Biodiversity in the Peel-Harvey Catchment

PART FOUR: The data processing model and the technical specifications

by

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*This document is part Four of Four.
The Final Report with all contracted phases completed in June 2004.

Contents (Part Four)

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The data processing model

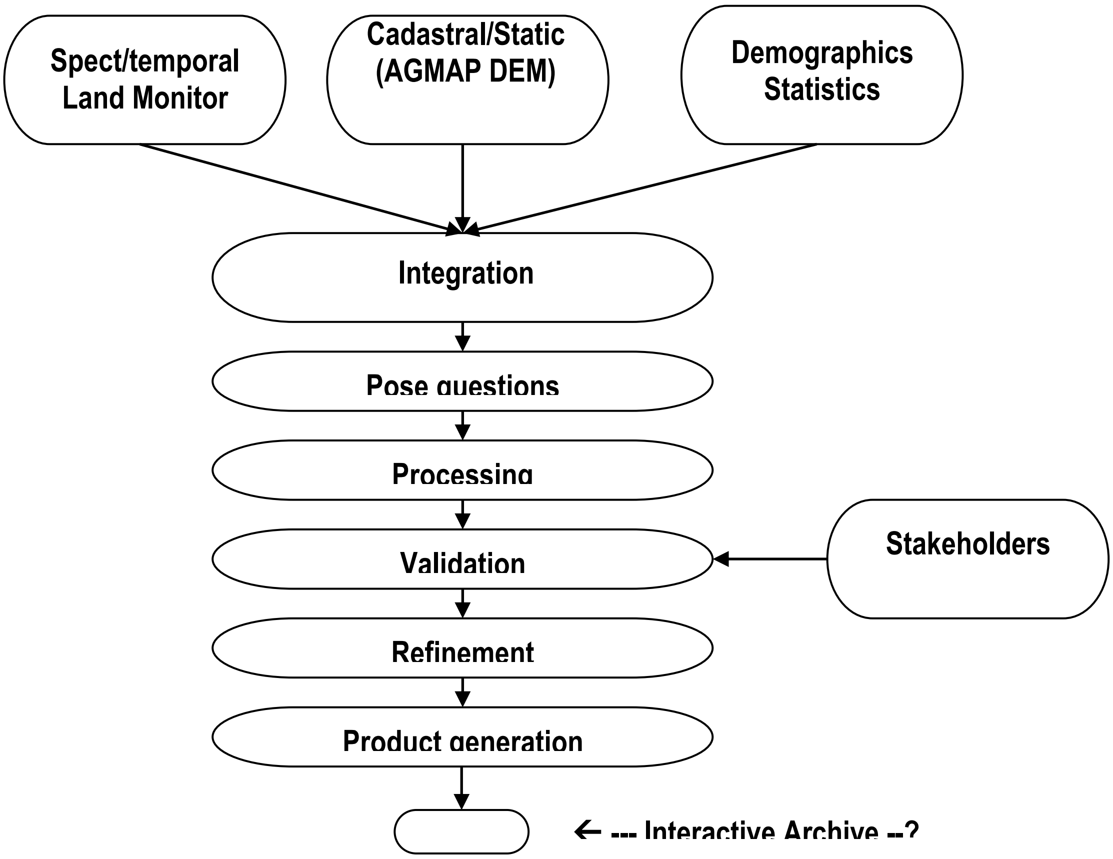

Figure 4.1: The data processing and validation model has for practical purposes been undertaken in three semi-iterative phases: accumulation, integration and validation.

Land Monitor

This is a project of the Western Australian Salinity Action Plan supported by the Natural Heritage Trust. It covers the SW Agricultural regions of WA. It is a coordinated initiative that uses satellite and photographic data coupled with other spatial datasets. Sequences of calibrated Landsat TM and ETM satellite imagery have been produced by the Land Monitor project. Being calibrated, these scenes are suitable for time-series analysis projects.

- Map and monitor changes in the area of salt-affected land from 1988 to present.
- Predict areas at risk from future salinisation.
- Monitor changes in the amount and quality of remnant vegetation and areas of revegetation from 1988.
- Produce highly accurate digital elevation models (DEM) from which 2 metre contour intervals can be created.
- Establish a baseline for continued monitoring.

The products that are of specific interest to assessing biodiversity in the PHC are:

- Vegetation Extent and Change from 1988 to 2003
- Vegetation Index Sequence from 1988 to 2003
- Vegetation History from 1988 to 2003
- Vegetation Trends from 1988 to 2003
- Salinity Monitoring from 1988 to 2000
- Prediction of Areas at Risk of Salinity

Also very importantly, high resolution Digital Elevation Models have previously only been available for a small proportion of the south-west. Through the Land Monitor project, high quality DEMs have been produced using automated techniques for the south-west of WA's agricultural area, accurate to produce 2 metre contours.

