K&C Phase 4 – Status report

Detection of Biomass and Structural Change using Japanese L-band SAR, Australia

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[6]University of Aberystwyth, Wales
[7]NSW Office of Environment and Heritage

Science Team meeting #24
Tokyo, Japan, January 29-31, 2018

Project outline and objectives

Objectives

1. Improvement of large area woody extent, height, cover, and above-ground biomass mapping using PALSAR-1 and PALSAR-2 mosaics
2. Determine if changes in woody structure due to processes of clearing, regeneration, fire and thickening may be detected using combined Landsat and PALSAR-1 and PALSAR-2 time-series

Supports K&C *thematic drivers*

Carbon cycle science – products are to be input to carbon data assimilation schemes, carbon offsets research and national reporting frameworks

Environmental **C**onservation – regional mapping at a scale relevant to land management and State Government vegetation management policy

Objective 1

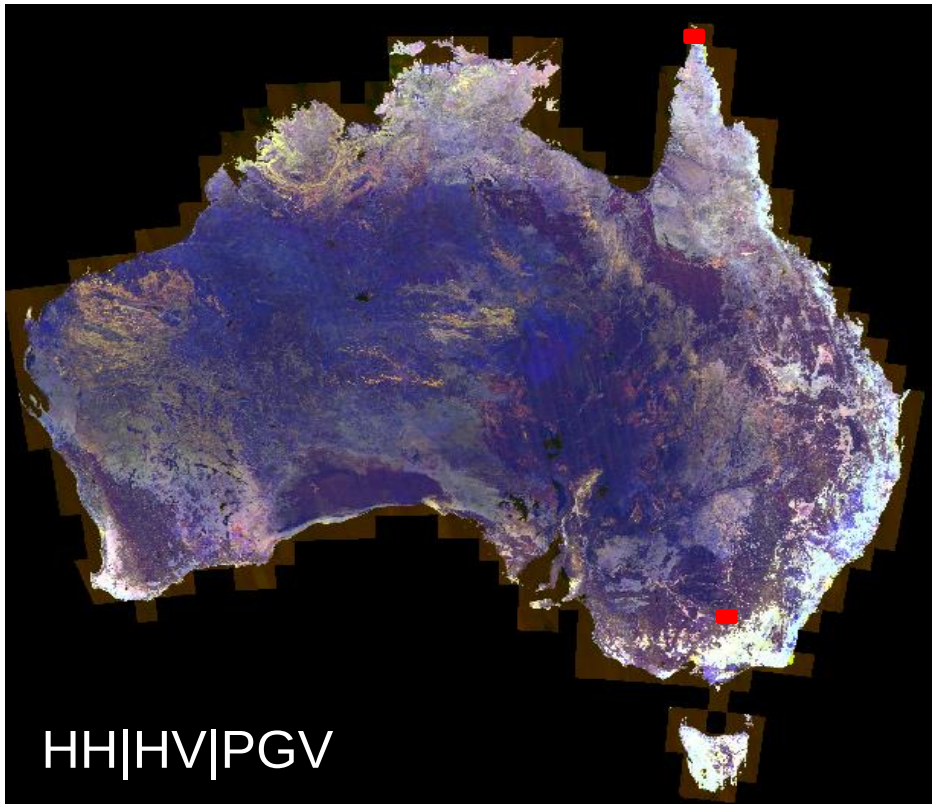
Improvements to large area woody extent, height, cover, and above-ground biomass mapping using PALSAR-1 and PALSAR-2 mosaics

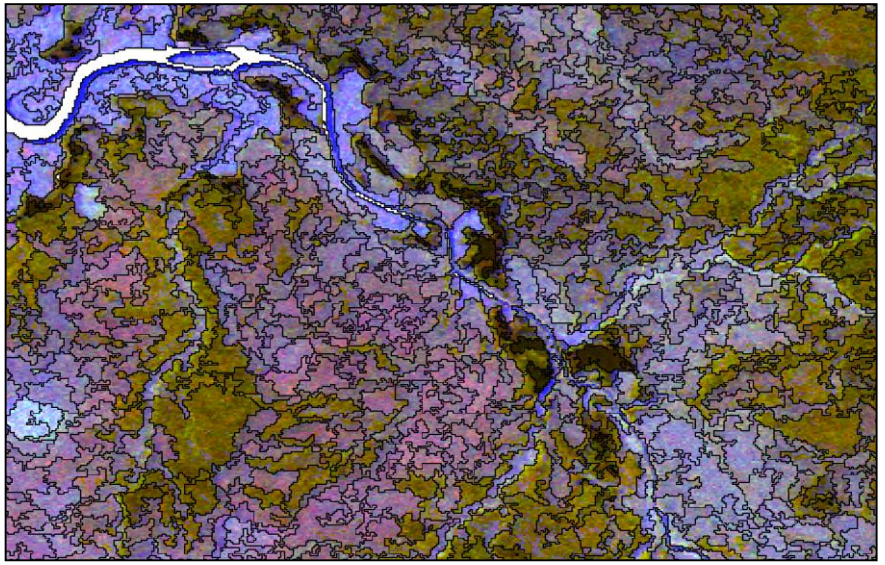
1. Australian vertical profile product improvements
   - ICESat GLAS vertical profile processing update
   - Validation using TERN AusCover Supersites

