Development of a satellite image-based land condition monitoring system for South Australian agricultural regions

University of Adelaide
Land condition monitoring reports: Report 3

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Executive summary

The effective management of crops, pastures and crop residues as soil cover is essential to the continuing profitability of agriculture in South Australia. Maintaining adequate levels of soil cover minimises water and wind erosion, and has the potential to increase soil organic carbon levels and soil fertility. The Department of Water, Land and Biodiversity Conservation monitors the adequacy of soil protection throughout South Australian agricultural districts through the Land Condition Monitoring Project (LCMP), initiated in 1998. The LCMP uses a windscreen survey (WSS) technique four times a year to monitor change in soil cover and has built up almost a decade of records of regional land cover.

Remote sensing technology has the potential to augment and enhance this field assessment by providing comprehensive, repeated and objective assessment of soil exposure and land cover, and hence the risk of erosion. This project built on previous research conducted by The University of Adelaide in collaboration with the Department of Water, Land and Biodiversity Conservation and former South Australian Soil Conservation Council. The specific goals of this project were to

1. Review methodologies for image based land condition assessment.
2. Further develop and test the University of Adelaide Vegetation Index (UAVI), the most promising index identified in previous studies, for quantifying and mapping land cover and soil exposure in the South Australian dryland cropping districts. Additionally NDVI was analysed for comparison, as an established, widely used and well understood vegetation index.
3. Calibrate and validate these indices for the South Australian dryland cropping districts by establishing relationships between image-derived variables and the location-specific field assessments of cover rating and erosion hazard index that have been collected by the LCMP since March 2006.
4. Recommend the most appropriate image indices and use these to establish baseline and time sequences of cover and erosion risk for the SA dry cropping districts.
5. Derive estimates of the area and proportion of land at risk of erosion in South Australian dry cropping districts from annual sequences of imagery and compare with current trend measures.

Outputs of this project of potential use and benefit for image-based land condition assessment include:

1. Identification of a suitable MODIS image product and source as a basis for intra- and inter-annual cover monitoring. The MODIS NBAR Adjusted Reflectance product is a 16 day composite which removes the influence of look and illumination angle on apparent reflectance, calibrated to reflectance by removal of atmospheric interference, cloud free, available from February 2001 to present, and is spatially extensive, covering the whole of South Australia daily, and is supplied free of charge.
2. Production of 23 UAVI and NDVI image indices, one for each 16 day composite MODIS NBAR images for 2006. These image indices, especially at critical periods of the year, may assist in monitoring cover and in identifying areas at risk of erosion.
3. Addition of two new regions, the Mt. Lofty Ranges and Kangaroo Island, and two new zones to the reporting areas.
4. Production of several image index products which may assist analysis of regional and local cover levels, and improve reporting. These image products include annual mean indices, annual variation in indices and cumulative deviation from regional mean.

5. Production of seasonal profiles for UAVI and NDVI for all land condition reporting regions. These show changes in cover as measured by the indices throughout the year, highlighting similarities and differences which could be indicative of differences in climate, land use, land management practices. The profiles derived from the image indices have a higher temporal frequency than the profiles derived from the windscreen survey data. The image index temporal profiles have 23 sample points, while the windscreen survey profiles have four sample points.

In analysing the site-specific Windscreen Survey (WSS) data this research has once again demonstrated a sound link between the WSS Cover Rating and the image indices. The analyses presented also demonstrate that overall the UAVI is a better measure of Cover Rating than NDVI, confirming the findings of our previous studies. Furthermore, we have demonstrated this link with greater statistical validity than previous studies, adding further weight to the potential of UAVI for operational soil exposure monitoring.

While the link between image indices and cover rating was statistically sound on the majority of dates and for the majority of regions, it was never strong: ranging from weak (r_s = -0.122) to moderate (r_s = -0.425). When all regions are combined the relationships were strongest in June, slightly weaker in May, slightly weaker in October and weakest in March. Relationships for the South East were weak at all times of the year and never statistically significant.

The nature and strength of the relationship between the image indices and Cover Rating may be limited by the inherently different approaches to assessing land cover involved in these two methods. Furthermore, the determination of an image index critical threshold, below which land would be considered at risk of erosion, was not possible due to the nature of the Cover Rating score, ordered classes, and the limited correlation between Cover Rating and image indices. It is difficult to further interpret the relationship between the image indices and Cover Rating without some independent measure of fractional cover for validation.

The image products produced for this report illustrate some of the potential methods of image-based soil exposure reporting. The predominant pattern in all maps was climatic, with the majority of pattern of soil exposure strongly related long-term average rainfall throughout all dry cropping regions of South Australia. However, the image indices clearly reveal moderate and fine scale geographic variation not related to broad climatic trends. This specific detail could potentially be used to target areas where changes in land management are required to reduce erosion risk.

Further studies are proposed to progress development of a satellite image-based soil cover monitoring program. These include cross validation of Cover Ratings, image indices and independent assessments of fractional cover; extension of the MODIS image analysis to the period 2001 to present, and approaches to improve separation of climatic and management influences on changing cover levels.

Acknowledgements

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Report chronology

This report is the third in a series by the University of Adelaide examining the potential of remote sensing for land condition monitoring (through measurement of soil cover). The two reports have previously been cited as follow.

Original citations:

> Grech, A., Ostendorf, B. and Lewis, M. (2003) Land condition monitoring: integrating ground surveys, Aussie GRASS and satellite remote sensing. Adelaide, the University of Adelaide.
>
> Clarke, K., Lewis, M. and Ostendorf, B. (2004) Assessing the potential of MODIS imagery for monitoring land condition in the crop lands and non pastoral lease rangelands of South Australia. Adelaide, the University of Adelaide.

In future we will cite these reports with the addition of the report number before the title and with a series name after the title. We request that others follow this convention. Additionally, Report 2 was revised and updated in 2009 to include results of some additional analyses performed in 2006/07 and this change is also reflected in the revised citation. The revised citation for reports 1 and 2 follow, changes are highlighted in bold.

Revised citations:

> Grech, A., Ostendorf, B. and Lewis, M. (2003) Report 1: Land condition monitoring: integrating ground surveys, Aussie GRASS and satellite remote sensing. Land condition monitoring reports. Adelaide, The University of Adelaide.
>
> Clarke, K., Lewis, M. and Ostendorf, B. (2004**,** rev. 2009) Report 2: Assessing the potential of MODIS imagery for monitoring land condition in the crop lands and non pastoral lease rangelands of South Australia. Land condition monitoring reports. Adelaide, The University of Adelaide.

This third report should be cited as follows:

> Clarke, K. and Lewis, M. (2009) Report 3: Development of a satellite image-based land condition monitoring system for South Australian agricultural regions. Land condition monitoring reports. Adelaide, The University of Adelaide.

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1 Introduction

1.1 Background

The effective management of crops, pastures and crop residues as soil cover is essential to the continuing profitability of agriculture in South Australia. Maintaining adequate levels of soil cover minimises water and wind erosion, and has the potential to increase soil organic carbon levels and soil fertility. The monitoring of adequacy of soil protection falls to the Department of Water, Land and Biodiversity Conservation (DWLBC), and to this end the Land Condition Monitoring Project (LCMP) was initiated in 1998.

The primary aim of the LCMP is to assess changes in soil erosion risk, including soil cover, through the year and determine whether soil erosion risk is being adequately minimised. The LCMP uses a windscreen survey (WSS) technique four times a year to monitor change in soil cover (McCord 2003) from year to year.

However, the WSS is not spatially extensive: only areas along transects are assessed, and the results are extrapolated to reporting regions. Neither is the WSS timely: it is run four times a year and takes a number of employees several days to conduct. Furthermore, oblique visual estimates of soil cover, the basis of the WSS, have been demonstrated to be prone to operator bias (Corak *et al.* 1993; Morrison *et al.* 1993). There is a need for a more objective, spatially extensive method for monitoring soil cover across the dry cropping districts of South Australia.

Remote sensing technology has the potential to augment and enhance this field assessment by providing comprehensive, repeated and objective assessment of soil exposure and land cover, and hence the risk of erosion. Research over the past two decades with first-generation satellite imagery has shown that image-derived vegetation indices, particularly NDVI can be correlated with vegetation productivity or condition to provide an empirical basis for mapping conditions over wide areas. In Australia NDVI has been related to rangeland vegetation cover (Bastin *et al.* 1995), while temporal sequences of NDVI data have been used to classify agricultural land uses (Walker and Mallawaarachchi 1998), regional pasture types (Hill *et al.* 1999) and to predict regional pasture growth rates (Hill *et al.* 2004). The few attempts to predict soil properties or exposure from AVHRR data have relied on red/near infrared data transformations (Odeh and McBratney 2000) or on NDVI/thermal emissivity behaviour (French *et al.* 2000).

In a project designed to address this gap in the research The University of Adelaide demonstrated that remotely sensed indices created from satellite imagery have the potential to accurately measure soil cover across the whole of the dry cropping districts of South Australia. Research by Grech *et al.* (2003) demonstrated that 62 % of the variation in field cover rating (as measured by the WSS) could be explained by an index of vegetation greenness (NDVI) generated from NOAA AVHRR imagery. Grech *et al.* (2003) speculated that the remaining variation in cover rating was related to dead plant material not detected by NDVI, or to soil variation and land management.

However, while NOAA AVHRR imagery has been used widely and successfully for regional and continental assessments of vegetation cover using NDVI, it lacks the spectral resolution for discrimination of soils from non-photosynthetic vegetation. The newer MODIS imagery captures the spectral responses of a wider range of cover types in addition to photosynthetic vegetation, and at higher spatial resolution. Research to date has focussed more heavily on the enhanced capability of this sensor to map photosynthetic vegetation, and less on its potential for soil and non-photosynthetic vegetation assessment.

Most research on discrimination of photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV) and soil using satellite imagery has largely omitted broad-scale, high-temporal-frequency satellite imagery like MODIS and AVHRR. However, this research has demonstrated considerable potential for distinguishing these important cover types. A variety of indices have been used successfully with a range of image types from field spectrometers, airborne hyperspectral to high to moderate resolution satellite hyperspectral and multispectral imagery (Asner and Heidebrecht 2002; Sullivan *et al.* 2004; Arsenault and Bonn 2005; Daughtry *et al.* 2005; Daughtry *et al.* 2006; de Asis and Omasa 2007; de Asis *et al.* 2008; Gowda *et al.* 2008). In summary, these studies identify the utility of the short wave infrared region of the spectrum for discrimination of PV, NPV and soil, and one index in particular stands out: the cellulose absorption index (CAI) (Nagler *et al.* 2003).

Recently, Clarke *et al.* (2004, rev. 2009) took advantage of the higher spectral resolution of MODIS (as compared to AVHRR) to develop a new index, the University of Adelaide Vegetation Index (UAVI). The UAVI is based on the CAI, but is not identical due to the lack of MODIS bands at 2.0 and 2.2 µm, and was theoretically better at measuring soil cover, both dead and living plant material, than the NDVI. In addition to the UAVI several other indices were evaluated: the NDVI as a standard measure; the Perpendicular Distance Vegetation Index (PD54); and thermal emissivity. Clarke *et al.* (2004, rev. 2009) found that UAVI performed the best overall, and was more closely related to field cover rating than NDVI, and that both UAVI and NDVI were capable of mapping soil cover in the dryer as well as the wetter seasons. Finally, the study recommended the recording of coordinates at WSS sites would allow better comparison of remotely sensed indices to field cover rating measurements.

In 2006 the LCMP methodology was updated, and coordinates collected for each of the WSS sites. In light of this improvement in the field data, and the ongoing need to improve soil cover monitoring, this project was initiated.

1.2 Aims

The specific goals of this project were to

6. Review methodologies for image based land condition assessment.
7. Further develop and test the UAVI for quantifying and mapping land cover and soil exposure in the South Australian dryland cropping districts. This was the most promising index identified by Clarke *et al.* (2004, rev. 2009). Additionally the NDVI should be analysed for comparison, as an established, widely used and well understood vegetation index. The UAVI index referred to in this report is the UAVI 01 from Clarke *et al.* (2004, rev. 2009).
8. Calibrate and validate these indices for the South Australian dryland cropping districts by establishing relationships between image-derived variables and the location-specific field assessments of cover rating and erosion hazard index that have been collected by the LCMP since March 2006.
9. Recommend the most appropriate image indices and use these to establish baseline and time sequences of cover and erosion risk for the SA dry cropping districts.
10. Derive estimates of the area and proportion of land at risk of erosion in South Australian dry cropping districts from annual sequences of imagery and compare with current trend measures.

2 Methods

2.1 Windscreen Survey (WSS)

The LCMP wind screen survey methodology has been described in detail by McCord *et al.* (2000). In summary, the cropping districts across four NRM Regions were divided into 45 zones of similar climatic, soil and land-use characteristics. These zones were then grouped into regions for reporting purposes. More detail on the original and updated reporting regions can be found in section 2.2.2 of this report. Road transects were then created to cover as much variability within zones as possible, except where precluded by a lack of roads or by native vegetation obscuring views of agricultural land. A map of WSS transects is shown in Figure 1.

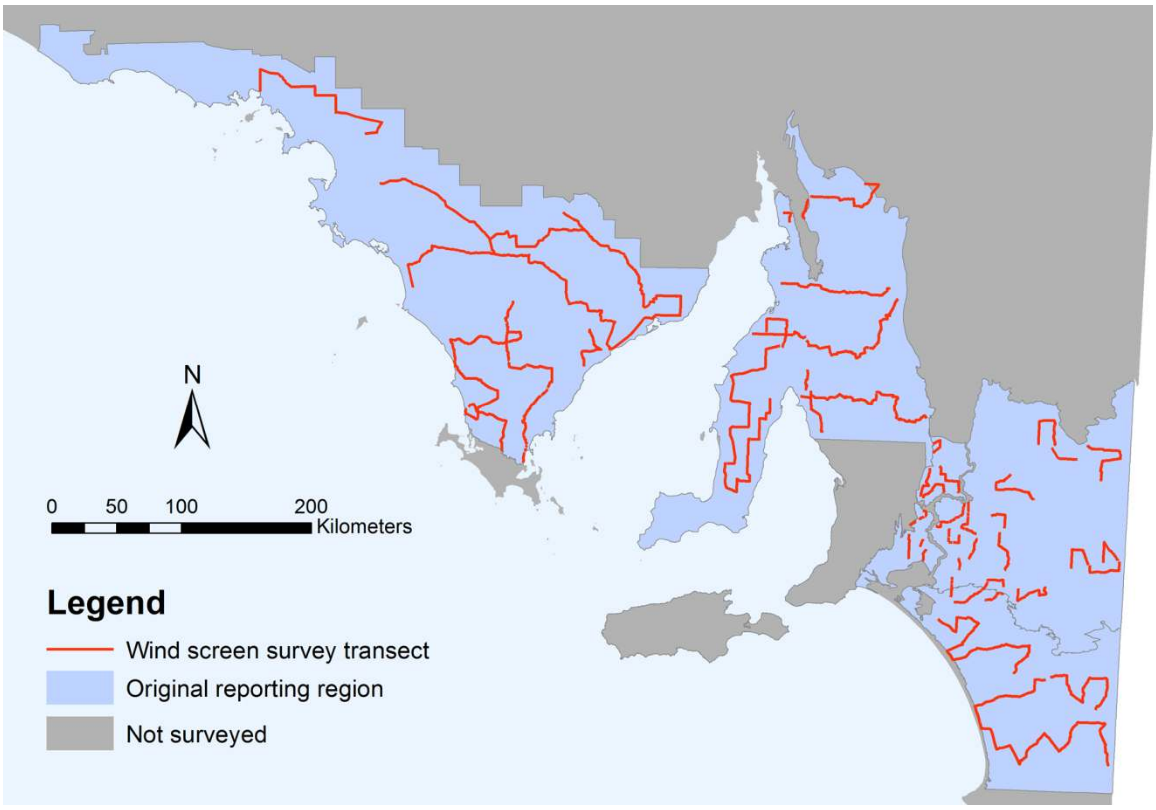

Figure 1. Windscreen survey transects.

