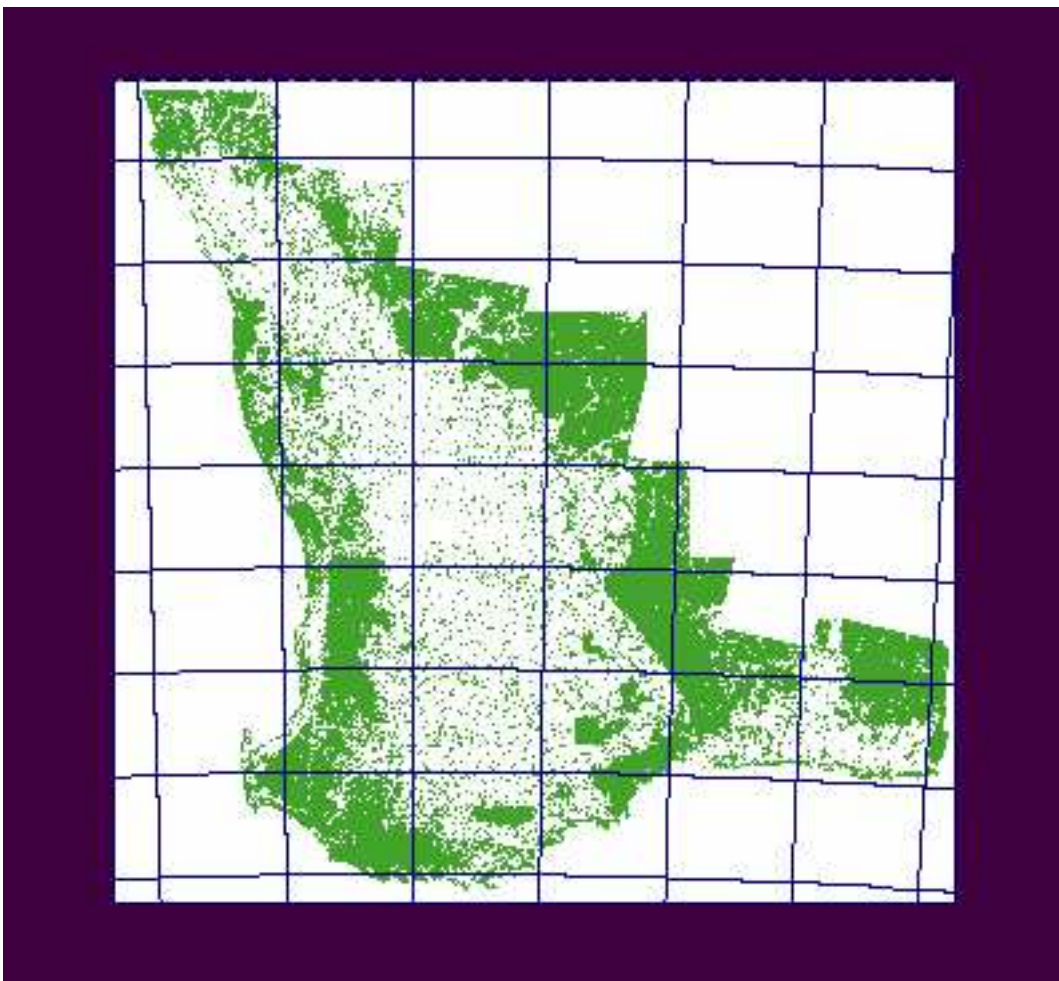


Vegetation Trends 1990-2008

South West Agricultural Region of Western Australia

2008 Update of the Land Monitor II Project

Product #3 – Vegetation Trends



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This report describes the 'Vegetation Trend' product for the south west region of Western Australia. The "Vegetation Trend" product is one component of a suite of vegetation change products produced by the Land Monitor II Project. This product provides an update of the vegetation trend product from the Land Monitor I Project.

The 'Vegetation Trend' product is a multi-channel image file that contains summaries of change in reflectance of vegetation over time. It is produced from thirteen dates of calibrated summer Landsat TM data from 1990, 1992, 1994, 1996, 1998, 2000, 2002, 2003, 2004, 2005, 2006, 2007 and 2008.