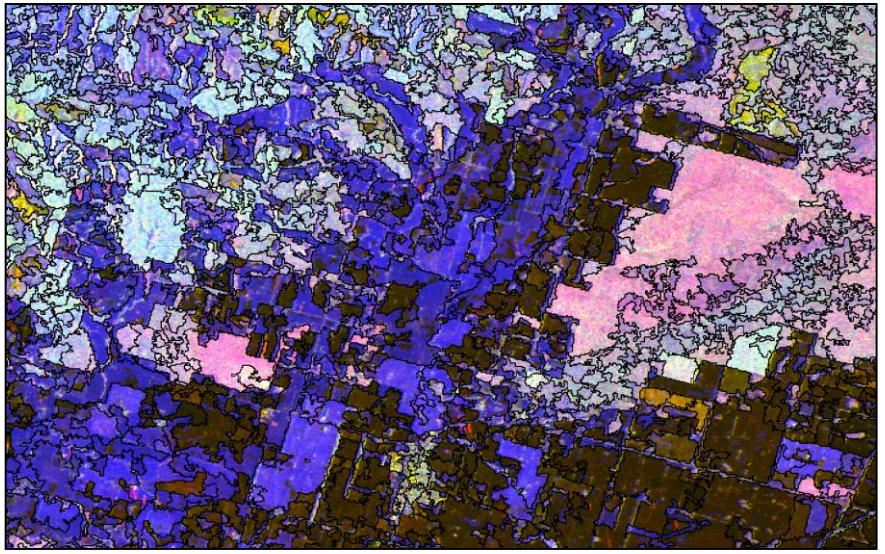
2. Completion of the Australian biomass plot library
   - TERN Auscover plot measurement spatial database
   - Biomass assessment and error propagation

3. Development of an Australian above ground biomass map

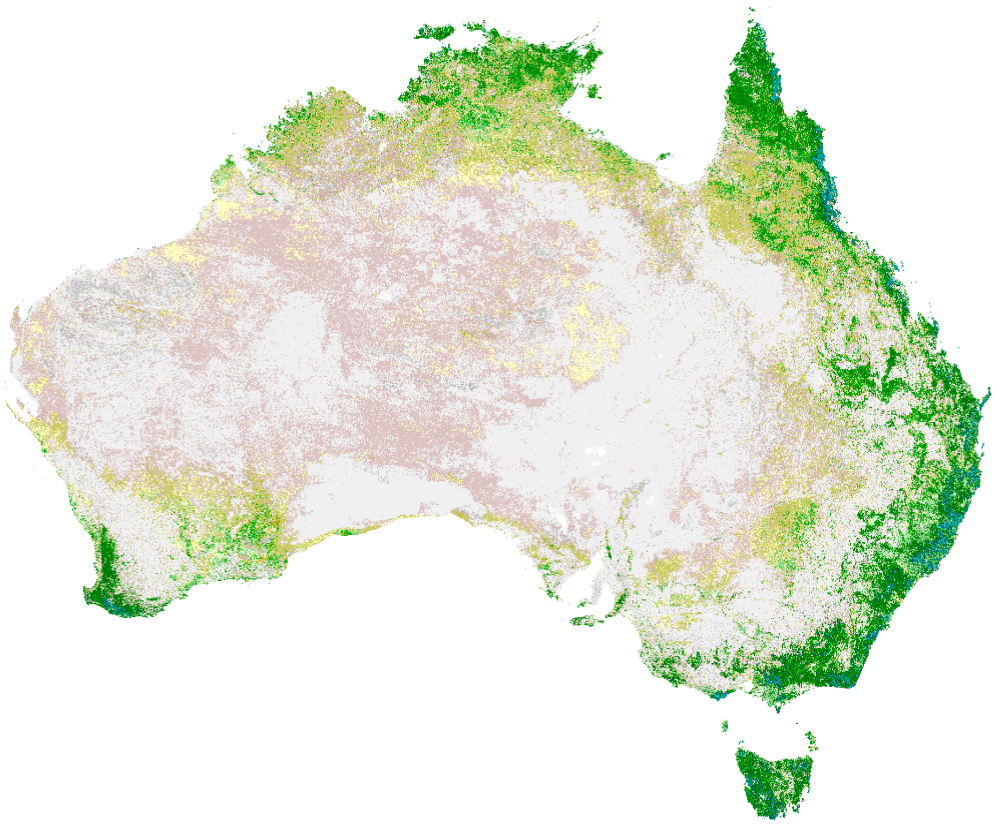
Segmentation of continental Landsat persistent green vegetation cover and ALOS PALSAR-1 HH/HV mosaics (Phase 3)



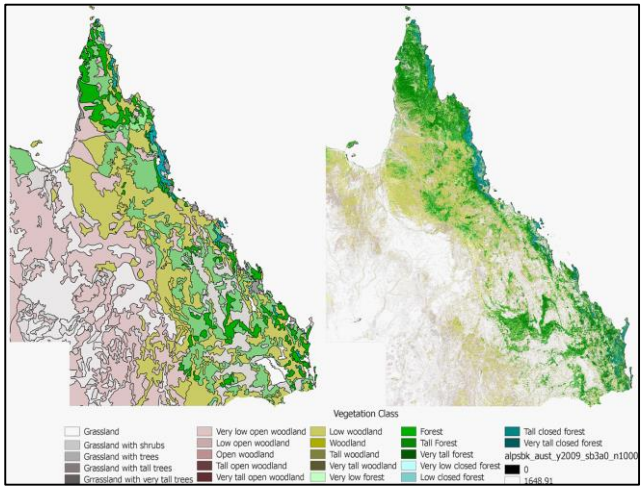




Australian Vegetation Structural Formation Product (Phase 3)

