All states and the Northern Territory completed training, with 54 people trained (Table 2).

Handbook

Queensland DERM has developed a nationally applicable handbook that details site selection, field measurement and data entry for validation of remotely sensed fractional cover. A draft handbook was presented to the National Committee on Soil and Terrain and the National Committee on Land Use and Management Information in April 2011. Input on the handbook was also sought from the Australian Collaborative Rangelands Information System Management Committee. The handbook has been revised as an Australian Collaborative Land Use and Management Program publication (Muir et al. 2011).
Figure 1 Training in fractional cover measurement

![Image of people conducting measurements in a cereal crop]

*Note*: Trainees learn how to conduct measurements in a cereal crop.

*Source*: Anna Dutkiewicz, Department of Environment and Natural Resources (South Australia), July 2010

Table 2 Training schedule

<table>
<thead>
<tr>
<th>Training undertaken</th>
<th>State</th>
<th>Organisation</th>
<th>Number attending</th>
</tr>
</thead>
<tbody>
<tr>
<td>27–29 July 2010</td>
<td>SA</td>
<td>Department of Environment and Natural Resources</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arid Lands NRM Board</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eyre Peninsula NRM Board</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Murray–Darling Basin NRM Board</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>University of Adelaide</td>
<td>1</td>
</tr>
<tr>
<td>11–15 October 2010</td>
<td>WA</td>
<td>Department of Agriculture and Food</td>
<td>7</td>
</tr>
<tr>
<td>24–25 November 2010</td>
<td>NSW</td>
<td>Department of Environment, Climate Change and Water *</td>
<td>13</td>
</tr>
<tr>
<td>28–29 March 2011</td>
<td>Vic.</td>
<td>Department of Primary Industries</td>
<td>10</td>
</tr>
<tr>
<td>30–31 March 2011</td>
<td>Tas.</td>
<td>Department of Primary Industries, Parks, Water and Environment</td>
<td>8</td>
</tr>
<tr>
<td>22–24 May 2011</td>
<td>NT</td>
<td>Department of Natural Resources, Environment, The Arts and Sport</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total trained</strong></td>
<td></td>
<td></td>
<td><strong>54</strong></td>
</tr>
</tbody>
</table>

*a* Now the Office of Environment and Heritage within the Department of Premier and Cabinet.

*Note*: Some states undertook refresher training before the national data collection campaign began in April 2011.

*Source*: ABARES

**Spatial database**

ABARES has established and maintains a spatial database containing fractional cover site data for 628 observations from 395 sites (Map 2 and Table 3). This includes data from previous Queensland DERM and New South Wales LMD field campaigns. A subset of this database containing only data from sites funded under the Ground Cover Monitoring for Australia project is available online from TERN AusCover through the [National Computational Infrastructure website](#) (2012d). At 14 June 2011 this Ground Cover Monitoring for Australia site database, created using PostGIS open source software, contained data from 81 sites, 52 of which were collected in May 2011 (Map 1).

Changes to current licensing arrangements are being investigated so that sites from Queensland DERM and New South Wales LMD can be included in the publicly available database.
Table 3 Sites in ground cover database (as at 14 June 2011)

<table>
<thead>
<tr>
<th>Source</th>
<th>Data collected</th>
<th>No. of sites (observations)</th>
<th>Sites in rangelands (observations)</th>
<th>Sites in intensive land use zone (observations)</th>
<th>Sites reporting cropping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qld DERM</td>
<td>July 2002–October 2010</td>
<td>282 (515)</td>
<td>175 (295)</td>
<td>107 (220)</td>
<td>n/a</td>
</tr>
<tr>
<td>NSW LMD</td>
<td>May 2009</td>
<td>32</td>
<td>32</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td>SA training</td>
<td>July 2010</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>WA training</td>
<td>October 2010</td>
<td>9</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>NSW training</td>
<td>November 2010</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Vic. training</td>
<td>March 2011</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Tas. training</td>
<td>March 2011</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>WA DAF</td>
<td>May 2011</td>
<td>13</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>SA DENR</td>
<td>May 2011</td>
<td>39</td>
<td>30</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>395 (628)</strong></td>
<td><strong>253 (373)</strong></td>
<td><strong>142 (255)</strong></td>
<td><strong>21</strong></td>
<td></td>
</tr>
</tbody>
</table>

Note: Data for sites funded under the Ground Cover Monitoring for Australia project (Map 1) can be downloaded at the National Computational Infrastructure website (2012d). New site data are added as they are provided to ABARES. Data from additional sites shown in Table 3 and Map 2 will be publicly available once license arrangements have been established.