The index used is the sum of TM band3 and band5; the summaries of change that are produced for each pixel are recorded as 6 bands, scaled to fit the 1-byte range of 0-255. The 6 bands are as follows:

- Band 1: Mean index brightness over all dates
- Band 2: linear trend (slope) in brightness over time (scaled)
- Band 3: Quadratic trend in brightness over time (scaled)
- Band 4: standard deviation (sd) about mean (scaled)
- Band 5: residual sd after fitting linear trend (scaled)
- Band 6: residual sd after fitting linear and quadratic trends (scaled)

Details of the processing and scaling are given in section 3 below. Areas that were never classified as having perennial vegetation cover over the period have been masked out and given a zero value in all bands; these include some areas of very thin native vegetation.

The bands can be displayed separately or together to summarise trends and stability of vegetation over time as measured by the index, and in particular to highlight areas with different patterns of change. One recommended display shows positive and negative linear trends in different colours while other bands can be used to examine deviations from these trends (see section 4 below).

A derived file, the 'TrendClass' product, is a simplified one-band summary of the linear trend over the whole period broken into five classes chosen from inspection only. The classes have been determined by numeric changes in the linear trend index without ground or ecological interpretation, and may be interpreted tentatively as follows:

- 1: Major positive trend in vegetation density over the entire period
- 2: Positive trend
- 3: No major change
- 4: Negative trend
- 5: Major negative trend

1. The Area

The region considered is shown in figure below. The region includes the area covered by the Landsat scenes of Kalbarri, Geraldton, Mullewa, Moora, Bencubbin, Jackson, Jurien Bay, Leeuwin, Perth, Kellerberrin, Southern Cross, Collie, Dumbleyung, Newdegate, Pemberton, Mount Barker, Bremer Bay, Ravensthorpe, Esperance and Malcolm.