The Windscreen Survey is run four times a year (October, March, May and June), with each survey date timed to coincide with critical phases in the annual cropping cycle. The same team drives the same transect each year, except where sickness or employee-turnover requires a change of surveyors. Sites are intended to be representative of the region, and hence anomalies are avoided.

Windscreen Survey sites are visually assessed obliquely from the car, and cover an imaginary 200 x 200 m square beginning 10 metres from the road and 50 metres from any fences perpendicular to the road. The wind screen survey records the following information for each site:

- Dune Presence (presence/absence)
- Cropping Phase (7 categories)

- Topographic Rating (a measure of potential for wind and water erosion: 5 categories)
- Erosion Rating (a measure of actual wind and water erosion: 5 categories)
- Detachment Rating (3 categories)
- Cover Rating (surface cover rating – combined dry and green material protecting the soil surface: 8 categories)
- Burn (whether the site has been burnt recently: 4 categories)

It is the Cover Rating data that is used for comparison with image indices in this study. Assessments are made with the aid of visual and descriptive standards, and rank the amount of cover in broad categories from 1 (complete cover) to 8 (no cover) (Appendix 1). Descriptors are based on the height of plant or residue cover, nature of land management and judgements about soil stability, although the photo-standards clarify the ratings in terms of perceived over.

In March 2006 survey site coordinates were recorded with global position system receivers (GPSR), and after this time the same locations were assessed each survey date. Prior to March 2006 no site location information was recorded, and different random sites were assessed on each survey date.

2.2 Pre-processing point and polygon data

2.2.1 Projection of points perpendicular to direction of travel

Geographic coordinates are now recorded at each windscreen survey (WSS) sample location for two reasons. Firstly, to ensure the same locations are assessed on each WSS date, and secondly to facilitate comparison of field cover rating to image index values. However, the coordinates recorded correspond to the location of the observer rather than the area assessed. To estimate the actual field area assessed by the observer it was first necessary to understand the observation procedure and the data recording format.

The WSS sampling methodology is illustrated in Figure 2. At each location the WSS observer assesses an area either to the left or the right of the vehicle, never both directions, and records a cover rating, and whether they were assessing the field to the left or right of the vehicle. The assessed area is 200 by 200 metres within the field, excluding a 10 metre margin along the roadside fence. Additionally, we estimated the road-reserve to be 8 metres wide, and assumed the observation vehicle was in the centre of the road. These assumptions will rarely be correct, but represent a reasonable average of likely road-reserve width and car position scenarios. From these variables it was determined that each point should be projected either left or right 114 metres perpendicular to the direction of travel, as appropriate for that point.

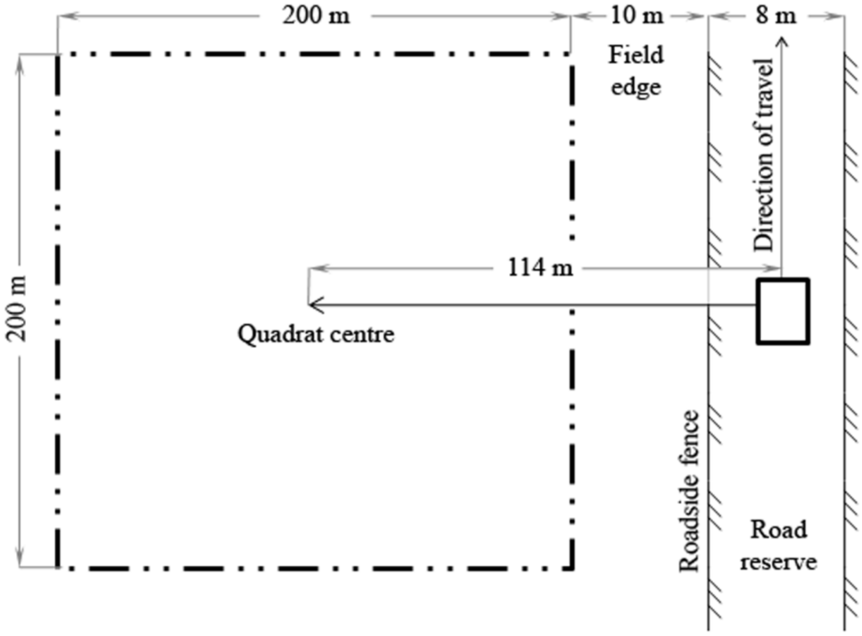

Figure 2. Windscreen survey sampling methodology.

Direction of travel was determined by calculating the direction to the next sample within 3 km. If the next sample point was greater than 3 km distant then direction of travel was assumed to be identical to the previous point. This step ensured that large gaps between samples, which might involve a change in transect direction, had a minimal impact on accurate estimation of travel direction. Finally, various quality assurance steps were taken to ensure all points were projected the appropriate direction, or to eliminate points for which it was difficult to determine the direction of travel accurately.

2.2.2 Reporting regions

The LCM has reported at several different scales, from very broad (the whole of the dryland cropping districts) to more moderate (regions) and finer scales (zones). Due to a lack of suitable road access two zones have been excluded from assessment. Additionally, due to a combination of obscuring roadside vegetation and land-use dominated by pasture which is unlikely to create erosive conditions, Kangaroo Island and the Mount Lofty Ranges have been excluded from assessment.

However, the remotely sensed imagery is not limited by accessibility, and roadside vegetation can be excluded from image reporting with simple masking techniques. We added Kangaroo Island and the Mount Lofty Ranges to the list of reporting regions, added two previously excluded abutting zones (29 and 30) to the Murraylands reporting region, and added the tip of Yorke Peninsula to the Northern and Yorke reorting region as zone 46. The original, new and revised reporting regions are presented in Figure 3, and brief descriptions of the regions follow.

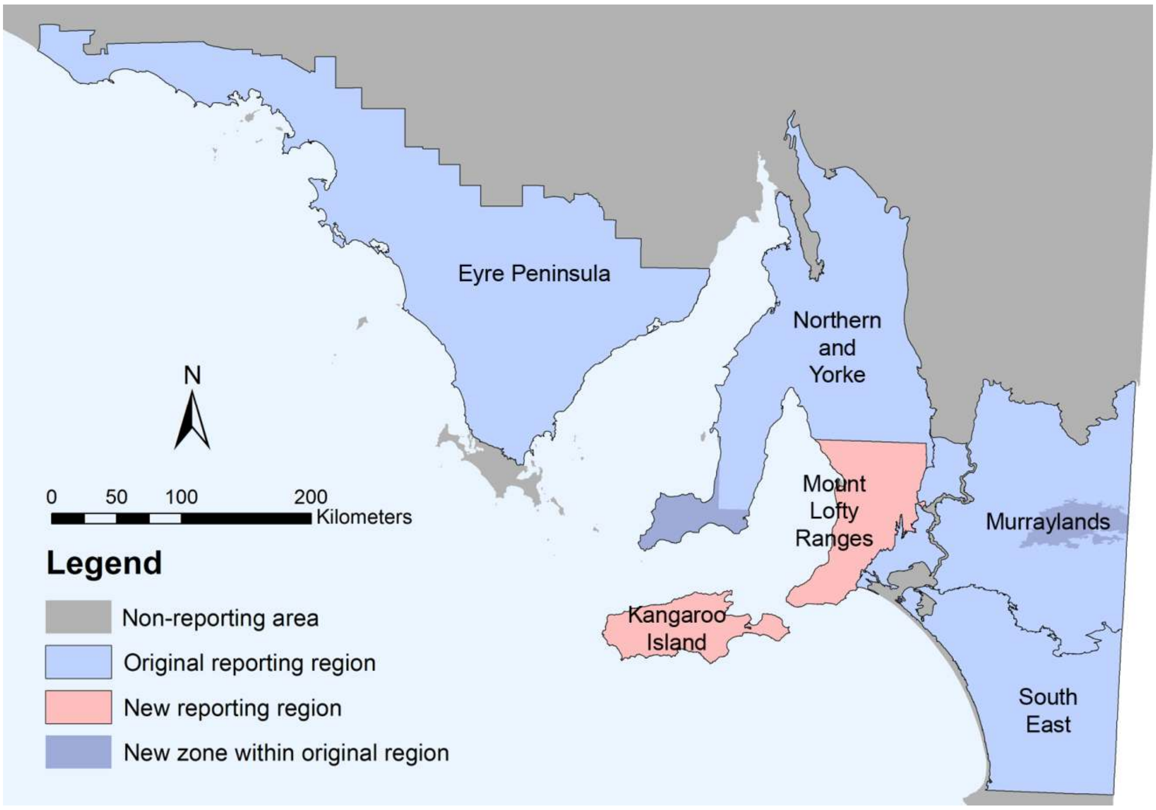

Figure 3. Original, new and revised reporting regions.

The Eyre Peninsula region has extensive sandy soils that are cropped, and which are susceptible to wind erosion, particularly in lower rainfall areas (290 – 400 mm). Significant areas of shallow soils on sheet limestone are mainly used for grazing. The lower Eyre Peninsula area has relatively more reliable and higher annual rainfall, and is more intensively cropped.

The Northern and Yorke region is extensively cropped, with some perennial horticulture in the Clare and Barossa areas. Much of the cropping occurs on sloping, hilly land along the northern Mt Lofty Ranges that is susceptible to water erosion. Conversely, on the coastal plains and Yorke Peninsula sandy soils predominate and are prone to wind erosion.

The Murraylands region is dominated by sandy soils, including dune/swale systems that are susceptible to wind erosion. The annual rainfall in cropping areas ranges from 275 – 400 mm.

In the South East region, agricultural cropping occurs in areas up to approximately 600 mm annual rainfall. The extensive areas of the South East which receive more than 600 mm annual rainfall are predominantly permanent pasture. Most soils are sandy and often water repellent, although are not particularly prone to wind erosion due to the relatively reliable rainfall.

The Mt Lofty Ranges region mostly comprises higher rainfall (600 – 1100 mm) hilly land and hence the main agricultural use is grazing permanent pastures, though small areas are used for horticulture. The land in this region can be prone to water erosion (including hillside erosion, gullying and landslips) in intense rainfall events but usually has adequate vegetative cover.

Agriculture on Kangaroo Island is predominantly grazed pastures, although some cropping occurs on suitable soil types. Rainfall is reliable and incidence of soil erosion is very low.

2.3 MODIS data product selection and pre-processing

2.3.1 Data product

The MODIS Nadir Bidirectional Reflectance Distribution Function Adjusted Reflectance (NBAR) 16 day composite data product was selected as the most appropriate for this project. This data is currently available from the United States Geological Survey (USGS) Land Processes Distributed Active Archive Center (LP DAAC), and will eventually be available from the Australian Centre for Remote Sensing (ACRES).

The DAAC make a range of MODIS products available on their website, including nadir BRDF-adjusted reflectance 16 day composite (500 m or 1000 m resolution).

Website: https://lpdaac.usgs.gov/lpdaac/products/modis_product_table

The two products are named MCD43A4v5 (500 m), and MCD43B4v5 (1000 m).

The DAAC website describes the MCD v5 products as distinct from the MOD43 product:

> *'The MODerate-resolution Imaging Spectroradiometer (MODIS) Reflectance product MCD43A4 provides 500-meter reflectance data adjusted using a bidirectional reflectance distribution function (BRDF) to model the values as if they were taken from nadir view. These MCD43A4 data are 16-day composites provided as a level-3 gridded product in the Sinusoidal projection.*
>
> *Both Terra and Aqua data are used in the generation of this product, providing the highest probability for quality input data and designating it as an "MCD," meaning "Combined," product.*
>
> *Version-5 MODIS/Terra+Aqua BRDF/Albedo products are Validated Stage 1, meaning that accuracy has been estimated using a small number of independent measurements obtained from selected locations and time periods and ground-truth/field program efforts. Although there may be later improved versions, these data are ready for use in scientific publications.'*

The NBAR correction removes the influence of differing look angles on the reflectance characteristics of land covers. The correction normalises reflectance values across the image to what would be seen if viewed from directly above. Additionally, this product corrects for atmospheric conditions and therefore provides a sound measure of the proportion of light reflected from the land-surface.

2.3.2 MODIS bands

This project focuses on four MODIS bands, numbered 1, 2, 6 and 7 on the sensor. Band 1 measures wavelengths from 620 to 670 nm, which fall within the red portion of the visible spectrum. This portion of the spectrum is useful for measuring the strong absorption of red light by chlorophyll in actively growing plants.

Bands 2, 6 and 7 all cover portions of the electromagnetic spectrum outside of the visible range. Band 2 measures wavelengths from 841 to 876 nm, a region of the spectrum referred to as the near-infrared. The near-infrared is useful for measuring the very strong reflectance of living vegetation. In combination the red and near-infrared are used by the normalised difference vegetation index (NDVI), also known as a "greenness" index, to differentiate growing vegetation from all other land covers.

Bands 6 and 7 fall in the short-wave infrared portion of the spectrum and measure wavelengths 1628 to 1652 nm and 2105 to 2155 nm respectively. Band 6 is sensitive to the turgidity or amount of water in plants (Jensen 1996), while band 7 rests over the cellulose absorption feature.

2.3.3 Imagery dates

23 MODIS MCD43Av5 images were downloaded to provide complete temporal coverage of 2006. The 16 day periods spanned by each image are presented in Table 1.

2.3.4 Reprojection through MODIS Reprojection tool v4 (MRT4)

The imagery comes in Hierarchical Data Format – Earth Observing System (HDF-EOS) data format in a sinusoidal projection. However, the parameters for this projection are not contained in many software packages. The MODIS Reprojection Tool was used to reproject the imagery to the Lambert Conformal Conic projection used for most South Australian spatial datasets. The MODIS Reprojection Tool was developed by the South Dakota School of Mines and Technology under contract from the LP DAAC. Details on exact steps and parameters used in the reprojection can be found in Appendix 2.

2.3.5 Import and re-scaling in ERDAS Imagine 9.2

Before further processing it is necessary to convert the imagery to a more interoperable format. The data comes in a scaled format, meaning that the digital numbers in all bands have been multiplied by 10000. The data was converted to ERDAS Imagine format to increase the ease of further processing, and multiplied by 0.0001 to convert pixel values back to Nadir BRDF reflectance. This process necessitated a conversion from integer to real number format to retain precision.

Table 1. Composite MCD43Av5 image start and end date.

Year covered	Start date	End date
2006	1-Jan	16-Jan
2006	17-Jan	1-Feb
2006	2-Feb	17-Feb
2006	18-Feb	5-Mar
2006	6-Mar	21-Mar
2006	22-Mar	6-Apr
2006	7-Apr	22-Apr
2006	23-Apr	8-May
2006	9-May	24-May
2006	25-May	9-Jun
2006	10-Jun	25-Jun
2006	26-Jun	11-Jul
2006	12-Jul	27-Jul
2006	28-Jul	12-Aug
2006	13-Aug	28-Aug
2006	29-Aug	13-Sep
2006	14-Sep	29-Sep
2006	30-Sep	15-Oct
2006	16-Oct	31-Oct
2006	1-Nov	16-Nov
2006	17-Nov	2-Dec
2006	3-Dec	18-Dec
2006 / 2007	19-Dec	3-Jan

2.3.6 Erroneous and null cells

The digital numbers (DNs) in the scaled imagery should have ranged from zero to one, and null cells should have had a value of 3.277. However, there were cells with erroneous DNs between one and 3.277. Proceeding without removing all erroneous and null cells from further calculations would have produced invalid results for those cells, which would later bias any statistical analysis.