Source: ABARES

Map 2 Ground cover sites in database (as at June 2011)

Note: Map shows all sites available for validation of the MODIS-derived vegetation fractional cover product. Licensing arrangements to be established for public release of data not collected under the Ground Cover Monitoring for Australia project. Map 1 shows sites with data available online at the National Computational Infrastructure website (2012d).

Source: ABARES
The PostGIS database contains data entered in the Microsoft Excel versions of site description and transect forms for each site (Appendix 3 in Muir et al. 2011). The data is stored in tables (Table 4). A user guide (Rickards et al. 2012) provides further details on the database for ground cover reference sites.

The database is structured to accommodate fractional ground cover measurements recorded at TERN AusPlots rangeland sites. Including data from TERN AusPlots sites should provide several hundred additional data entries.

**Table 4 Tables in the ground cover reference site database**

<table>
<thead>
<tr>
<th>Table name</th>
<th>Content for each site</th>
</tr>
</thead>
<tbody>
<tr>
<td>fc_raw</td>
<td>Raw data for each point along the transect layout (300 or 200 observations)</td>
</tr>
<tr>
<td>landsat</td>
<td>An index of Landsat imagery – relevant scene and processed output</td>
</tr>
<tr>
<td>photos</td>
<td>An index of 7 or 5 photographs taken along the transect layout</td>
</tr>
<tr>
<td>site_desc</td>
<td>Other information describing the site such as land use, vegetation species, soil surface condition, soil colour etc</td>
</tr>
<tr>
<td>sites_geom</td>
<td>Location in latitude and longitude</td>
</tr>
<tr>
<td>fc3</td>
<td>Totals for the ground layer fractions PV, NPV and BS and ground cover (PV + NPV) (as a percentage)</td>
</tr>
<tr>
<td>fc_summary</td>
<td>Totals for each cover category (as a percentage)</td>
</tr>
<tr>
<td>sum_check</td>
<td>Total cover to identify errors (as a percentage)</td>
</tr>
</tbody>
</table>

PV = photosynthetic vegetation; NPV = non-photosynthetic vegetation; BS = bare soil.

*Source: Table 1 in Rickards and colleagues (2012)*
4 Vegetation fractional cover derived from MODIS satellite imagery

Data archive

Version 2.1

CSIRO Land and Water regularly update the data archive of the MODIS-derived vegetation fractional cover using the method developed by Guerschman and colleagues (2009). The data archive consists of 16-day composites produced every 8 days, from March 2000, at 500 metre resolution (Map 3). The MODIS-derived vegetation fractional cover data archive (Version 2.1) is published as a TERN AusCover product through the National Computational Infrastructure website (2012b).

Map 3 MODIS-derived vegetation fractional cover (as at 22 March 2011)

Note: Example of a 16-day composite image. The three cover fractions are: PV photosynthetic vegetation (green); NPV non-photosynthetic vegetation (red); BS bare soil (blue).

Data source: MODIS fractional cover (version 2.1) Quicklook image for March 22, 2011 (NCI 2012b)
CSIRO Land and Water will soon release Version 2.2 of the MODIS-derived vegetation fractional cover data archive. Version 2.2 has been recalibrated using the existing site data from Queensland DERM, New South Wales LMD and the South Australian training data (Table 3), together with 14 sites collected by CSIRO Land and Water in 2010 in the Murrumbidgee catchment, New South Wales. Version 2.2 of the MODIS-derived vegetation fractional cover data archive will be available through the National Computational Infrastructure.

Validation of MODIS-derived vegetation fractional cover product

After undertaking a validation of Version 2.1 of the MODIS-derived vegetation fractional cover product, Guerschman and colleagues (2012) recalibrated the algorithm to produce Version 2.2. The validation used data from 359 sites (567 observations) from Queensland, New South Wales and South Australia (Map B1).