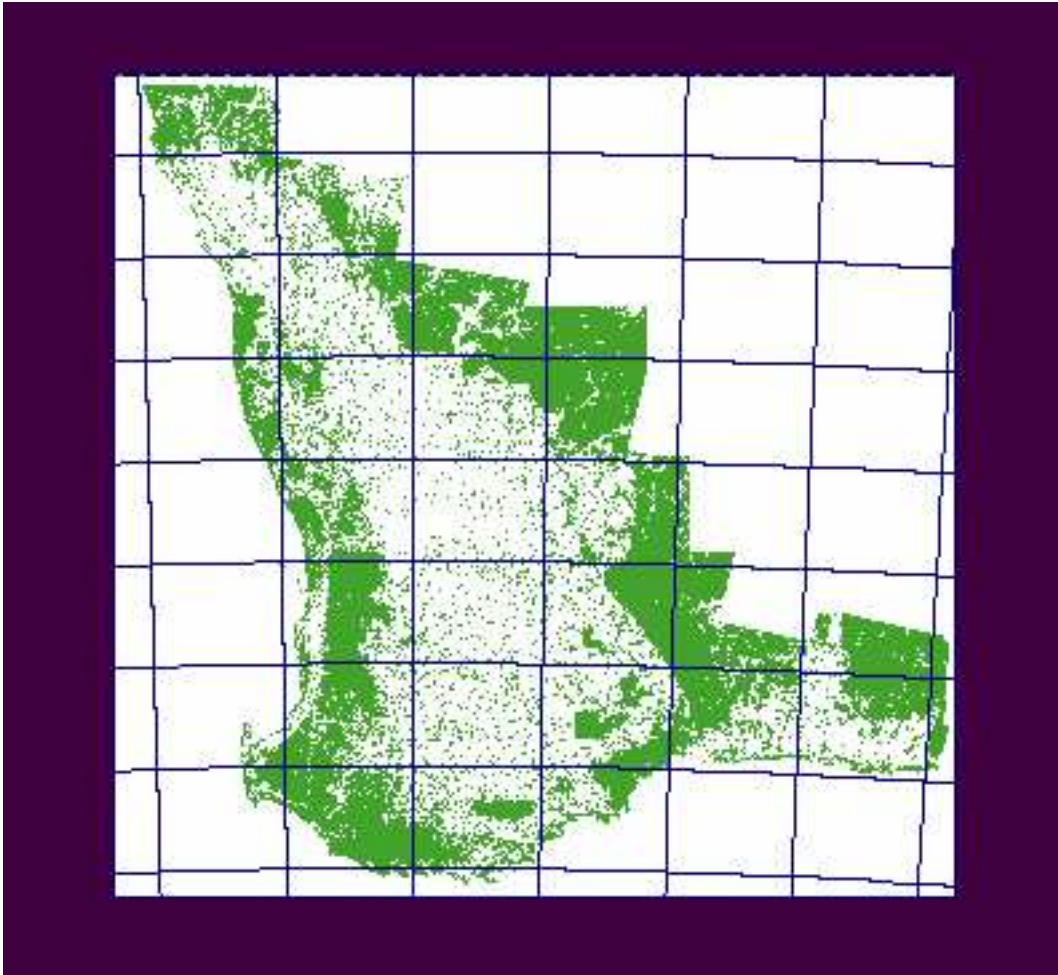


Figure 1: Coverage of vegetation products of the south west region of WA. The grid represents standard 1:250000 map sheets over the region.

To keep files sizes within convenient storage and processing limits, each product is formed in four regions:

- north-west: 300km wide coastal strip from Kalbarri to just north of Perth
- north-east: 350km wide strip east of the above region
- south: from just north of Perth to the south coast, east to Ravensthorpe
- vesp: from Ravensthorpe east to the edge of the cleared agricultural area

2. The Satellite Image Data

The satellite data used to form these products is listed in the “Land Monitor Vegetation Scene Dates” document.

All data were ortho-rectified using Land Monitor DEM and calibrated to the Land Monitor Landsat TM Summer 1994 base prior to processing.

Final products are provided in datum GDA94, UTM zones MGA50 or MGA51 (for ‘rvesp’ region).

3. Outline of data processing methodology

1. Co-register the sequence of images to a common map base.
2. Calibrate the images to a common radiometric base so that the numerical values through time may be compared. The land monitor summer 1994 base has been used.
3. Calculate the chosen index $(b3+b5)/2$ for each time period.
4. Calculate scaled temporal summaries of the index for the period 1990-2008. The linear and quadratic components of the response are estimated independently using orthogonal polynomials (Draper & Smith, ch 5). The calculated trends (e.g. slope over time) and deviations are real numbers. These are rescaled linearly to fit in the 1-byte range of 0-255. Inversion of the scaling will recover the real values if required for quantitative analysis. The six scaled bands are written to a file. Note that the input values are the index values $[(b3+b5)/2]$ at different dates, so the units for (e.g.) the slope are index counts per year.

Table 1: Scaling of bands in the VEGTRENDS file

Band	Scaling and translation applied
1 Mean $(b3+b5)/2$	No scaling; mean of seven index values
2 Slope (linear trend over time)	Lin coeff * $(255/10) + 127.5$ <i>[scales slopes from -5 to +5 into the 0-255 range]</i>
3 Quadratic curvature	Quad coeff * $(255/8) + 127.5$ <i>[scales coefficients from -4 to +4 into the 0-255 range]</i>
4 Standard deviation (SD)	SD * 4
5 SD of residuals: linear model	SDlin * 4
6 SD of residuals: quadratic	SCquad * 4

5. Apply a ‘never-bush’ mask to mask out all areas that were never classified as having perennial vegetation cover over the sequences. These areas include

cleared land, and also other areas of low vegetation cover such as rocks or salt lakes. Some bush areas of consistently thin vegetation will be masked out. This mask has been derived from the image sequence as described in the report on the 'Vegetation Change' product #1.

6. Produce the 'Trendclass' classification by application of a series of thresholds to the scaled linear trend over time (see 4 above). A positive linear trend in brightness corresponds to a decrease in vegetation density, while a slope close to zero (recorded as value 127 in band 2) indicates little change over time in the linear trend summary. The thresholds have been chosen by inspection and interpretation and are relative only.