Other non-core products can also be produced that will have relevance to the Biodiversity Project despite being very large data files include:

- Ortho-photos and satellite Imagery merged.
- Ortho-photos with contours down to 2 metre intervals.

AGMAPS

AGMAPS is a range of CD-ROM based products for integrating and extending agricultural land development and management information. AGMAPS is packaged land resource maps and related technical information. There are three basic AGMAPS products being developed for areas throughout the agricultural region of Western Australia. These are the Land Profiler, the Land Manager and the Land Use Explorer. Demonstrations of the new Land Profiler and Land Manager

Land Profiler CD-ROM
This is the base product of the AGMAPS range and it contains the following:

- Maps of soil-landscape units and land use capability (e.g. horticulture, grazing and cropping capability).
- Descriptions of broad systems and detailed land units.
- A guide to development potential and management issues for land units.
- Links to explanatory information.
- Maps showing remnant vegetation and pre-1750 vegetation (optional).
- Description of vegetarian complexes

Land Manager CD-ROM
This product contains the same features as the Land Profiler plus:

- Maps showing areas of land degradation risk.
- Land management units (LMUs) identified.
- Issues and options for LMUs identified.
- Linkages to over 150 land management guidelines.

Land Use Explorer CD-ROM
This product contains the same features as the Land Manager plus:

- Land capability maps for specific agricultural land uses.
- Development information (e.g. Farmnotes) provided for specific land uses
- Financial information including enterprise budgets.
- A prototype of this product is planned for the Peel-Harvey region commencing in the 2003/2004 financial year.

Digital Elevation Model

This file is to be provided with Digital Elevation Models created as part of the National Dryland Salinity Program under the guidance of the Land Monitor Group.

DATA FORMATS
The files provided are in ASCII format with X , Y and Z coordinates.

PHOTOGRAPHY SCALE
Grid elevation data provided has been generated from 1:40,000 scale black and white images from either film diapositives or digital images metrically scanned at 14 micron intervals.

AEROTRIANGULATION
Aerotriangulation was carried out using a well designed survey control layout with additional GPS coordinates for photography exposure stations.
The observation process was generally performed using image correlation techniques with some observations using pugged film diapositives on a ZEISS analytical workstation.
Adjustment of blocks were performed using either MatchAT or PATB software.

DIGITAL ELEVATION DATA
Data has been generated using digital photogrammetric workstations (DPW) softcopy systems.
The data has a grid layout with a 10 metre horizontal spacing on the Australian Map Grid (AMG)
Grid data using automated image correlation techniques has an expected vertical accuracy of +/-1.5 metre at the 90% confidence level.
Due to the automated processes used, isolated large errors may be found in this data due to poor correlation in paddocks, large rock outcrops, sharply rising breakaway country, sand dunes and heavy tree covered areas.

Vegetation Extent and Change 1988-2002

The methodology that was been used to produce the vegetation monitoring product known as "Vegetation Change 1988 - 2002" from the Land Monitor II Project as reported by J.L.C. Chia & J.F. Wallace, CSIRO Mathematical and Information Sciences, August 2002. The data product is an update to 'summer 2002' of the 'Vegetation Extent and Change product 1988-2000' from the Land Monitor Project.

This product is a series of classifications of the extent of perennial vegetation provided as an eight-band raster file. Each band represents a date from 1988-2002 at a 2-year interval.

The steps used to produce the series of vegetation maps are listed below. This is the standard methodology used for monitoring vegetation change.

1. Co-register the images to a common map base. This allows ground sites to be traced through time and the satellite data to be compared with ancillary map data.

2. Calibrate the images to a common radiometric base.

3. Produce 'vegetation probability' map from TM imagery (year 2002) using the CMIS index-threshold approach that produces measures of confidence of 'perennial' and 'non-perennial' vegetation at each date. The approach uses two indices, TM band3+band5 (index1), and a band4-band3 'greenness' index (index2). The threshold values for these indices are known to vary spatially. For Index 1, smoothed threshold surfaces which defined upper and lower 'certain-perennial' and 'certain non-perennial' cover types were fitted to the whole south-west region. For Index 2, a fixed set of thresholds was defined for each scene. Data values that fall between the thresholds were given a probability (0-100%), and scaled linearly with distance relative to the thresholds.

4. Process the sequence of cover class probabilities from all dates (1988 – 2002) using "Conditional Probability Network" (CPN) approach (Caccetta 1997, Kiiveri and Caccetta 1998). This approach uses the probabilities from neighbouring dates to modify the probabilities of each pixel. The effect of the method is that it 'smooths out' sudden changes (e.g. from cultivation), and reduces uncertainty and errors in the individual dates. The result is a series of modified probability images for each date.

