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Methodology for Correlating Vegetation Extant Data with Forestry Canopy Change Data

Author:
Anthony Greenhalgh
Central West Catchment Management Authority, Dubbo, NSW

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Purpose

The purpose of this report is to briefly demonstrate how time series datasets can be used to aid correlation of vegetation extent over time. The methodology tests the relationships between indicators of the 2006 Vegetation Extent Mapping, composition and configuration of the Central West Catchment Management Authority (CWCMA) against 1972-2011 satellite imagery depicting forest canopy change and extent.

Background

The CWCMA was asked to participate in a National Environmental Accounts Pilot Project conducted by the Wentworth Group of Concerned Scientists. The CWCMA's participation involved submitting data for several environmental indicators namely, vegetation, flora and fauna, and floodplain accounts.

Data Sources

The spatial data given to the CWCMA was provided by the Department of Climate Changes, National Inventory Systems and Reporting Branch, based in Canberra. Their Geospatial Unit provided the actual data in various forms for the CWCMA to analyse. Naturally, the data has inherent limitations and a scale factor, and is a fit-for-purpose product. This means that the data provided to the CWCMA provides a straight 0 or 1 answer in the raster table, i.e. canopy cover or not. The data is at a resolution of 1:250,000, and is therefore broad scale.

The CWCMA vegetation study of 2006 was used to establish the base reference condition value for the vegetation indicator. The vegetation extant layer was used to generate areas of vegetation types based on Keith classes.

What is Being Measured

It has been noted that the satellite sensor actually sees the reflected electromagnetic radiation from the foliage and other surfaces. Foliage cover is defined as the percentage of the site occupied by the vertical projection of the foliage and branches, while projected foliage cover is the percentage of the site occupied by the vertical projection of the foliage only. Use of the measurement of foliage as the basis for describing the presence, distribution and density of woody crowns is, therefore, likely to be more accurate than simply using canopy or crown cover. For this study, Australia's current national forest definition is used. See **Appendix 1**.

A forest is defined as having a minimum of 20% tree crown cover and a minimum height of two metres at maturity. A minimum area of 0.2 hectares is also imposed for inclusion as forest. Note that canopy cover, or crown cover, is usually assumed to be a measure of the coverage of the outer boundary of the crown and everything contained therein is assumed to be completely covered by foliage (Furby, 2002).

The Department of Climate Change aimed to explicitly identify all areas of forest cover that are evident on the imagery between 1972 and 2011, down to patch sizes commensurate with the spatial frequency and resolving capability of the available imagery. It will indicate the status of these patches as at 1990, noting whether they are unchanged, no longer detectable (deforested) or new (reforestation or afforestation) at any time over the period of analysis. Estimation of change in the biomass and soil carbon pools was not done directly from the remote sensing program. Ancillary data to describe soil and biomass condition was used, along with the age, area and location data from the remote-sensing program, to support calibrated soil carbon and biomass models. Further information on their methodologies for deriving the datasets can be read at the following links: http://pandora.nla.gov.au/pan/102841/20090728-0000/www.climatechange.gov.au/ncas/reports/pubs/tr09final.pdf, (Furby, 2002).

Known Errors in Satellite Data

EROS (1972 to 1980) and ACRES (Landsat MSS - 1979 to 1991, Landsat TM - 1987 to present) are the major archives of potentially suitable images. Other archives of images perceived as potentially suitable include the Landsat MSS collection of Dean Graetz of the 1980's and early 1990's, held by the Environmental Resources Information Network (ERIN) of Environment Australia. However, these images were found to have 100 megapixel resolution and hence are unsuitable for use in this project.

Known limitations in the ACRES Landsat MSS archive in the time interval of interest to this project (1979-1988) include:

- 1982: Landsat-3 MSS suffered from late line problems. These datasets, while listed in the catalogue, were not transferred to new tapes and data may no longer exist; and
- 4 October 1984 to 29 April 1991: Landsat-4 MSS data were unavailable as the tapes have been recycled.