An Imagine Model converted all DNs greater than one and less than or equal to 3.277 to a standard null cell value of -9999.

2.4 Image product generation

2.4.1 Index calculation in ERDAS Imagine 9.2

Image indices were calculated in ERDAS Imagine version 9.2, and excluded erroneous and null pixel values. The indices were calculated according to the following equations:

NDVI ((Band 2 – Band 1) / (Band 2 + Band 1)) (1)

UAVI ((Band 6 – Band 7) / (Band 6 + Band 7)) (2)

High NDVI values correspond to greater “greenness”, or more strongly growing vegetation, while low values correspond to a lack of greenness, which can result from either soil exposure or senescent (dead) vegetation.

High UAVI values theoretically correspond to strongly growing vegetation, moderate values to senescent vegetation, and low values to exposed soils.

2.4.2 Import to ArcGIS

Prior to linking field cover rating measures to the remotely sensed indices it was necessary to convert the imagery from Imagine to ArcGIS grid format. All images were converted in ArcGIS from Imagine to float format, and then from float to grid format. This caused the null values to be correctly recognised as such in the final grid format. The simpler approach of conversion directly from Imagine to grid format was not taken due to the inability of ArcGIS software to convert 32 bit Imagine imagery.

2.4.3 Masking of non-reporting areas

The Land Condition Monitoring regions and zones included non-cropping areas such as water bodies and native vegetation. To ensure final maps and reporting statistics related solely to cropping areas these non-cropping areas were removed from the image indices by masking.

Mask creation started with the Australian Government Department of the Environment and Water Resources’ “Present native vegetation subgroups” (PNVS) raster. This raster was derived from all data in the National Vegetation Information System (NVIS) as at 2006, at a resolution of 100m.

Creation of the mask from the PNVS was complicated by the distribution of much of South Australia’s native vegetation in narrow roadside reserves, and narrow strips around or small patches in fields. We considered this vegetation large enough to alter an overlying MODIS pixel’s signature, but too small to cause that pixel to be removed with a simple mask operation.

To resolve this, the PNVS was converted to a polygon and buffered by 250 m to ensure the masking of the smallest patches. Finally water-bodies and non-reporting regions (*i.e.*, pastoral lease rangelands, and the South East of South Australia) were added to the mask. The metropolitan Adelaide region is masked out in subsequent maps, but was included in the rank correlation statistics.

All subsequent image products and statistics excluded the masked features displayed in Figure 4.

2.4.4 Twice-monthly time trace

As an analogue of the temporal graphs produced for the LCM reports from the WSS survey results, a similar temporal graph was produced for each image index. For each reporting region the mean and standard deviation of index values were extracted for each image date, and the results plotted.

2.4.5 Average and variation in image index values

To examine their potential use in reporting both mean and variation (standard deviation) in image index maps were produced. In the maps of mean pixel values each pixel is the mean of all values for that pixel throughout all 23 image dates for the year. For the variation each pixel value is the variation in standard deviations of index values at that pixel across all 23 image dates.

2.4.6 Cumulative difference from regional mean

Another potentially useful reporting tool is a map of cumulative difference of index values from the regional mean. These maps were created for each reporting region separately by firstly calculating for each image date the difference of each pixel from the mean index value for that region, creating 23 individual difference from regional mean maps. Finally the 23 difference maps were added together creating one cumulative difference from regional mean map. Values in this final map indicate whether a pixel has had consistently higher or lower index values than the regional mean throughout 2006.

2.5 Relation of Cover Rating to Image products

2.5.1 Sub-sampling

It was necessary to sub-sample the windscreen survey (WSS) data to reduce oversampling of MODIS pixels. This oversampling occured when two or more WSS sites fell within one MODIS pixel, and was due to either the close proximity of sites on either side of the road or the close proximity of many sites on the same side of the road. In some areas the high density of WSS sites resulted in a pixel being compared to up to four WSS cover ratings (Figure 5).

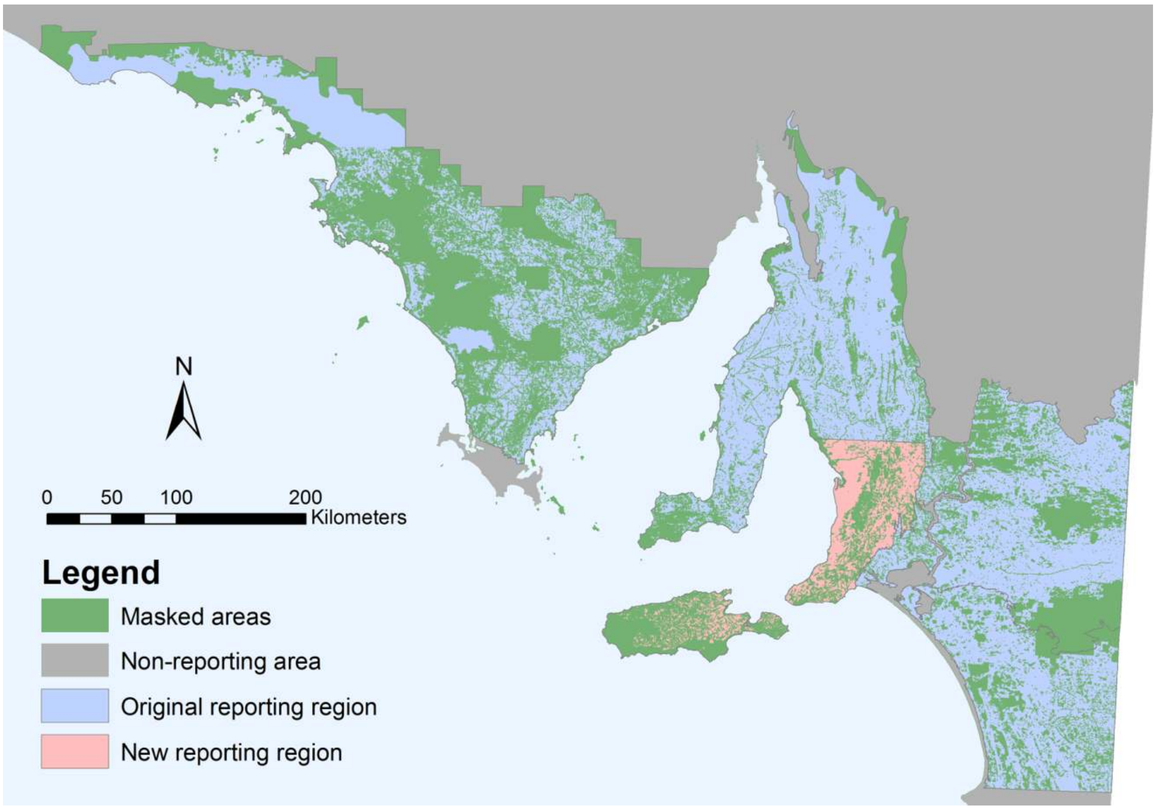

Figure 4. Non-reporting area mask: green areas were removed from further image and statistic calculations.

To eliminate these errors the WSS data was sub-sampled by retaining every fifth point, reducing the total number of points from 5464 to 1088 (Table 2). This reduced dataset was then used to examine relationships between Cover Rating and the image indices.

Table 2. Number of windscreen survey (WSS) sties before and after sub-sampling.

Region	No. of sites prior to sub-sampling	No. of sites post sub-sampling
Eyre Peninsula	1105	220
Kangaroo Island	0	0
Mount Lofty Ranges	2	0
Murraylands	1317	262
Northern and Yorke	1966	392
South East	1074	214
Total	5464	1088

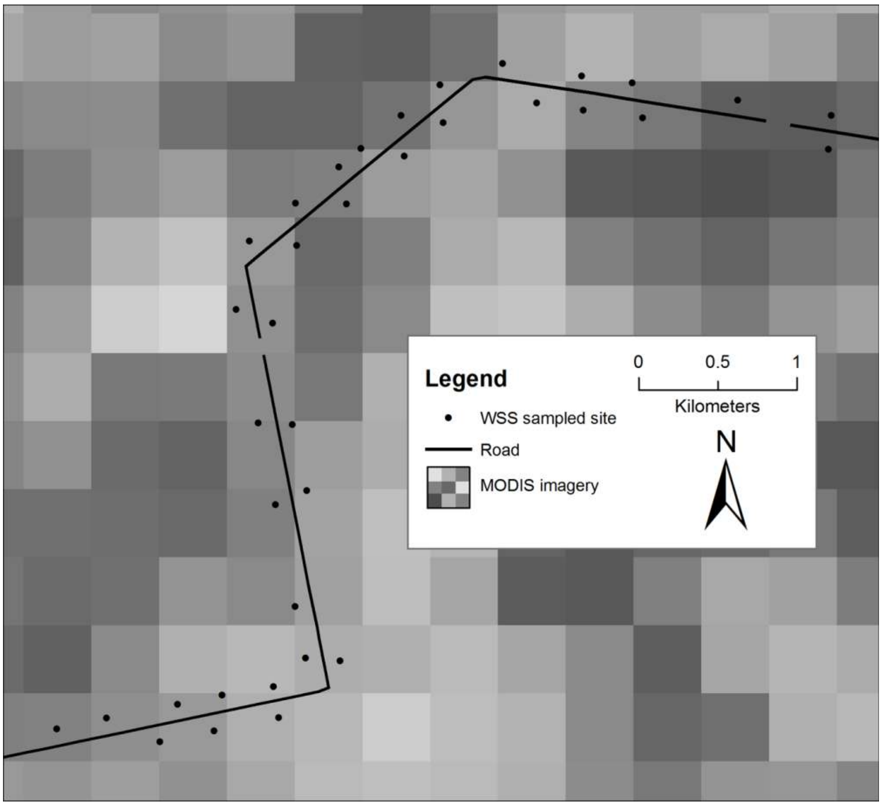

Figure 5. Over sampling of MODIS pixels due to close proximity of left and right wind screen survey (WSS) sites, and frequency of WSS sites on the same side of the road.

2.5.2 Statistical analysis

To examine the relationship between WSS cover rating and the remotely sensed indices it was necessary to select appropriate statistical methods, and that selection depends on the data types to be compared: WSS cover rating is ordinal data, while the remotely sensed indices are real numbers in a continuum.

We previously used linear regression and the coefficient of determination (R^2) to examine the relationships between means of Cover Rating and image indices for region reporting (Clarke *et al.* 2004, rev. 2009). However, linear regression assumes that both data comprise real numbers on a continuum, an assumption which is violated by the ordinal nature of the WSS cover rating.

Spearman rank correlation is a more appropriate method. Spearman's correlation is a non-parametric measure of correlation, which ranks the two variables to be compared, and then measures the correlation of the ranks. The ordinal nature of the cover rating already meets the assumptions of this method, and the real image index values can be validly converted to rank order for this test.

The correlation between WSS Cover Rating and both image indices was calculated for the study area as a whole, and for all reporting regions.

3 Results

3.1 Image products

3.1.1 Twice-monthly time trace by region

The twice-monthly time trace for both NDVI and UAVI and for all reporting regions is presented in Figure 6. The area (post-masking) in each region is presented in Table 3. Each point on this graph indicates the regional mean index value. Both graphs display similar trends for all regions: a generally flat start until a steep rise at the end of March, a peak in mid May followed by a dip in mid June and another peak in mid August and finally a decline until the end of the year.

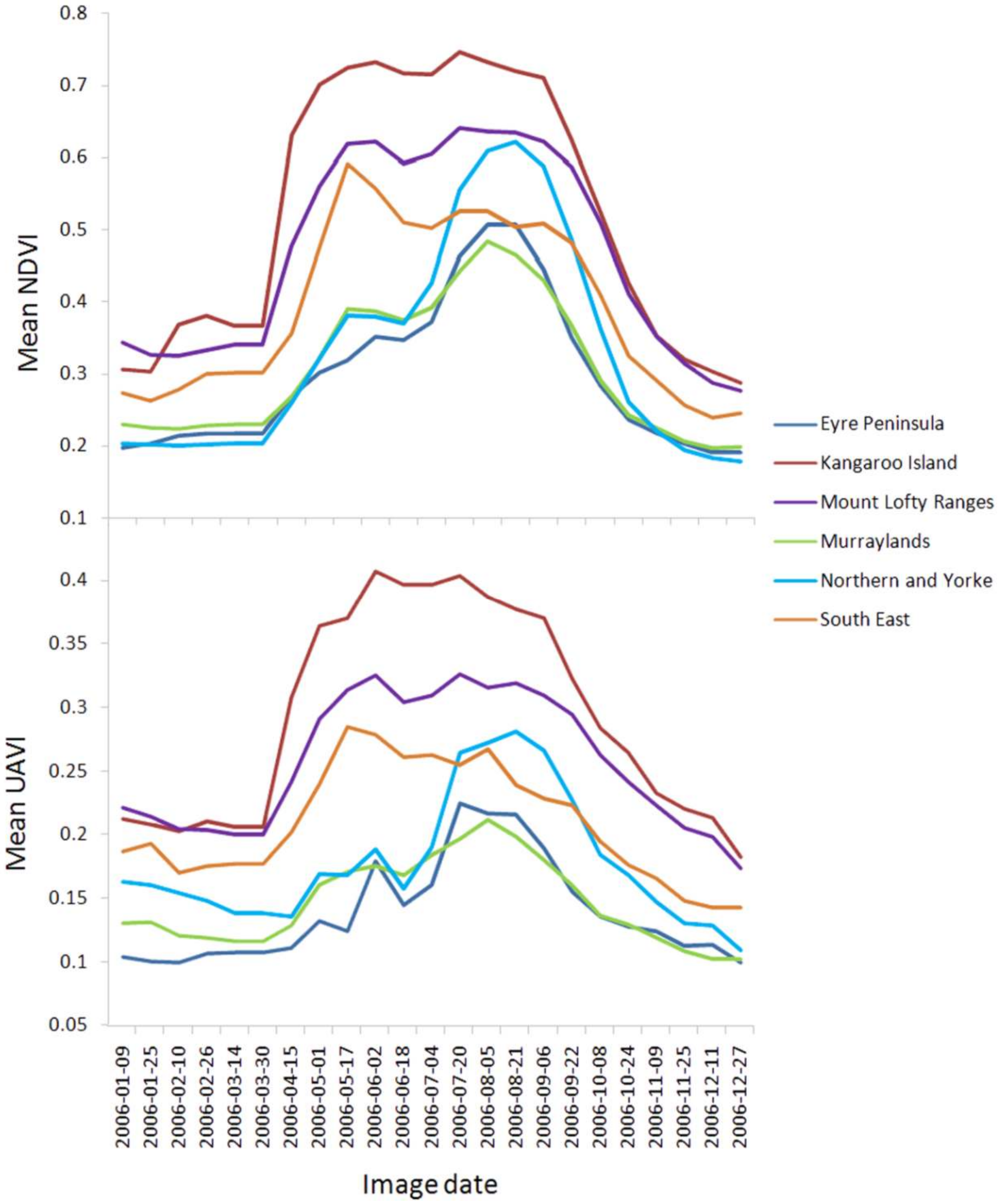

Figure 6. Twice-monthly index time trace by reporting region, 2006

The general shape of the graphs corresponds strongly with expected weed and crop growth and senescence and management patterns throughout the year. Annual crops are almost completely senesced from early summer, which corresponds to the flat start of the graph (January to March). However, summer weeds and pastures can thrive during this period, and produce significant green vegetation. This is followed by rainfall and weed and pasture growth (the peak in May) until chemical spraying off of weeds and seeding, or direct-drill seeding which reduces cover somewhat (the dip in mid June) and then crop germination and growth (the peak in August). Finally the crop senesces, and is then harvested (the decline to the end of the year).