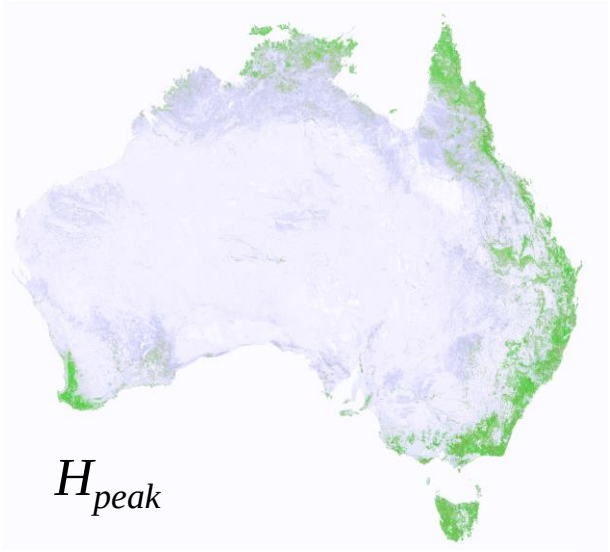


- No Data
- Grassland
- Grassland with shrubs
- Grassland with trees
- Grassland with tall trees
- Grassland with very tall trees
- Very low open woodland
- Low open woodland
- Open woodland
- Tall open woodland
- Very tall open woodland
- Very low woodland
- Low woodland
- Woodland
- Tall woodland
- Very tall woodland
- Very low forest
- Low forest
- Forest
- Tall Forest
- Very tall forest
- Very low closed forest
- Low closed forest
- Closed forest
- Tall closed forest
- Very tall closed forest

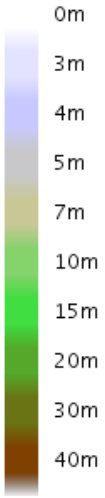


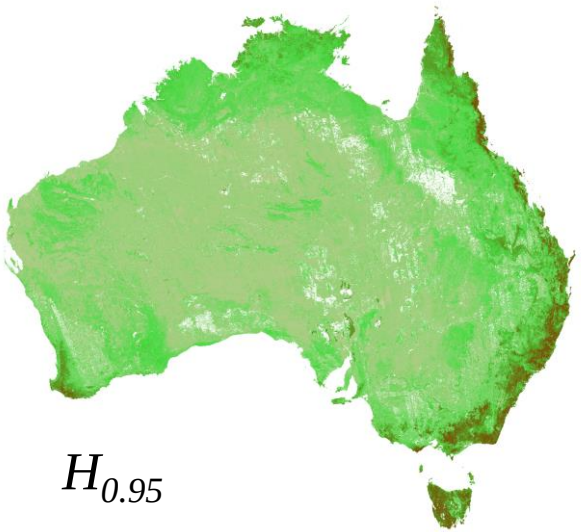
Significantly improved detail and accuracy compared with existing mapping

Australian Vertical Plant Profile Products (Phase 4)

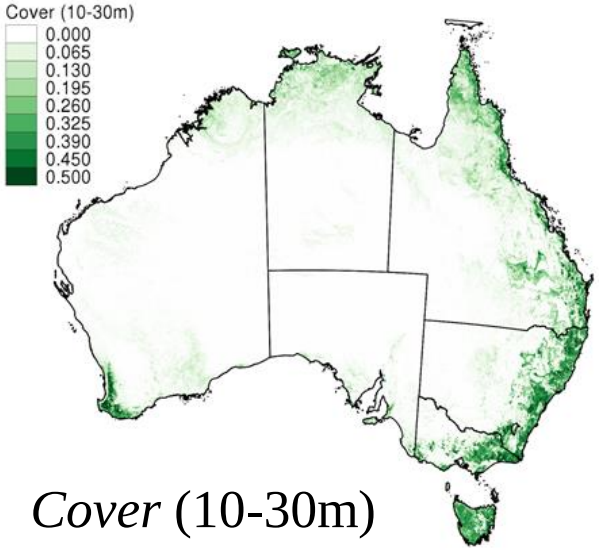


H_{peak}

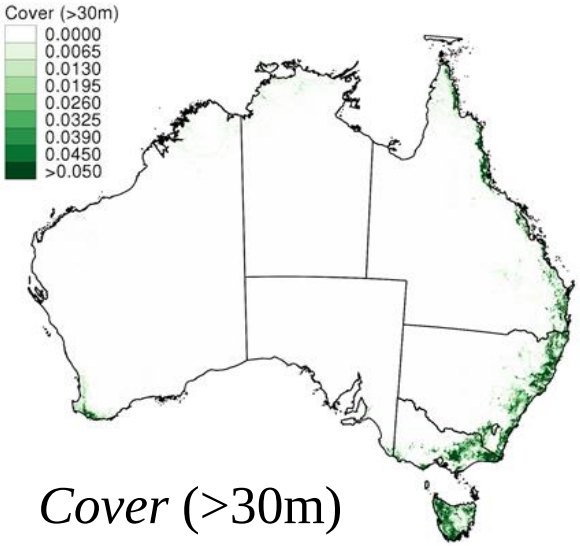




$H_{0.95}$



Cover (10-30m)



Cover (>30m)