Known limitations in the ACRES Landsat TM archive in the time interval of interest (1989-present) include:

- Poor quality data was recorded in the period from 28 March to 15 May 1989.
- No data was recorded in the following periods: 19 October to 31 October 1989; 6 December to 7 December 1989; 18 December 1989; 4 January to 21 February 1990; 1 March 1990 for paths 92 and 108; 3 March to 21 March 1990 for paths 88, 90, 97, 104, 106 and 113; and Some data was recorded from test passes during the antenna upgrade. The available data were:
  - Path 113: 31 January 1990
  - Path 111: 2 February 1990
  - Path 102: 3 February 1990
  - Path 112: 9 February 1990
  - Path 94: 10 February 1990
  - Path 110: 11 February 1990
  - Paths 92 and 101: 12 February 1990

Known Limitations of CSIRO Model

The products from the land cover change mapping provided the location, spatial extent and time of forest to non-forest transitions (and the reverse) between 1972 and 2000 that were input into the carbon modelling process. However, the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines require that only carbon stock change that is associated with directly human-induced land use change be included in the national account. The land cover change products had to be attributed so that the areas where the cover change was not a land use change or where the change was not directly human-induced could be excluded.

Masks of the areas affected by fire were created as part of the thresholding processing. A tenure mask was used to exclude tenures that did not reflect a land use change (eg state forestry and national parks). However, further masks needed to be created to exclude areas of land cover change attributable to factors such as dieback, salinisation, droughting and seasonal flushing where there was no clear land use change after the deforestation or regrowth event. Areas of privately owned forestry operations were not included in the tenure masks; therefore further masks were also created to exclude areas of land cover change attributable to forestry activities.

Examples of non human-induced land cover change (annual variability) include (but are not limited to):

- Seasonal fluctuations in forest cover in rangelands areas (drought and dominance by annuals in wet seasons);
- Fire and associated recovery (in forest and non-forest areas);
- Seasonal fluctuations in cover along salt-lake chains (spring versus summer);
- Decline in forest cover due to salinity or erosion;
- Variations in forest cover due to over-grazing or destocking;
- Fluctuating water levels in wetland areas;
- Terrain illumination effects; and
- Misclassification due to sensor limitations in the MSS time slices.

Examples of directly human-induced land use change include (but are not limited to):

- Deforestation of grazing lands for an activity other than the original grazing, eg cropping;
- Deforestation of forest cover in an area of size and shape that make it obvious that trees have been cut down rather than lost through natural attrition or density variations (eg an entire clump of forest cover is completely removed or partially removed in a regular pattern rather than speckle at the edges of existing cover) that does not recover;
- Urban expansion or infrastructure development (eg roads, dams, power lines and airstrips); and
- Planting of trees for commercial or conservation purposes.

The strategy for performing this attribution (or masking) depended on the predominant level of human activity in each map sheet. In the intensive land use areas of Australia the majority of the land cover change is directly human-induced land use change. In these areas, masks were created to exclude areas of land cover change that did not meet the accounting requirements. In the rangeland areas of Australia, the majority of the land cover change is seasonal variation in vegetation cover. In these areas, masks were created to include areas of directly human-induced land use change that meet the accounting requirements.

Method of Attributing

Each individual exclusion polygon had to have an attribute identifying the basis on which the area was excluded. The list of identifiers is:

1. Irrigation areas where wet paddocks can look spectrally identical to forest cover **(IRR)**;
2. Fluctuating water levels in wetland areas **(WET)**;
3. Seasonal fluctuations in forest cover in rangelands areas (drought and dominance by annuals in wet seasons) **(RANGE)**;
4. Seasonal fluctuations in cover along salt-lake chains (spring versus summer) **(SALT)**;
5. Decline in cover due to salinity or erosion **(DEGRAD)**;
6. Terrain illumination effects **(TERR)**;
7. Misclassification due to sensor limitations in the MSS time slices **(MISC)**; and
8. Wetness/greenness fluctuations not in rangelands areas **(GREEN)**.
9. Mask polygons were not required in areas already masked by fire or tenure.

The polygons enclose the entire area of change that is not directly human induced land use change in each local region. No individual polygon enclosed any area of change that was likely to be directly human-induced land use change if it could be avoided. The polygons adhere to the natural boundaries of the area of carbon change being masked (i.e. do not contain extensive areas with no carbon change). The areas masked (and their attributes) meet seamlessly at the boundaries between all adjacent map sheets being attributed.

Only one attribute identifier was associated with each polygon. Areas being excluded for different reasons were digitised in separate polygons.

