Australia’s National Multitemporal Landsat Land Cover Database for Carbon Accounting

Dr Brian Turner
School of Resources, Environment & Society
Australian National University

and

Dr Gary Richards
Australian Greenhouse Office
The Australian Deal in the Kyoto Protocol (1997)
Because Australia is an energy exporter and was a net emitter from land clearing in 1990, a limit on emissions of +8% on 1990 by the commitment period (2008-12) was allowed, whereas most other developed countries had to reduce emissions by 5%.

The Penalty
Required to include in 1990 base year data, emissions by sources minus removals by sinks from LUC to calculate “assigned amount”
→ Intense scrutiny by world’s scientists.

The Benefits
– Kyoto Forests
– Carbon trading?

→ Verifiable, detailed knowledge of forest resource and changes in it
Sampling not good enough
National Carbon Accounting System

• To provide a complete accounting & forecasting capability for land-based sources & sinks of GHG
  – First priority: Creditable & verifiable carbon account for Land Use Change and Forestry activities in 1990
  – location and growth of post-1990 forests and revegetation
  – land use after clearing
  – historic and current agriculture and forest management practices
  – impacts of climate variability on soil, vegetation systems and activity eg land clearing
• forest cover change since ~ 1970 by short time periods
Dynamic Approaches to Carbon Accounts

Dynamic
land cover
climate
management practices
production

Static
soils
vegetation
terrain

Static
soils (t1)
vegetation (t1)
terrain

Static
soils (t2)
vegetation (t2)
terrain

Carbon Model

Carbon account

Change t1 → t2

Cause?
Possible intervention?
Why Remote Sensing?

• Desired Outcome
  – Consistent and agreed world class methodology
  – World class dataset available throughout government
  – Increase competitive service providers capable of delivering useful products

• Existing Digital Datasets
  – Unable to deliver required temporal or spatial resolution at national level
Why Landsat?

• **Aim:** estimate change over continent at 1 hectare resolution in 1-3 yr time slices from about 1970 on
  – Air photos too expensive
  – AVHRR too coarse, archive inconsistent

• **Need consistency in:**
  – Registration
  – Radiometric calibration
  – Change detection methods

• **Landsat program could deliver!**
25m resolution imagery
Operating Procedure

Two stage pilot studies for methods development and capacity building → 5 step process

1. Identify best scenes from US/Aust. archives
2. Build Year 2000 mosaic base
3. Register & calibrate earlier scenes to 2000 mosaic
4. Mosaic individual scenes for each time slice into 1: million map sheet regions
5. Carry out threshold analysis to produce maps of woody vegetation cover at each time slice
1. Scene ID & Acquisition

Coverage - full continent in 2000, excluding deserts in all others

- 1972-3, 1976-8, 1980, 1985, 1988 @50m (Landsat MSS) – from EROS (1972-80), ACRES (1980-)
- 2000 mosaic @ 25m (Landsat 7 ETM)

~3000 scenes in all
2. **Year 2000 Mosaic**

- Base for rectification & calibration of all other dates
- 369 scenes
- Landsat 7 ETM, resampled to 25m (no thermal, Pan)
- Aim: Radiometrically consistent base across continent
- Same rectification & calibration as used for all other scenes (full scale test)
- Mosaiced to 1:million tiles
- Picture mosaic (seamless, resampled to 300m, conic)
Rectification of Y2K Mosaic

• Merged DTM produced from AUSLIG 9 sec & 3 sec 1:million tiles

• Ortho-rectification done using PCI’s OrthoEngine s/w
  – Minimum 27 GCP’s/scene
  – Minimum of 10 tie-points in scene overlap zones
  – Ortho-rectification performed ~24 scenes at a time

• Accuracy Assessment
  – Check GCP used – av. shift for best 95% was <40m.
  – Problems mostly in desert – ground errors?
Calibration of Y2K Mosaic

- Correction to scaled top-of-atmosphere reflectance by:
  - correction for sensor & on-ground gains & offsets
  - Correction for sun angle & earth-sun distance
- Correction for surface reflectance properties by 2-kernel empirical BRDF model
  - 3 parameters calculated by solving equations based on overlap area of images
- Some further gain corrections made on a few images
- CSIRO Mathematical & Information Sciences (Norm Campbell, Suzanne Furby) responsible for most of algorithm development.
Landsat scenes & 1: million tiles

- 370 scenes mosaiced to 37 1:million tiles
Year 2000 Mosaic

“I was amazed at what they had accomplished in a relatively short period of time”

Darrel Williams - NASA Landsat Project Scientist (July 2001)

• Picture mosaic (seamless, resampled to 300m, conic projection)
3. Registration & Calibration of Earlier Scenes to Y2K Mosaic

- Registration contractors used:
  - PCI’s OrthoEngine for ortho-rectification
  - DEM mosaic used for 2000 Mosaic
  - Choice of commercial packages for GCP selection
  - CSIRO MIS s/w for image correlation (matching)

- Calibration contractors used:
  - S/w supplied by CMIS
  - Same 2-stage process as used for 2000 Mosaic, except linear correction based on invariant targets applied if poor matching with 2000 Mosaic in surface reflectance correction stage (esp. MSS scenes)
Calibration against Reference Image

Raw Image (Pre-2000 TM)  Reference Image (Y2K Mosaic)  Calibrated Image (Pre-2000 TM)
4. Quality Control & Mosaicing of Time Slices

• Quality Control:
  – Following registration & calibration all scenes were returned to AGO for quality audit (visual inspection of all scenes)

• Mosaicing:
  – Single contractor mosaiced images into 37 1:million tiles, then split these into 4 quadrats
  – Boundaries identical for all 10 time slices
  – Simulated MSS layer created from 1989 TM data for comparison with earlier MSS data
5. Thresholding for Woody/Non-woody Discrimination

- Training sites chosen in each tile for range of cover types, generally from air photos
- Canonical variate analysis used to find linear combination of bands that maximises difference between training classes
  - Contrasts used to get an index (or indices) that optimally separates woody and non-woody classes
- Threshold values of index chosen that separates woody, non-woody and uncertain
  - Thresholds may vary within broad landscape strata (GIS layers supplied to contractors by AGO)
Thresholding for Woody/Non-woody Discrimination
Thresholding for Woody/Non-woody Discrimination

- Multitemporal data used to resolve uncertainties
- Conditional probability networks procedure, developed by CMIS used for this
- Example

<table>
<thead>
<tr>
<th>Time slice</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability Of Woody</td>
<td>1.0</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>Clearing event</td>
</tr>
<tr>
<td></td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
<td>Tree decline</td>
</tr>
</tbody>
</table>

- Data aggregated to 1 ha pixels by ‘cleaning’
- Masks applied for clouds, smoke, etc, if necessary
How will database be used?

- One hectare prediction and projection for woody biomass estimation using FullCAM model developed by AGO
Current Status

• Completion date Feb 2002

Residual Problems:

  – Topographic effect [DEM inadequate]
  
  – Quality of MSS data
  
  – Demand for slabs of data – facilitated by loosening of licencing agreements
For further information...

- Website: