

Forest information monitoring in Tasmania using Synthetic Aperture Radar

GEO Forest Carbon Tracking task

A.L. Mitchell¹, A. Milne¹, I. Tapley¹, K. Lowell², P. Caccetta³, E. Lehmann³,
Z-S. Zhou³, A. Held⁴

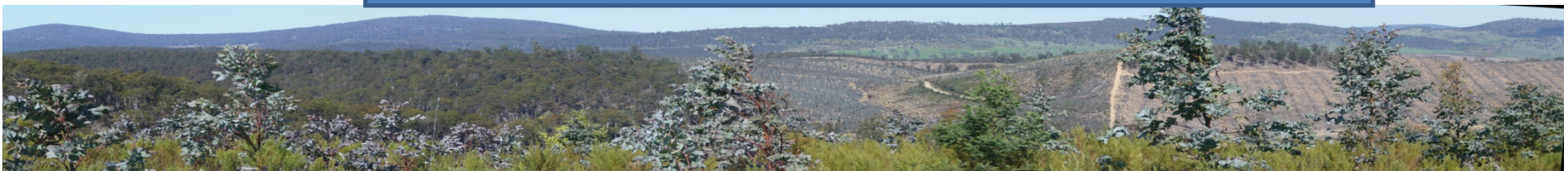
¹Cooperative Research Centre for Spatial Information (CRC-SI), School of Biological, Earth and
Environmental Sciences, The University of New South Wales, Sydney, Australia
(a.mitchell@unsw.edu.au; t.milne@unsw.edu.au, hgciant@bigpond.net.au)

²CRC-SI, Department of Geomatics, University of Melbourne, Carlton, Victoria, Australia
(klowell@unimelb.edu.au)

³CSIRO Mathematics, Informatics and Statistics, Floreat, Western Australia (peter.caccetta@csiro.au;
eric.lehmann@csiro.au; zheng-shu.zhou@csiro.au)

⁴CSIRO AusCover Facility, Canberra, Australia (alex.held@csiro.au)

7th ISDE Wallis Forum 2011, 23-25 August, Perth,



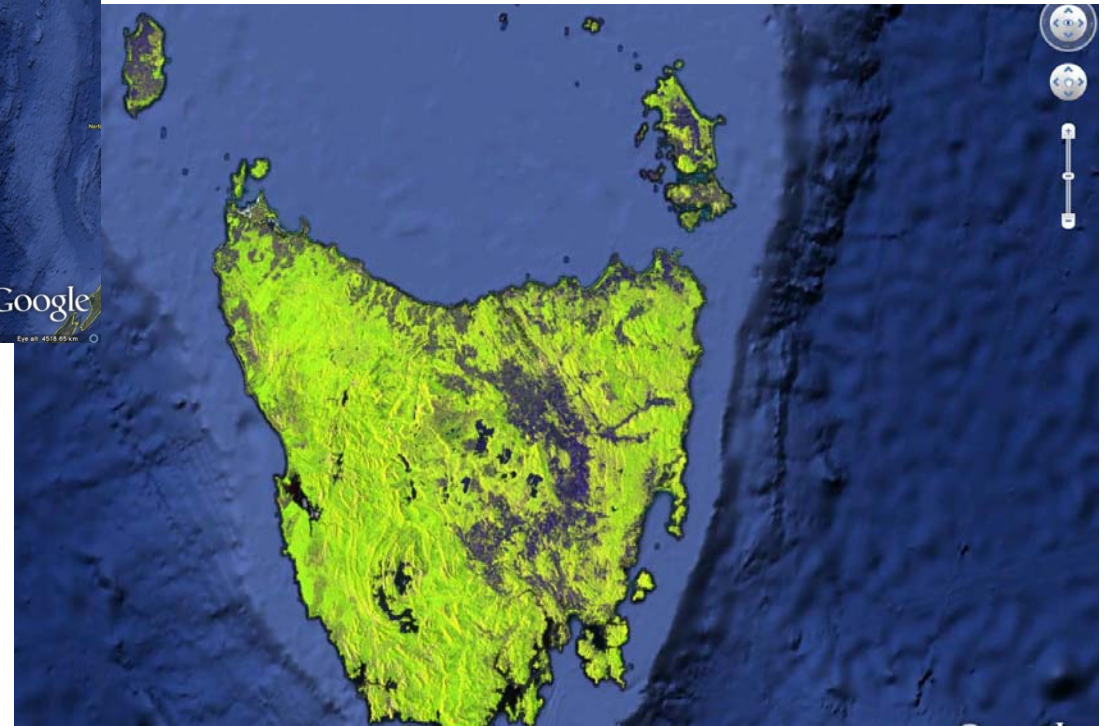
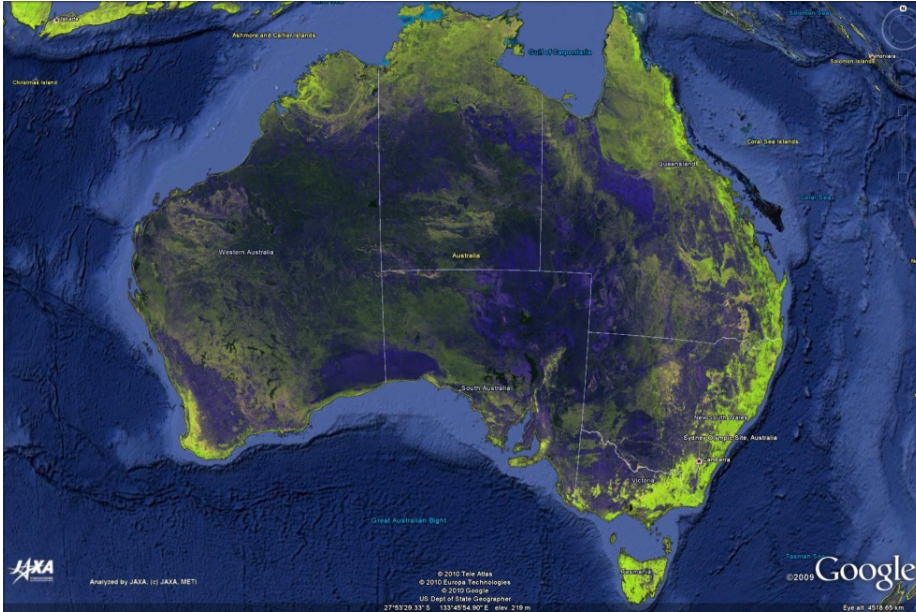
GEO Forest Carbon Tracking (FCT) task

- Global forest information monitoring
 - Consistent wall-to-wall time-series forest change estimates
 - Standardised methods: link, extract, evaluate
 - Reliable forest information for accurate carbon modelling
 - Contribute to MRV and international reporting
- ‘Tasmania Demonstrator’
 - SAR capabilities for forest monitoring
 - Independent (recent) source
 - Interoperable use with optical time-series (NCAS)
 - Spatially and temporally consistent, wall-to-wall radar mosaics
 - Standard forest information products
 - Change detection and trend metrics



Tasmania ND site

2009 PALSAR mosaic shows extent of Australia's non-tropical rainforests and wet sclerophyll forests



Tasmania 62,409 square kilometres : 49.5% (3.4mHa) of the island is forest –
98% native forest
2% plantation forest

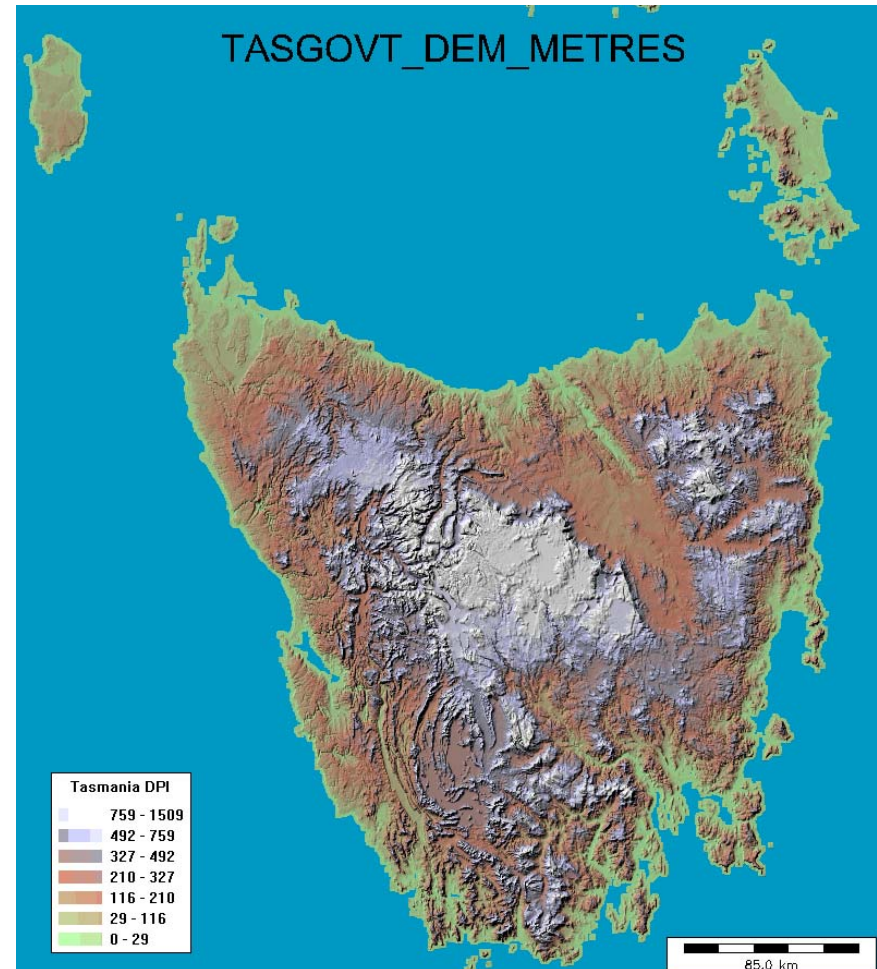


TAS Demonstrator SAR data

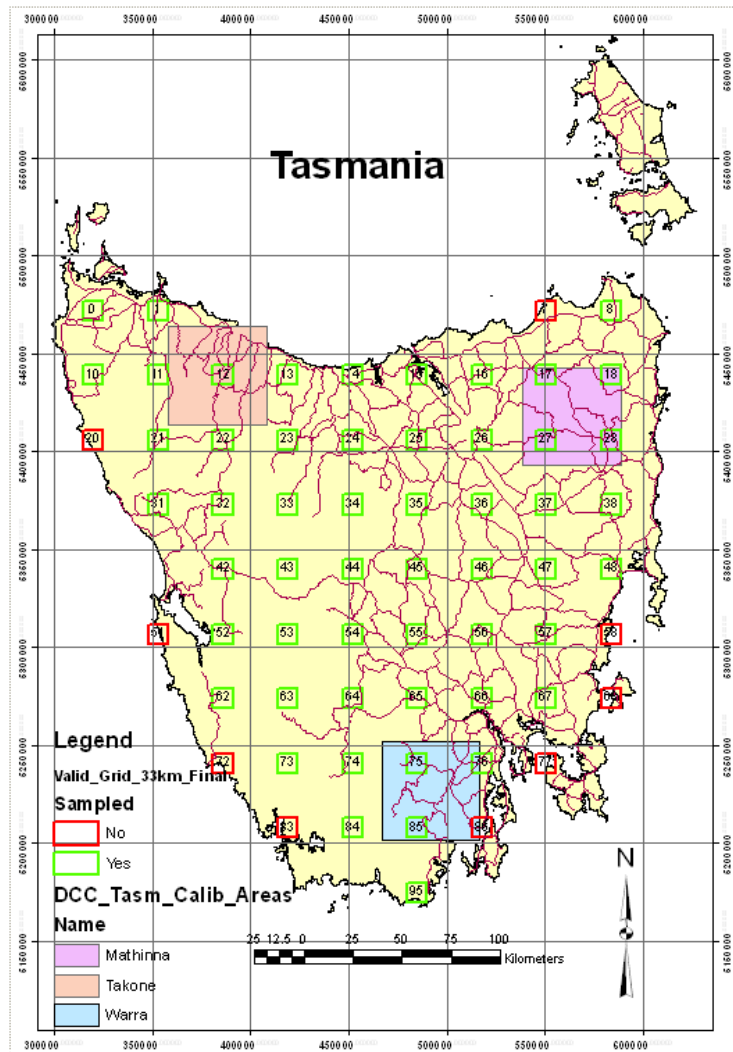
Sensor	Availability	Mode	Incidence angle	Spatial resolution (m)	Swath width (km)
ALOS PALSAR (JAXA)	189 images Aug-Oct 2007 – 2010	FBD L-HH, HV Asc.	34.3	12.5	70
JERS-1 (JAXA)	37 images Mar 1994	L-HH Desc.	32 – 38	18	75
Radarsat-2 (CSA)	38 images July-Dec 2009 – Jan 2010 2010 (to be)	W3 C-VV, VH Asc.	39 – 45	13.5 x 7.7 (rng x az, 1x1 looks)	150
ASAR (ESA)	18 images July-Sept 2009 2010 (to be)	Alternating pol mode (AP) IS4, C- VV, VH Desc.	34	30	81
TerraSAR-X (DLR)	8 images Mar-May 2010	Scansar X-HH Stripmap X-VV, VH or HH, HV Asc.	31		
Cosmo-SkyMed	1 image				

Available DEMs

- Statewide coverage:
 - TAS DPIPWE 25 x 25 m
 - SRTM 90 x 68 m
 - SRTM 30 x 30 m
 - ASTER 30 x 30 m
- Investigate influence of DEM resolution on



Tasmania calibration/validation sites

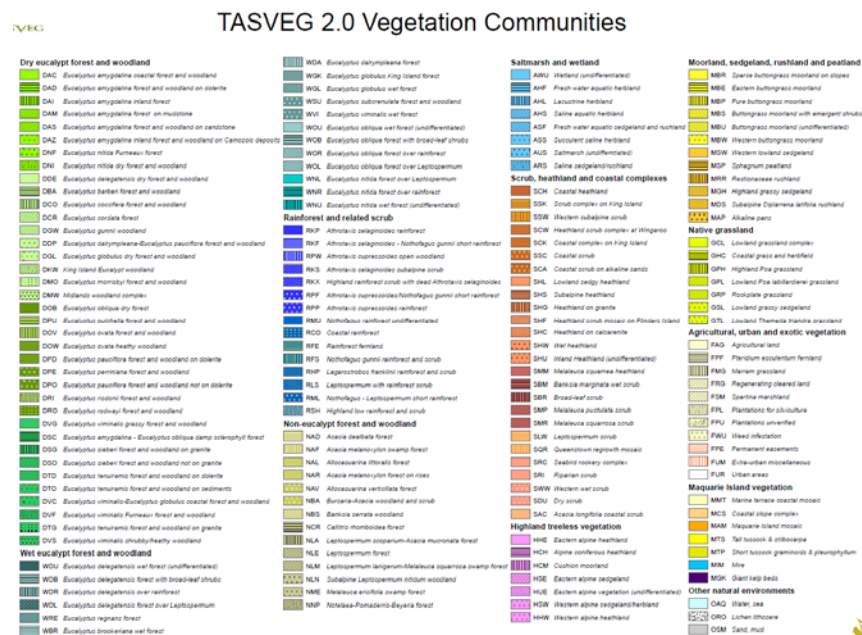
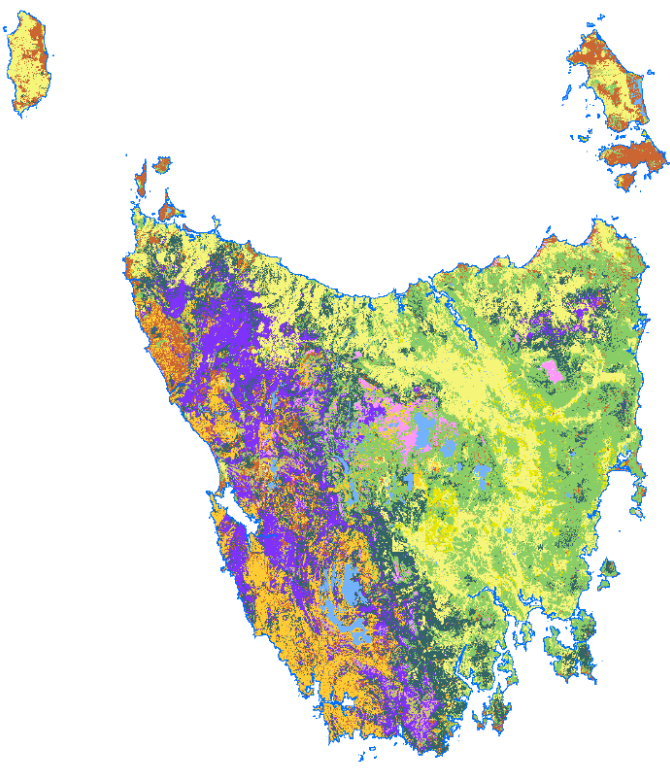