If it was impossible to avoid including small areas of directly human-induced land use change in the exclusion polygons, an additional vector file containing polygons identifying areas of land use change was treated inside the exclusion polygons.

Polygons that should not be excluded were created. The human-induced change was digitised as closed polygons contained in a single vector file per 1:1,000,000 map sheet tile in either ARCINFO export or DXF format. Attributes were not required for each individual polygon in this file. It was not necessary to digitise all directly human-induced land use change. It was necessary only to specifically identify those areas of directly human-induced land use change that were unavoidably contained inside the exclusion polygons.

Central West Catchment Management Methodology

The Federal NCAS Forestry Extent dataset was used as the basis for determining a trend of vegetation change over time. The NCAS dataset contained a set of 18 raster images from 1972 to 2011, covering mapping sheets, sh55, sh56, si55 and si56. The dataset was supplied as raw raster images, and unprocessed.

A simplistic view of the methodology for creating the final dataset is shown below:

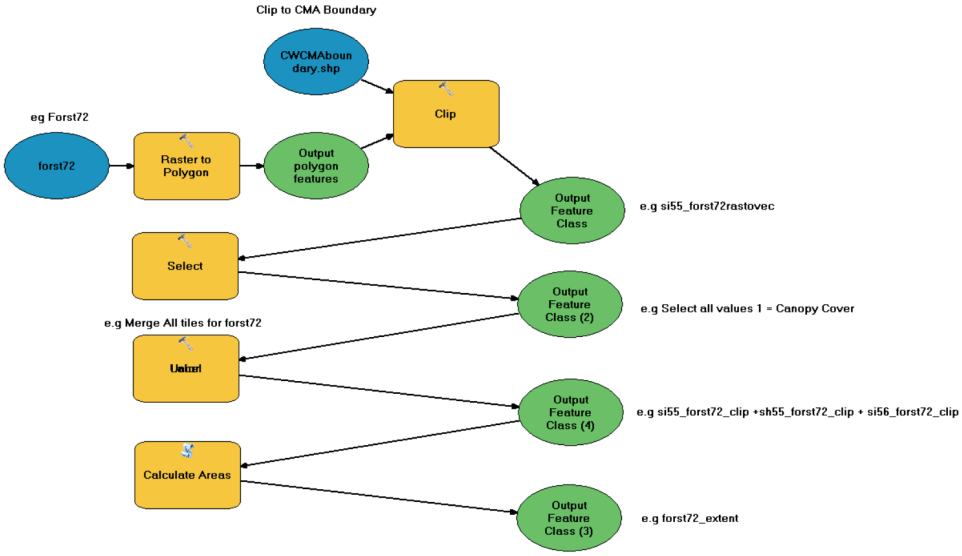


Figure 24: A simplistic view of the methodology for creating the final dataset

Once final mapping layers were created, an .avi (or windows media file) was created to animate the extent of cover change between 1972 and 2011.