Table 2: Thresholds to produce the classes from linear trend

Class code in trend class file	Thresholds applied to band2 of vegtrend file – the scaled linear trend (slope) over time
0	Not processed, or masked as never perennial vegetation
1	band2 < 90 Large negative linear trend in brightness – increase in vegetation density
2	90 <= band2 < 110
3	110 <= band2 < 145 slope close to zero, stable <i>[note value of 127 corresponds to a slope of zero]</i>
4	145 <= band2 < 190
5	band2 >= 190 Large positive linear trend in brightness – decrease in vegetation density

4. Data display and guide to interpretation

The vegetation trend data can be displayed in a number of ways to highlight different trends over time. The temporal response of the index values for a patch of vegetation may be smooth over time, or more complex depending on the timing of disturbance and rates of change. For example, clearing result is a sudden increase in brightness within a single time interval, while grazing may result in more gradual and subtle change. If the response is stable or smooth, then the trend bands (mean, linear and quadratic) will provide an adequate summary over time. The residuals (bands 4,5,6) can be used to identify areas where the response deviates from simple trends.

Simple summaries of trends over the period can be made by displaying positive and/or negative linear trends in different colours, with or without display of the quadratic trend. One display commonly used by the authors is to display the positive slopes (decline in vegetation) in red, and the negative slopes (increase in density) in green with suitable

thresholds. A standard display of more complex changes through time is made by assigning those trends to red and blue respectively, and assigning the negative quadratic trends to green; a negative quadratic indicates disturbance followed by recovery of vegetation density in the period (e.g. from fire), and mixed colours in this display indicate different degrees and shapes of overall change and recovery. An ERMapper algorithm to produce this display is provided on the data DVD; it can be easily modified by ERMapper users to alter the display.

The simplified 'trend classification' file can be easily displayed in appropriate colours with the interpretations below. An ERMapper algorithm to produce this display is provided on the DVD. Users should note that this display can be easily understood, but cannot show the range of responses in the trend file. For example, vegetation which is disturbed and recovered during the period may have a small overall linear trend, and hence be displayed as 'relatively stable', clearing at any stage will be identified as class 4 or 5, but will not be distinguished from gradual decline of similar slope over time. The table below suggests a suitable colour display for the classified file; note that a similar display with user-altered thresholds can be created from band 2 of the trend file if desired.

Table 3: Guide to interpretation and suggested display colours for trend classes.

Class code in linear trend class file	Interpretation – of linear trend over the whole period only	Suggested colour for display
0	Mask – never dense perennial vegetation – includes very thin bush, rocks, water and unprocessed areas	White
1	Large increasing trend in vegetation density (i.e. large negative trend in brightness)	Blue
2	Increasing vegetation density	Green
3	Stable or relatively stable	Light grey
4	Decreasing vegetation density	Orange
5	Large decreasing trend in vegetation density	Red

4.1 Interpretation and Limitations

It is important to note that understanding and ecological interpretation of the physical changes shown in these data require other data and knowledge. The trends and interpretations are based on the spectral contrast between perennial vegetation and other cover types. The changes in the index over time at a location indicate physical changes on the ground at that location, and these changes can be associated with changes in vegetation. It is important to note that there are many causes and interpretations of changes in vegetation reflectance, and that the physical changes which result in a similar numerical reflectance response will vary with vegetation type and background. The numerical values, while consistent and comparable through time, have not been calibrated to vegetation density on the ground, and inferences drawn about change at a location should be validated by other means, and may not transfer across vegetation types. For example, while these data may indicate recovery after fire or clearing in terms of reflectance values, no inference can be drawn from these data alone

concerning the type or condition of the vegetation in comparison with the pre-fire vegetation.

The mask of non-perennial vegetation cover types is based also on TM spectral data (Land Monitor Vegetation Product #1), and may have excluded from the data areas of perennial vegetation which remained very thin or highly reflective over the period of the image sequence (1988-2008). Limitations of these masks are described in the documentation for product #1.

It has been noted that the index used – the sum of bands 3 and 5 – is less sensitive to fires in the green forests (on the scarp and the karri and jarrah forest in the south-west). Recently burnt areas in these forest regions are usually very dark in the image data (more dense) and appear to recover very quickly to an equivalent greenness to before the fire. Burnt areas in less green forest tend to appear brighter (less dense) and persist for much longer. A disturbance due to fire in green forests may not show up in the trend data.