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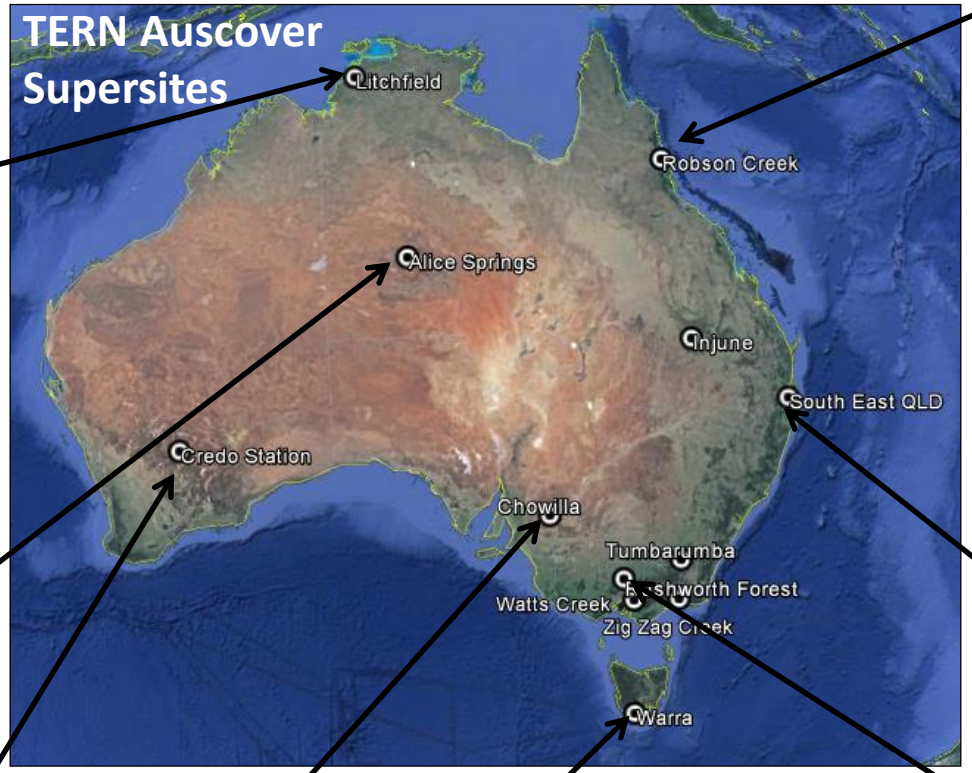
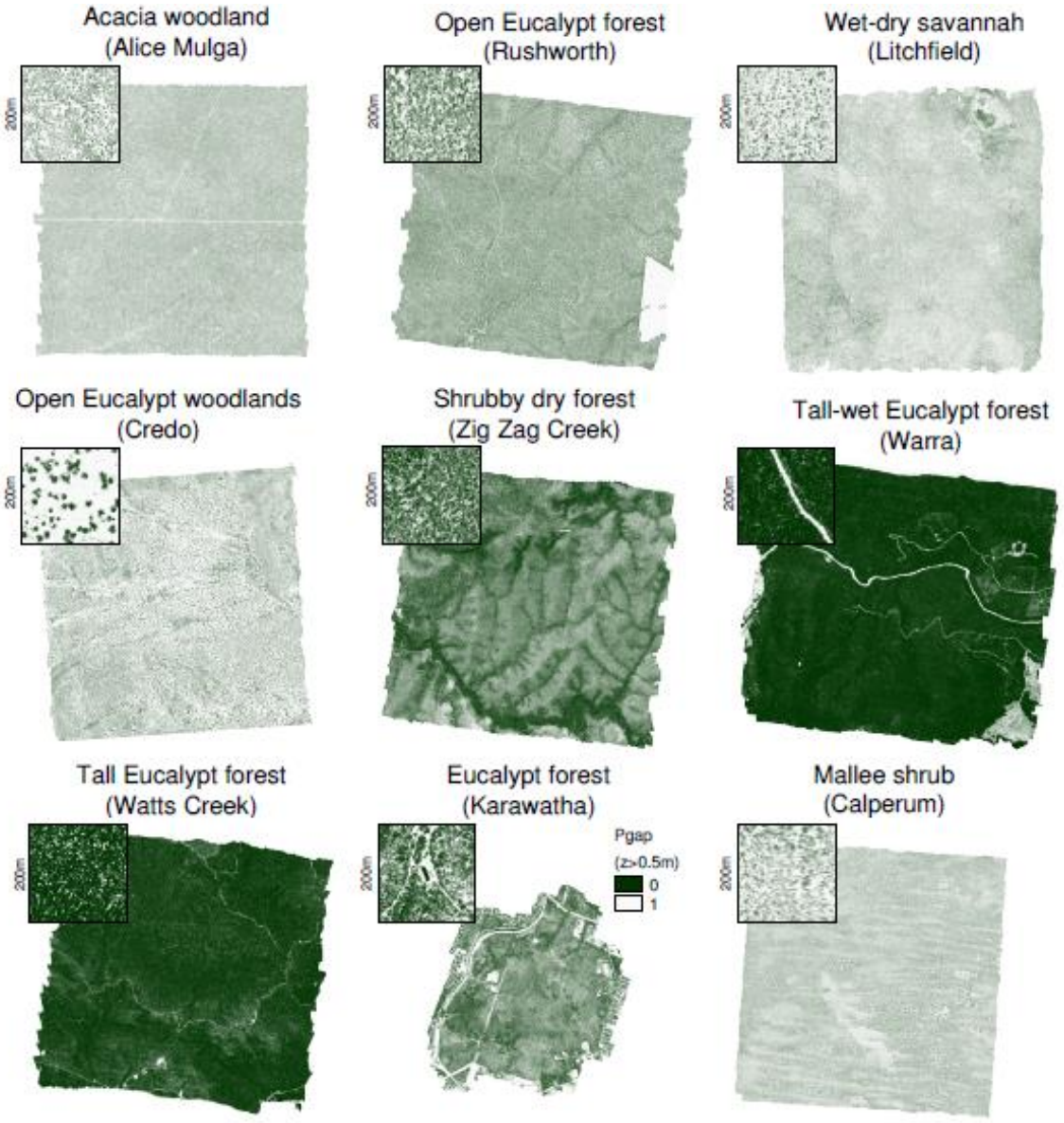