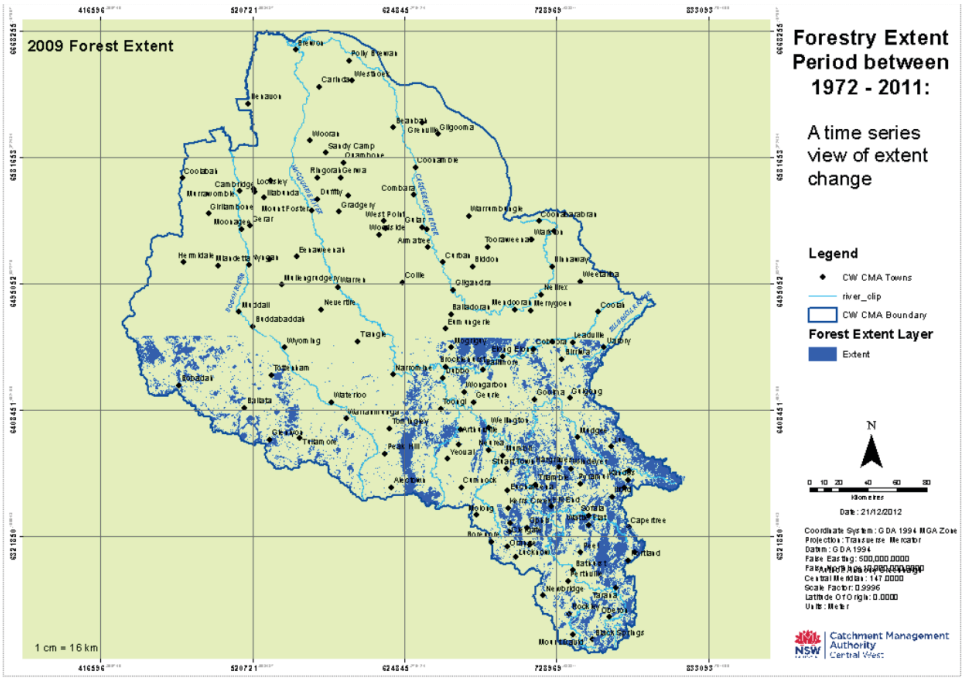


Figure 25: .avi or windows media file that was created to animate extent of cover change between 1972 and 2011

A standard layout view was created in ArcGIS10 to animate each time series sequence. Each map layout view was saved as a bitmap image. Using the ArcGIS tool – Raster to Video, a movie file was made. The ArcGIS tool points to a folder containing the series of images and automatically sequences them. It was essential that all images were the same scale, orientation and extent. Symbology was also consistent across all images. The purpose of the animation is to visually observe how change has occurred over time.

The image below depicts correlation of tree canopy (blue) with the CWCMA vegetation extant layer (Orange). The blue correlates very well with the orange. The tree canopy overlays with the BVTs very well.