The validation of Version 2.1 showed that non-photosynthetic vegetation cover is underestimated and bare soil is overestimated. The recalibration has eliminated this bias and also reduced the root mean square error (RMSE) in the estimates of the three fractions. The RMSE of Version 2.2 is 14.7 per cent for photosynthetic vegetation, 20.6 per cent for non-photosynthetic vegetation and 17 per cent for bare soil, reduced from 17.2 per cent, 25 per cent and 26 per cent respectively in Version 2.1. A lower RMSE indicates less difference between the modelled fractional cover data and the data collected at field sites. Lower than 10-15 per cent RMSE is recommended by Guerschman and colleagues (2012).

Possible approaches for further improving the algorithm include:

1) having variable endmembers, depending on environmental conditions
2) incorporating more bands or indices to increase the ability of the model to estimate fractional cover
3) increasing the number of field visits where spectral measurements are taken.

Comprehensive collection of field data representing vegetation conditions, preferably at homogeneous sites and with coincident Landsat imagery, will help validate the extent that these approaches improve the model. Also to be resolved are the effect of soil colour and soil moisture on model performance.

More detail is provided in the brief on the initial validation presented to the National Committee on Land Use and Management Information and the National Committee on Soil and Terrain in April 2011 (Appendix B).
5 Reporting products

MODIS-derived vegetation fractional cover metrics

ABARES has prepared a selection of metrics from the MODIS fractional cover archive (Version 2.1) (Randall & Smart 2011). The metrics have been produced for the whole archive and for each year (from 2000 onwards), season and month. Available metrics, as requested by users, include mean, minimum, maximum, and the frequency of processing errors (where fractions are estimated or cannot be determined or data is missing). The MODIS fractional cover metrics are available online at the National Computational Infrastructure website (2012c) and include over 4000 datasets with accompanying metadata and user guide. The metrics summarise the fractional cover product for ease of reporting (Section 6).

Landsat-derived products

ABARES provides Landsat imagery, as close as possible to each site visit date, to Queensland DERM for processing as:

1) angle-adjusted, top-of-atmosphere reflectance
2) foliage projective cover
3) bare ground index
4) fractional cover.

These products provide a finer resolution fractional cover product (30 x 30 metre pixel) for selected scenes near the time of the site visit. This enables assessment of the variability and accuracy of Landsat and MODIS-derived fractional cover products with the site data.

Site data collected in the Ground Cover Monitoring for Australia project is being used by Queensland DERM to produce an annual Landsat-derived vegetation fractional cover product for Australia. This will also be a TERN AusCover product.

Upscaling

A preliminary investigation was undertaken using training sites in South Australia and Western Australia to consider methods for upscaling from site data to Landsat imagery and then using the Landsat data to inform a MODIS-derived fractional cover product. Investigating methods of upscaling fractional cover measurements from field site data through Landsat imagery to MODIS was a recommendation at the national ground cover workshop in November 2009 (Stewart et al. 2011). A report will be produced in 2012 evaluating possible approaches of upscaling from site data to MODIS-derived fractional cover data.
6 Monitoring fractional ground cover

Maintenance of adequate ground cover (at least 30 per cent) provides soil protection against erosion (Leys et al. 2009). Monitoring ground cover will help provide more reliable estimates of erosion rates.

Remote sensing provides estimates of the total vegetation fractional cover—photosynthetic vegetation, non-photosynthetic vegetation and bare soil. For ground cover monitoring, areas with less than 12 per cent foliage projective cover (or 20 per cent tree canopy cover) are considered suitable for collection of field data for validation of the remote sensing product. Ground cover vegetation and bare soil are masked in satellite imagery in areas with high foliage projective cover. Ground cover is calculated by adding the photosynthetic fraction value to the non-photosynthetic fraction value (PV + NPV).