5 km × 5 km
TERN AusCover
Supersites

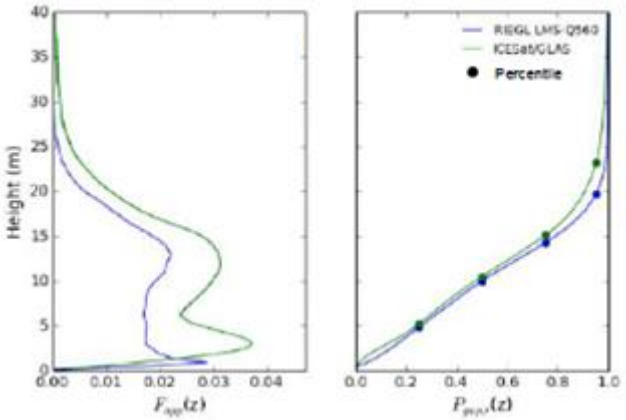
ALS Data Products:

Height percentiles

Cover ($1-P_{gap}$)

Vertical Plant profile (F_{app})

Above Ground Biomass (TBC)



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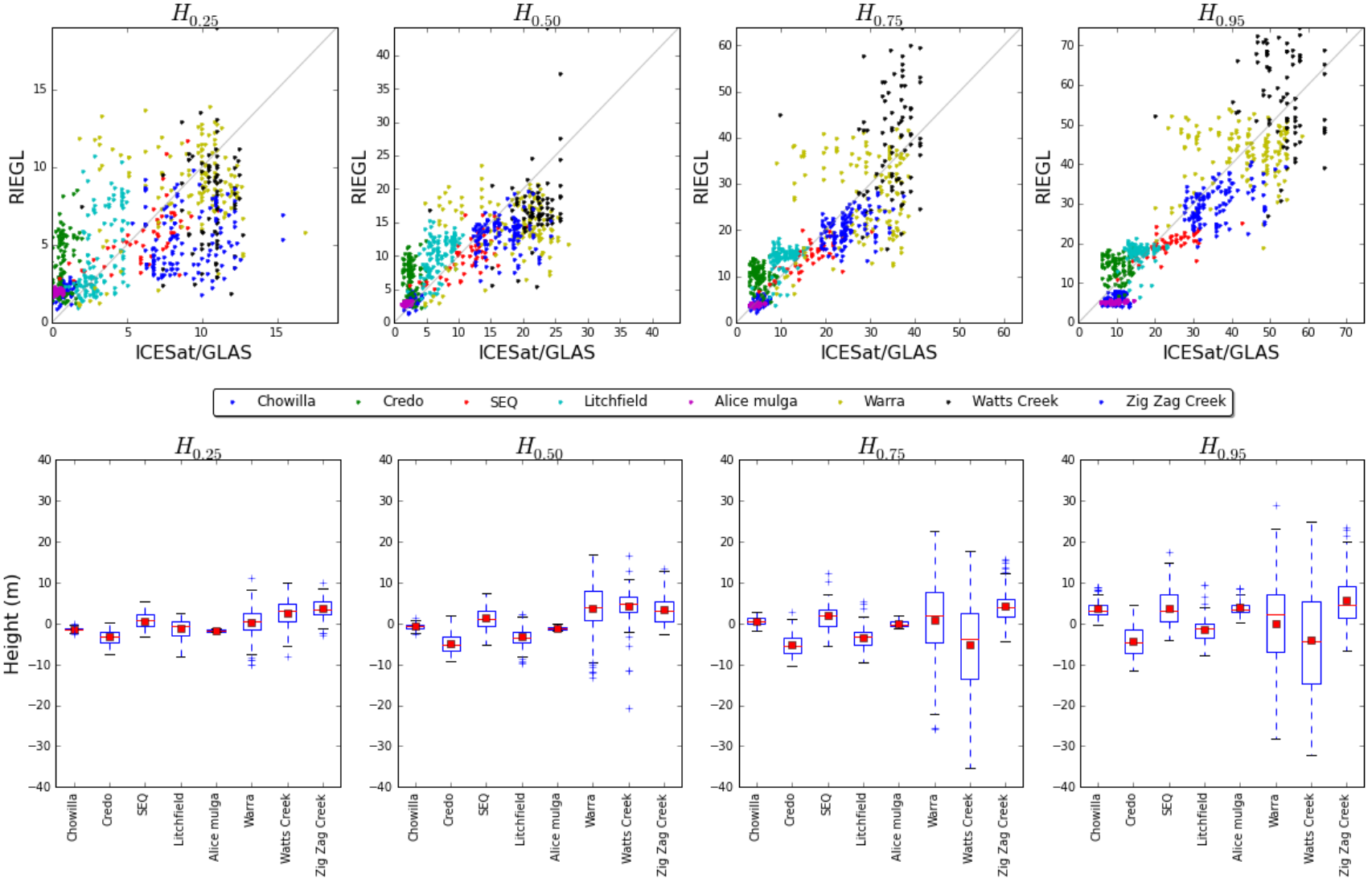
Validation of Revised Vertical Plant Profile Products



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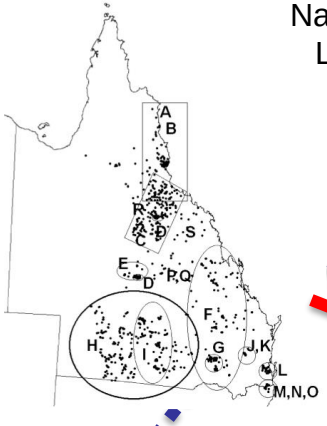
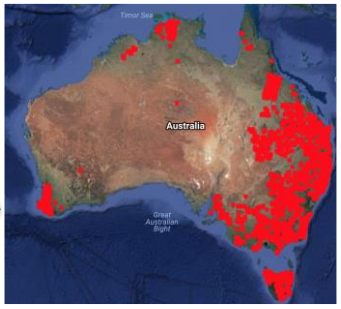
Queensland Biomass Library (2009)

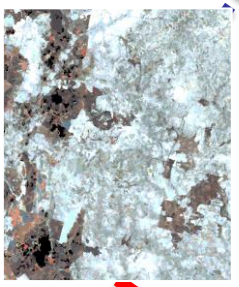


National Biomass Library (2016)