There are several important differences between the NDVI and UAVI time traces. Firstly, the NDVI is almost horizontal at the start of the year (January to the end of March), which is expected if the NDVI is incapable of discriminating between exposed soil and dry vegetation. Over the same time period UAVI decreases slightly, which would be expected if it is capable of discriminating exposed soil from dry vegetation, and if the relative amount of dry vegetation were slowly decreasing over this time period.

Secondly, the NDVI decreases steeply from the end of September to the end of October, before decreasing more slowly until the end of the year. The steep decline in NDVI values corresponds to the expected time of crop senescence, and the slow decline in greenness to the expected time of harvest. Over this same period UAVI declines at a continuous rate, which would be expected if it is influenced by both green and dry plant matter: as crops senesce the index would drop to a moderate value, and as crops were harvested soil would began to show through and the index would drop to a lower value.

Finally, there are potentially important differences in relative index values during the dry start of the year. During this period NDVI values for the Murraylands, Eyre Peninsula and Northern and Yorke regions are very low, and Northern and Yorke region is lowest the majority of the time. While these three regions still have the lowest UAVI index values over the same period, importantly the relative pattern of index values is different. The Northern and Yorke region exhibits the highest UAVI values of the three regions, followed by the Murraylands region, and finally the Eyre Peninsula region.

Table 3. Area of reporting regions, excluding masked areas.

Region	Area (km^2)
Eyre Peninsula	16179
Kangaroo Island	864
Mount Lofty Ranges	4182
Murraylands	13130
Northern and Yorke	19277
South East	9809

3.1.2 Variation in time trace

Variation in the twice-monthly time trace for both NDVI and UAVI and for all reporting regions is presented in Figure 7. Each point on this graph indicates the regional mean index value, and the bars above and below indicate one standard deviation in index value at that image date. All regions show the same overall trend in both indices, from less variation in index values early in the year, greater variation from approximately May through to October, and less variation again from October until the end of the year. A sudden increase in variation might have been expected in June, coincident with tillage and seeding, due to the sudden increase in soil exposure. However, such an increase is not observed in the graphs. Variation in values for both indices is highest for the Mount Lofty Ranges region, as might be expected because of the wide range of rainfall, crop and pasture types within the region. Variation in NDVI during the summer months is lower than UAVI variation in most regions, possibly because NDVI records only green vegetation while UAVI responds to both green and dry vegetation cover.

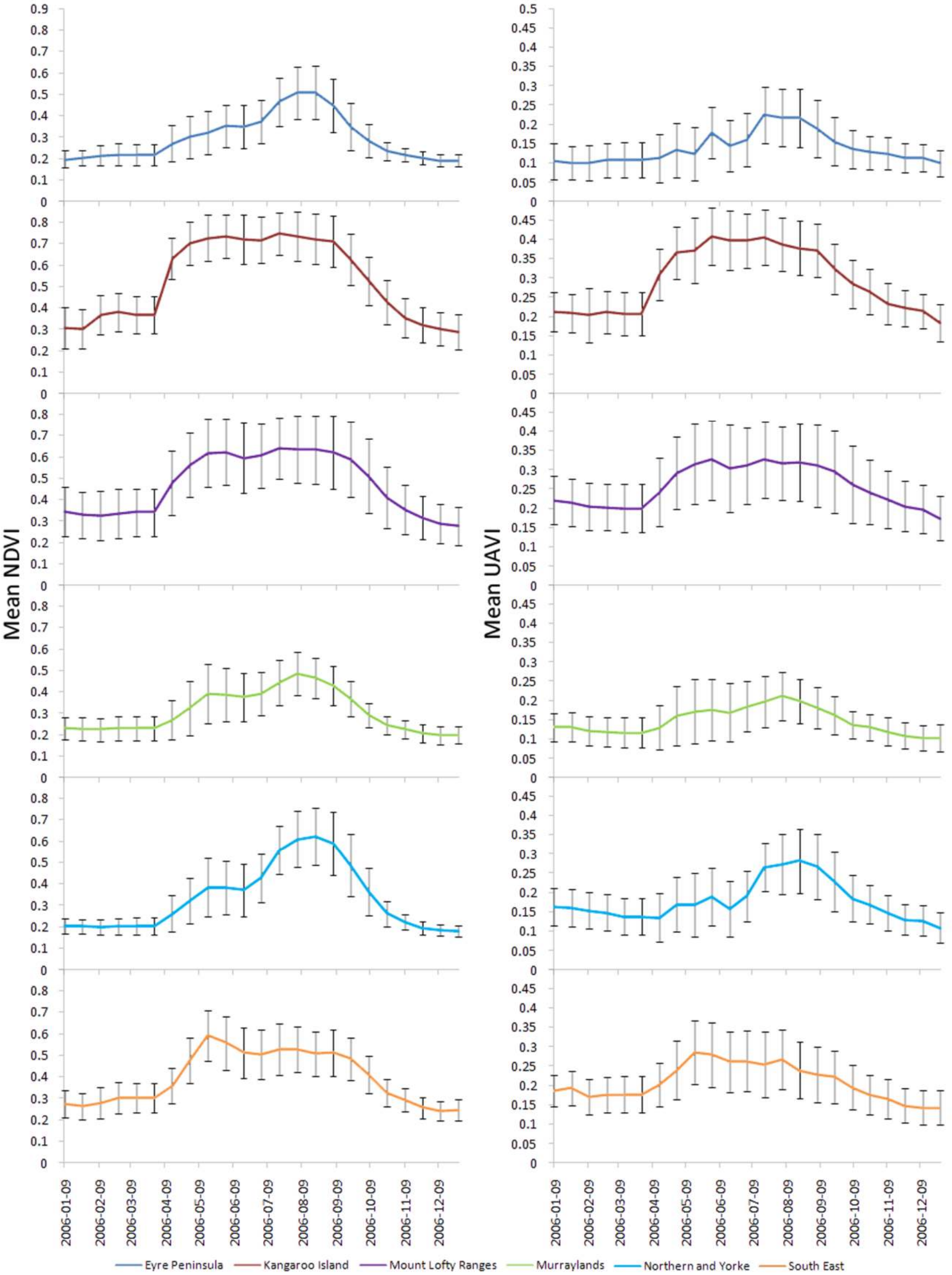

Figure 7. Variation in twice-monthly index time trace for all reporting regions, 2006.

3.1.3 Annual average index

The annual mean index maps show the same overall pattern for both NDVI (Figure 8) and UAVI (Figure 9), despite the slightly different range of values produced by the two indices. Visual differences between maps of the indices may be indicative of true differences or simply differences in the values of the indices relative to the displayed scales.

The predominant spatial pattern in both images relates strongly to average annual rainfall pattern, which is illustrated by the overlain long-term (30 years) average annual rainfall isohyets. While the overlain isohyets are unlabelled to reduce visual clutter, the map of long-term average annual rainfall (30 years) is included in Figure 12. Low index values in the north of the Eyre Peninsula and north east of the Northern and Yorke and Murraylands regions correspond to the regions of lowest annual rainfall. High index values in the Kangaroo Island region, along the Mount Lofty Ranges and the south west of the South East region all correspond to the areas of highest average annual rainfall within the LCM reporting regions.

However, closer inspection reveals moderate and fine scale variation in index values, below the scale of climatic influences. The moderate scale variation can be seen in particular in the north-west of the Eyre Peninsula region, where a decrease in rainfall values is not reflected by a decrease in index values; and in the south of the Murraylands, where there is a gradient from west to east of decreasing index values within a band of similar rainfall. However, the rainfall gradient in these areas, particularly in the north-west of the Eyre Peninsula, is subtle, and this might explain the lack of visible relation to the image index. The fine scale variation visible across all regions may be indicative of land-management influence.

3.1.4 Annual variation in index value

The annual variation or deviation from the monthly mean maps show the same overall pattern as the mean index maps (NDVI, Figure 10; UAVI Figure 11). Once again, visual differences between the two indices may be indicative of true differences or simply differences in the scale of the index relative to the legend.

These maps show high intra-annual variation in index value in south east of the Eyre Peninsula region; the majority of the Northern and Yorke region, excluding the far north east; all of the Kangaroo Island region; the majority of the Mount Lofty Region, except for urban Adelaide; the south west of the Murraylands region; and the south west of the South East region.

Comparison of the pattern of index variation in relation to average annual rainfall distribution suggests that index variation is primarily determined by annual rainfall patterns, as is the mean index value. The regions with highest variation in index values generally have higher rainfall; lower variation in index values occurs at the northern margins of the Eyre Peninsula and Northern and Yorke regions, and across the northern and eastern Murraylands and South East regions.

However, as is the case with mean index value, there is fine scale variation below the scale of climatic influences. This localised variation is more likely to be a result of management influence than climate.

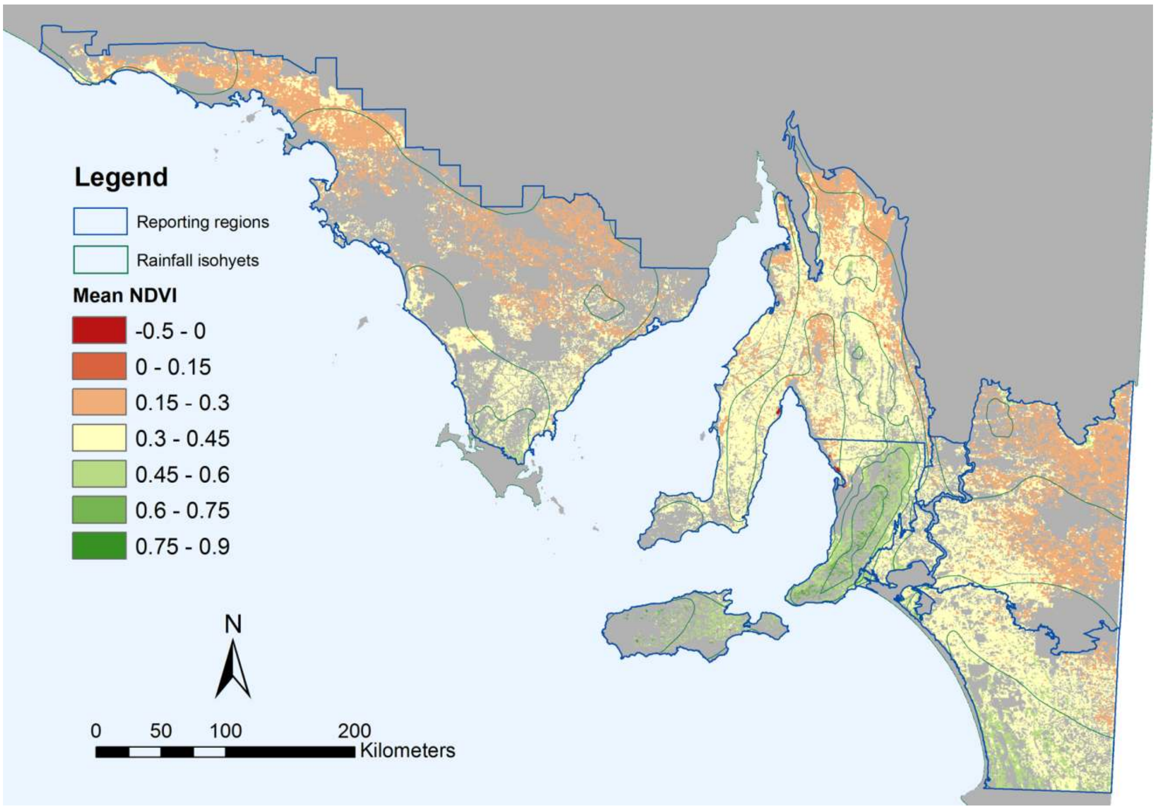

Figure 8. Annual mean NDVI, all reporting regions, 2006.

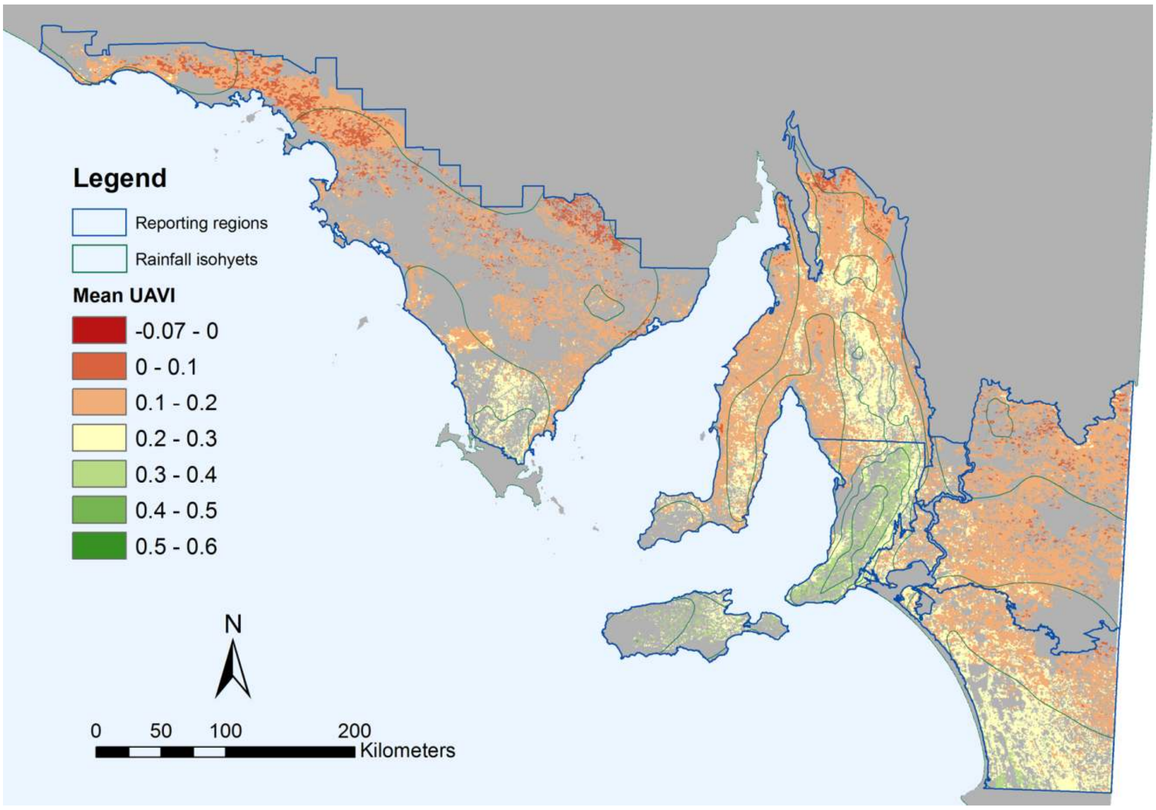

Figure 9. Annual mean UAVI, all reporting regions, 2006.