- Calibration sites (50x50 km):
 - Mathinna (NE)
 - Takone (NW)
 - Warra (S)
- Validation squares:
 - 53 10x10 km sample squares
 - Collate available *in situ* and satellite data for each square



Validation data

- DPIPWE TASVEG: 154 communities
- FTAS expert field mapping, permanent inventory plots
- Aerial photography – 1:25,000
- Scattered IKONOS chips

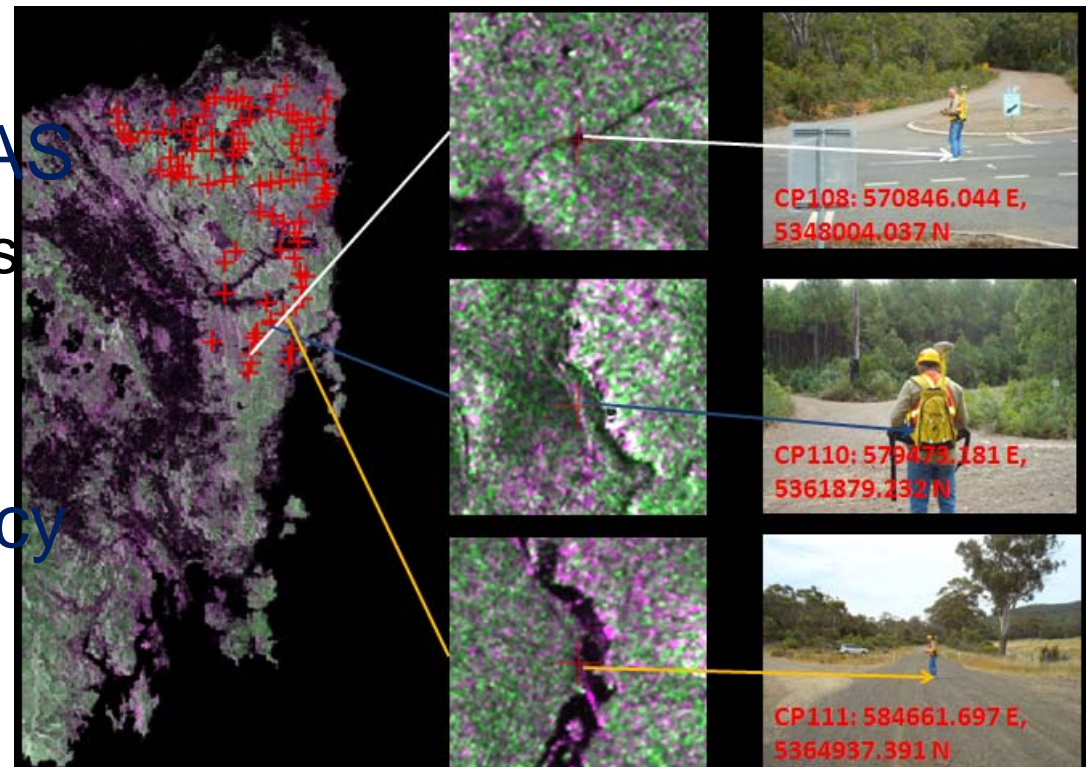


PALSAR geo-locational accuracy assessment

- Pixel-to-pixel accuracy achieved between multi-date ALOS PALSAR imagery

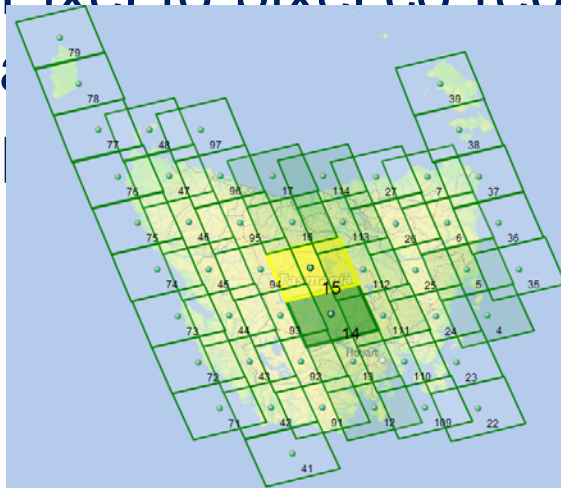
Individual point error	Error X (Easting)	Error Y (Northings)
Mean (m)	6.53	-6.82
Minimum (m)	0.195	-12.46
Maximum (m)	12.44	-0.11
RMSE (m)	3.196	

- Comparison with 91 GCPs provided by FTAS
 - Ongoing as more GCPs become available
- Co-registration accuracy with SPOTmap data
 - (To do)

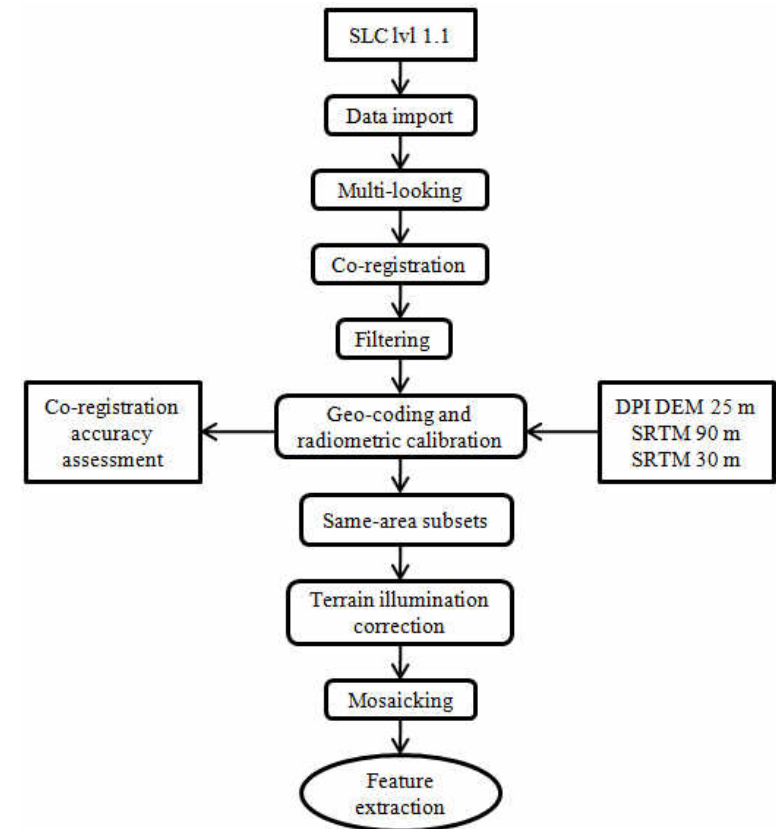


Radar data and processing

- 189 Fine Beam Dual (FBD) ALOS PALSAR images acquired between Aug-Oct timeframe over 2007 – 2010
- Ascending mode, 34.3° incidence angle
- Pixel-to-pixel co-registration



t full resolution

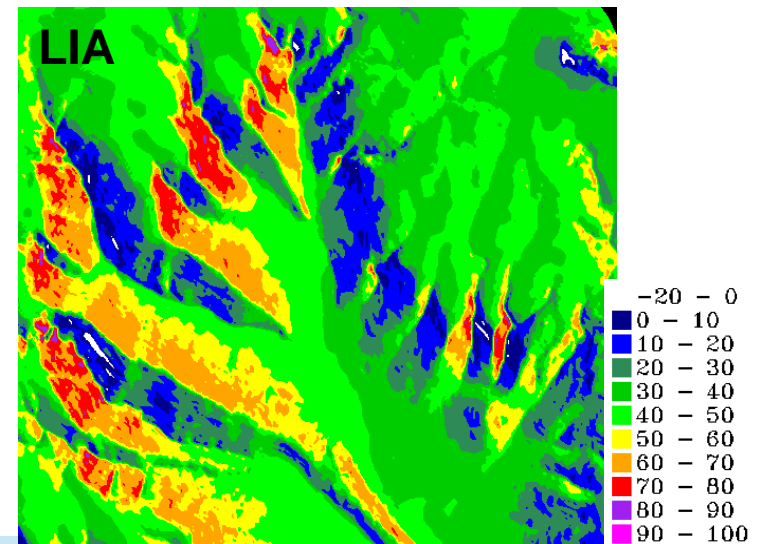
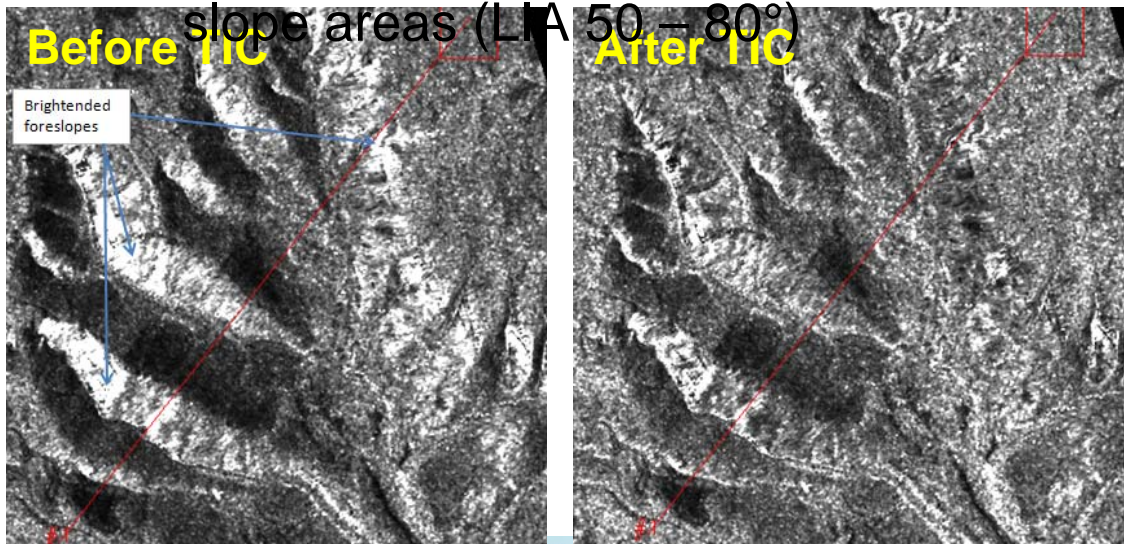
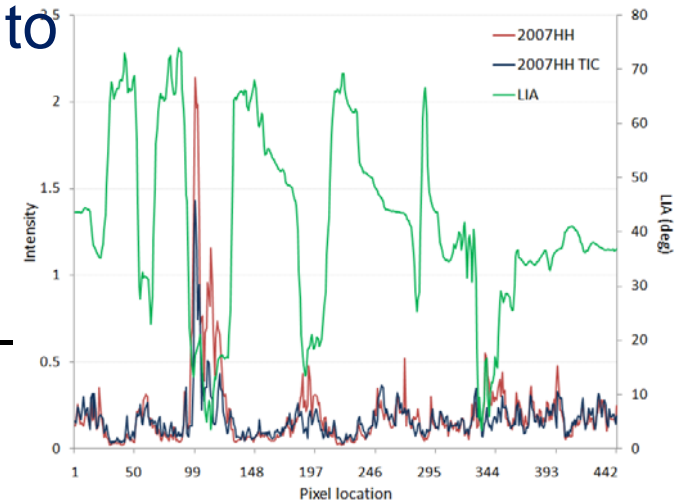


Processing sequence applied to generate wall-to-wall PALSAR mosaics

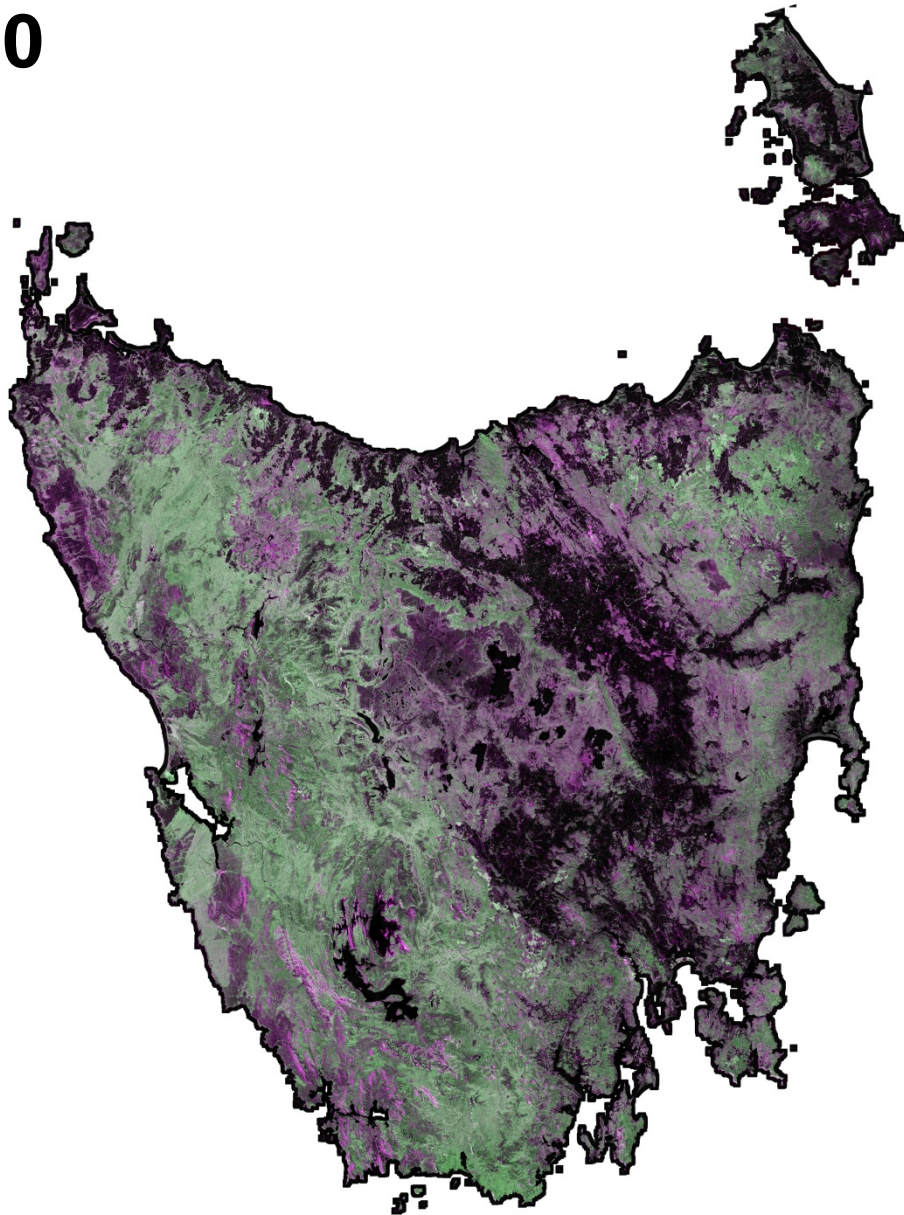


Terrain Illumination Correction

- TIC uses cosine of surface tilt angles to correct for terrain slope illumination variations (Zhou et al., 2011)
 - Compensates for local illumination
 - Reduced intensity across illuminated fore-slopes (LIA 0 – 30°) and smoothing/increase in intensity in back-slope areas (LIA 50 – 80°)