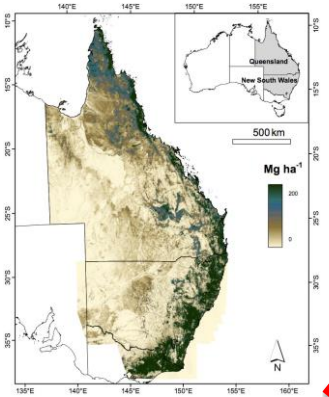
Landsat PG, ALOS HH and HV 50 m mosaic (2009)

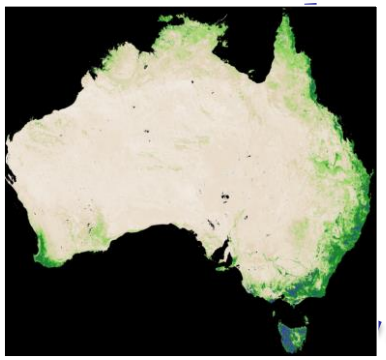
Australian Biomass Change (2018)



NASA PACRIM Injune (2000)

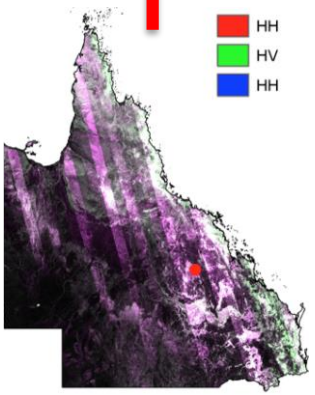
Queensland/NSW Biomass Map (2011)

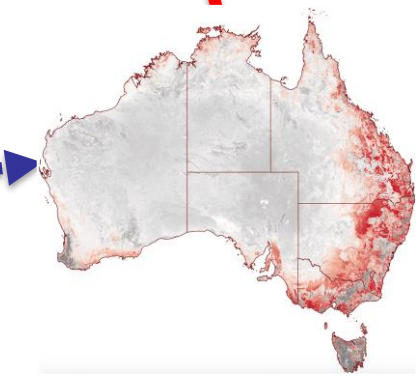




Australian Biomass Map (2017)

JRSRP (2007)





Australian Biomass Restoration (2017)

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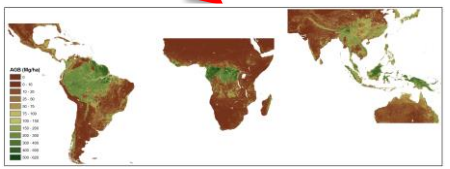
Provision of ALOS PALSAR strip data



JRC Global Biomass Map

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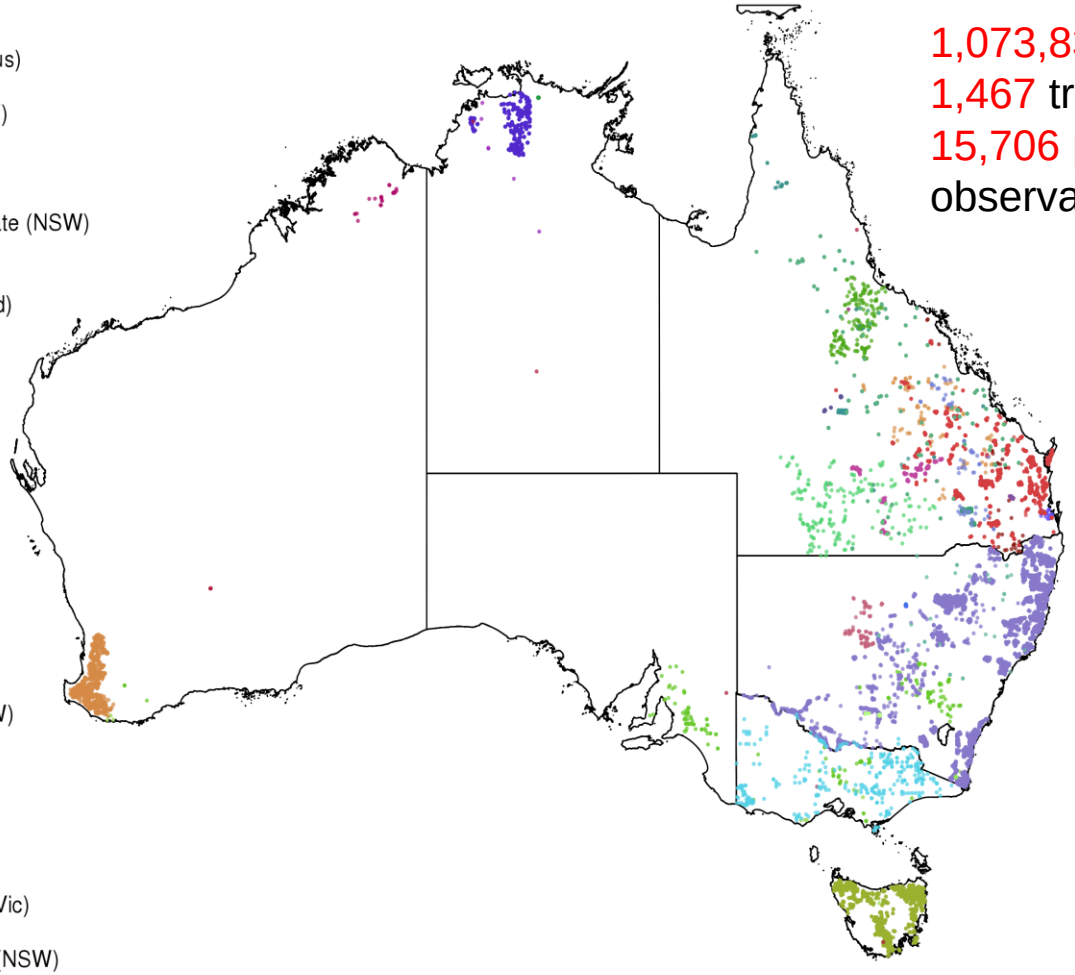
The TERN AusCover Australian Plant Biomass Library