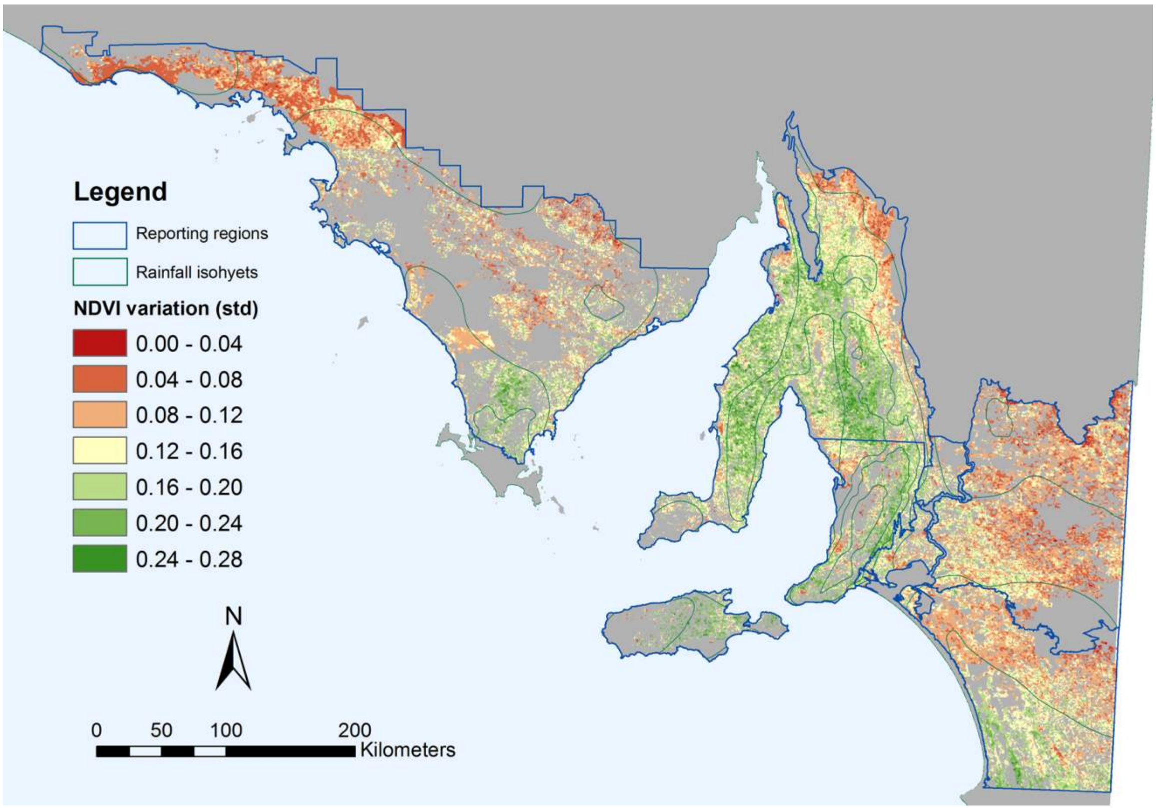

Figure 10. Annual variation in NDVI, all reporting regions, 2006.

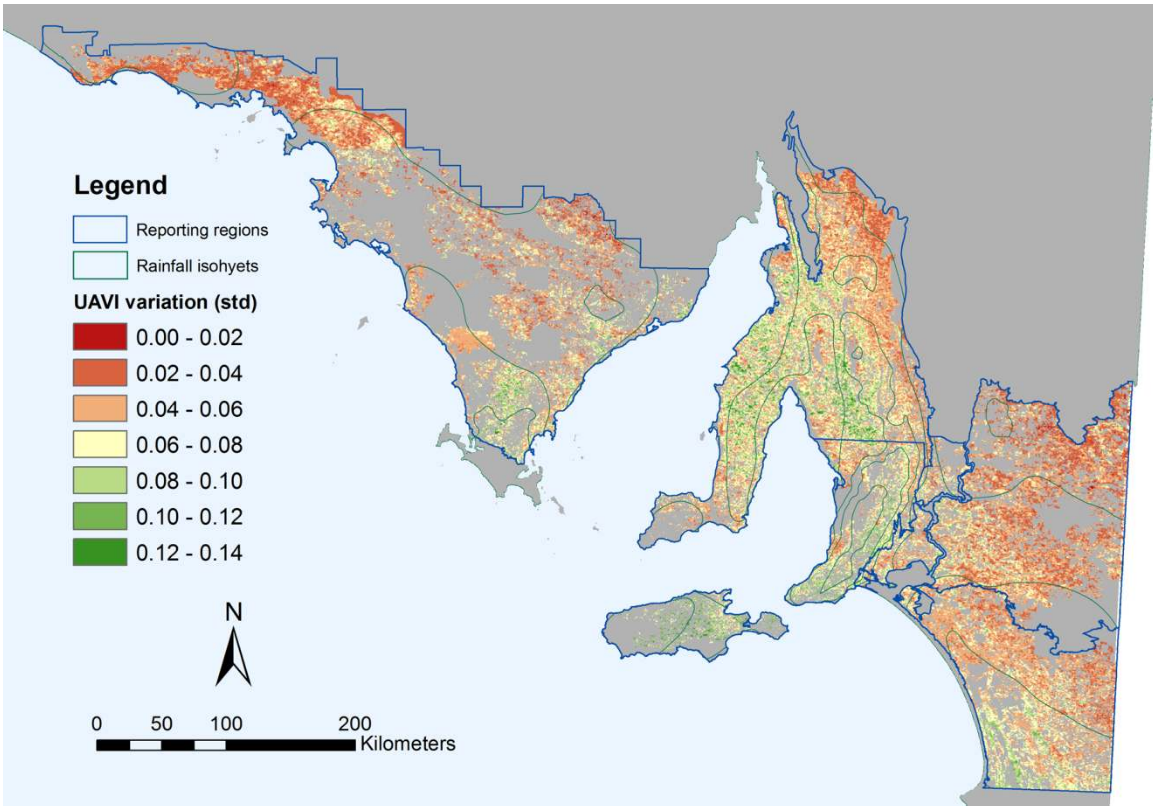

Figure 11. Annual variation in UAVI, all reporting regions, 2006.

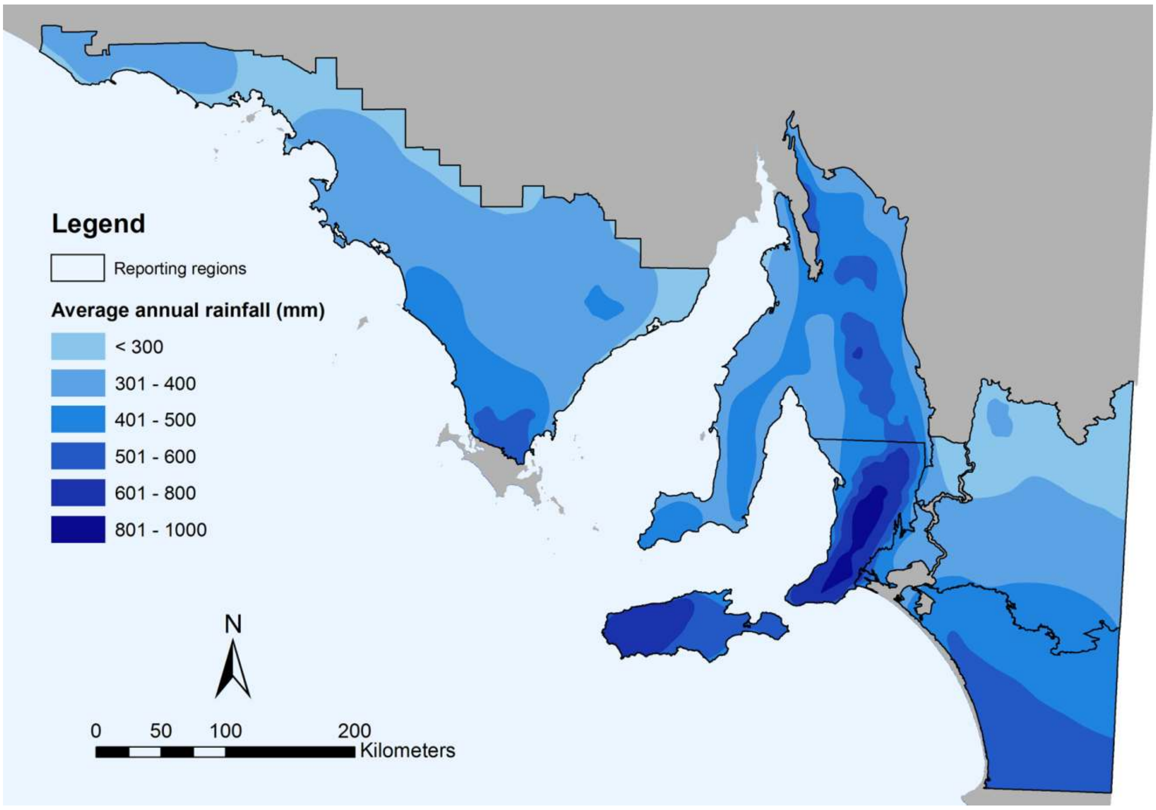

Figure 12. Average annual rainfall (mm; 30 year average).

3.1.5 Cumulative difference from regional mean index value

The maps in this section show the cumulative difference of each pixel from the regional mean at each image date. Negative values indicate an area with index values consistently below (worse than) the regional mean, while positive values indicate an area with index values consistently above (better than) the regional mean.

Once again, the observed pattern is strongly influenced by average annual rainfall distribution, and once again closer inspection of all regions reveals localised variation in index values. This variation is below the scale of climatic influences and is therefore more likely to be a result of management influence than climate.

Eyre Peninsula

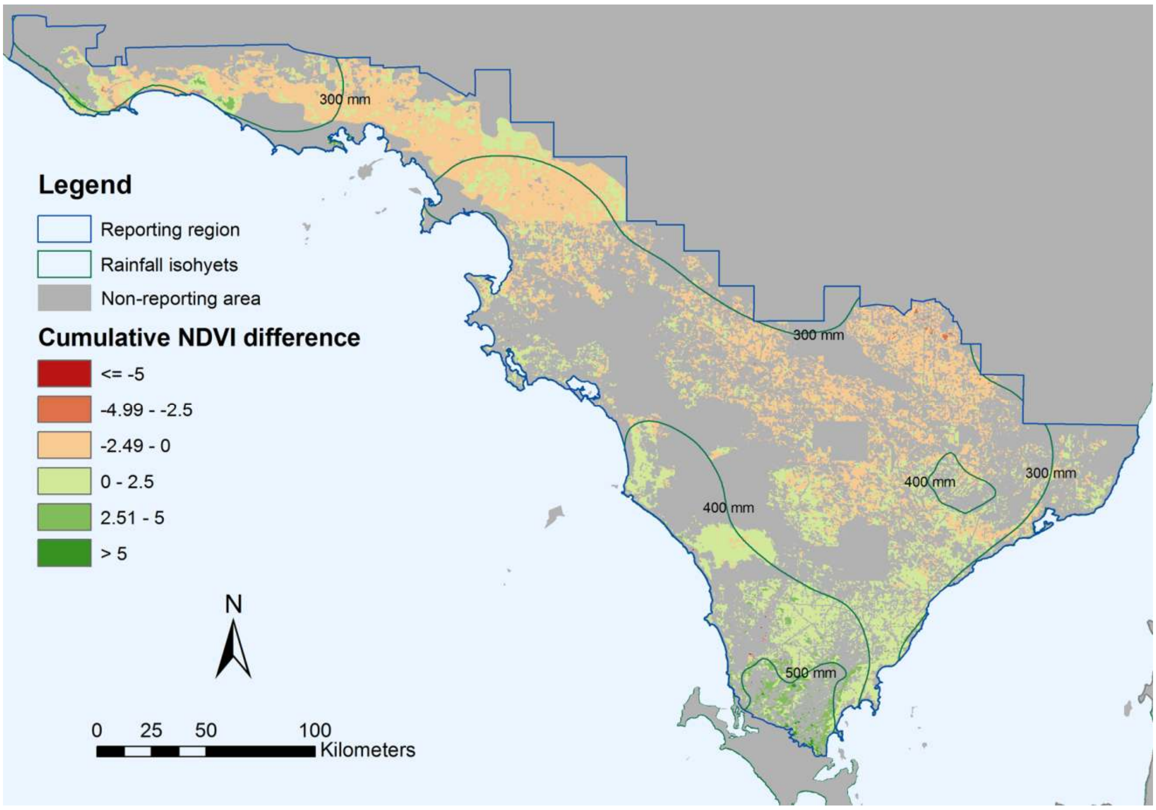

Figure 13. Cumulative NDVI difference from Eyre Peninsula average, 2006.

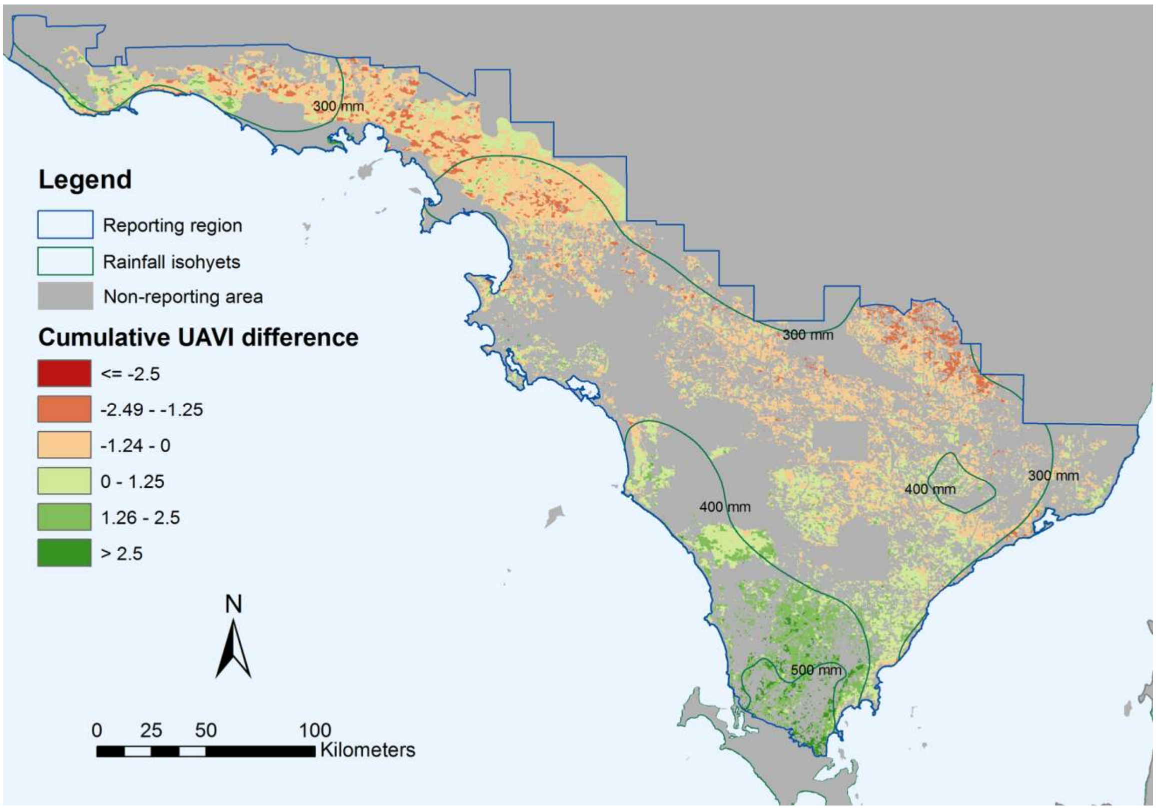

Figure 14. Cumulative UAVI difference from Eyre Peninsula average, 2006.