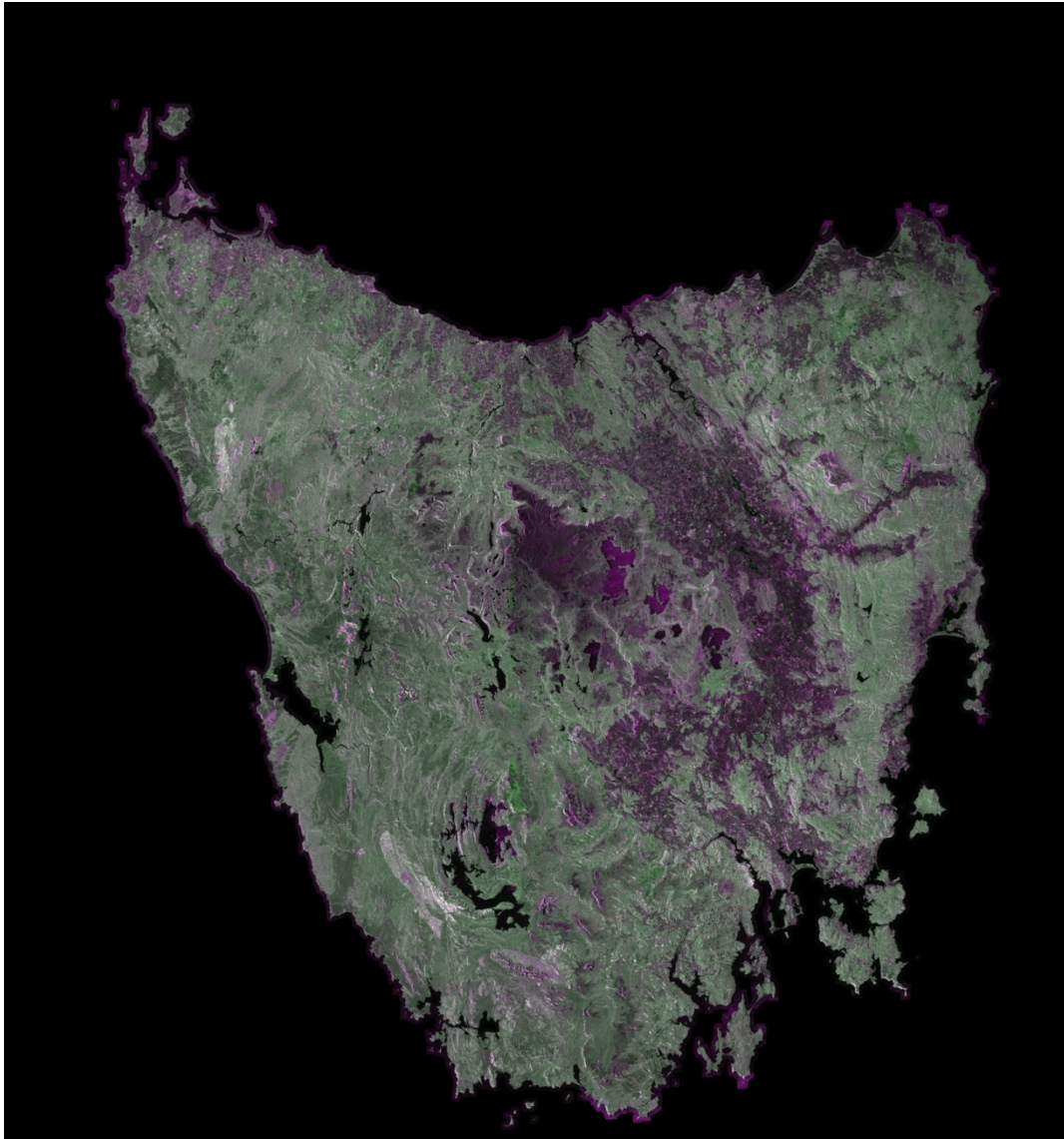
200
7



PALSAR mosaics

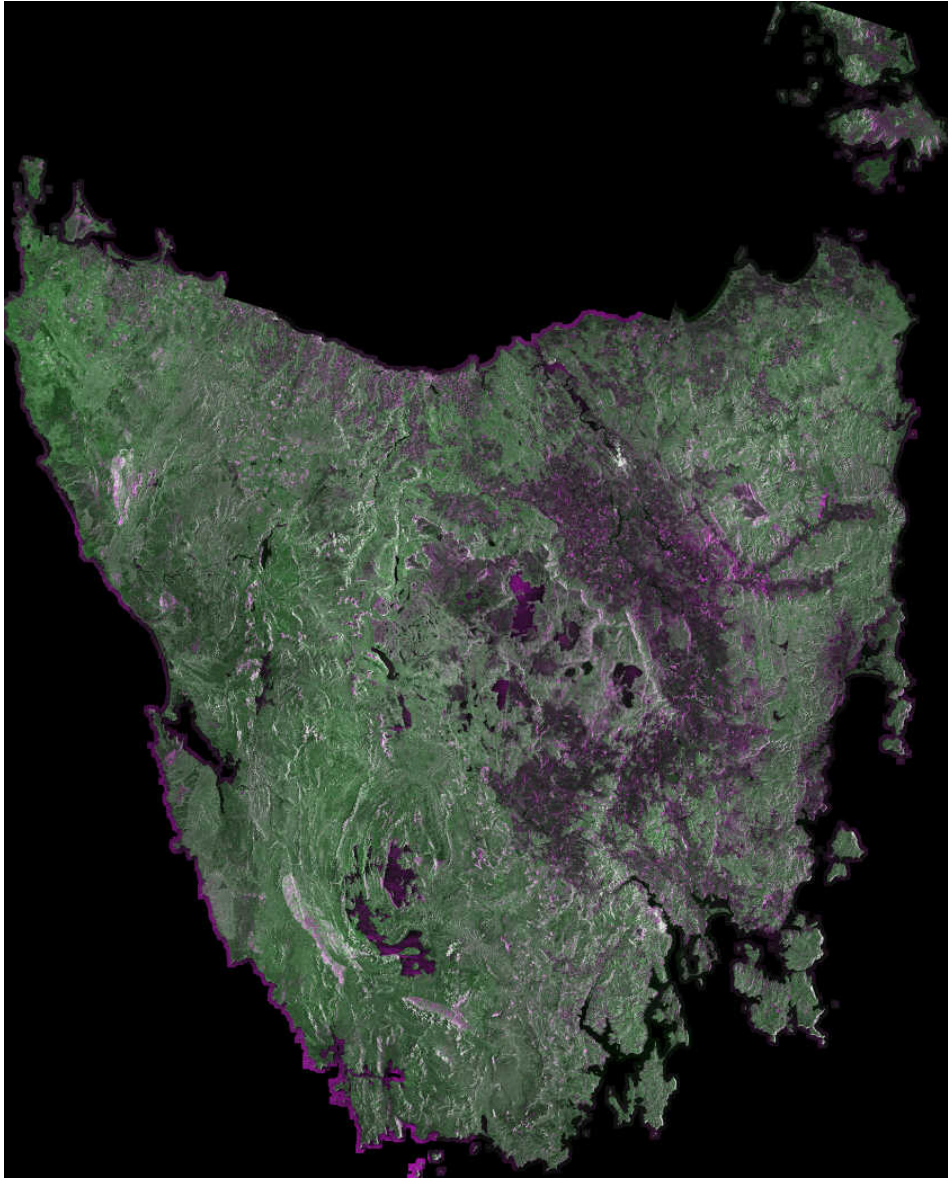
- Annual, ortho-rectified, radiometrically calibrated, seamless, wall-to-wall mosaics
- HH:HV:HH in RGB
12.5 m spatial resolution





**RSAT-2
mosaic
Aug 2009
VV:VH:VV**





**ASAR
mosaic
July-Sept
2009
VV:VH:VV**

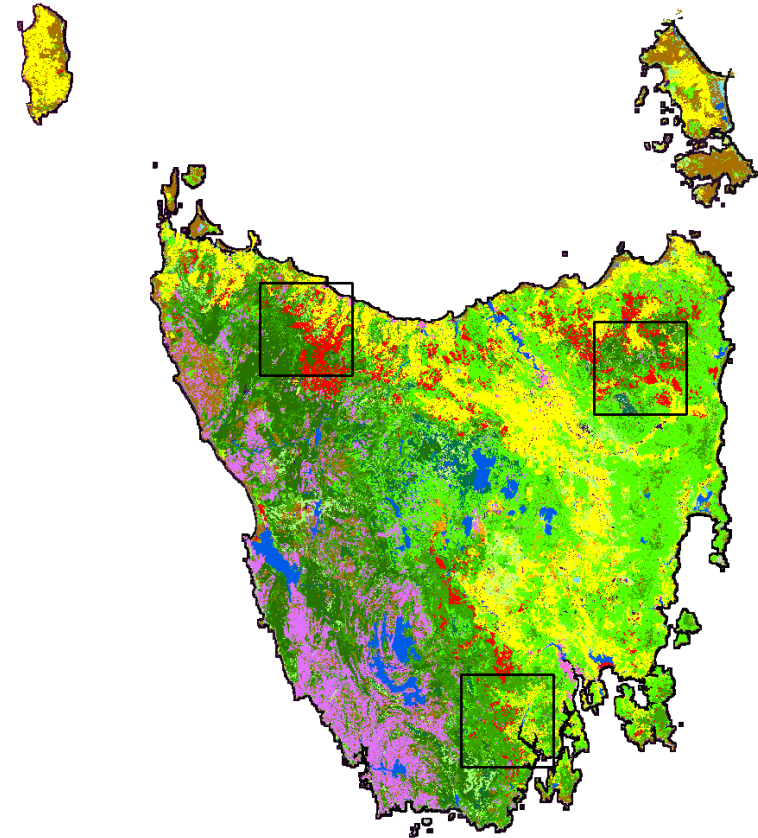


Land cover classification strategy

- Initial exploration over 3 calibration sites

- Identification of cover classes: field survey, TASVEG and optical data
- Object-based approach to classification using Definiens eCognition
 - Inputs: HH + HV, DEM
 - Fine scale segmentation
 - Rule set development: spatial and spectral incl. HH and HV backscatter, height, segment shape and area, distance...
 - Membership functions and/or region growing




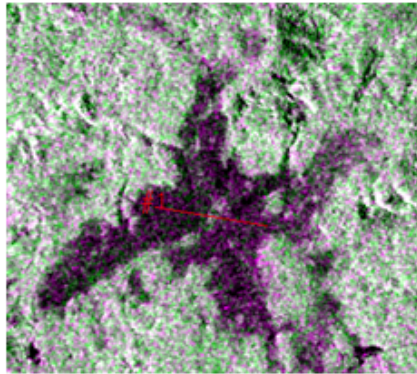
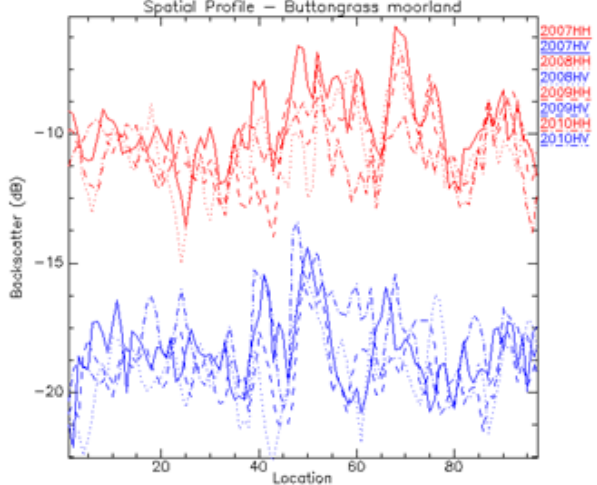


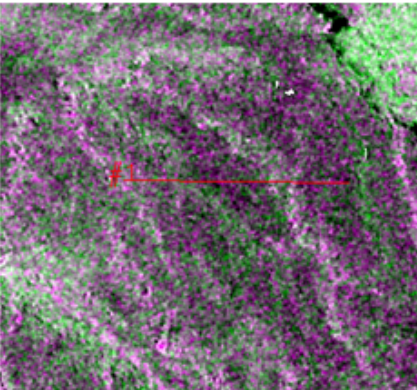
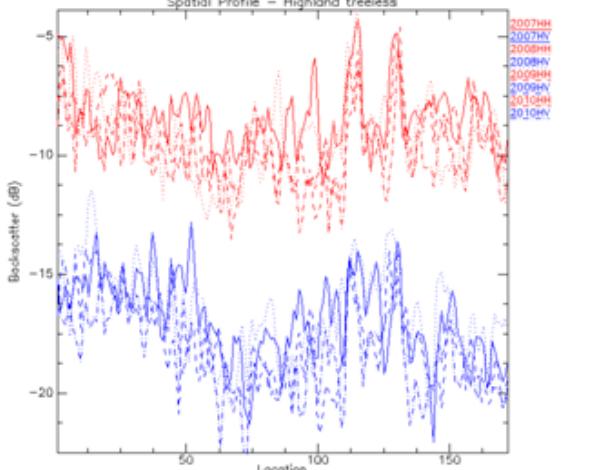
- Export mean HV segments for change analysis





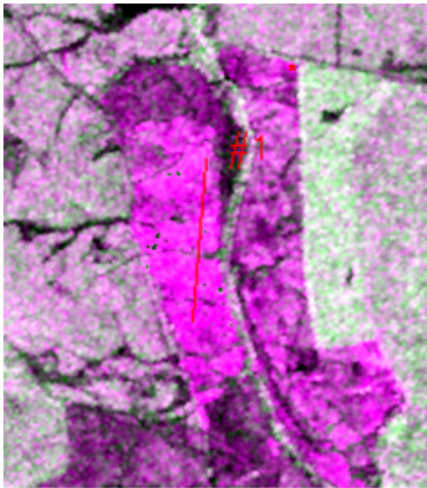
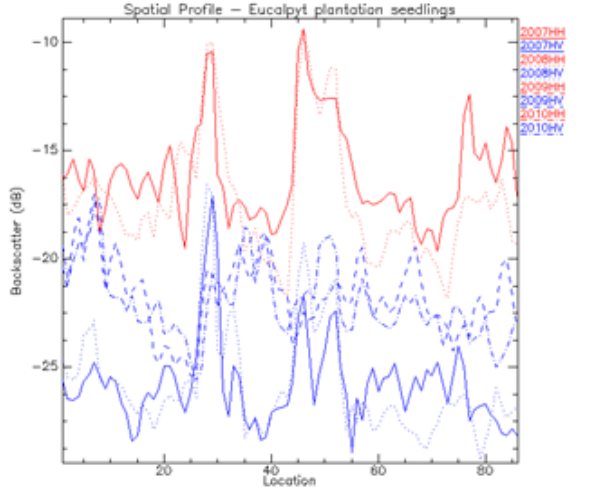
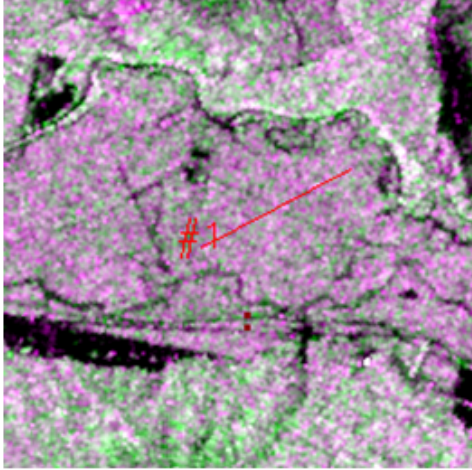
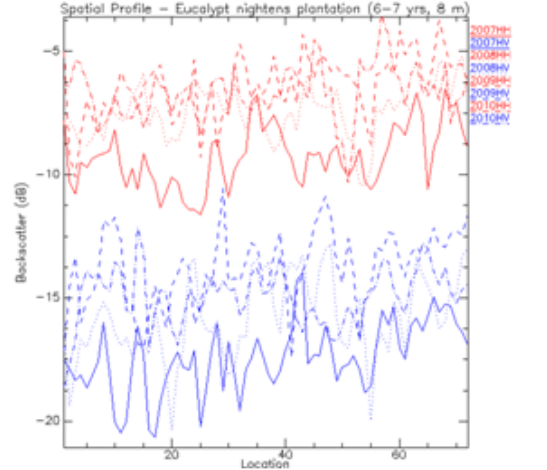


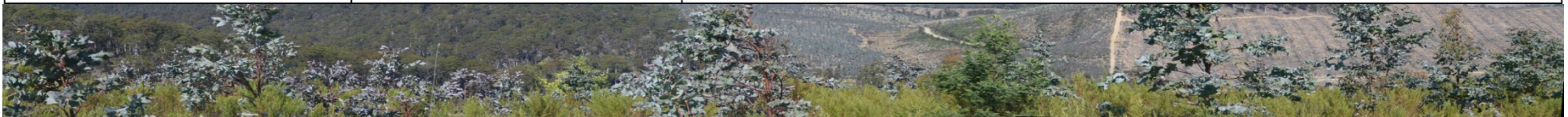
State-wide vegetation mapping (TASVEG) and calibration sites