Source project

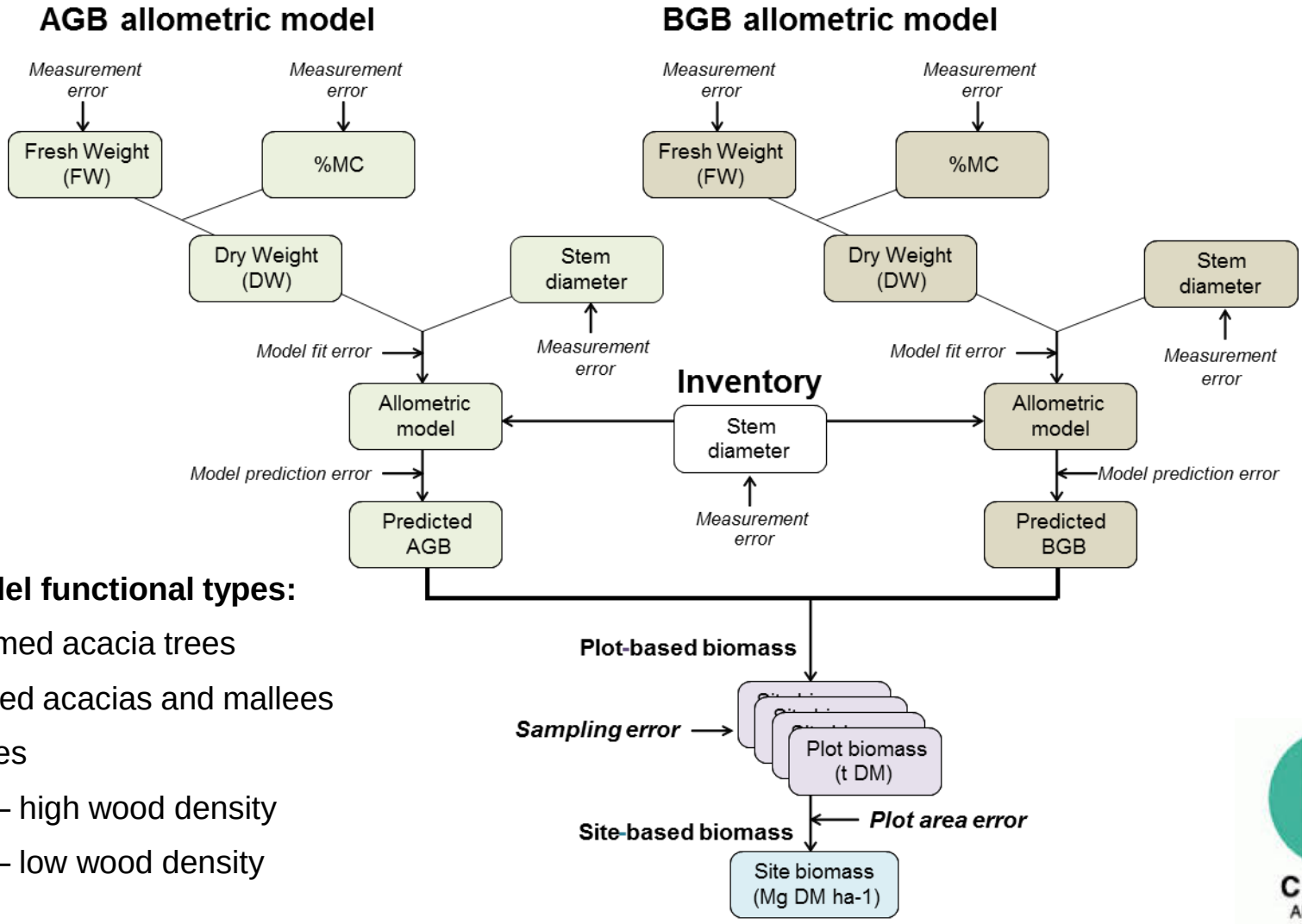
- Ausplot Forest Monitoring Network (Aus)
- CATER (Qld)
- Cobar Peneplain biomass study (NSW)
- CSIRO Environmental Plantings (Aus)
- Cyclone Monica (NT)
- DSITI RSC (Qld)
- Forestry Corporation Commercial Estate (NSW)
- Forestry Tasmania Lidar (Tas)
- Herbarium - Biocondition (Qld)
- Herbarium - Brisbane City Council (Qld)
- Herbarium - Bunya Mountains (Qld)
- Herbarium - Cali1 (Qld)
- Herbarium - Cali2 (Qld)
- Herbarium - Gidgee (Qld)
- Herbarium - GlennInnes (Qld)
- Herbarium - Grid (Qld)
- Herbarium - Mulga drought (Qld)
- Herbarium - NQ dieback (Qld)
- Jarradale thinning experiment (WA)
- NATT (NT)
- NFPP (Qld)
- NT Bushfires - Cape York (NT)
- NT Bushfires - Kimberley (NT)
- NT Bushfires - Three parks (NT)
- OEH Forest Monitoring Program (NSW)
- SMAPEX (NSW)
- TERN Supersite Network (Aus)
- TRAPS (Qld)
- UNSW redgum study (NSW)
- UQ brigalow habitat study (Qld)
- UQ brigalow regrowth - Dwyer (Qld)
- Victorian Forest Monitoring Program (Vic)
- WAPW South West Forests (WA)
- Wog Wog Fragmentation Experiment (NSW)