The metrics of the MODIS-derived vegetation fractional cover can demonstrate ground cover levels over time and the impact that management practices may have. Maximum ground cover levels changed seasonally in 2010. Larger areas of bare soil are visible in central Australia in summer and Western Australia in spring, while maximum ground cover is higher in these areas in winter (Map 4). ABARES are producing a report which describes in more detail how metrics from the MODIS-derived vegetation fractional cover data archive (Version 2.1) can be interpreted in the rangelands and in areas of broadacre cropping.
Map 4 Seasonal ground cover levels for 2010

Note: Summer: December 2009–February 2010; Autumn: March–May 2010; Winter: June–August 2010; Spring: September–November 2010.

Data source: MODIS fractional cover seasonal metrics for 2010 (NCI 2012c)
7 Activities for 2011–12

For the Ground Cover Monitoring for Australia project 2011–12 will be a year of consolidation. Tasks carried forward from 2010–11 are:

- developing a sampling strategy to assist in the selection of ground cover reference sites (Malthus et al. in prep.)
- reporting on validation of the MODIS-based vegetation fractional cover product (Version 2.1) (Guerschman et al. 2012)
- preparing an investment plan for ground cover reference sites
- reporting on upscaling field to MODIS ground cover estimates
- reporting on ways in which monitoring ground cover can show trends for Australian agriculture, using Version 2.1 of the MODIS-derived vegetation fractional cover data archive and associated metrics.

Other tasks for 2011–12 are:

- overseeing the ongoing national field campaign for collection of fractional ground cover (187 sites to be funded; Table 1)
- maintaining and updating the database of ground cover reference sites as site data provided to ABARES
- updating the archive of Version 2.2 of the MODIS-derived vegetation fractional cover product
- producing associated metrics for Version 2.2 of the MODIS-derived vegetation fractional cover product for the data archive to February 2012
- reporting on temporal change in ground cover levels (2000–February 2012) focusing on the current year
- preparing an annual report on progress to June 2012.
Appendix A: Sampling protocol for 2010–11

Background

A national field data collection campaign commenced in 2010–11 to validate the MODIS-derived vegetation fractional cover product developed by Guerschman and colleagues (2009). To prioritise where to locate sites for this campaign a sampling protocol was developed based on expert advice from a sampling strategy workshop held on 17 and 18 August 2010.

Site selection for measurement of fractional ground cover for site data collected in 2010 and 2011 was stratified based on:

- soil colour—to interpret reflectance of bare soil
- agricultural land uses—focused on rangelands and extensive grazing systems (excluding conservation or indigenous protected areas)
- non-treed areas and open woodlands—where tree canopy cover was less than 20 per cent.

Partner agencies were trained in site description and measurement of fractional cover based on Queensland DERM’s Statewide Landcover and Trees Study methodology. This document provides protocols which were used for site selection only. Refer to the field manual (Muir et al. 2011) for further details on establishing, describing and measuring a site.

Fractional ground cover has been considered as three components:

- photosynthetic vegetation (PV)—green attached leaf
- non-photosynthetic vegetation (NPV)—dry attached leaf and litter
- bare soil (BS)—crust, disturbed, rock and cryptogam.

Steps

The sampling process consisted of five steps that can be briefly summarised as:

- Step 1: Partner agencies selected sites according to cover and soil colour
- Step 2: Partner agencies calculated the proportion of field sites for each soil colour
- Step 3: Partner agencies selected an image tile using sampling.mxd
- Step 4: Partner agencies selected a cloud-free image from the GloVis website
- Step 5: Partner agencies collected site data based on field manual.


Step 1

Partner agencies selected sites that represented the:

- soil colours of interest (Table A1, Table A2 and Map A1)
- range of fractional cover, given seasonal conditions:
  - low brown (NPV) or green (PV) cover
  - high green cover
  - high brown cover.

Partners were advised to ensure that site observations span the complete range of fractional cover by sampling at a particular time of year or over several years. For example, sampling following heavy rains would be likely to observe high green cover. The partners could then target high brown cover for sampling in the following season.