5. From the probability images produced in step 4, "yes/no bush masks' for each date were formed, using probability thresholds of 50% for each year, except for the final year, where a probability threshold of 70% was used based on the recommendations of Renzullo (2000).

6. Produce a separate 'water-mask' mosaic from existing data for overlay and map production.

Accuracy and Limitations of the data

The perennial vegetation masks are derived from reflectance signals detected by Landsat TM, and depend on a contrast between vegetation and other cover types (soil, crops, bare rocks etc). The thresholds for classification of bush have been derived from interpretation and comparison with earlier maps where detailed air photography was used.

This classification as 'perennial vegetation' relies on the spectral contrasts of cover types resulting from physical differences on the ground, and effectively requires a certain density of vegetation. Hence thin, scattered vegetation with a high proportion of soil background may be omitted. Certain dense but highly reflective vegetation types may also be omitted, but no cases of such omissions are known.

In particular, bare or very thin areas within bush remnants will not be classified as 'perennial vegetation cover'. Common examples are tracks, rocks, fire-scars, and salt-affected vegetation.

Hence the areas mapped as vegetation at particular dates will not necessarily correspond to administrative definitions of reserves etc.

There is a time lag in detection of re-vegetated areas, which varies with region and vegetation type. Re-vegetated areas will not be mapped until the vegetation achieves a sufficient density. Hence some recent, slow-growing, or sparse re-vegetated areas will not be detected.

Errors of commission may occur when other land covers give a similar spectral response to perennial vegetation. The temporal smoothing of the CPN removes most of the transient cultivation effects that might cause these errors. However, there are cases where errors of commission may remain after the CPN processing. Examples include cleared areas with persistent dark soil, and in also lake fringes and normally dry lake surface where changes in water level have dramatic effects on the cover and reflectance. Errors that are incurred in these areas may result in incorrect mapping of change in lake edge vegetation. However, these errors have not been removed by manual digitising as some may be real vegetation change.

Special comments

- Cloud-affected areas have been masked out prior to processing. Where clouds are masked in the latest imagery, the vegetation cover for the 2002 layer is inferred from the historic sequence. Cloud mask vectors for present update study (year 2002) are provided with product CD.

- The mapping of perennial vegetation has been assessed in rural areas. It is less reliable within urban areas, especially Perth and its suburbs, because of the variation in background and small-scale variation resulting in mixed pixels. Interpretations of cover and change within the Perth urban area should be made with caution.

- 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.

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.

Vegetation Trend 1988-2003

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, developed by X. L. Wu, J. L. C. Chia and J. F. Wallace, CSIRO Mathematical and Information Sciences, July 2003

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 nine summer dates of calibrated Landsat Thematic Mapper data (TM) data, at approximately 2-yearly intervals from 1988-2003 except the last two dates, which only have 1-year interval.

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 where the 6 bands are defined as follows:

Band 1: Mean index brightness over all dates
Band 2: linear trend (slope) in brightness over time (scaled)
Band 3: Quadratic trend (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 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

A derived file, the 'Trend class' 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

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 current date (year 2002) and combine it with the previous 7-date index file, thereby producing a 8-date index file.

4. Calculate scaled temporal summaries of the index over time. 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 *[scales slopes from –5 to +5 into the 0-255 range]*
3 Quadratic curvature	Quad coeff * (255/8) + 127.5 *[scales coefs from –4 to +4 into the 0-255 range]*
4 Standard deviation (SD)	SD * 4
5 SD of residuals: linear model	SDlin * 4
6 SD of residuals: quadratic	Sdquad * 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 'Trend class' 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 *[note value of 127 corresponds to a slope of zero]*
4	145 <= band2 < 190
5	band2 >= 190 Large positive linear trend in brightness – decrease in vegetation density

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 will 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 CD. 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

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 (1988-2002). Limitations of these masks are described in the documentation for product #1.

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 two 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.

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.

Vegetation Density

CONDENSED DRAFT ONLY

Vegetation Density Estimate Map for the
South West Agricultural Region of Western Australia

A study from the Land Monitor Project by

Joanne Chia[1] , Peter Caccetta[1], Graeme Behn[2] and Dave Bebbington[2]

December 2003

The project uses satellite imagery and information on ground vegetation cover to produce a result that can be interpreted to represent vegetation cover density for the South West region of Western Auatralia. Behn *et al,* (2001) showed measurements of Projected Foliage Cover (PFC), using ortho-photography, can be useful in the processing of satellite imagery to provide these outcomes.

Methods

Estimates for the spatial distribution of cover density are made using Landsat satellite TM observations extrapolated from a limited number of photo-interpreted *ground* sites. Landsat TM imagery over the project region was stratified into broad bio-geographic zones that best reflect vegetation variations prior to processing. Within each zone sites of high and low vegetation densities were selected.