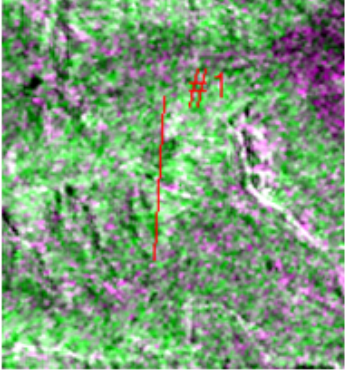
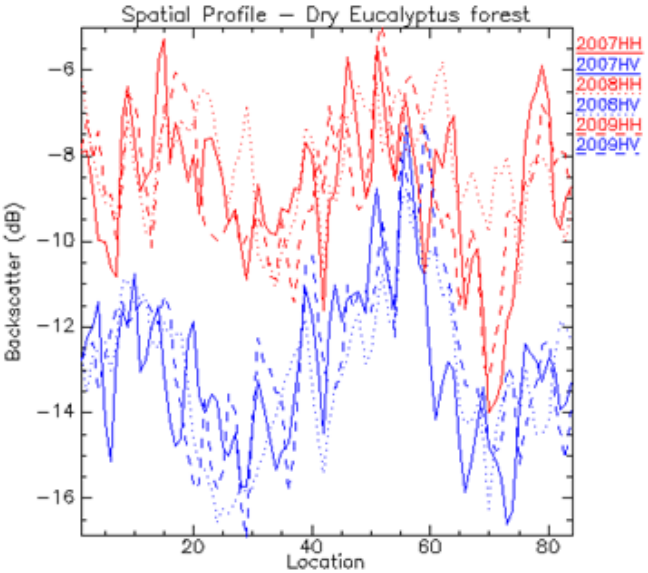

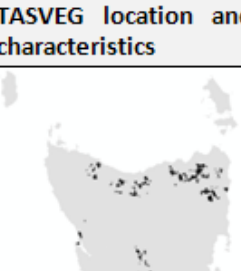
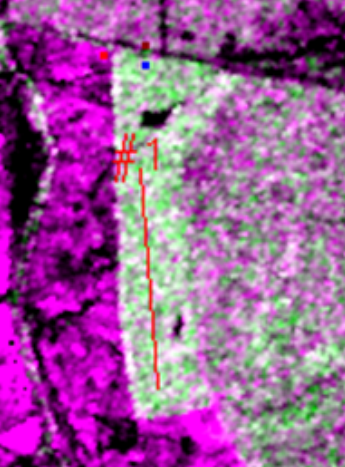
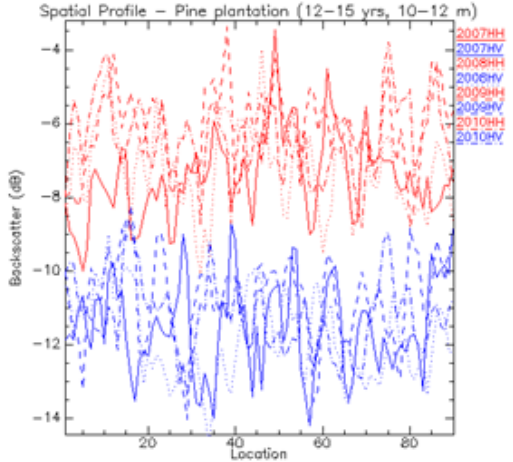


Vegetation communities described

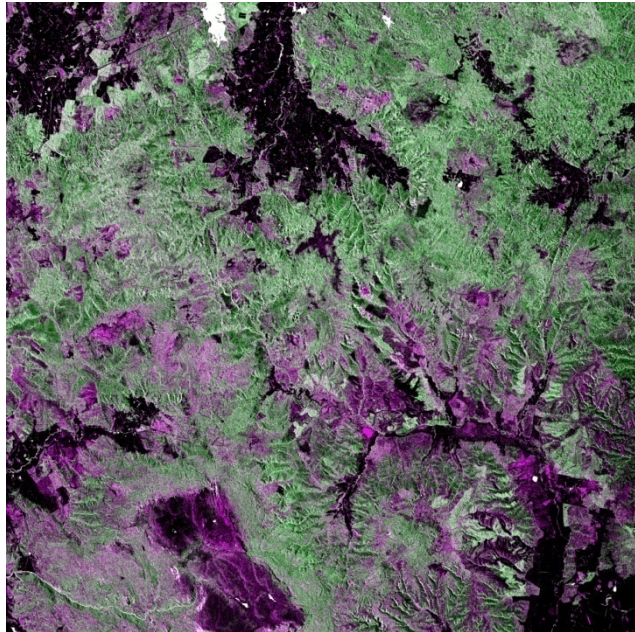
Vegetation community	TASVEG location and structural characteristics	PALSAR observations
<p>Buttongrass moorland</p>  <p><i>Close-up Buttongrass, Mathinna</i></p>  <p><i>Teatree and Buttongrass, Mathinna</i></p>	 <ul style="list-style-type: none"> - Hummock-forming tussock sedge Species: <i>Gymnoschoenus sphaerocephalus</i> - Variable structure: dense sedge/heathland to low open scrub/woodland - Areas where Tea tree is encroaching on Buttongrass - Structural form: height <1 m, 80 - 90 % cover 	  <p><i>L) 2010 PALSAR over Buttongrass moorland, Mathinna. Location of profile indicated in red.</i></p> <p><i>R) Multi-date PALSAR spectra extracted over Buttongrass moorland (HH in red, HV in blue), Mathinna.</i></p>
<p>Highland treeless</p>  <p><i>Alpine vegetation, Ben Lomond (bl1)</i></p>	 <ul style="list-style-type: none"> - Occur within alpine zone where tree growth is impeded above a certain elevation - Includes alpine heathland, sedge/land and moorland communities, grassland, herbfields and sedgy grasslands - Structural form (BL): fairly dense clumps of low-lying shrubs. Scattered boulders and streams 	  <p><i>L) 2010 PALSAR over highland treeless vegetation, Ben Lomond summit, Mathinna. Location of profile indicated in red.</i></p> <p><i>R) Multi-date PALSAR spectra extracted over highland treeless (HH in red, HV in blue), Ben Lomond summit, Mathinna.</i></p>

Vegetation community	TASVEG location and structural characteristics	PALSAR observations
<p data-bbox="168 150 544 177">Plantation - hardwood (Eucalypt)</p>  <p data-bbox="168 480 575 539"><i>Eucalyptus nightens</i> plantation seedlings, Mathinna (m4)</p>  <p data-bbox="168 839 575 898"><i>Eucalyptus</i> plantation, age ~2 yrs, height 2 m, Mathinna (m42)</p>  <p data-bbox="168 1206 575 1265"><i>Euc. nightens</i> plantation, age ~3-4 yrs, height 2-2.5 m, Mathinna (m59)</p>	 <ul style="list-style-type: none"> - Plantations scattered throughout the north and south east - Hardwood species typically <i>Eucalyptus nightens</i> or <i>globulus</i> - Rows spaced a few metres apart, variable understorey 	  <p data-bbox="1005 647 2065 738"><i>L</i>) 2010 PALSAR over <i>Eucalyptus</i> plantation seedlings, Mathinna (m4). Location of profile indicated in red. <i>R</i>) Multi-date PALSAR spectra extracted over <i>Eucalyptus</i> plantation seedlings (HH in red, HV in blue), Mathinna (m4).</p>   <p data-bbox="1005 1254 2065 1345"><i>L</i>) 2010 PALSAR over <i>Eucalyptus nightens</i> plantation, Mathinna (m11). Location of profile indicated in red. <i>R</i>) Multi-date PALSAR spectra extracted over <i>Eucalyptus nightens</i> plantation (HH in red, HV in blue), age 6-7 yrs, height 8 m, Mathinna (m11).</p>

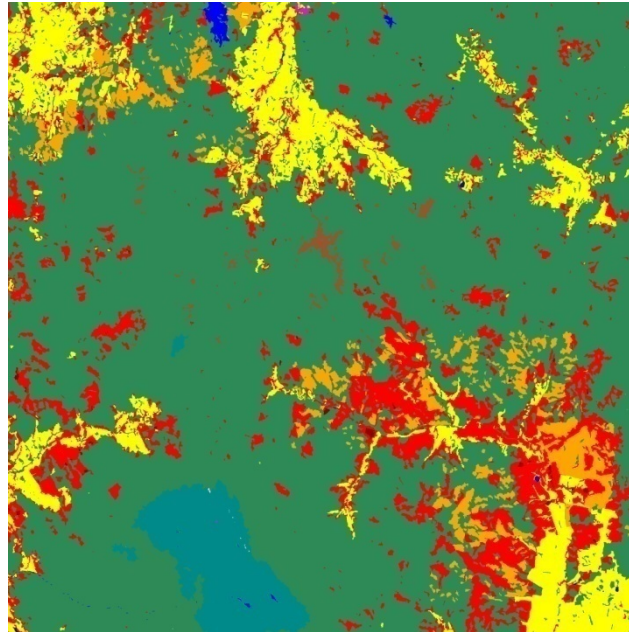


Vegetation community	TASVEG location and structural characteristics	PALSAR observations
<p data-bbox="174 145 389 172">Dry Eucalypt forest</p>  <p data-bbox="174 480 548 539"><i>Euc delegatensis</i> forest, Mathinna (m32)</p>  <p data-bbox="174 847 577 874"><i>Euc delegatensis</i> forest, Mathinna</p>	 <ul data-bbox="600 448 987 703" style="list-style-type: none"> - Extensive over central and eastern parts of State, with greatest diversity of Eucalypt species in SE. - Usually distinguished by dominant species in canopy, with varied understorey. 	  <p data-bbox="1010 788 2065 847">L) 2009 PALSAR over dry <i>Eucalyptus</i> forest, Mathinna. Location of profile indicated in red. R) Multi-date radar spectra extracted over dry <i>Eucalyptus</i> forest (HH in red, HV in blue), Mathinna.</p>
<p data-bbox="174 884 434 911">Vegetation community</p> <p data-bbox="174 954 495 981">Plantation - softwood (Pine)</p>  <p data-bbox="174 1289 577 1348"><i>Pine</i> plantation, age ~12-15 yrs, height 10-12 m, Mathinna (m3)</p>	 <ul data-bbox="600 1225 987 1353" style="list-style-type: none"> - Plantations scattered throughout the north and south east - Lower branches stripped prior to cutting 	  <p data-bbox="1010 1426 2065 1517">L) 2010 PALSAR over <i>Pine</i> plantation, Mathinna (m3). Location of profile indicated in red. R) Multi-date radar spectra extracted over <i>Pine</i> plantation, age 12-15 yrs, height 10-12 m (HH in red, HV in blue), Mathinna (m3).</p>

2007 Forest information products: Mathinna



PALSAR 2007
HH:HV:HH in RGB



Land cover
2007

- TASVEG - urban
- TASVEG - water
- Agricultural land
- Highland treeless
- Buttongrass moorland
- Forest
- Pine plantation
- Eucalypt plantation



Forest/non-forest extent
2007

- Non-forest
- Forest



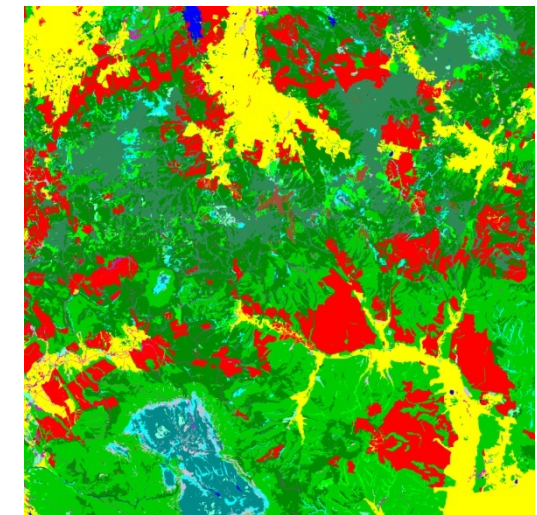
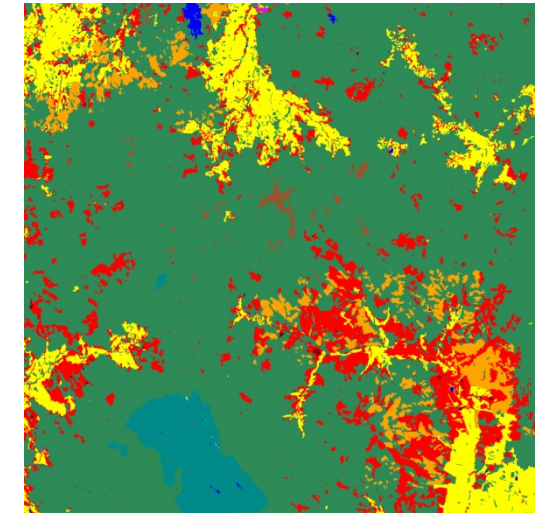
Mathinna: Accuracy assessment

REFERENCE	Ag land	Alpine veg	Buttongrass moorland	Forest	Pine plantation	Eucalypt plantation	Scrub	ROW TOTAL
CLASSIFIED	36					4		40
Ag land								
Alpine veg		8		1				9
Buttongrass moorland		3	7				4	14
Forest	1			201	8	27	7	244
Pine plantation					24			24
Eucalypt plantation	1			6	6	14		27
Scrub								0
COLUMN TOTAL	38	11	7	208	38	45	11	358

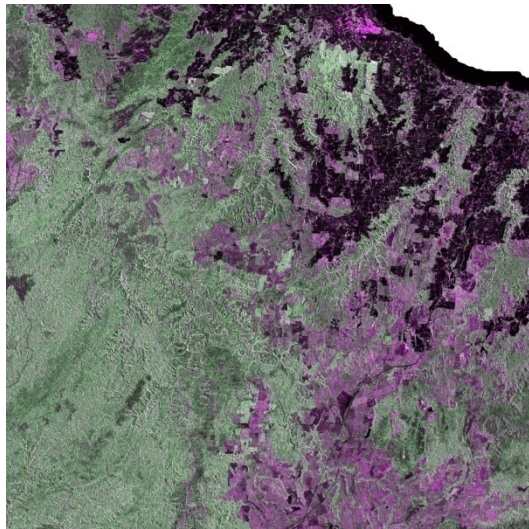
REFERENCE	Forest	Non-forest	ROW TOTAL
CLASSIFIED	286	9	295
Forest			
Non-forest	5	58	63
COLUMN TOTAL	291	67	358

	Land cover class		%
Producers accuracy	Agricultural land	0.95	94.7
	Alpine vegetation	0.73	72.7
	Buttongrass moorland	1.0	100
	Forest	0.97	96.6
	Pine plantation	0.63	63.2
	Eucalypt plantation	0.31	31.1
Users accuracy	Agricultural land	0.9	90
	Alpine vegetation	0.89	88.9
	Buttongrass moorland	0.5	50
	Forest	0.82	82.4
	Pine plantation	1	100
	Eucalypt plantation	0.52	51.9
Overall accuracy		0.8	81

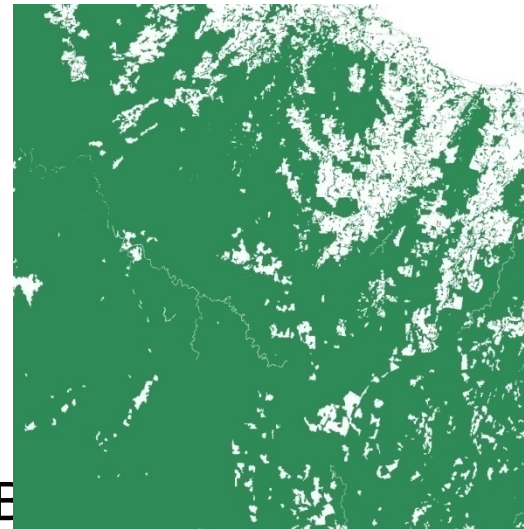
	Forest/non-forest		%
Producers accuracy	Forest	0.98	98.3
	Non-forest	0.87	87.1
Users accuracy	Forest	0.97	96.9
	Non-forest	0.92	92.4
Overall accuracy		0.96	96.1