Table A1 Soil colour, by per cent under agricultural land uses, for each jurisdiction

<table>
<thead>
<tr>
<th>State</th>
<th>Broadacre agriculture (%)</th>
<th>Pastoral rangelands (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red</td>
<td>Black</td>
</tr>
<tr>
<td>NSW</td>
<td>51</td>
<td>3</td>
</tr>
<tr>
<td>Vic.</td>
<td>10</td>
<td>41</td>
</tr>
<tr>
<td>Qld</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>SA</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>WA</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Tas.</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>NT</td>
<td>0</td>
<td>13</td>
</tr>
</tbody>
</table>

Source: ABARES

Table A2 Soil colour, by area under agricultural land uses, for each jurisdiction

<table>
<thead>
<tr>
<th>State</th>
<th>Broadacre agriculture ('000 ha)</th>
<th>Pastoral rangelands ('000 ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Red</td>
<td>Black</td>
</tr>
<tr>
<td>NSW</td>
<td>4383</td>
<td>219</td>
</tr>
<tr>
<td>Vic.</td>
<td>543</td>
<td>2299</td>
</tr>
<tr>
<td>Qld</td>
<td>264</td>
<td>192</td>
</tr>
<tr>
<td>SA</td>
<td>534</td>
<td>246</td>
</tr>
<tr>
<td>WA</td>
<td>1674</td>
<td>12</td>
</tr>
<tr>
<td>Tas.</td>
<td>50</td>
<td>32</td>
</tr>
<tr>
<td>NT</td>
<td>–</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>7447</td>
<td>3003</td>
</tr>
</tbody>
</table>

Source: ABARES
Step 2
Partner agencies calculated the proportion of field sites for each soil colour based on the amount of each soil colour estimated to be under broadacre agriculture and pastoral rangelands. Partner agencies multiplied the total number of sites to be collected by the soil colour percentages in Table A1.

Step 3
Partner agencies selected an image tile using the spatial data layers provided by ABARES in an ArcMap GIS project file called sampling.mxd.

- Soil colour based on the *Digital Atlas of Australian Soils* (ABARES 1991), interpreted into colours using Northcote (1979) and then refined by expert opinion. Gibber targets derived using land systems data for South Australia, IBRA sub-regions (DSEWPC 2008) and expert opinion.
  - red (Code 3)
  - black (Code 5)
  - bright (Code 2)
  - gibber (Code 1)
  - other (Code 0) was not identified as a priority.
• Land use/cover

a. Tree cover mask included:
   - no tree cover (Code 0)
   - forest/plantation (Code 1) based on *Forests of Australia 2008* (ABARES 2008).

b. Agricultural mask derived from *Catchment scale land use of Australia—Update March 2010* (ABARES 2010). Classified into:
   - grazing of native pastures, modified pastures and cropping (Code 0)
   - non-agricultural (Code 1).

c. Rangeland boundary (Bastin et al. 2008) included:
   - rangelands (Code 0)
   - non-rangelands (Code 2) from rangeland boundary.

• Site accessibility included:
   - distance from field team—states created using location and straight-line distance
   - distance from all roads—included in ArcMap project
   - existing sites—included in ArcMap project
   - tenure—included in ArcMap project
   - Landsat tiles—included in ArcMap project.

• Other data—to ensure that the imagery represents the field conditions:
   - image was to be within one month of field data collection
   - sites where there has been rainfall subsequent to the image were avoided
   - sites where there have been recent fires were avoided
   - collection was to be coordinated with roadside erosion surveys, if applicable.

**Step 4**

Partner agencies selected a cloud-free image from the *United States Geological Survey Global Visualization Viewer* (USGS 2012). Landsat 5 TM imagery was preferred. Where Landsat 7 ETM+ imagery was collected, only the centre portion of the image could be used. Partners used the imagery to select at least five sites based on the following criteria:

• Sites were to be away from soil colour edges and at least 500 metres from a change in cover. This is to ensure sites are homogenous at the MODIS fractional cover scale.

• Existing sites were used, where feasible, to decrease time and cost.

• Sites were to be accessible by road—as included in ArcMap project.

• Property and landholder information was to be identified using existing state datasets.
Step 5
Partner agencies collected site data based on field manual (Muir et al. 2011) to include:

- location—latitude and longitude
- date of field collection
- field attributes
- fractional cover data.