In general, no training site was sampled in zones where ortho-photo validation was not available. For each sampled site, the following data were recorded.

- zone number
- vegetation type (non-forest, medium forest, low-forest or plantation)
- estimated vegetation density in percentage

For each training site, the mean band value of all 6 of the Landsat Thematic Mapper bands was extracted from corresponding satellite image data with date of acquisition closest to date of the ortho-photo used to pick the site. The band values are used to predict vegetation density in a predictive model. A total of 593 training sites were sampled

The software “Cubist” was used to build the predictive models from data. More information on Cubist can be found at the website http://www.rulequest.com/ .

Cubist is a tool that generates rules to form predictive models from data. In Cubist, each data point concerns one case and its attributes. Each case has a target value (which is like the dependant variable in a regression model), and relevant attributes that give information to help predict the target value.

Cubist estimates the target value by building a model that contains one or more rules, where each rule is made up of the attributes in a linear expression. Thus, a Cubist model resembles a piecewise linear model. Prior to implementing Cubist, training sites with zero density were removed. In this project, Cubist was implemented with vegetation density as the target value, and the zone numbers and band values of band 2 – band 6 as attributes.

Comments

[1] CSIRO Mathematical and Information Sciences

[2] CALM

- The average error magnitude for both models (1) and (2) are 11.8 and 12.4 respectively.

- The relative error magnitude is the ratio between the average error magnitude and the error magnitude results from always predicting the mean value. This value should be less than 1 for models to be useful for prediction. The relative error magnitude for both models (1) and (2) are 0.59 and 0.66 respectively.

- The correlation coefficient is a measure of the agreement between the actual values of the target attribute and those predicted by the model. That is, a correlation coefficient of 1 indicates total agreement. The correlation coefficients of models (1) and (2) are 0.76 and 0.72 respectively. These values indicate rather good agreement between the actual and the predicted values.

- The predicted densities are dependant upon the data recorded for the training sites. In this project, the vegetation density values recorded are based on the judgement of the operator interpreting the ortho-photos. Field sampled data was not available at this stage of the project, and such data should be considered for validating the product. Thus the densities recorded (and hence the predicted densities) may differ from the ground truth values.

Limitations and Liabilities

The information contained in this vegetation map 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 Information, Department of Environment Protection, Water and Rivers Commission, Agriculture Western Australia, Department of Conservation and Land Management, Department of Planning and Infrastructure, Water Corporation, and the Commonwealth agency CSIRO Mathematical and Information Sciences) accepts no responsibility for any inaccuracies in this vegetation density estimate map, and persons relying on these maps do so at their own risk.

Connectivity Index

The spatial relationship of patches of remnant vegetation is as important as their size vegetation type, condition and landscape morphology. Avarian, marsupial and floral corridors are important. Penetration into natural vegetation from cleared land by predatory animals or variant processes often has known spatial limits.

A product has been developed that allocates a specific numeric value to each remnant that shows on the vegetation mask to be connected at the spatial resolution of the Landsat satellite picture elements (25 x25 m)

Other such products allocate values on non-connected remnants based on their proximity to another remnant. This product has not been evaluated in the field validation phase of the project but it's inclusion may be worth consideration.

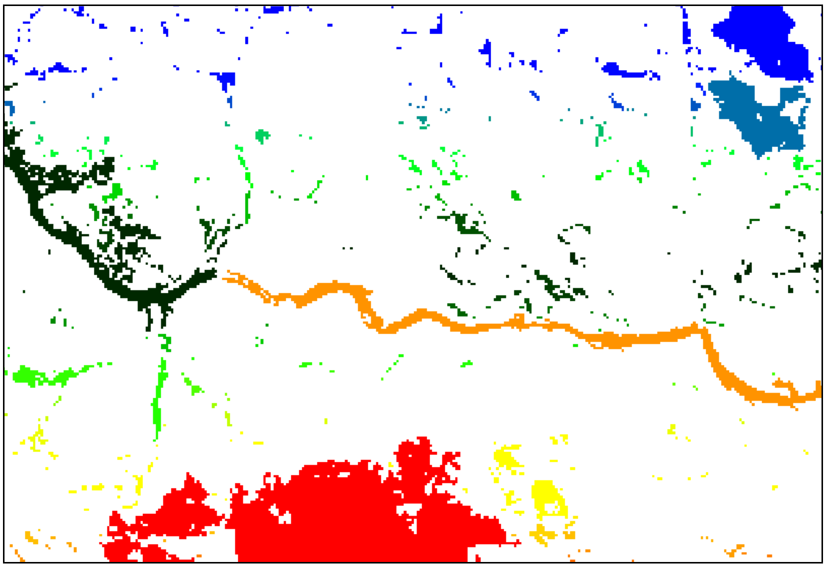

Figure 4.2: An example of the Connectivity Index Image for the Williams River Area.

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