Kangaroo Island

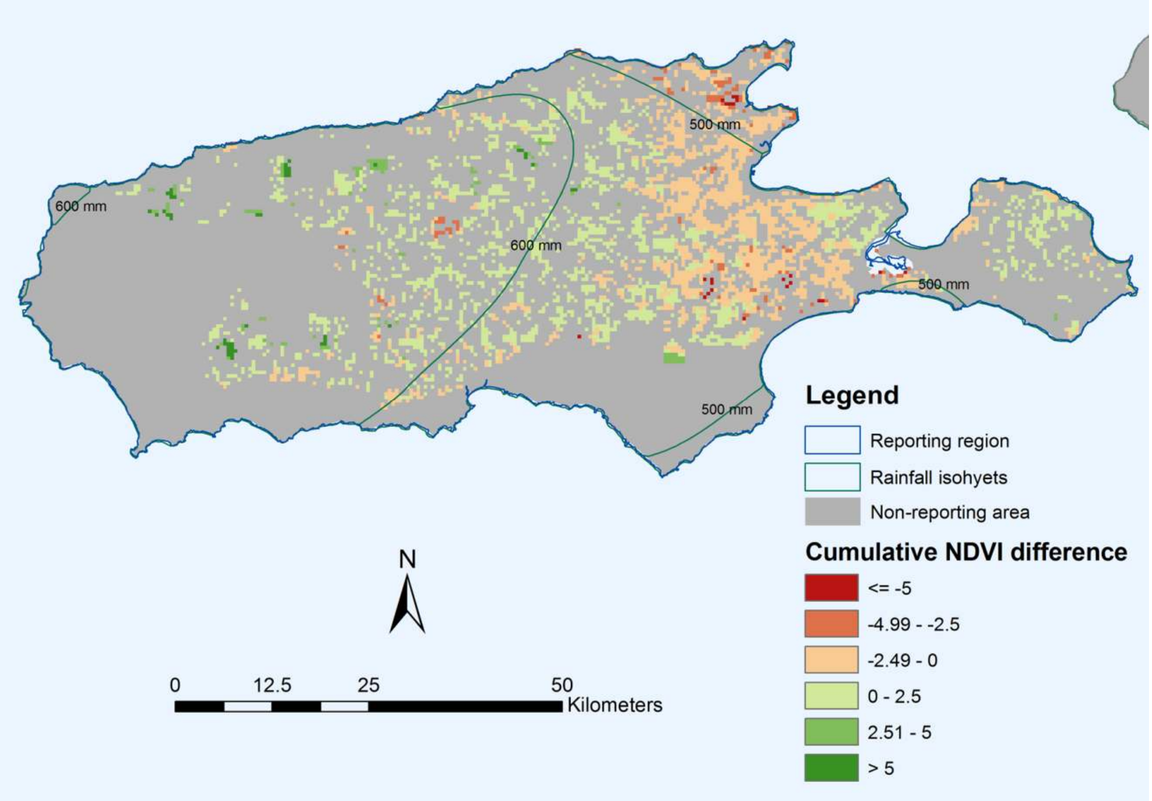

Figure 15. Cumulative NDVI difference from Kangaroo Island average, 2006.

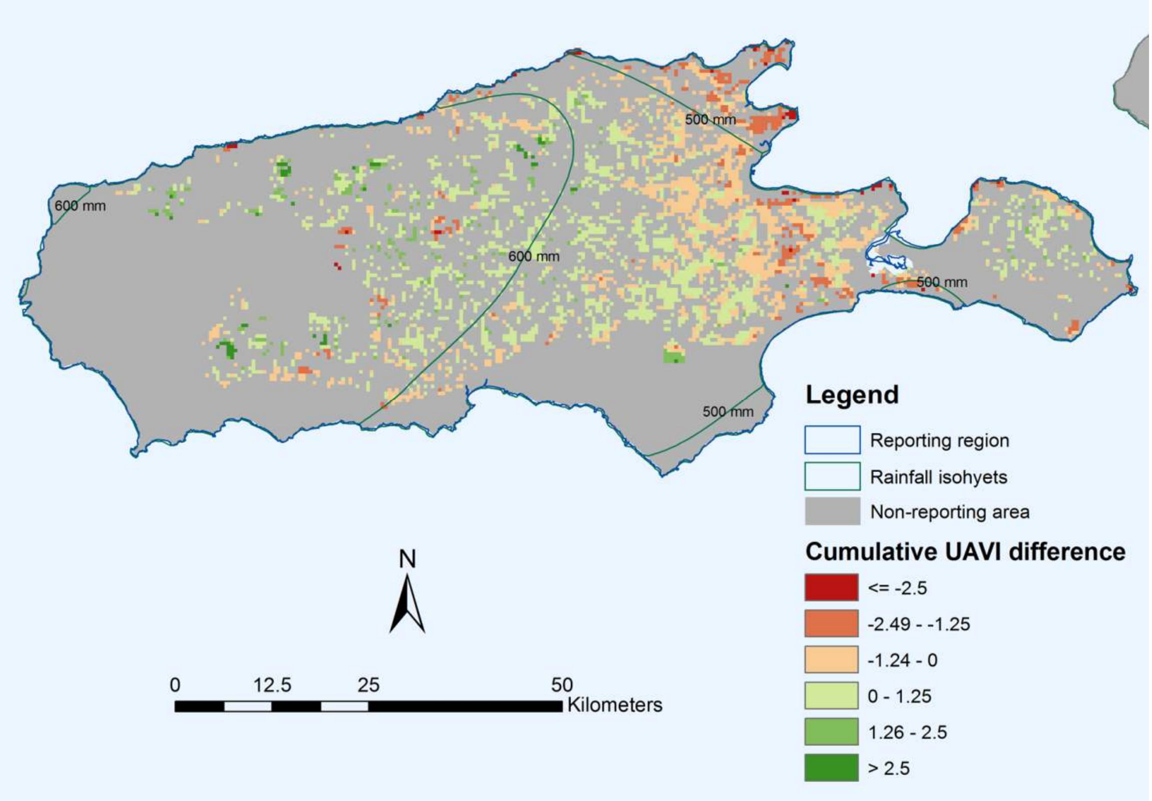

Figure 16. Cumulative UAVI difference from Kangaroo Island average, 2006.

Mount Lofty Ranges

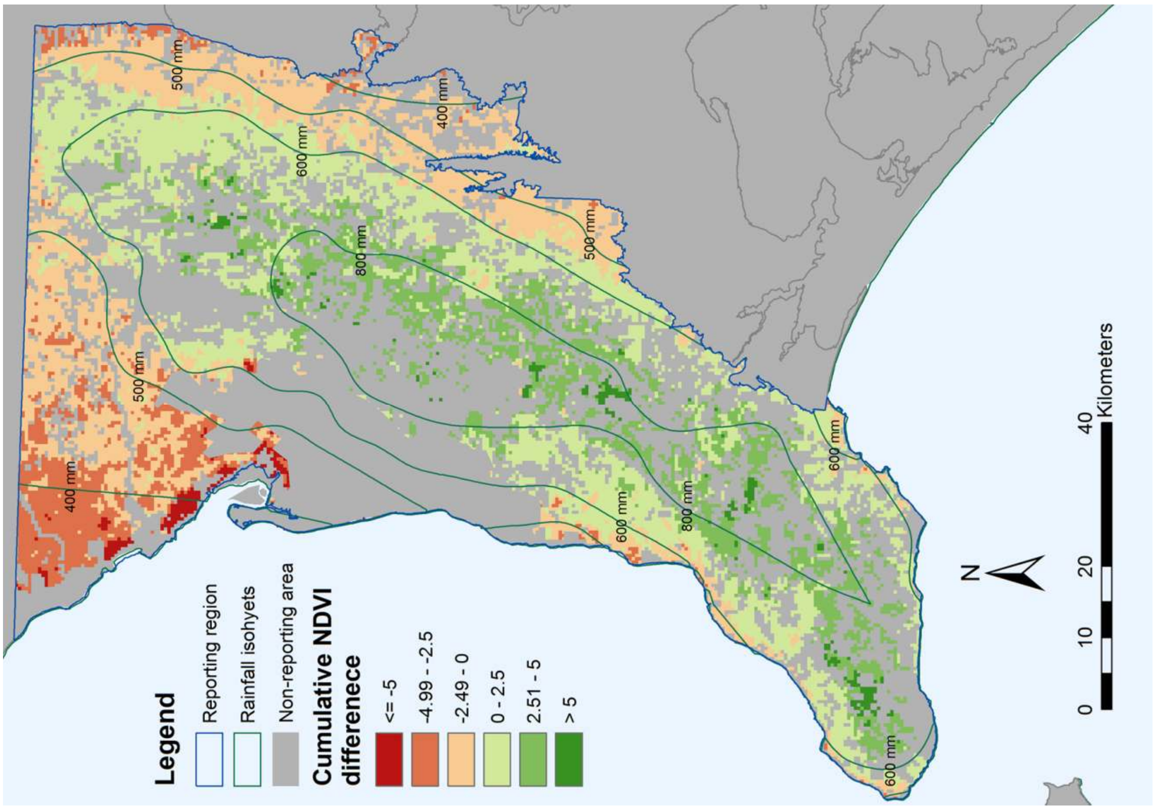

Figure 17. Cumulative NDVI difference from Mount Lofty Ranges average, 2006.

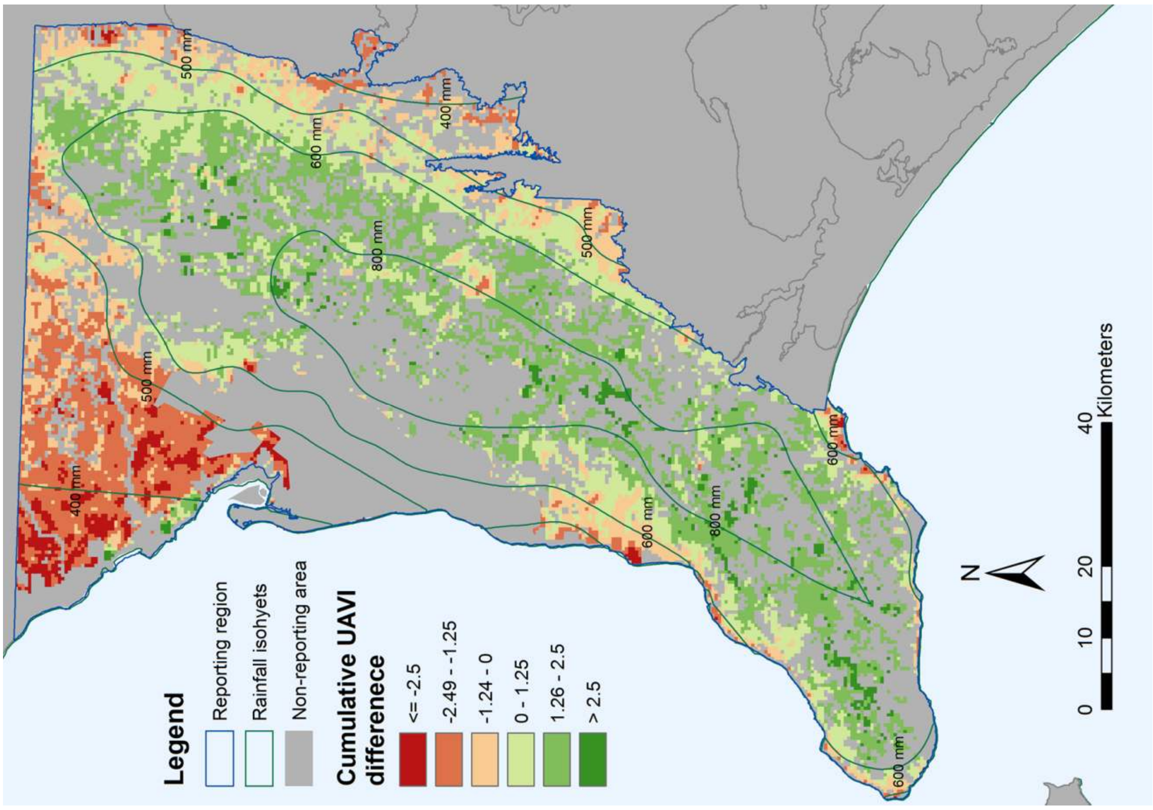

Figure 18. Cumulative UAVI difference from Mount Lofty Ranges average, 2006.

Murraylands

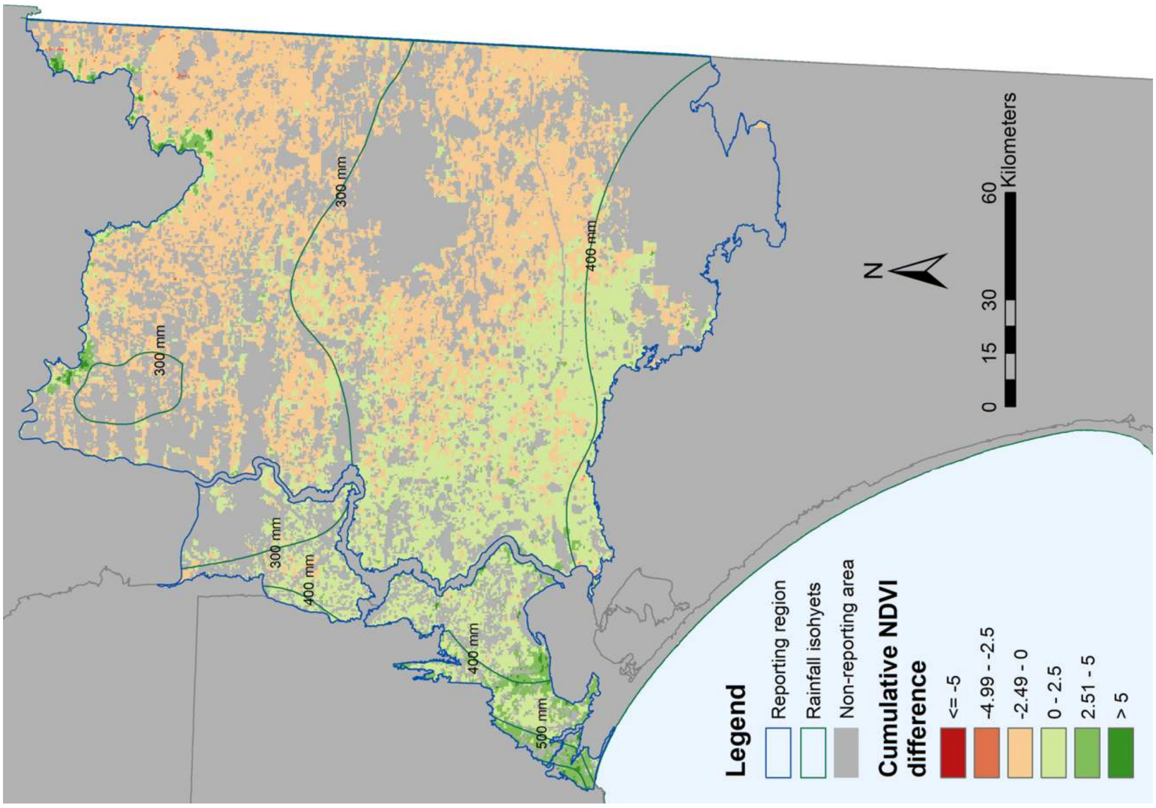

Figure 19. Cumulative NDVI difference from Murraylands average, 2006.