2007 Forest information products: Takone

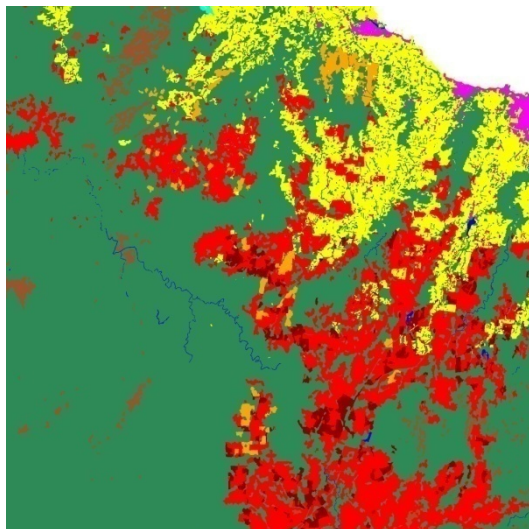


PALSAR 2007
HH:HV:HH in RGE

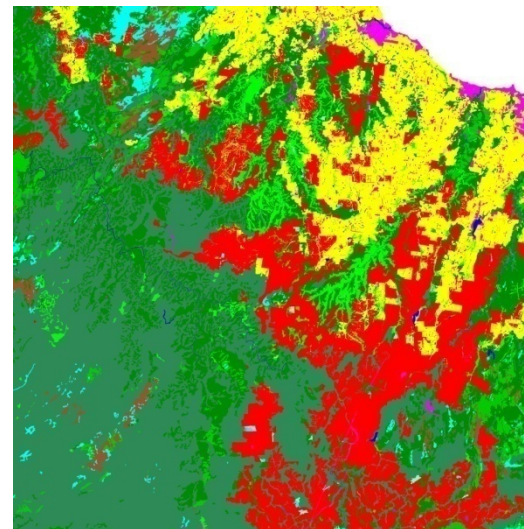


Non-forest
Forest

Forest/non-forest 2007

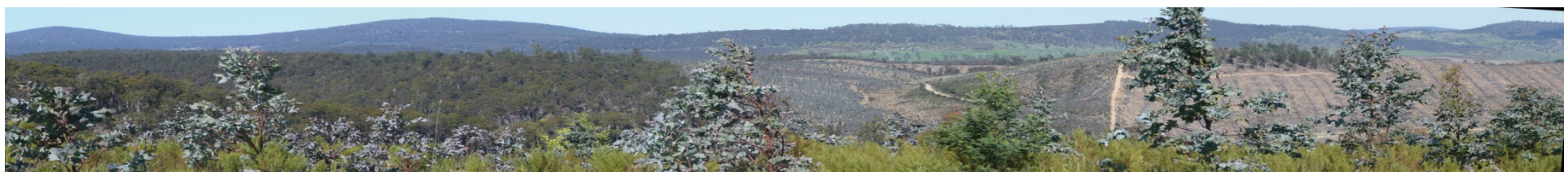


Land cover 2007

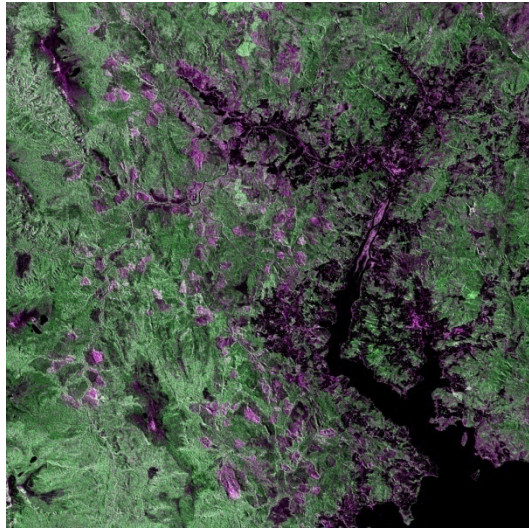


Highland treeless
Moorland
Scrub
Agricultural land
Non-Euc forest
Dry Euc forest
Wet Euc forest
Rainforest
Plantation
Urban misc
Wetland
Grassland
Other (lichen/mud)
Water

TASVEG



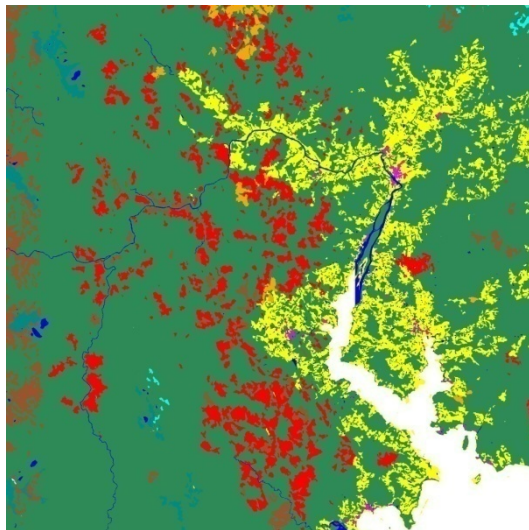
2007 Forest information products: Warra



PALSAR 2007
HH:HV:HH in RGE

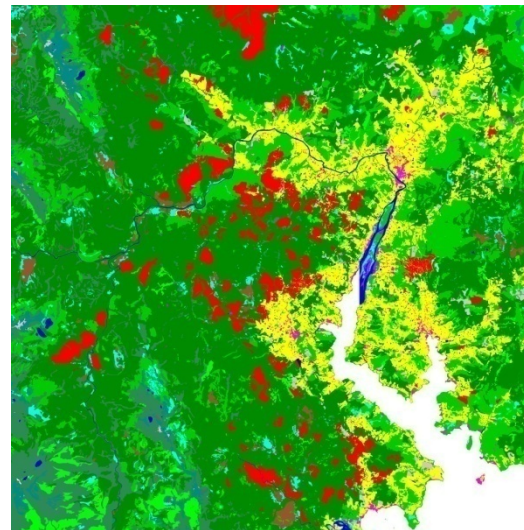


Non-forest
Forest
Forest/non-forest 2007



- TASVEG - urban
- TASVEG - water
- Agricultural land
- Highland treeless
- Buttongrass moorland
- Forest
- Pine plantation
- Eucalypt plantation
- Scrub

Land cover 2007



- Highland treeless
- Moorland
- Scrub
- Agricultural land
- Non-Euc forest
- Dry Euc forest
- Wet Euc forest
- Rainforest
- Plantation
- Urban misc
- Wetland
- Grassland
- Other (lichen/mud)
- Water

TASVEG



Takone and Warra: Accuracy assessment

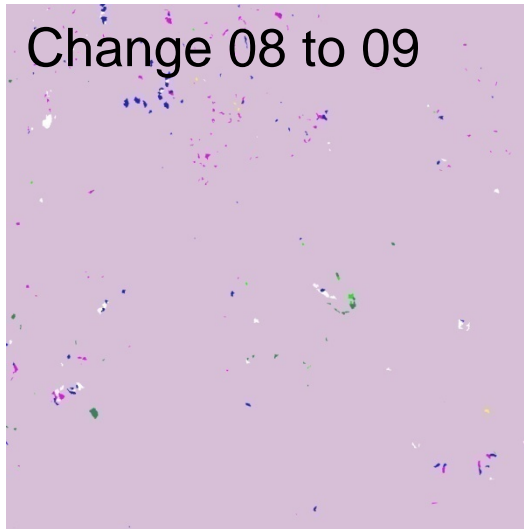
TAKONE	Land cover class		%
Producers accuracy	Agricultural land	0.95	95.3
	Buttongrass moorland	0.8	80
	Forest	0.96	96.2
	Pine plantation	0.6	60
	Eucalypt plantation	0.72	72.1
	Eucalypt plantation cleared	1	100
Users accuracy	Agricultural land	0.98	98.4
	Buttongrass moorland	0.73	72.7
	Forest	0.88	88.1
	Pine plantation	1	100
	Eucalypt plantation	0.92	91.7
	Eucalypt plantation cleared	0.25	25
Overall accuracy		0.9	89.6
	Forest/non-forest		
Producers accuracy	Forest	0.97	97.3
	Non-forest	0.93	93.3
Users accuracy	Forest	0.98	98.1
	Non-forest	0.91	90.9
Overall accuracy		0.96	96.4

WARRA	Land cover class		%
Producers accuracy	Agricultural land	0.73	72.7
	Highland treeless	0.71	70.6
	Scrub	0.22	22.2
	Buttongrass moorland	0.75	75
	Forest	0.91	90.8
	Pine plantation	0.58	58.3
	Eucalypt plantation	0.54	54.1
Users accuracy	Agricultural land	0.89	88.9
	Highland treeless	0.71	70.6
	Scrub	0.25	25
	Buttongrass moorland	0.55	54.5
	Forest	0.83	83.5
	Pine plantation	1	100
	Eucalypt plantation	0.65	64.5
Overall accuracy		0.8	80.5
	Forest/non-forest		
Producers accuracy	Forest	0.95	95.2
	Non-forest	0.73	73.1
Users accuracy	Forest	0.93	93.4
	Non-forest	0.79	79.2
Overall accuracy		0.91	90.8



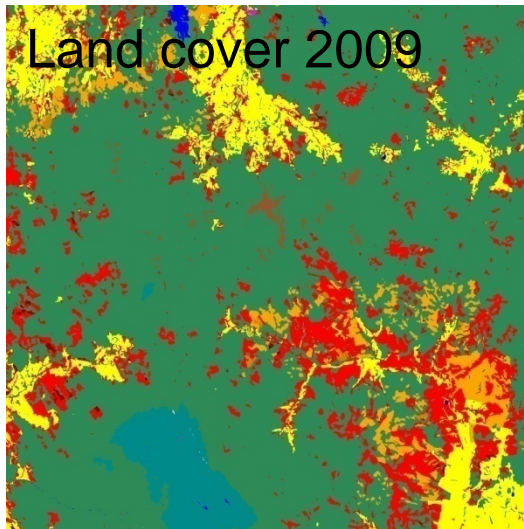
Mathinna: Annual land cover mapping

Change 08 to 09



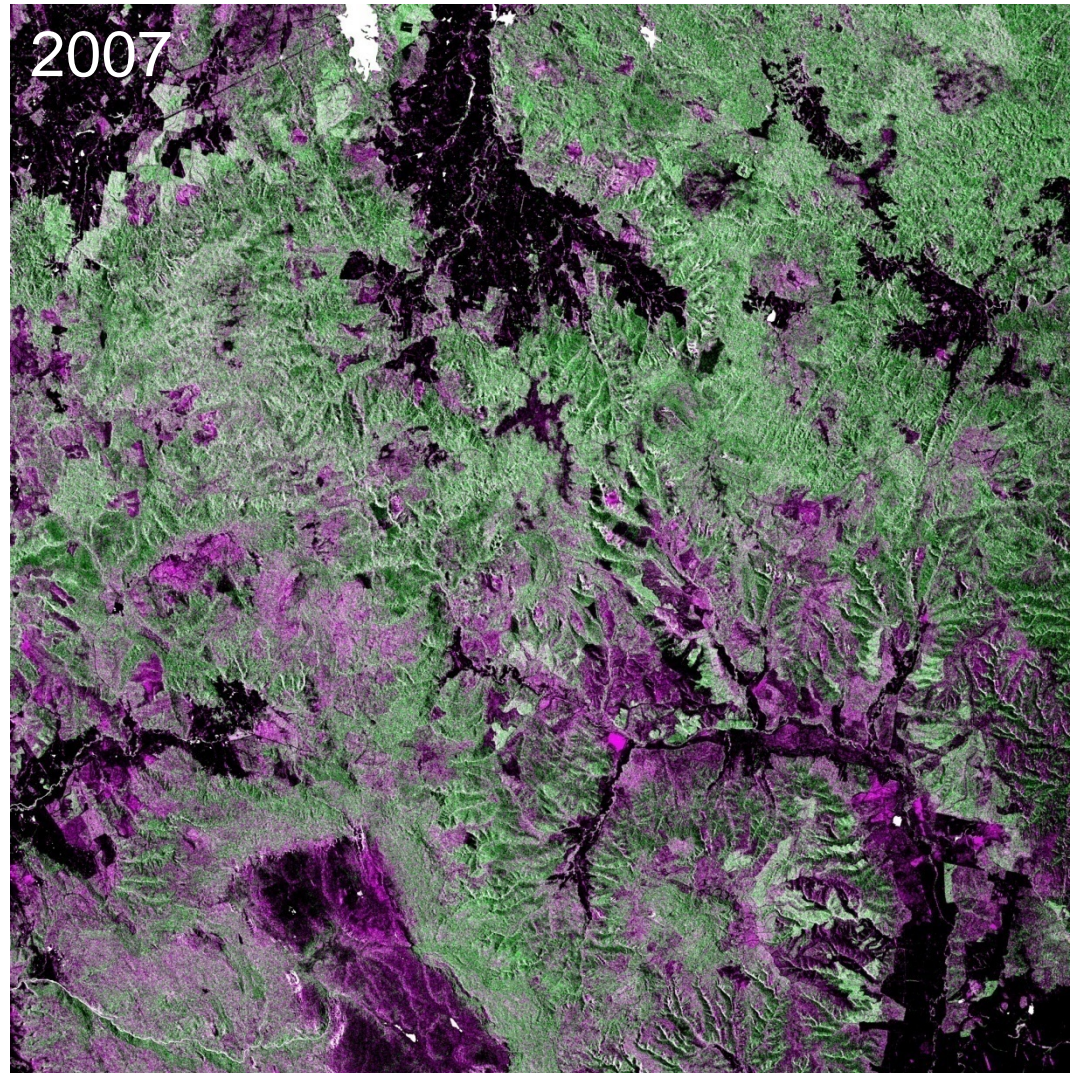
- Change (>3)
- Change (2-3)
- Change (1-2)
- No Change (-1 to 1)
- Change (-1 to -2)
- Change (-2 to -3)
- Change (<-3)

Land cover 2009

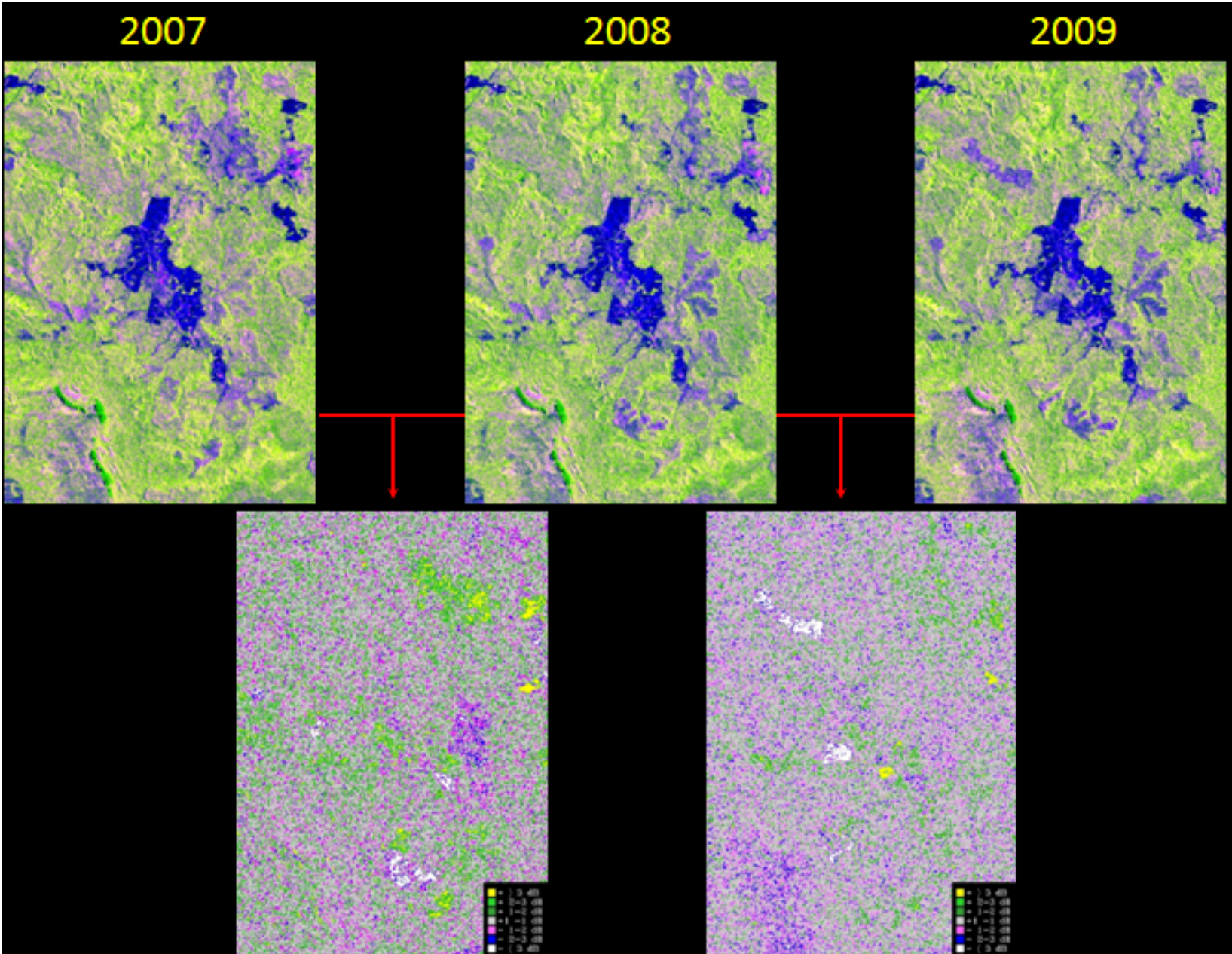


- TASVEG - urban
- TASVEG - water
- Agricultural land
- Alpine vegetation
- Buttongrass moorland
- Forest
- Eucalypt plantation
- Eucalypt plantation cleared
- Pine plantation
- Pine plantation cleared