Field campaign checklist
Partner agencies were responsible for:

- identifying Landsat scene (path/row) for field data collection
- identifying property and landholder, contacting landholder and obtaining permission in principle to sample their property; if cropping site, checking growth phase or timing of land management practice
- checking cloud-free Landsat imagery available
- sending details of Landsat scene (sensor L5 path/row) and date (dd/mm/yyyy) to ABARES
- keeping a watching brief for subsequent fires and/or rainfall; and changing sites or cancelling field work if these occurred between image collection and the scheduled field visit
- organising staff availability, vehicles and equipment, accommodation and other needs
- confirming field dates with landholders
- collecting field data, photographs, filling in field data forms
- sending data to ABARES.
Appendix B: Initial validation of MODIS-based vegetation fractional cover product

Briefing notes—March 2011

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\(^3\) Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)

Background

The MODIS-based vegetation fractional cover product developed by Guerschman and colleagues (2009) was selected for national monitoring of ground cover (Stewart et al. 2011). The current ABARES/TERN-sponsored project Ground Cover Monitoring for Australia aims to:

1) produce the existing MODIS fractional cover product for Australia
2) perform field measurements to validate and recalibrate the existing algorithm
3) make improvements to the algorithm to improve its accuracy.

Validation

Why validate?

A limited validation of the current version of the MODIS fractional cover method was performed on 10 sites across Australia. The method worked well at some sites but had a significant bias at others. Additional qualitative evidence showed that it fails in a number of areas around the country, including areas with black and bright soils (Gary Bastin 2010, pers. comm.) and areas with persistent green vegetation (Lucy Randall 2011, unpublished). In some areas seasonal behaviour in estimated ground cover appears to be realistic with perhaps some over/underestimation at the extremes of ground cover (Tim Danaher 2010, pers. comm.). A more extensive, quantitative validation is needed to provide uncertainty bounds around model estimates (error bars) and will also provide insights into the best ways to improve the algorithm.

Possible influences on variations in the algorithm include:

- background soil colour
- soil moisture content
- variations in vegetation colour/greenness, such as those caused by changes in phenology or differences in species
• amount of vegetation, in particular the model does not appear accurate where there is low vegetation cover and therefore sources of erosion may be highest

• variations in solar zenith angle.

Data used

Field observations of vegetation fractional cover for 359 sites distributed in Queensland, New South Wales and South Australia were used from several sources (Map B1 and Table B1).

Map B1 Distribution of field data used in present analysis

Source: Figure 6 in Guerschman and colleagues (2012)

Table B1 Summary of field data used in analysis

<table>
<thead>
<tr>
<th>Source</th>
<th>State</th>
<th>Date of first observation</th>
<th>Date of last observation</th>
<th>No. of sites</th>
<th>No. of sites with repeat observations</th>
<th>Total no. of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>DERM</td>
<td>Qld</td>
<td>July 2002</td>
<td>October 2010</td>
<td>299</td>
<td>64</td>
<td>515</td>
</tr>
<tr>
<td>LMD CMA</td>
<td>NSW</td>
<td>April 2009</td>
<td>May 2009</td>
<td>32</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>DENR</td>
<td>SA</td>
<td>July 2010</td>
<td>July 2010</td>
<td>14</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>CSIRO Land and Water</td>
<td>NSW</td>
<td>February 2010</td>
<td>October 2010</td>
<td>14</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>359</strong></td>
<td><strong>64</strong></td>
<td><strong>567</strong></td>
</tr>
</tbody>
</table>

DERM = Department of Environment and Resource Management, Queensland; LMD CMA = Lower Murray–Darling
Note: Catchment Management Authority, New South Wales. DENR = Department of Environment and Natural Resources, South Australia.
Source: Table 1 in Guerschman and colleagues (2012)

All measurements were taken following the Statewide Landcover and Trees Study (Queensland) method as described by Muir and colleagues (2011). Sixty-four of these sites had measurements taken on more than one occasion (with a maximum of 19 visits) to make a total of 567 site
observations. This list is continuously growing as more field data is collected as part of the Ground Cover Monitoring for Australia project. In addition to the field measurements of ground cover, spectral measurements with an Analytical Spectral Devices handheld spectroradiometer were taken in 14 sites in the Murrumbidgee catchment in New South Wales by the CSIRO Earth Observation group.

**Site heterogeneity**

The Statewide Landcover and Trees Study method was originally designed to comprehensively sample across 3 x 3 Landsat TM pixels (30 x 30 metres each). To assess the effects of using this field sampling method for validating the lower resolution MODIS-based method (with a pixel of 500 x 500 metres) the heterogeneity in the vicinity of the site was analysed using Google Earth imagery and Landsat data (Figure B1).

**Figure B1 Assessing site heterogeneity using Google Earth**

Note: Google earth images show field site locations (yellow pins) surrounded by red circles enclosing ~25 and ~225 hectares, (approximately 1 x 1 and 3 x 3 MODIS pixels). The image on the right shows two sites where large areas of water in the 3 x 3 MODIS pixels mean that the surface surrounding the site is heterogeneous and the 100 x 100 metre field transects are unlikely to represent the fractional cover of the 3 x 3 MODIS pixels. The image on the left contains large areas of bright soil; however, as the regions of bright soil are more evenly distributed throughout the 3 x 3 MODIS pixels the satellite imagery more accurately represents ground cover over the broad area.

Source: Guerschman and colleagues (2012)

**Results**

Preliminary results from the validation show that the overall root mean square error of the green vegetation, dry vegetation and bare soil fractions are 19, 25 and 27 per cent respectively when all sites and dates are considered simultaneously. The model appears to underestimate the fraction of dry vegetation and overestimate the fraction of bare soil.

Contrary to the initial hypothesis, the level of heterogeneity of the site did not have an important effect on model performance. A number of explanations for this are under investigation, including:

- the Landsat imagery from 2004 did not account for the actual heterogeneity when the field measurement and the MODIS observation took place
• model uncertainty or error is of similar or higher magnitude than the one introduced by the heterogeneity
• metrics used for characterising heterogeneity were not appropriate.

Soil colour also did not show any clear relationship with the ability of the model to estimate fractional cover. It is important to note that the soil colour derived from the Digital Atlas of Australian Soils (Map A1) did not agree on a number of occasions with the soil colour reported in the field sheet.

The observations taken with a handheld spectroradiometer at 14 sites in the Murrumbidgee catchment show a good level of agreement between site reflectance (~1 hectare) and the reflectance observed by MODIS (~25 hectares). These sites were selected for having low heterogeneity at the MODIS scale as estimated using Google Earth imagery. In these sites there was also a good level of agreement between the observed fractional cover and the fractional cover estimated with the model using:

1) the full range spectra (using the Normalised Difference Vegetation Index (NDVI) and the Cellulose Absorption Index)
2) ‘synthetic’ MODIS spectra (full range spectra aggregated to the MODIS bands)
3) actual MODIS data.

MODIS fractional cover model improvement

Recalibration

The data used for validating the current version of the fractional cover algorithm was also used for recalibrating the existing model. The vertices of the triangle in the NDVI-ratio 7/6 space were relocated in order to minimise the differences between the observed and the predicted values. An initial exploration showed that the root mean square errors of the green vegetation, dry vegetation and bare soil fractions could be reduced to 15, 21 and 18 per cent respectively (from an initial 19, 25 and 27 per cent). Improvements to model performance are ongoing. However, it is likely that the current model configuration is not able to improve performance any more than has been achieved with these initial explorations.

Options for future improvement

There are a number of options that can be explored to improve model performance. These are listed below by increasing level of sophistication:

1) Adaptive endmember adjustment: Same as the recalibration but the position of the endmembers vary in space, depending on soil type/bioregion or other factors identified as contributors.
2) Inclusion of more bands or indices: It is likely that the two indices currently used are not capturing the full extent of the spectral variability of the three fractions and their mixtures. The addition of more MODIS bands or indices will probably improve model performance to a larger degree than what may be achieved using Option 1.
3) Non-linear mixing: The current approach assumes that spectral mixing is of a linear nature. This assumption can be challenged and it is possible that a better fit could be obtained.
4) Endmember bundles: Current methodology assumes that each endmember (a pure pixel with 100 per cent green vegetation or 100 per cent dry vegetation or 100 per cent bare soil) will always have the same location in the triangle (in a vertex). A consequence of that assumption is that any given mixture of photosynthetic vegetation, non-photosynthetic vegetation and bare soil will always be located in the same position. An alternative approach is to consider the endmembers as a bundle that occupies a region in spectral space.
References