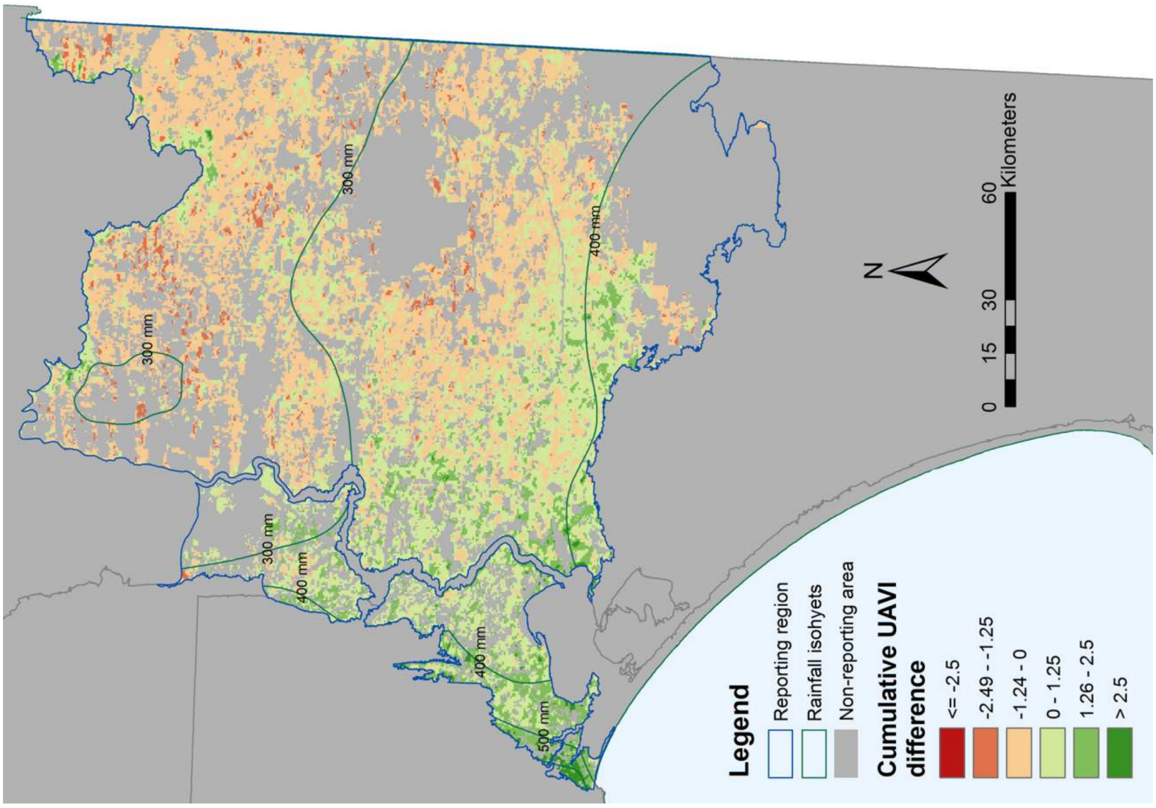

Figure 20. Cumulative UAVI difference from Murraylands average, 2006.

Northern and Yorke

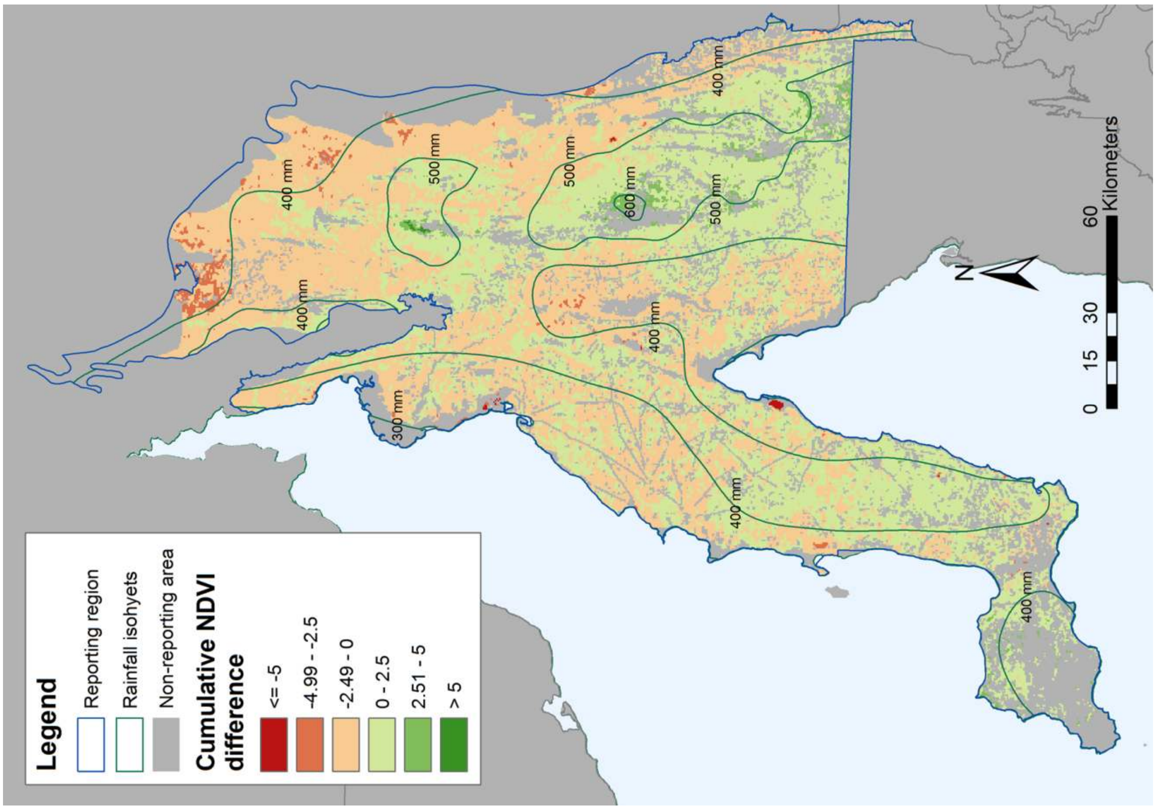

Figure 21. Cumulative NDVI difference from Northern and Yorke average, 2006.

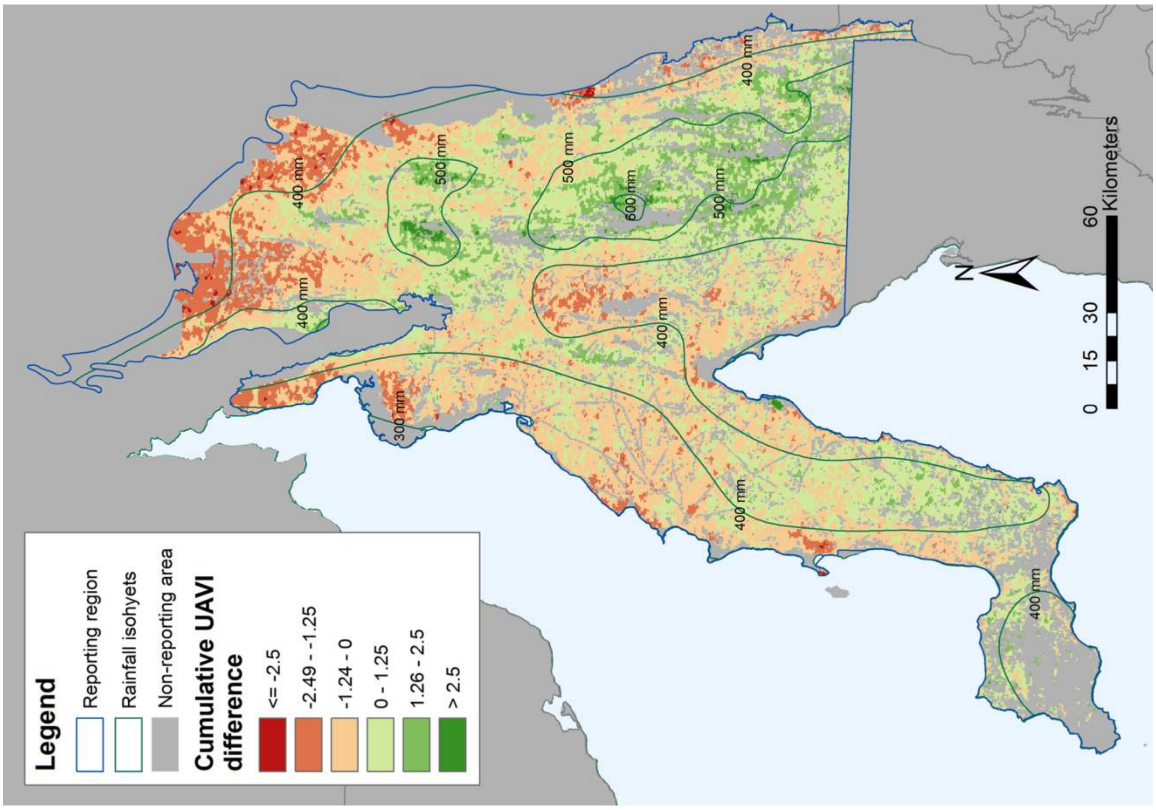

Figure 22. Cumulative UAVI difference from Northern and Yorke average, 2006.

South East

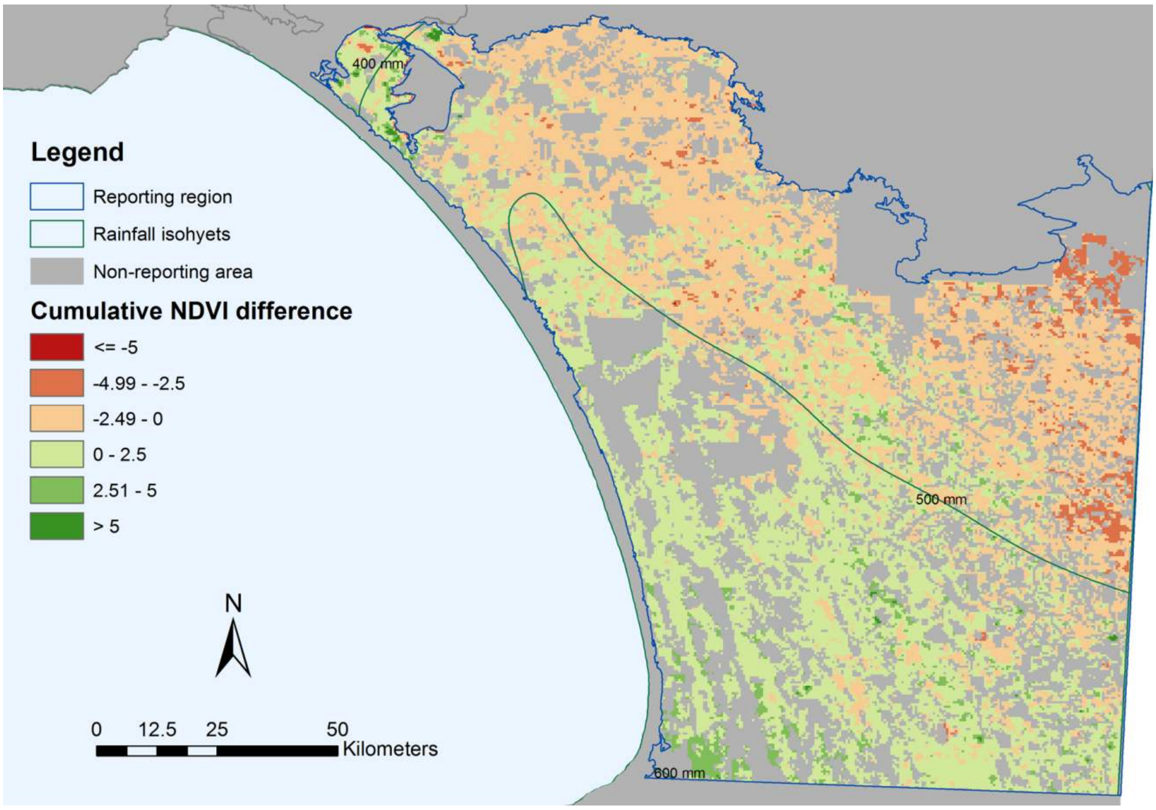

Figure 23. Cumulative NDVI difference from South East average, 2006.

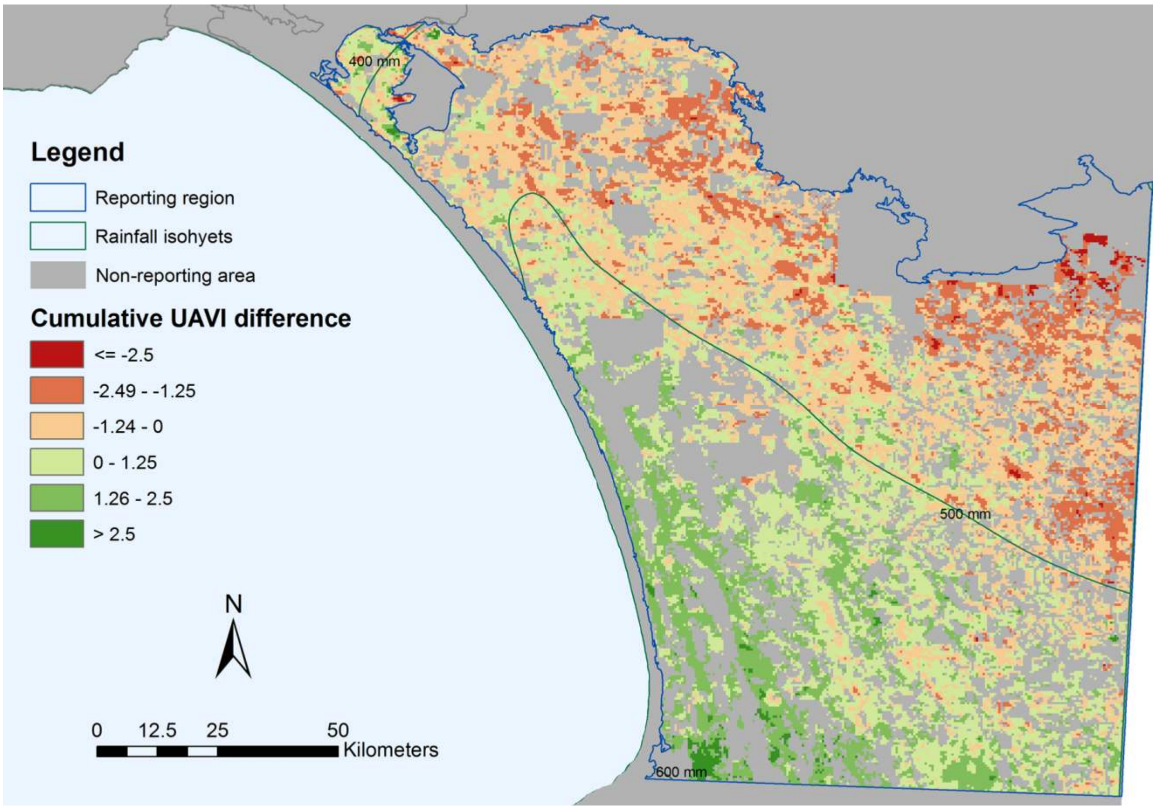

Figure 24. Cumulative UAVI difference from South East average, 2006.

3.2 Management impact

This section illustrates the some of the potential fine scale influences on cover indices by examining the distribution of index values in relation to property boundaries (cadastral) and higher resolution satellite imagery.

The first example focuses on the township of Point Pearce, which is located in the large rectangular property to the right of the central peninsula (Figure 25). This region of low mean UAVI index values corresponds closely with the property boundary, which may indicate a management influence. Examination of high resolution QuickBird imagery of the same area (Figure 26; reproduced from Google Earth without permission) reveals a furrow pattern, and a distinctive mottling. The furrow pattern indicates that the area is cropped, while the mottling might be indicative of soil salinity, a common problem in the region.

The second example focuses on an area around the town of Tarlee (Figure 27). The green area right of centre in this image corresponds closely with five properties. Examination of the high resolution satellite imagery (Figure 28; reproduced from Google Earth without permission) reveals that these properties run along the north-south hills east of Tarlee. The very western edge of these properties appears to be devoted to cropping, while the rest of these properties contain to permanent pasture, and so would be expected to have high annual average cover.