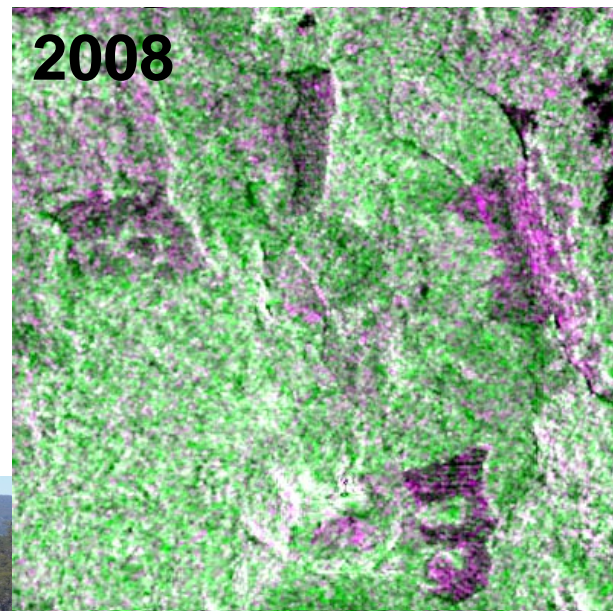
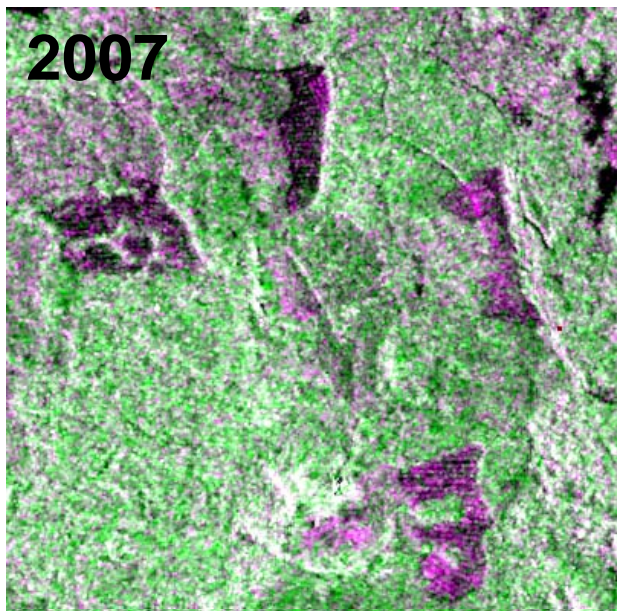
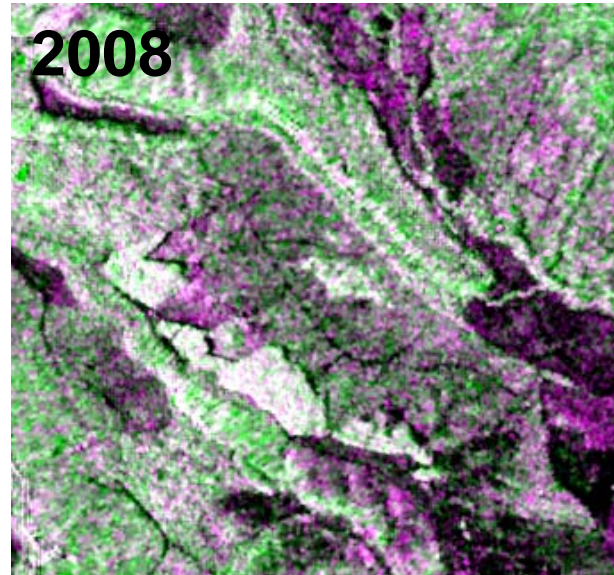
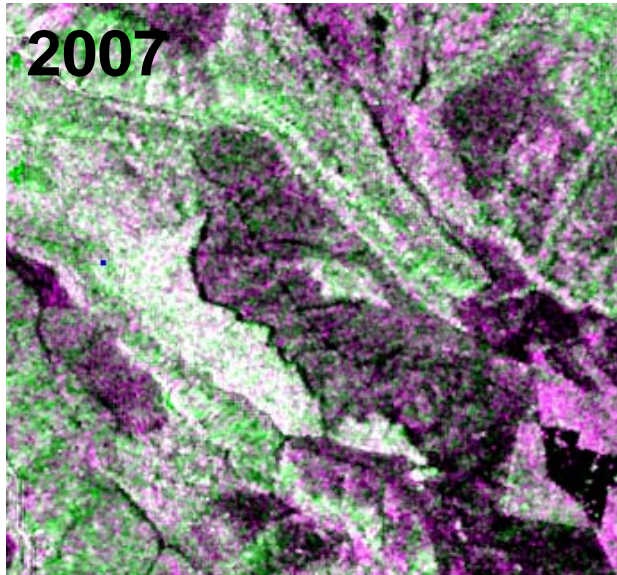
2007



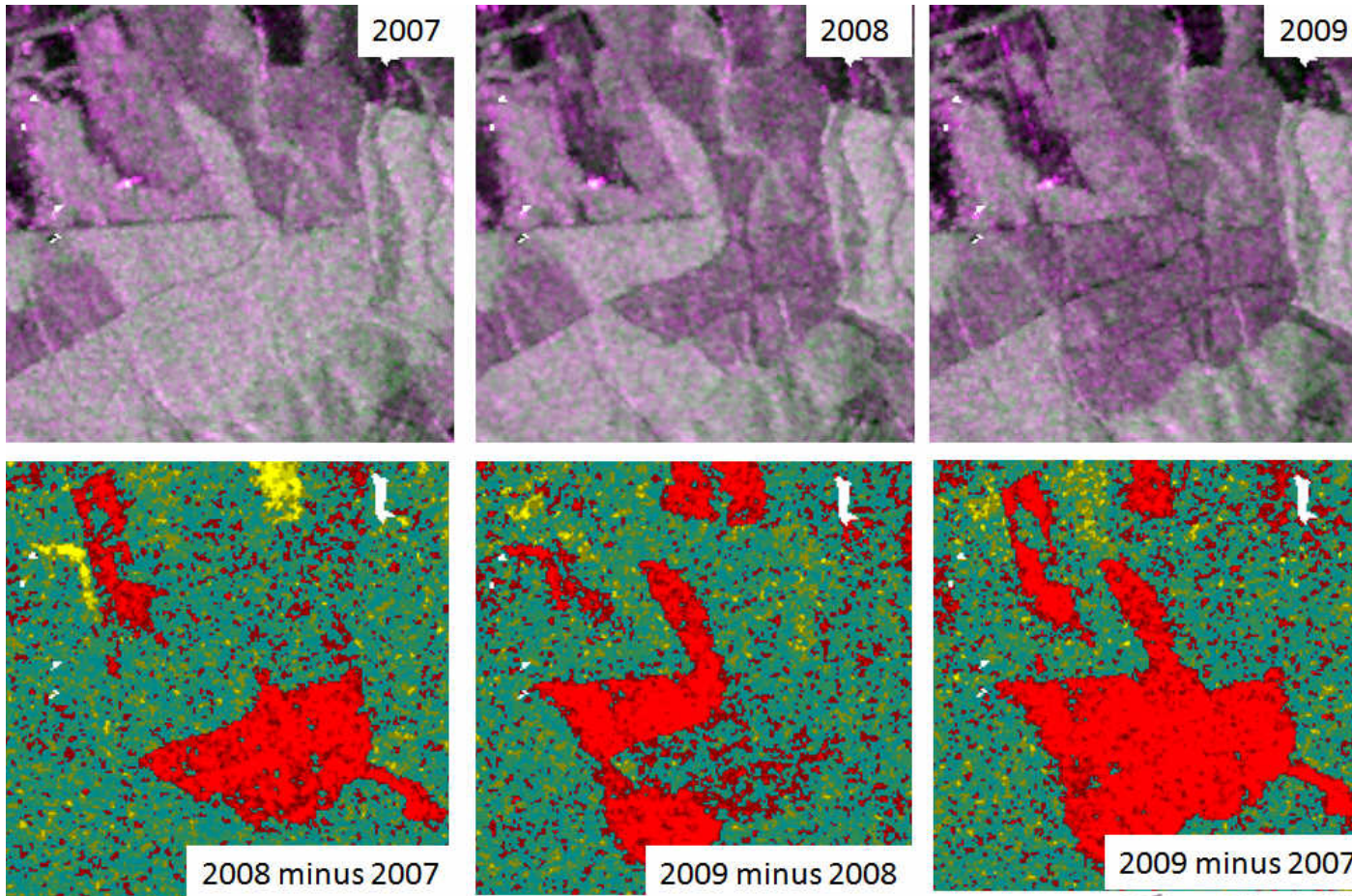
Change mapping



Change mapping examples



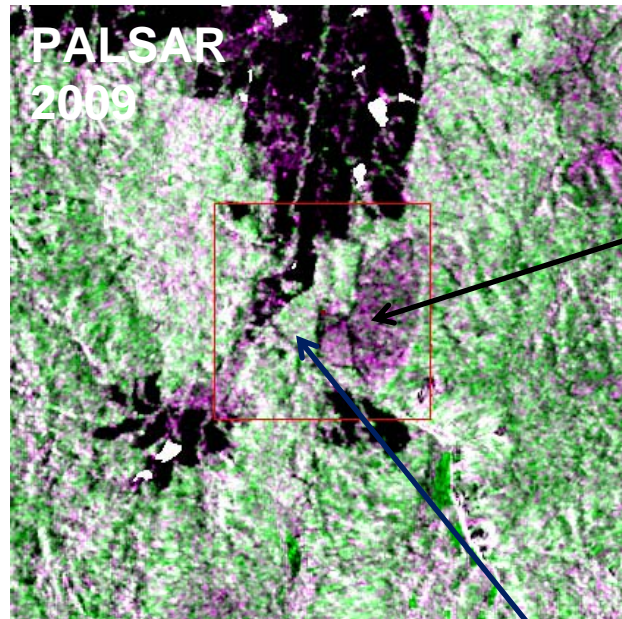
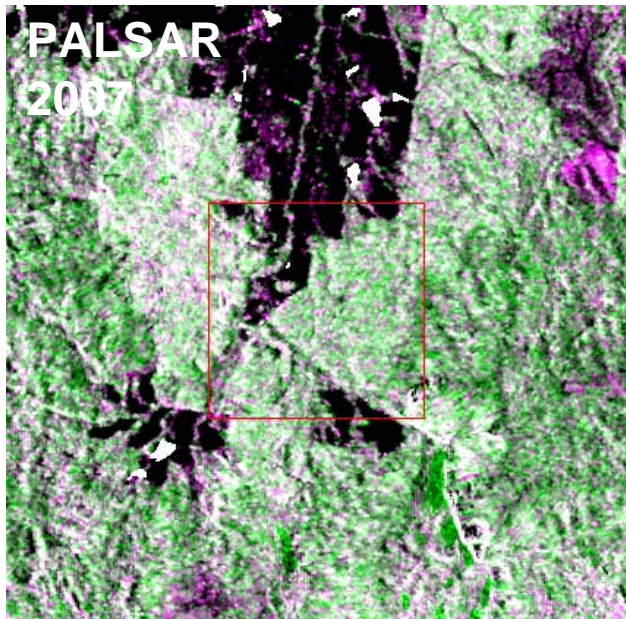
Change mapping



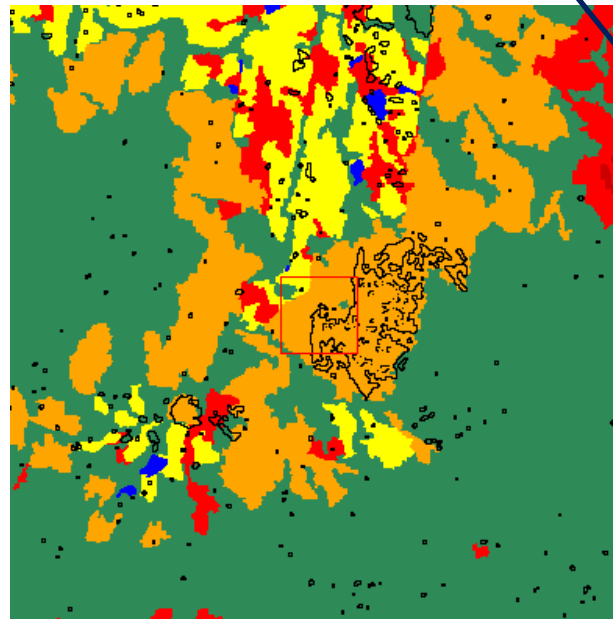
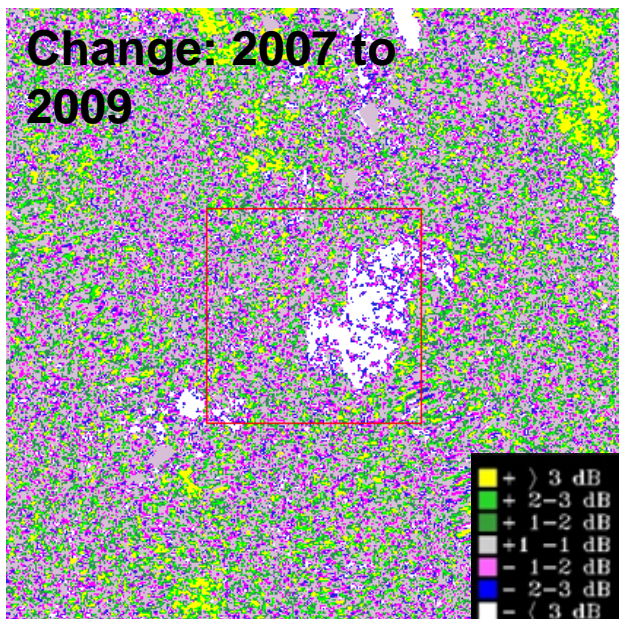
Clearing of forest for plantation