4.2 Special Comments – missing data

Where data are missing on one or more dates, the trend data are not directly comparable with areas where the data history is complete. There are two principal reasons for missing data in the historical sequence:

- Cloud-affected areas are masked out prior to processing.
- For some small 'edge areas' of the region, complete historic data sequences were not processed in the Land Monitor I project. These include a small area around Cape Naturaliste, and a wedge-shaped coastal region near Lancelin north of Perth. Historic temporal change information in these regions is limited.

Where data are missing on one or two dates, the trends are calculated and represented in the data. Where data are missing on three or more dates, a 'null' value is inserted in the file. The 'Index History' product #4 can be examined to determine when data are missing from such areas.

5. Limitations and Liabilities

The information contained in these vegetation maps is necessarily based in part upon various assumptions and predictions. The Land Monitor II Project (comprising the Western Australian State Government agencies, Department of Land Administration, Department of Environment, Water and Catchment Protection, Department of Agriculture, Department of Conservation and Land Management, Department of Environmental Protection, Department of Land Administration, and the Ministry of Planning and Infrastructure, the Water Corporation of WA, and the Commonwealth agency CSIRO Mathematical and Information Sciences) accepts no responsibility for any inaccuracies in these vegetation maps, and persons relying on these maps do so at their own risk.

6. DVD Contents: Land Monitor Product #3 – Vegetation Trend

All geo-referenced files are provided in map projection MGA50 or MGA51 with datum GDA94. The pixel resolution is 25 metres.

Raster Files are provided in ERMapper raster format with standard header files (.ers).

For reasons of convenience, data products are provided as mosaics, each of which covers several complete 1:250000 map sheets. Due to data storage limitations, separate mosaics are provided for the North-West, North-East and South portions of MGA50. A separate file is provided for the region in MGA51. Table 1 describes the region covered by each mosaic.

Table 4. 1:250,000 Map sheets in each mosaic region.

Mosaic files	1:250000 map sheets covered Note: The data cover either the full land mapsheet area, or (for mapsheets on the northern and eastern edges of the agricultural region) the agricultural areas within the mapsheet.
LM50_NWEST_VegMask LM50_NEAST_VegMask	Ajana, Geraldton, Yalgoo, Dongara, Perenjori, Ninghan, Hill River, Moora, Bencubbin, Jackson, Perth, Kellerberrin, Southern Cross
LM50_SOUTH_VegMask	Pinjarra, Corrigin, Hyden, Busselton, Collie, Dumbleyung, Newdegate, Augusta, Pemberton, Mt Barker, Bremer Bay, Irwin Inlet, Albany
LM51_RAVESP_VegMask	Ravensthorpe*, Esperance, Lake Johnston*, Norseman (* portions also in the south mosaic)

The DVD contents for each region are:

1. Vegetation trend (6-band) and trend class (1-band) files:

LM50_NWEST_VegTrend_1990-2008.ers [ERMapper image header file]

LM50_NWEST_VegTrend_1990-2008 [BIL format image file]

LM50_NEAST_VegTrend_1990-2008.ers [ERMapper image header file]

LM50_NEAST_VegTrend_1990-2008 [BIL format image file]

LM50_SOUTH_VegTrend_1990-2008.ers [ERMapper image header file]

LM50_SOUTH_VegTrend_1990-2008 [BIL format image file]

LM51_RVESP_VegTrend_1990-2008.ers [ERMapper image header file]

LM51_RVESP_VegTrend_1990-2008 [BIL format image file]

LM50_NWEST_TrendClass_1990-2008.ers [ERMapper image header file]

LM50_NWEST_TrendClass_1990-2008 [BIL format image file]

LM50_NEAST_TrendClass_1990-2008.ers [ERMapper image header file]

LM50_NEAST_TrendClass_1990-2008 [BIL format image file]

LM50_SOUTH_TrendClass_1990-2008.ers [ERMapper image header file]

LM50_SOUTH_TrendClass_1990-2008 [BIL format image file]

LM51_RVESP_TrendClass_1990-2008.ers [ERMapper image header file]

LM51_RVESP_TrendClass_1990-2008 [BIL format image file]

2. Combined 'Ever Bush' mask:

LM50_NWEST_EverbushMask_1990-2008.ers [ERMapper header file]

LM50_NWEST_EverbushMask_1990-2008 [BIL format image file]

LM50_NEAST_EverbushMask_1990-2008.ers [ERMapper header file]

LM50_NEAST_EverbushMask_1990-2008 [BIL format image file]

LM50_SOUTH_EverbushMask_1990-2008.ers [ERMapper header file]
LM50_SOUTH_EverbushMask_1990-2008 [BIL format image file]
LM51_RVESP_EverbushMask_1990-2008.ers [ERMapper header file]
LM51_RVESP_EverbushMask_1990-2008 [BIL format image file]

This image product combines the outputs from 1990 to 2008 to identify areas that have ever been bush (or conversely never been bush). The data for the initial 1988 is considered too unreliable to include in the processing. This mask is used to exclude the 'never' bush area from displays of the vegetation trends products supplied as product 4.

CLASSIFICATION CODES:

0= not processed
 1= never bush
 2= mapped as bush in at least one time period

3) Water mask files:

LM50_NEAST_WaterMask.ers [ERMapper header file]
LM50_NEAST_WaterMask [BIL format image file]
LM50_NWEST_WaterMask.ers [ERMapper header file]
LM50_NWEST_WaterMask [BIL format image file]
LM50_SOUTH_WaterMask.ers [ERMapper header file]
LM50_SOUTH_WaterMask [BIL format image file]
LM51_RVESP_WaterMask.ers [ERMapper header file]
LM51_RVESP_WaterMask [BIL format image file]

The 'water mask' files for the regions are derived from various dates of TM imagery (generally 1998 and 2005). These files are intended for display purposes only to exclude usually inundated areas from the trends displays; they do not represent a definitive mapping of the extent of water bodies at any particular time. Each water mask is a single-band raster file

CLASSIFICATION CODES:

0 = not water
 1 = water

4. ERMapper algorithms:

LM50_NWEST_VegTrend_1990-2008.alg
LM50_NEAST_VegTrend_1990-2008.alg
LM50_SOUTH_VegTrend_1990-2008.alg
LM51_RAVESP_VegTrend_1990-2008.alg

LM50_NWEST_TrendClass_1990-2008.alg
LM50_NEAST_TrendClass_1990-2008.alg
LM50_SOUTH_TrendClass_1990-2008.alg
LM51_RAVESP_TrendClass_1990-2008.alg

Using these algorithms to produce particular colour displays of vegetation trends and trend class data. They can be readily modified by ERMapper users to alter the display.

5. Ancillary Files:

LM50_DateBound_(1988,...,2008).erv [ERMapper vector header file]
LM50_DateBound_(1988,...,2008) [ERMapper vector file]
LM51_DateBound_(1988,...,2008).erv [ERMapper vector header file]
LM51_DateBound_(1988,...,2008) [ERMapper vector file]

LM50_(1988,...,2008)_[region]_cloudmsk.erv [ERMapper vector header file]
LM50_(1988,...,2008)_[region]_cloudmsk [ERMapper vector file]
LM51_(1988,...,2008)_[region]_cloudmsk.erv [ERMapper vector header file]
LM51_(1988,...,2008)_[region]_cloudmsk [ERMapper vector file]

The 'DateBound' vector files contain the polygons which show the boundary of individual image scenes in the mosaic image for each time period.

The 'cloudmsk' vector files contain the polygons which show the boundaries of masked cloud and noise in each time period from 1988 to 2007. If a region name is included in the file name, the data applies to just that mosaic region. If no region is included it applies to the whole of the MGA zone. These two vector file contain the polygons which show the boundary of mosaics. The directory 2008_cloud contains the cloud masks for the 2008 data. These were created for individual images rather than whole mosaics.

All these vectors are in the 'ancillary' directory on the DVD.

6. Documentation:

LM2008_VegTrend_1988_2008.pdf [this report]
Land_Monitor_scene_dates.pdf [summary of images dates]
Scene_Reports_2008 [Directory]

The 'Scene Reports' directory contains the individual rectification and calibration reports for the 2008 imagery.

References

Draper. N. R. and Smith. H. (1981). Applied Regression Analysis. New York. Wiley

Acknowledgements

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