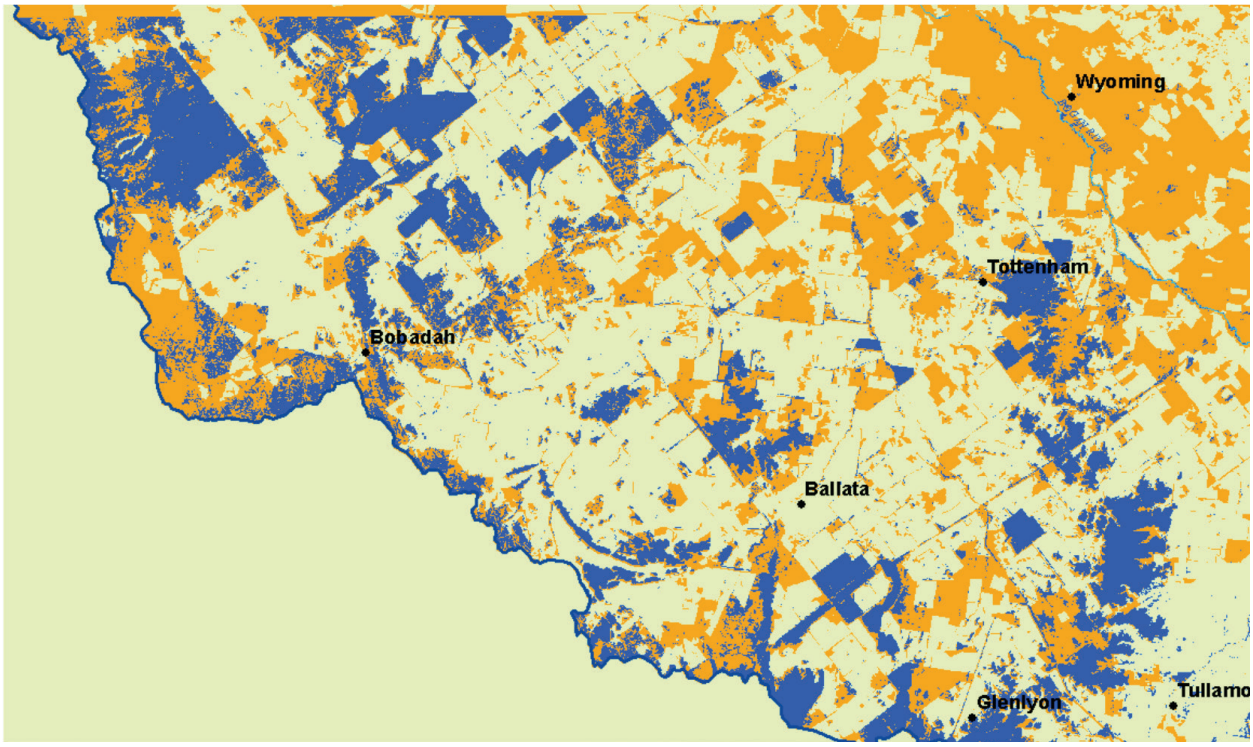


Figure 26: Correlation of 2006 data to time series 2006 data

Analysis and Discussion

The final area calculations made on the final layer for each year are shown below in **Table 16**. The results show that there has not been a significant change in canopy extent over the years. Given our understanding that agricultural activities have impacted on ground cover, and that over time since European settlement vast areas of land have been cleared, during the period between 1972 and 2011 there appears to be no real change in forestry canopy. It must be emphasised this is based on the best data available and that these results could be highly inaccurate given the simplistic method of processing.

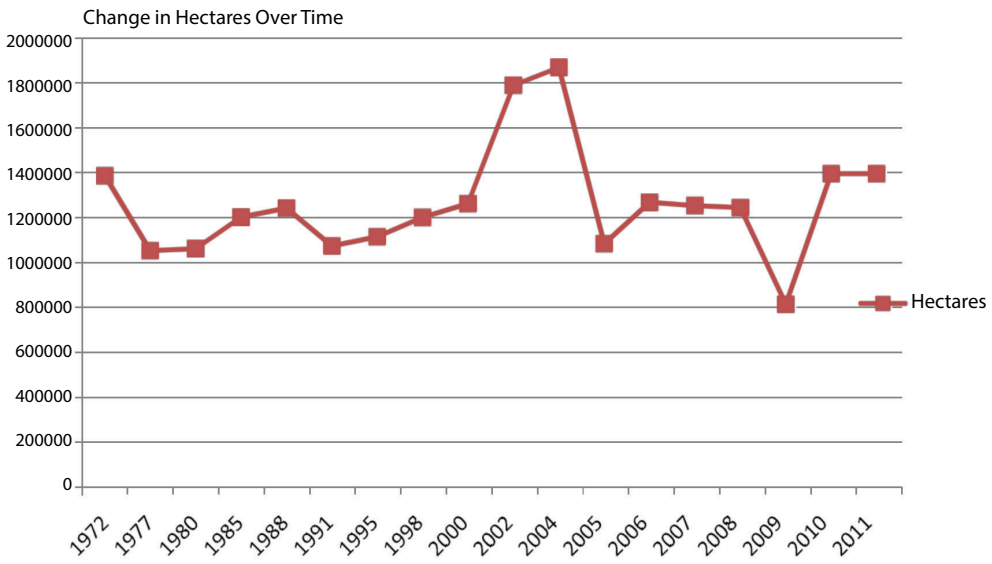
However, the results shown do give an understanding of the trend of forest canopy extent. When overlaid with the Central West CMA 2006 Vegetation dataset (i.e the vegetation extant layer), there is definite correlation between canopy extent at year 2005 and the CMA BVTs. Given that the time series data is only a snapshot over 40 years, it was expected that the extent of forest canopy be denuded more. As shown in **Figure 26**, the Central West Study of 2006 and the Broad Vegetation Types (BVT) correlate well with the blue canopy data for Year 2006. The orange is more extensive and covers all vegetation types. Clearly the blue overlaps the orange. This provides a good indication and benchmark for measuring the *Econd* values for vegetation in the CWCMA.

In the years 2002 and 2004 there are spikes in the dataset. These high points may be attributed to higher rainfall in previous years contributing to higher growth in vegetation and canopy. MODIS satellite data indicates that between the years 2000 and 2004, rainfall was reasonably significant over the region, hence elevated vegetation or greenness occurs, and is depicted in the satellite imagery reflectance values.

Inadequate data at Year 2009 contributed to the dip in the graph (See **Appendix 2**). There was no dataset made available for the Sh55 sheet which covered the top half of the CWCMA area. If data was made available, one would assume that the graph would be within the bounding envelope of the surrounding year's hectare values.

Table 16:

Year	Hectares
1972	1386373
1977	1053291
1980	1062150
1985	1202018
1988	1241992
1991	1074113
1995	1115117
1998	1200887
2000	1261885
2002	1789034
2004	1868616
2005	1083904
2006	1267736
2007	1253746
2008	1244477
2009	814169
2010	1395453
2011	1395364



Summary

The graph depicts a gently diminishing trend line from significant cover in 1972 to 2008, then a gentle rise in 2009 onwards. It indicates that there was generally no net change in forestry canopy or extent over the period between 1972 and 2011.

As shown in the overlay image described in **Figure 26**, the blue areas correlate well with the BVTs of the 2006 Central West Study. The methodology used in this report has highlighted that using time series data has reinforced the values of the base reference dataset (vegetation extant) for measuring *Econd* value for vegetation.

Appendix 1 – Metadata NCAS Project

Custodian: Department of the Climate Change and Energy Efficiency

Publication Date: January 2012

Abstract

Landsat satellite imagery was used to discriminate between forest and non-forest cover. A forest is defined as vegetation with a minimum 20 per cent canopy cover, potentially reaching 2 metres high and a minimum area of 0.2 hectares.

Forest change over each transition period is derived by differencing the forest cover in consecutive epochs and then applying specific policy parameters. The aim is to identify areas of land use change relevant to international carbon accounting obligations.

Satellite imagery was sourced from Landsat MSS, TM and ETM+ for the following epochs:
1972, 1977, 1980, 1985, 1988, 1989, 1991, 1992, 1995, 1998, 2000, 2002, 2004, 2005,2006, 2007, 2008, 2009, 2010 and 2011.

See National Carbon Accounting System (NCAS) technical Report No. 9 *Land Cover Change: Specifications for Remote Sensing Analysis for details of the analytical methodology.* http://pandora.nla.gov.au/pan/102841/20090728-0000/www.climatechange.gov.au/ncas/reports/tech09.html

Defined region: Australia

Date range: 28 July 1972 - 9 September 2011

Maintenance and update frequency

Each update of the National Carbon Accounting System results in a new suite of products from the entire time series. Changes are also undertaken due to the implementation of a Continuous Improvement and Verification Program.

Access constraint: By arrangement with the CWCMA.

Conditions of use

The data were designed for the purpose of providing a nationally consistent analysis of human-induced change in forest extent. Use for other purposes should consider the appropriateness of the data.

Lineage

The probability of forest cover is mapped across Australia at a 25-metre resolution from Landsat imagery. Regionally appropriate thresholds are placed on these forest probabilities to create forest extent data. Differencing consecutive epochs allows the creation of both deforestation and regrowth layers.

The attributed change products identify human-induced change resulting in a change in the land use such as forest clearing for agricultural purposes. It does not include temporary changes to the forest such as fire.

Cell size: 0.00025 degrees (~25m)

Coordinate system: Geographic; Datum: GDA 1994

Positional accuracy

The positional accuracy of these data is assumed to be around 10 metres based on an assessment of the underlying registration base imagery.

Logical consistency

The method used for processing the data was standardised across all areas. Systematic error between operators was checked and corrected.

Attribute completeness

Forest extent is only attributed as present where certainty levels are high, thus eliminating any possibility of false change records. The statistical probability of a forest being confidently attributed as present requires two subsequent epochs to be present in the analysis. Therefore, the latest epoch in the analysis is a conservative (interim) estimate of forest extent.

Completeness

Geographic completeness is defined by the available Landsat images for each epoch. This is complete for Australia from 2000 – 2006, and maps of previous coverage are available in NCAS technical report 9 (see abstract). The 2007, 2008, 2009, 2010 and 2011 data is currently only available for the intensive land use zones (shaded yellow on map).

Metadata contact

GIS Manager
National Carbon Accounting System - NCAS Department of Climate Change and Energy Efficiency
GPO Box 854
CANBERRA ACT 2601
Phone: (02) 6159 7193
Fax: (02) 6159 7014
NCAS-GIS-RS@climatechange.gov.au