Change detection: Clearing of pine plantation

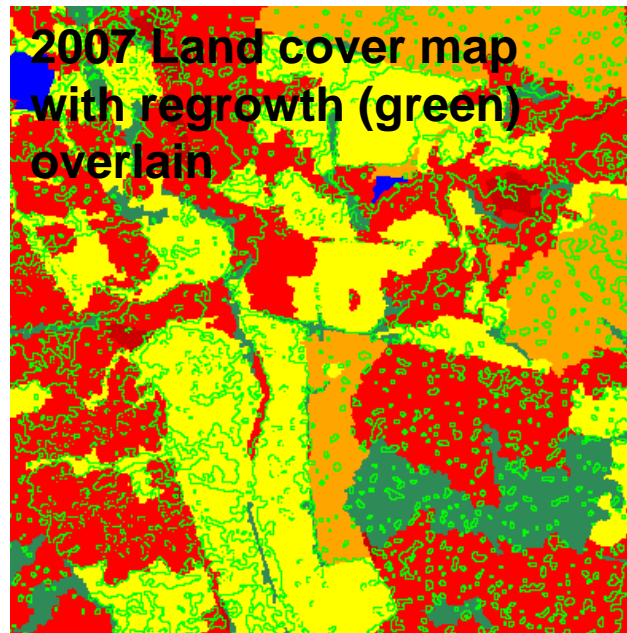
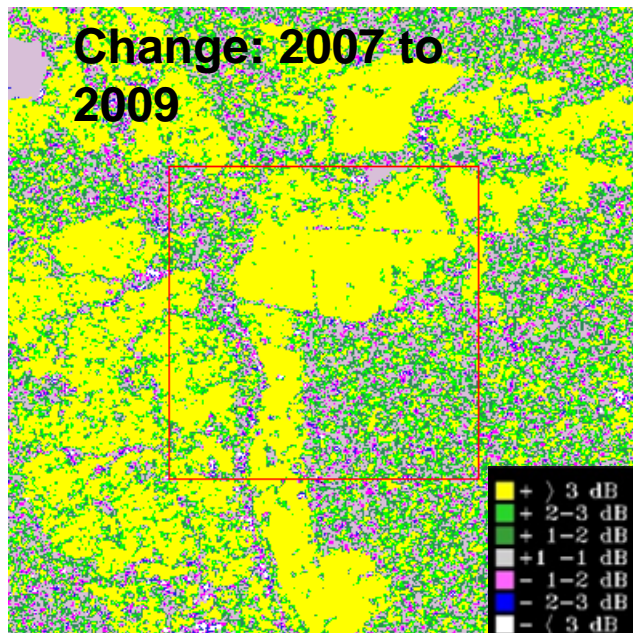
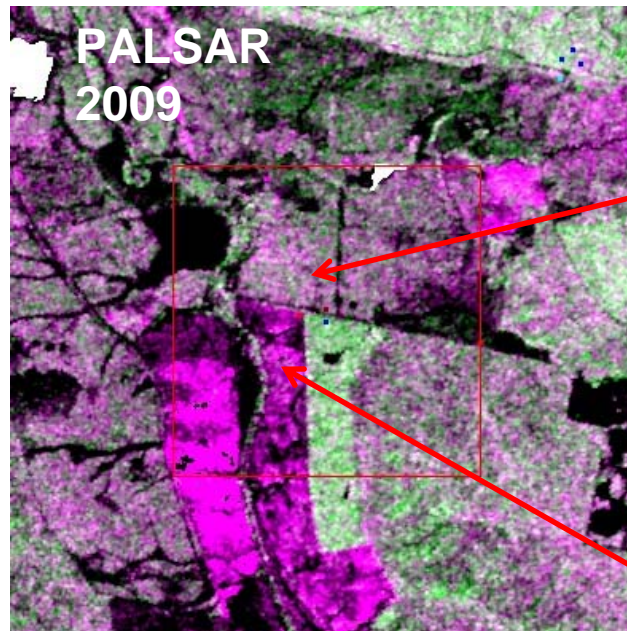
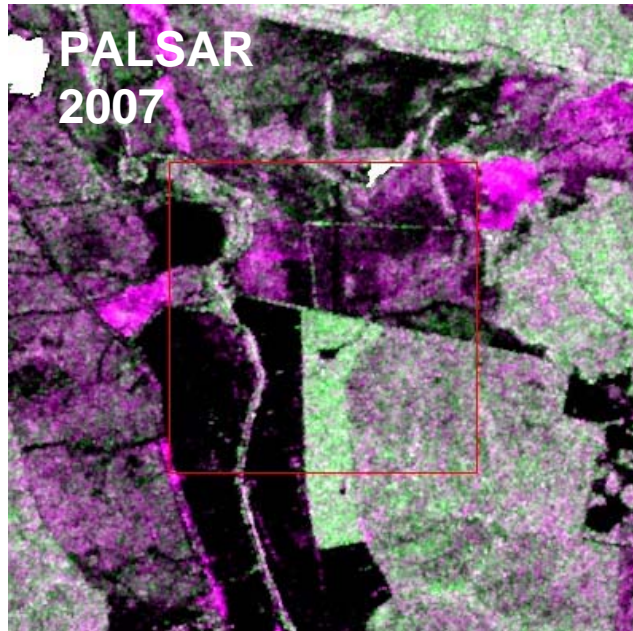


Clearing of pine plantation
in 2009

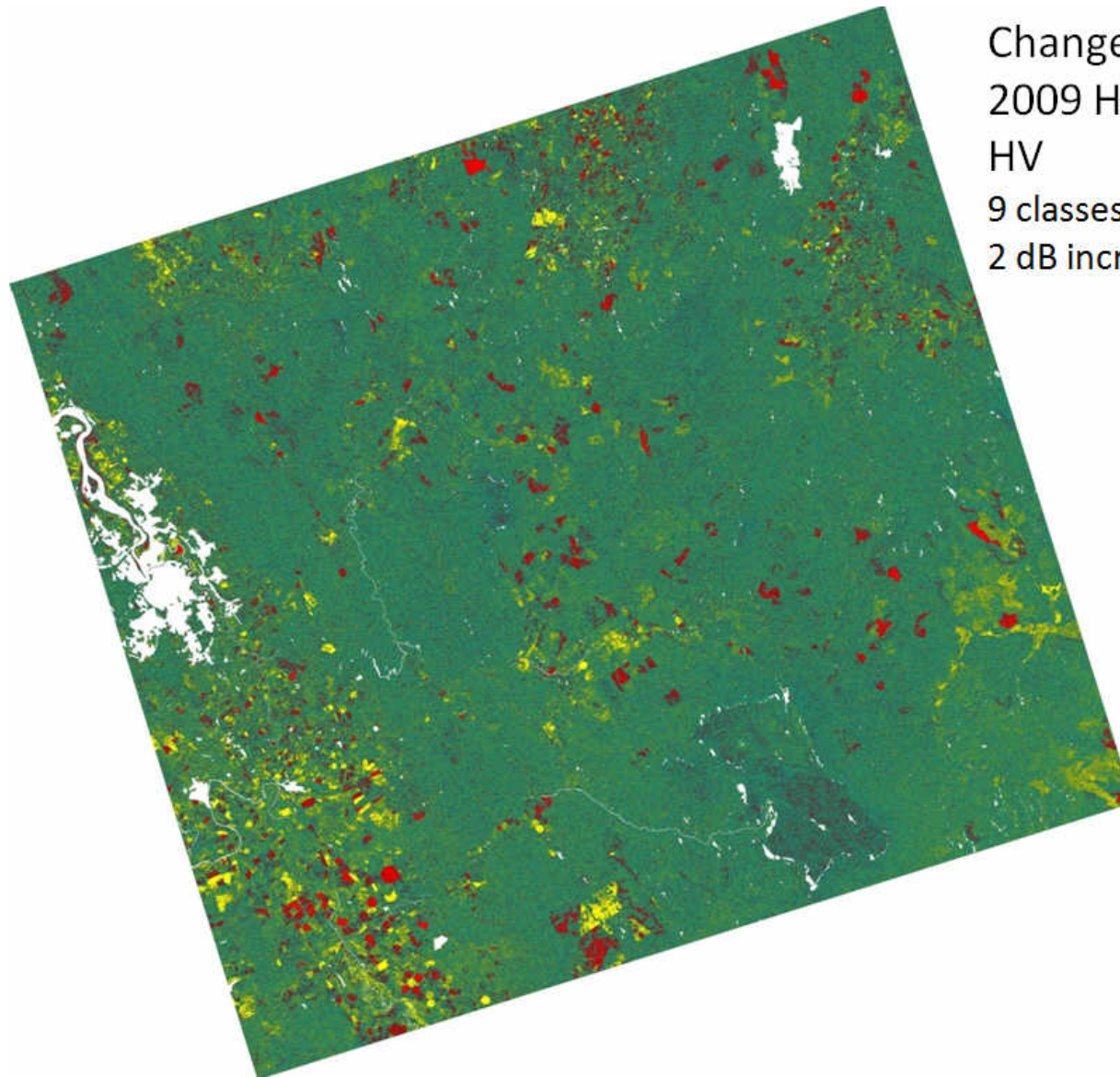


Adjacent pine plantation

Change detection: Regrowth



PALSAR scene - change image



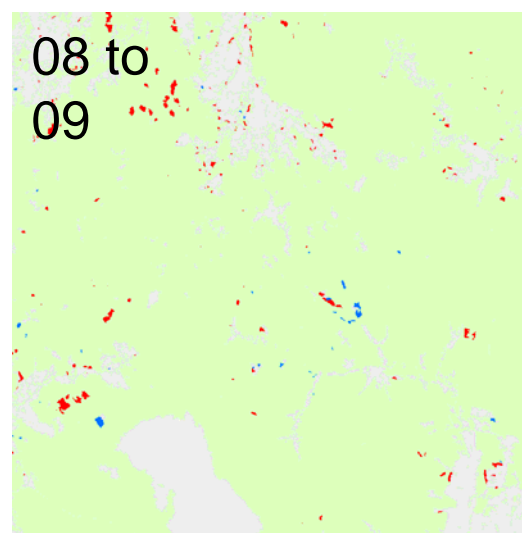
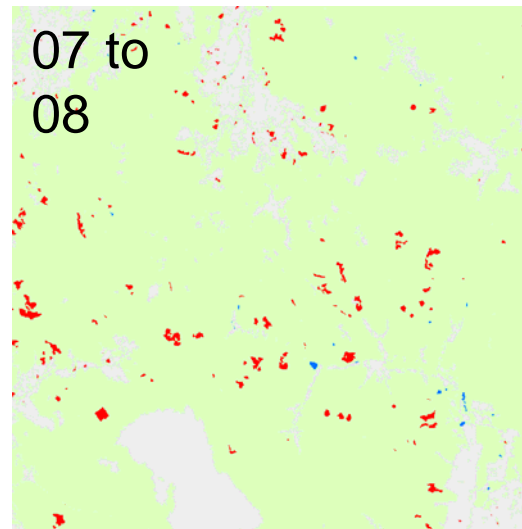
Change detection
2009 HV minus 2007
HV
9 classes
2 dB increments



Mathinna: Land use/cover change mapping

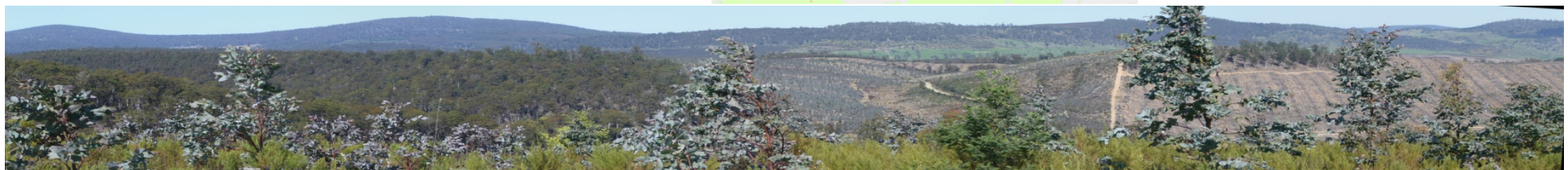
- Summarise spatial extent and location of deforestation (red), regeneration (blue) and no change (green – forest, grey – non-forest)
- Re-classification of annual land cover maps
- Extract trend metrics
- Applicable to modelling scenarios

- 1 Non-forest (no change)
- 2 Forest (no change)
- 3 Deforestation
- 4 Regeneration



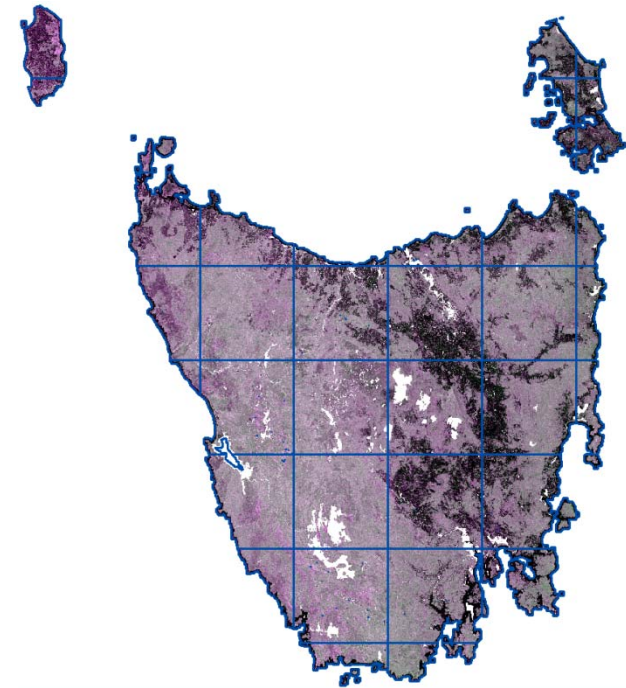
Change 2007 – 2008	Area (ha)	Area (%)
No change (forest)	210,210.7	84.09
No change (non-forest)	36,909.6	14.76
Deforestation	2,733.6	1.09
Regeneration	137.7	0.06
TOTAL	249,991.6	100

Change 2008 – 2009	Area (ha)	Area (%)
No change (forest)	210,826.6	84.33
No change (non-forest)	37,480.95	14.99
Deforestation	1,430.5	0.57
Regeneration	253.6	0.1
TOTAL	249,991.6	100



2007 Baseline land cover mosaic

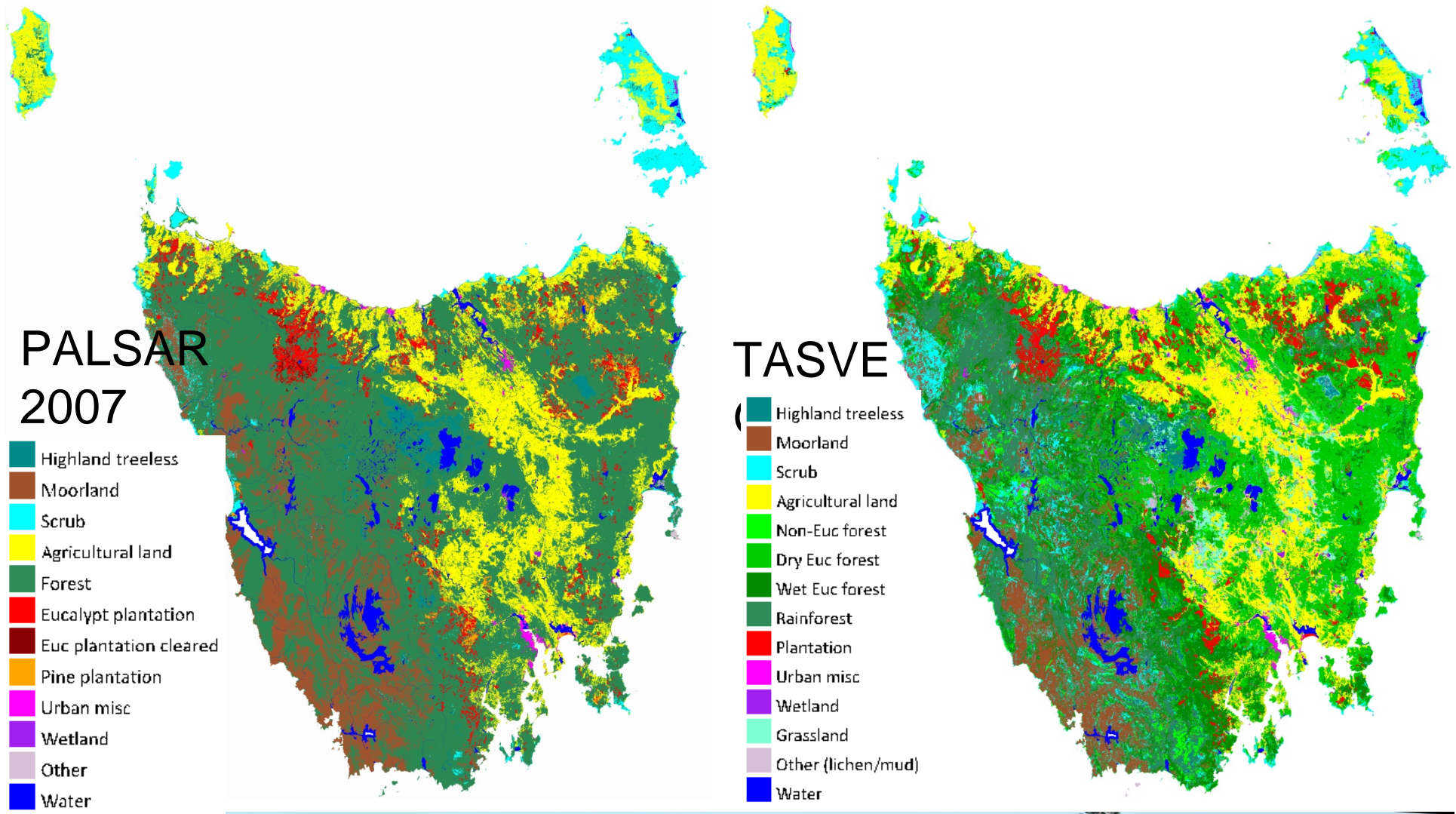
- Initial masking of mosaics using TASVEG (water and urban)
- Object-based approach to classification
 - Local tiling: 34 tiles
 - Chessboard and multi-resolution segmentation
 - Local stitching using variables
 - Rule set development: adjust per tile
 - Apply classification and export
- Change analysis and generation of annual forest information products