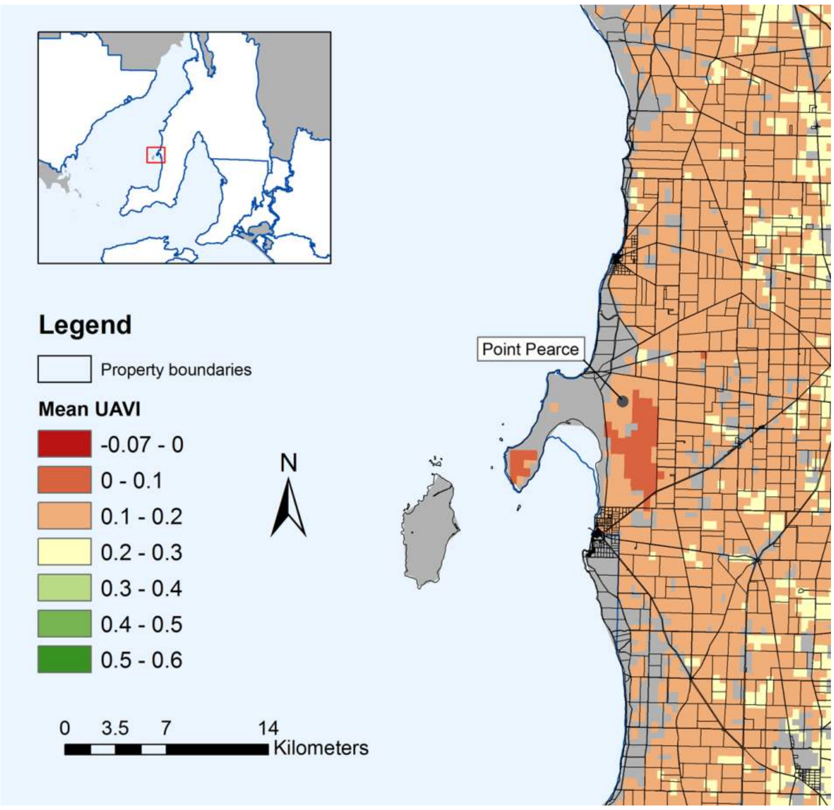

Figure 25. Relation of UAVI index values to property boundaries in the vicinity of Point Pearce, South Australia.

Figure 26. High resolution imagery illustrating the properties containing the lowest mean UAVI index values in Figure 25. Region of interest highlighted. Reproduced without permission from Google Earth.

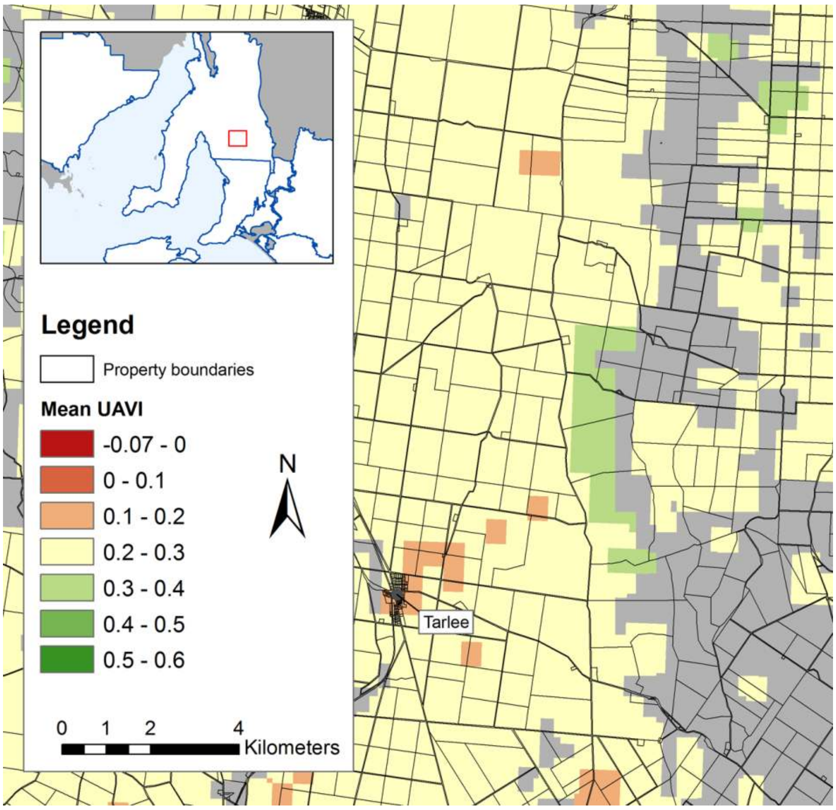

Figure 27. Relation of UAVI index values to property boundaries in the vicinity of Tarlee, South Australia.

Figure 28. High resolution imagery illustrating the properties containing the highest mean UAVI index values in Figure 27. Region of interest highlighted. Reproduced without permission from Google Earth.

3.3 Relationships between Cover Rating and image products

3.3.1 Correlations

The Spearman correlation coefficients are presented in Table 4, with significance denoted in superscript. The majority of correlation coefficients are negative, because of the difference in Cover Rating and image index scales: Cover Rating increases in index value as amount of cover decreases; both image indices decrease in value as amount of cover decreases.

Two general but important points can be drawn from an examination of this table. When examining the month by month correlations for all regions combined, the highest (best) correlations for both image indices are obtained in June, when the greatest range of cover levels is expected, from completely exposed due to recent tilling to completely covered due to pasture or early crop sowing. Again, when examining all regions combined, the UAVI performs better than the NDVI in all months, and when the data for all of 2006 is examined as a whole.

Closer examination of the table reveals that these general points do not hold when the analysis is broken up into reporting regions. For instance sometimes better correlations are obtained in October.

Finally, it is notable that there are generally poor correlations in March, and that there is almost no relationship between the Cover Rating recorded in the South East and either of the image indices.

Table 4. Spearman's rank correlation coefficient (r_s), cover rating versus image index.

Region/ index	March 2006	May 2006	June 2006	October 2006	All 2006
NDVI					
Eyre Peninsula	-0.038	-0.286 ***	-0.353 ***	-0.425 ***	-0.108
Murraylands	+0.031	-0.281 ***	-0.371 ***	-0.241 ***	-0.124 *
Northern and Yorke	-0.032	-0.251 ***	-0.296 ***	-0.374 ***	+0.052
South East	+0.076	-0.031	-0.065	+0.007	-0.196 **
All regions combined	**-0.122** ***	**-0.305** ***	**-0.382** ***	**-0.234** ***	**-0.022**
UAVI					
Eyre Peninsula	-0.223 **	-0.304 ***	-0.305 ***	-0.407 ***	-0.187 **
Murraylands	-0.098	-0.275 ***	-0.381 ***	-0.143 ***	-0.241 ***
Northern and Yorke	-0.358 ***	-0.365 ***	-0.277 ***	-0.372 ***	-0.278 ***
South East	+0.023	-0.054	-0.094	+0.052	-0.037
All regions combined	**-0.201** ***	**-0.339** ***	**-0.398** ***	**-0.258** ***	**-0.211** ***

* p = 0.05

** p = 0.01

*** p = 0.001

3.3.2 Identification of image index ‘critical cover level’ threshold

Current LCM reporting relies on the designation of a ‘critical cover level’ at a Cover Rating of 5. Land assessed as having a Cover Rating above this level is considered ‘at risk’ of erosion. In conjunction with the total area of each reporting region, the proportion of WSS sites in the ‘at risk’ category is used to estimate the proportion of each reporting region ‘at risk’ from erosion.

One of the aims of this project was to determine the image index values corresponding to this ‘critical cover level’. However this was not possible; the categorical nature of the Cover Rating precludes the building of regression models to describe a mathematical relationship between Cover Rating and image index. Furthermore, the wide spread of values in the Cover Rating/image index correlations, and the variation in those correlations with season, means that a Cover Rating threshold cannot be translated confidently into a single image index threshold.

4 Discussion and conclusions

This project aimed to further the development of satellite image-based soil cover monitoring in South Australia, and has succeeded in that goal. As a pilot study on one year of data, this project encountered and solved many of the same problems a full scale image-based cover monitoring program may encounter. This section summarises the specific outputs and findings of this project, and then makes recommendations for future research.

4.1 Outputs

Outputs of this project that have potential use and benefit for image-based land condition assessment include the following:

1. Identification of a suitable MODIS image product and source as a basis for intra- and inter-annual cover monitoring. The MODIS NBAR Adjusted Reflectance product is a 16 day composite which removes the influence of look and illumination angle on apparent reflectance, calibrated to reflectance by removal of atmospheric interference, cloud free, available from February 2001 to present, and is spatially extensive, covering the whole of South Australia daily, and is supplied free of charge.
2. Production of 23 UAVI and NDVI image indices, one for each 16 day composite MODIS NBAR images for 2006. These image indices, especially at critical periods of the year, may assist in monitoring cover and in identifying areas at risk of erosion.
3. Addition of two new regions, and two new zones to the reporting areas.
4. Production of several image index products which may assist analysis of regional and local cover levels, and improve reporting. These image products include annual mean indices, annual variation in indices and cumulative deviation from regional mean.
5. Production of seasonal profiles for UAVI and NDVI for all land condition reporting regions. These show changes in cover as measured by the indices throughout the year, highlighting similarities and differences which could be indicative of differences in climate, land use, land management practices. The profiles derived from the image indices have a higher temporal frequency than the profiles derived from the windscreen survey data. The image index temporal profiles have 23 sample points, while the windscreen survey profiles have four sample points.

4.2 Findings

In analysing the site-specific Windscreen Survey (WSS) data we have demonstrated once again a sound link between the WSS Cover Rating and the image indices. The analyses presented also demonstrate that overall the UAVI is a better measure of Cover Rating than NDVI, confirming the findings of Clarke *et al.* (2004, rev. 2009). Furthermore, we have demonstrated this link with greater statistical validity than previous studies, adding further weight to the potential of UAVI for operational soil exposure monitoring.

It should be noted that while the link between image indices and cover rating is statistically sound on the majority of dates and for the majority of regions, it is never strong: ranging from weak ($r_s = -0.122$) to moderate ($r_s = -0.425$). When all regions are combined the relationships are strongest in June, slightly weaker in May, slightly weaker in October and weakest in March. Relationships for the South East are weak at all times of the year and never statistically significant.

The nature and strength of the relationship between the image indices and Cover Rating may be limited by these methods using inherently different approaches to assessing fractional cover. The image indices are based on the combined spectral response of projected cover, for MODIS of a ground area of approximately 25 ha, averaged over 16-day periods, whereas the Cover Ratings are derived from oblique observations of areas of approximately 4 ha, scored by different observers against descriptions based on plant and residue height as well as management. Site observations are made over a few days within a fortnight. Furthermore, the determination of an image index critical threshold, below which land would be considered at risk of erosion, was not possible due to the nature of the Cover Rating score, ordered classes, and the limited correlation between Cover Rating and image indices. It is difficult to further interpret the relationship between the image indices and Cover Rating without some independent field based measure of fractional cover for validation.

The image products produced for this report illustrate some of the potential methods of image-based soil exposure reporting. Although three different image products were produced, the predominant pattern in all maps was climatic. Specifically, the majority of pattern of soil exposure is strongly related to long-term average rainfall throughout all dry cropping regions of South Australia. This parallels the finding of Grech *et al.* (2003), that the majority of variation in Cover Rating is determined by climate. However, the image indices are clearly revealing moderate and fine scale variation in index values not related to broad climatic trends. This specific detail could potentially be used to target areas where changes in land management are required to reduce erosion risk.

4.3 Future research

To progress development of a satellite image-based soil cover monitoring program we must understand the sensitivity of the Windscreen Survey Cover Rating to quantitative levels of plant cover, the accuracy and consistency of individual surveyors, and the agreement or disagreement of Cover Rating estimates between surveyors. Furthermore, we need to understand the dynamics of the image indices in relation to the full range of on-ground fractional cover, both green and senescent.

To improve our understanding of the dynamics of the image indices, we propose a study based on an existing set of laboratory reflectance spectra (Summers *et al.* 2009). These spectra record full range of fractional covers of photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV), over several different soils. The MODIS bands required for UAVI and NDVI can be simulated from these spectra image indices calculated and tested against the precisely recorded levels of green and dry plant cover. This analysis will clarify the sensitivity of the image indices to fractional PV, NPV and soil cover.

To improve cross validation of both the image indices and the Windscreen Survey Cover Rating, we propose a field-based study hinging upon a quantitative measure of fractional cover of PV, NPV and soil. This study would require that several different surveyors independently assess Cover Rating at pre-selected field sites; that the quantitative fractional cover measure is used to assess the same sites on the same day (or as near as possible); and that the image indices are produced for the same sites on the same day (or that the composite imagery centre on that day). Data from such a survey would improve understanding of the relationships between Cover Rating and image indices, and the sensitivity of both to fractional cover.

Future research towards an image-based system for monitoring soil erosion risk and land condition will expand the period over which the 16-day MODIS image indices are traced, from

2001 to the present. This will allow analysis of inter-annual as well as seasonal variation in land cover, and improve separation of climatic and management influences on changing cover levels. Calibration of image indices to fractional cover, and the use of temporal unmixing analyses should allow clearer documentation of changing soil exposure, as well as green and dry plant cover across the agricultural landscape through time.

Finally, future work should utilise actual rainfall from the period under analysis for comparisons, rather than the 30 year mean rainfall.

If these studies are successfully conducted an operational satellite image-based method of soil exposure monitoring will be possible. In the face of a changing climate the significance of such a method is great, both for South Australia and dryland cropping areas around the world. As climate zones change historical patterns of crop vigour will change. Areas of historically low erosion risk may become vulnerable, while other areas may receive more rainfall and become less vulnerable to erosion. The effective allocation of scarce resources to these changing areas of erosion vulnerability will only be possible with sound soil exposure information. Without this information erosion prevention resources may stay committed to regions in which they are no longer required. Worse, without this information the identification of and intervention in new areas of erosion risk would take longer, allowing unnecessary soil loss.

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Appendix 1: Land Condition Monitoring Project Cover Ratings

Descriptors for Cover Rating classes (McCord 2003).

Rating	Amount of surface cover*	Stability
1	Residues knee height or greater	Stable
2	Residues > Ankle height and < knee height. Relatively even coverage.	Stable
3	Cover variable from < ankle height to knee height. Stubble may be a mixture of upright and flattened.	
4	Residues 2cm-anke height, but sufficiently dense for stability. Stubble may be flattened by grazing.	Stable
5	Grazed moderately heavily, harrowed, cultivated stubble or pasture, partially burnt or saline land. Cover light but minimal for immediate soil stability.	Stable
6	Grazed moderately heavily, harrowed, cultivated stubble or pasture, partially burnt or saline land. Cover patchy and may vary from < ankle height to bare. Residue colour may still dominate but soil is exposed in places.	Soil stability at risk
7	Mostly bare although some residues may be seen. Soil colour dominates what you see in the paddock. Grazed or cultivated virtually bare.	Insufficient residues to protect soil surface from erosion.
8	Nil cover (bare)	

***** These descriptors are supported by photo standards and sketches

Appendix 2: MRT4 process and parameters

The following are instructions for using the MODIS Reprojection Tool version 4 (MRT4) to reproject the LP DAAC MODIS data to a more interoperable format and projection. These instructions will reproject the imagery to Lambert Conformal Conic projection and HDF format.

1. Start the MRT4
2. Open target image in the MRT4
3. 'Specify Output File...' as 'MODIS_ MCD43A4_rep_yyyy_mm_dd_SALCC_WGS84.hdf'
    a. Where yyyy is the image year, and mm and dd are the month and day of the middle of the 16 day period over which the image composite was collected
    b. LCCSA denotes the output projection, South Australian Lambert Conformal Conic
    c. WGS84 denotes the output datum, World Geodetic System 1984, is very similar to the Geodetic Datum of Australia 94 (GDA94), which will be used later. The GDA Technical Manual discusses the differences between WGS84 and GDA94, and states that 'for most practical applications where an accuracy of only a meter or greater is required, GDA94 coordinates can be considered the same as WGS84 (Steed and Luton 2000).'
4. Select Nearest Neighbour for resampling type
5. Select Lambert Conformal Conic for output projection type
6. 'Edit Projection Parameters..." and enter the following projection parameters
    a. 1st standard parallel: -28
    b. 2nd standard parallel: -36
    c. Central meridian: 135
    d. Latitude of origin: -32
    e. False easting: 1,000,000
    f. False northing: 2,000,000
    g. Datum: WGS84
7. Hit 'Run'