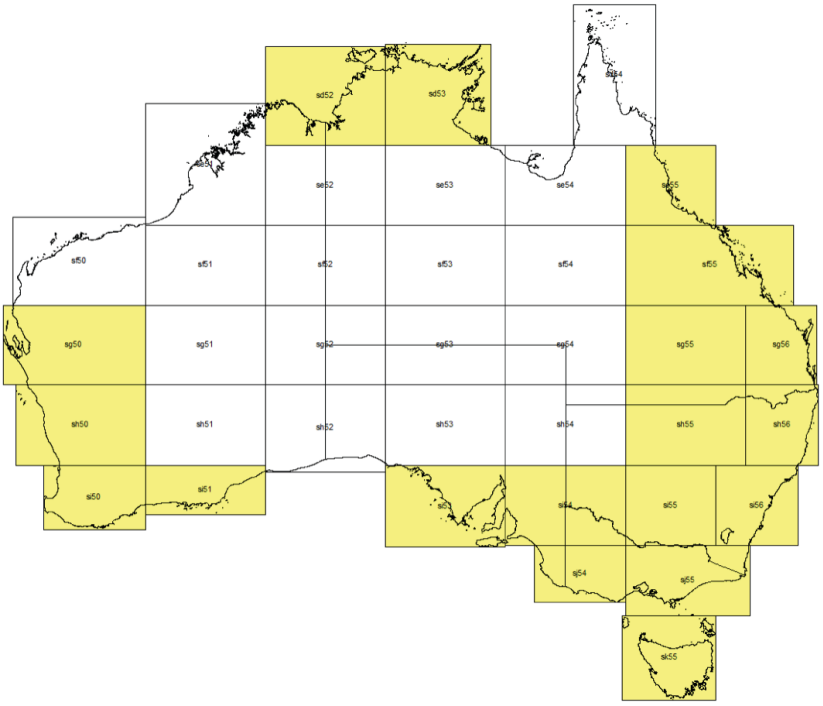
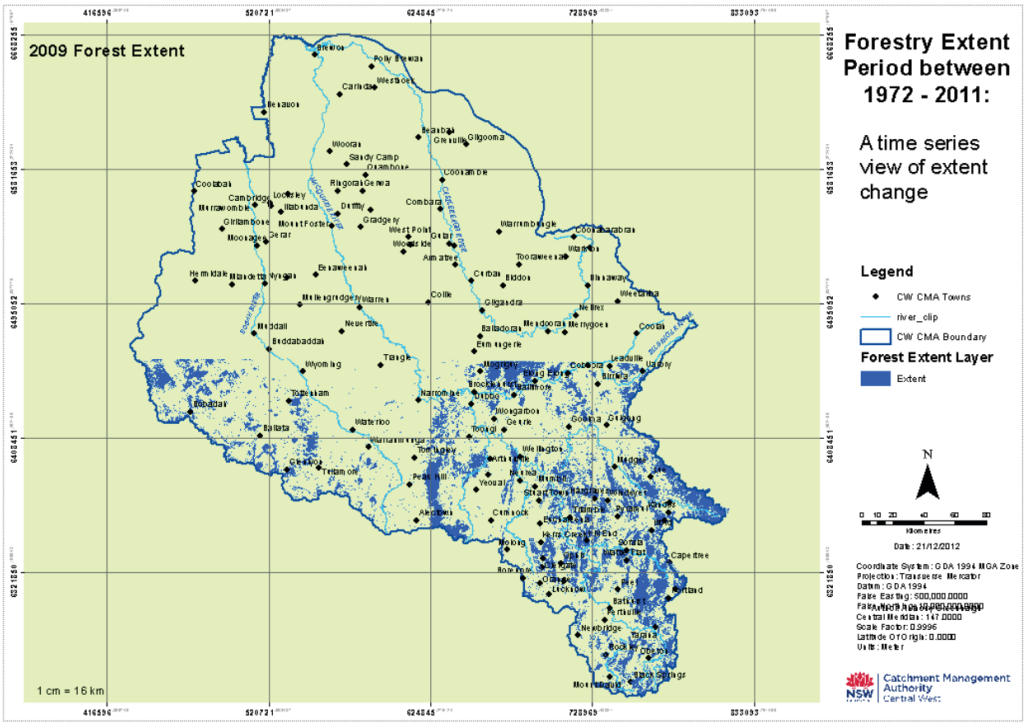


Figure 27: Change in hectares overtime (1972 - 2011)

Appendix 2 – Data Missing from 2009 Dataset

Data Extent of 2009 Raster tile showing incomplete data coverage over the northern part of the CWCMA. This was not supplied to the CWCMA. The graph depicts this anomaly as a drop in hectares, and is therefore not a reliable indicator.



References

Furby S., 2002, National Carbon Accounting System Technical Report No. 9, Australian Greenhouse Office, Canberra.

Fitzgerald N., 2012, Pers. comm., Department of Climate Changes, National Inventory Systems and Reporting Branch, Canberra