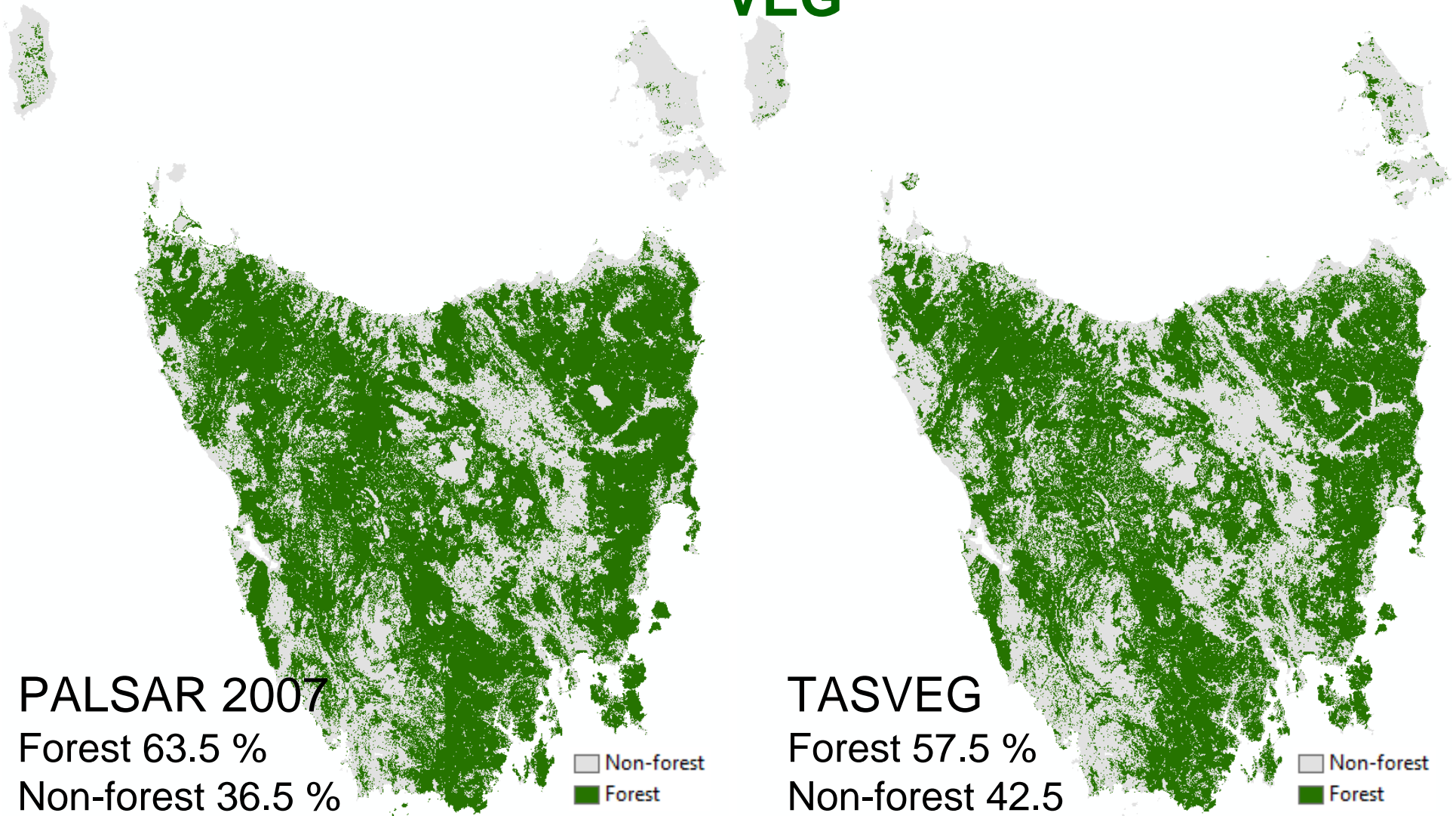
Local tiling approach applied to PALSAR 2007 mosaic



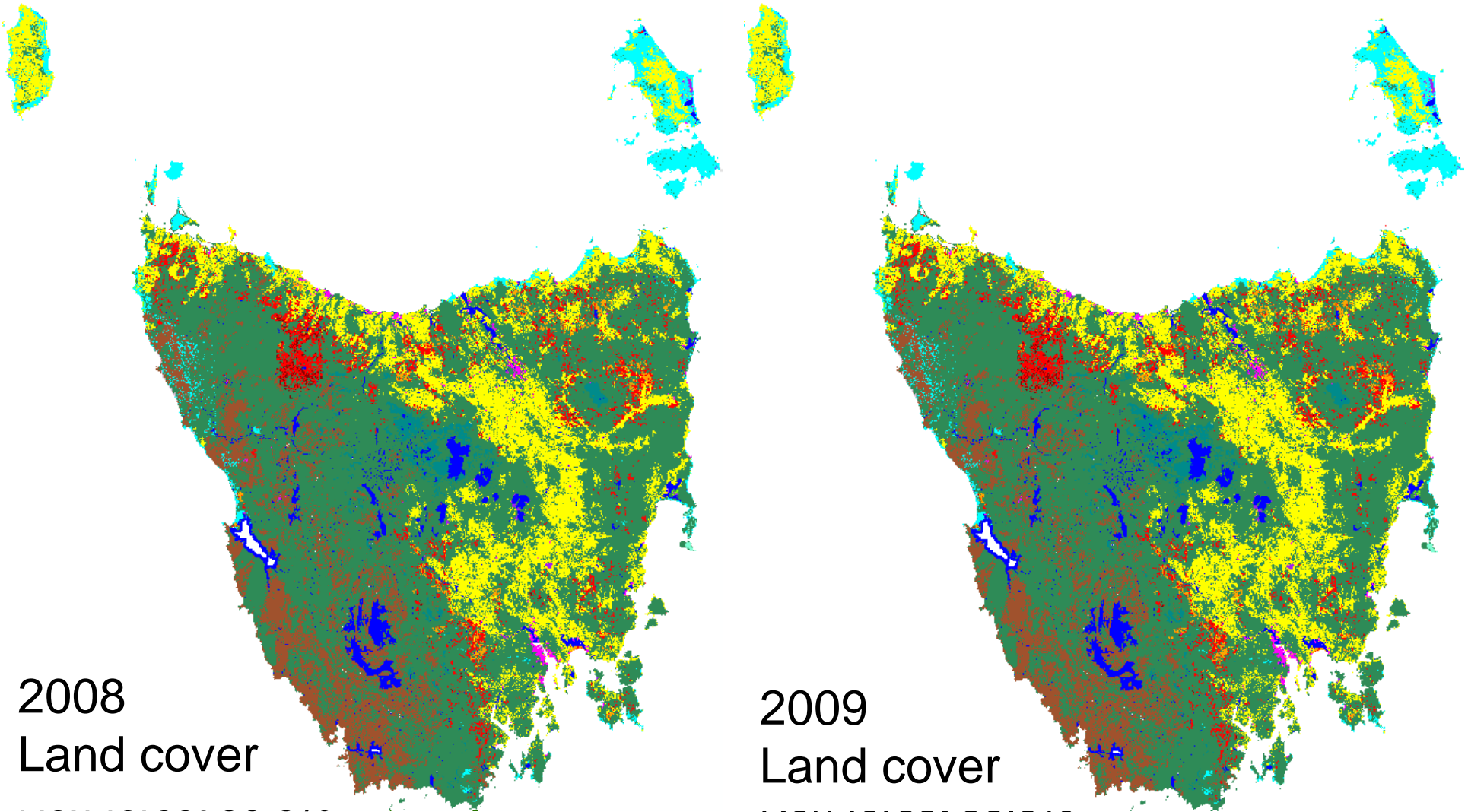
PALSAR derived land cover (2007) and TASVEG



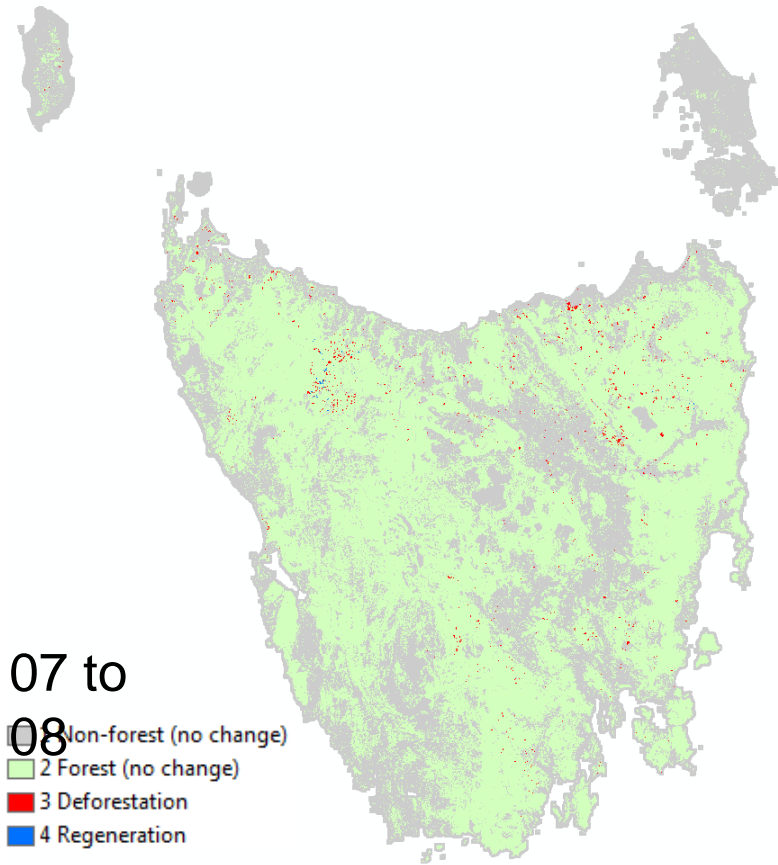
PALSAR derived forest/non-forest (2007) and TASVEG



Annual forest information products

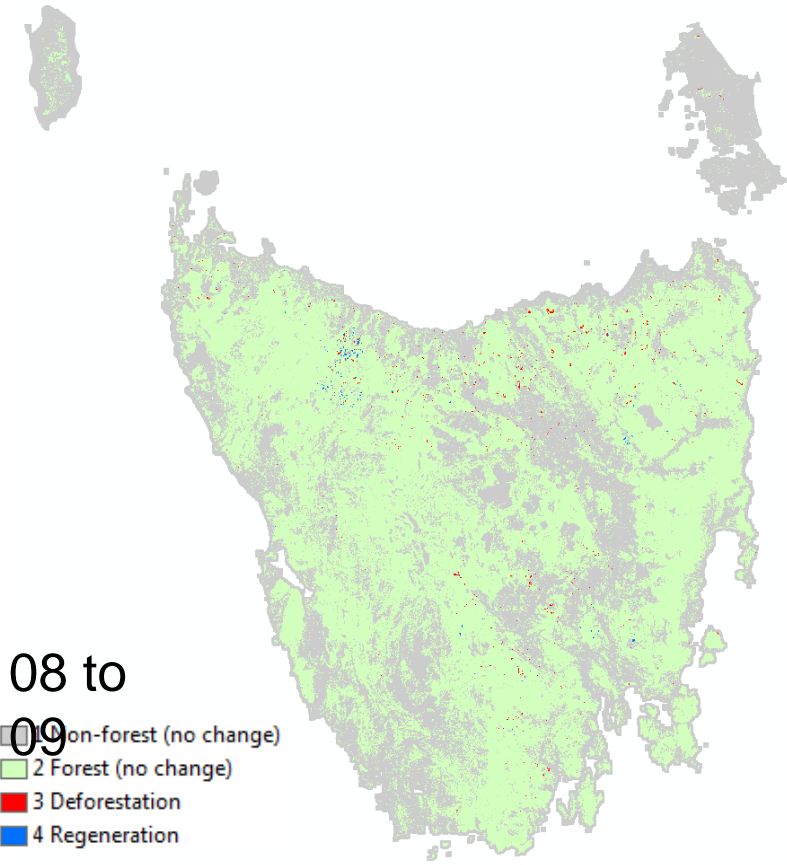


Land use/land cover change



07 to

- 08 Non-forest (no change)
- 2 Forest (no change)
- 3 Deforestation
- 4 Regeneration



08 to

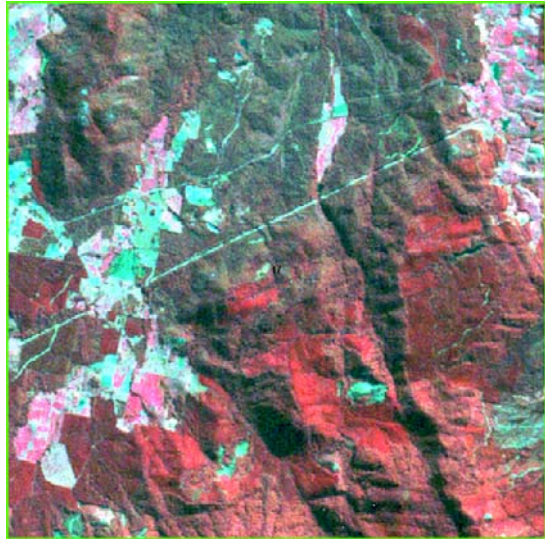
- 09 Non-forest (no change)
- 2 Forest (no change)
- 3 Deforestation
- 4 Regeneration

Change 2007 – 2008	Area (ha)	Area (%)
No change (forest)	4,343,655.2	63.29
No change (non-forest)	2,490,750.2	36.29
Deforestation	27,024.4	0.39
Regeneration	1,274.75	0.02
TOTAL	6,862,704.56	100

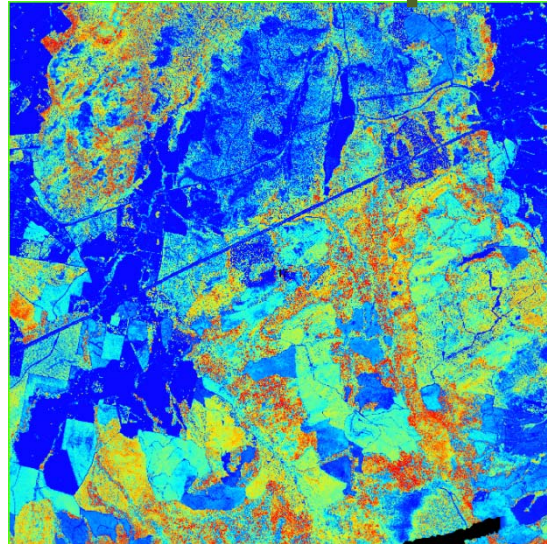
Change 2008 – 2009	Area (ha)	Area (%)
No change (forest)	4,344,781.75	63.31
No change (non-forest)	2,496,046.5	36.37
Deforestation	16,342.31	0.24
Regeneration	5,534	0.08
TOTAL	6,862,704.56	100



Forest non-forest maps – radar/optical interoperability ?



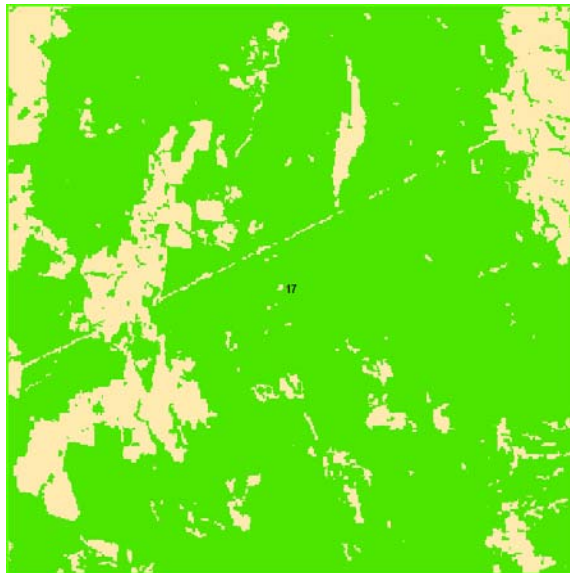
Landsat,



Lidar (hgt)



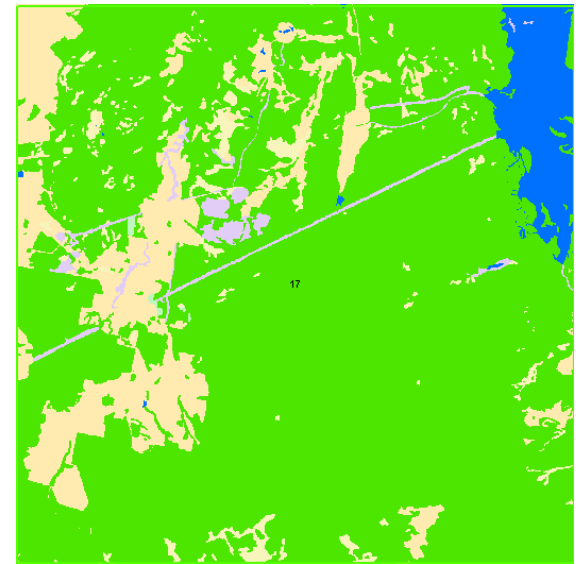
SPOT



Landsat,



Radar,



TasVEG

Deforestation leaves one tree behind



Acknowledgements:

GEO IFCI, Department of Climate Change and Energy Efficiency
Forestry Tasmania, Sarmap, JAXA, Geoscience Australia

<http://www.geo-fct.org>