1,073,837 hugs of 839,866 trees
1,467 tree species
15,706 plots from 16,391 observations across 12,663 sites

http://qld.auscover.org.au/public/html/field

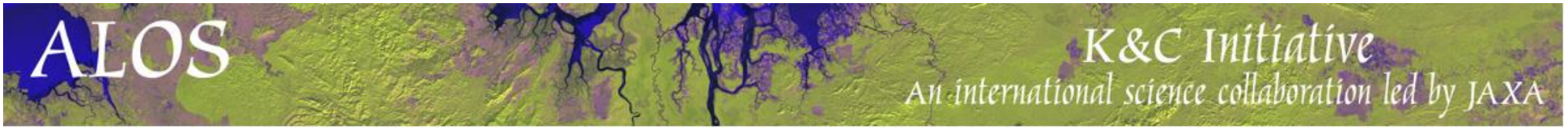
The TERN AusCover Australian Plant Biomass Library



Allometric model functional types:

- Single stemmed acacia trees
- Multi-stemmed acacias and mallees
- Eucalypt trees
- Other trees – high wood density
- Other trees – low wood density
- Shrubs

CSIRO AUSTRALIA



The TERN AusCover Australian Plant Biomass Library

FIELD DATA PORTAL

Joint Remote Sensing Research Program

Select Dataset

Biomass

Site Level

Start Date to End Date

Define Region

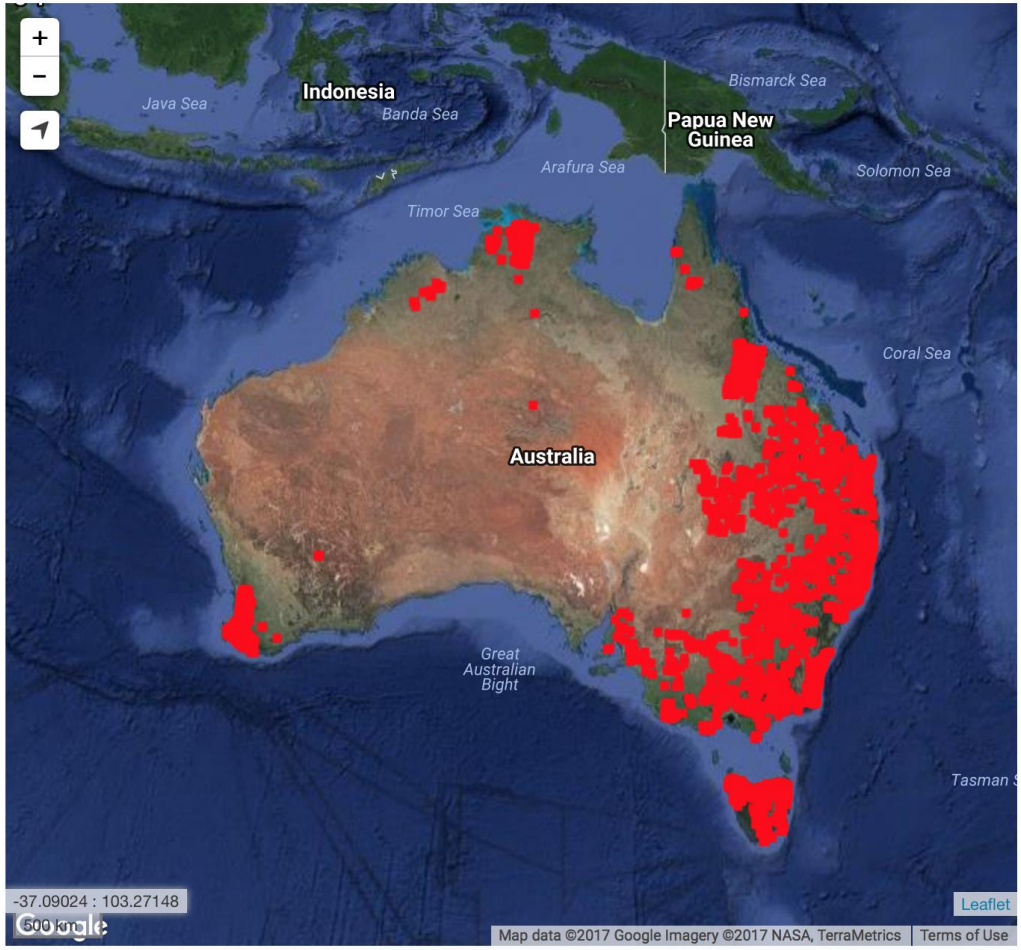
Draw a New Polygon

Zoom to Selected Polygons

Edit Tools

Download Data

Select Your Format



- obs_key: 14914329_02273373_19970101_000000
- source: DSITI Queensland Herbarium
- project: Herbarium - Cali1
- site: Cali1_10
- estsurvey: 1997
- estdate: 1/01/97 12:00 AM
- survey: 1997
- obs_time: 1/01/97 12:00 AM
- nplots: 1
- sampledarea_ha: 0.12
- sitearea_ha: 0.12
- sitedmin: 0.0
- longitude: 149.14329437519865
- latitude: -22.733725066045988
- live_basal_area_ha: 0.9634217471008693
- dead_basal_area_ha: 0.0
- live_tree_density_ha: 392
- dead_tree_density_ha: 0
- agb_drymass_ha: 0.44
- agb_drymass_se_ha: 0.1
- bgb_drymass_ha: 0.14
- bgb_drymass_se_ha: 0.04
- tb_drymass_ha: 0.58
- tb_drymass_se_ha: 0.12
- universal_agb: 0.0
- universal_count: 0.0

- obs_key: 14905555_02270719_19970101_000000
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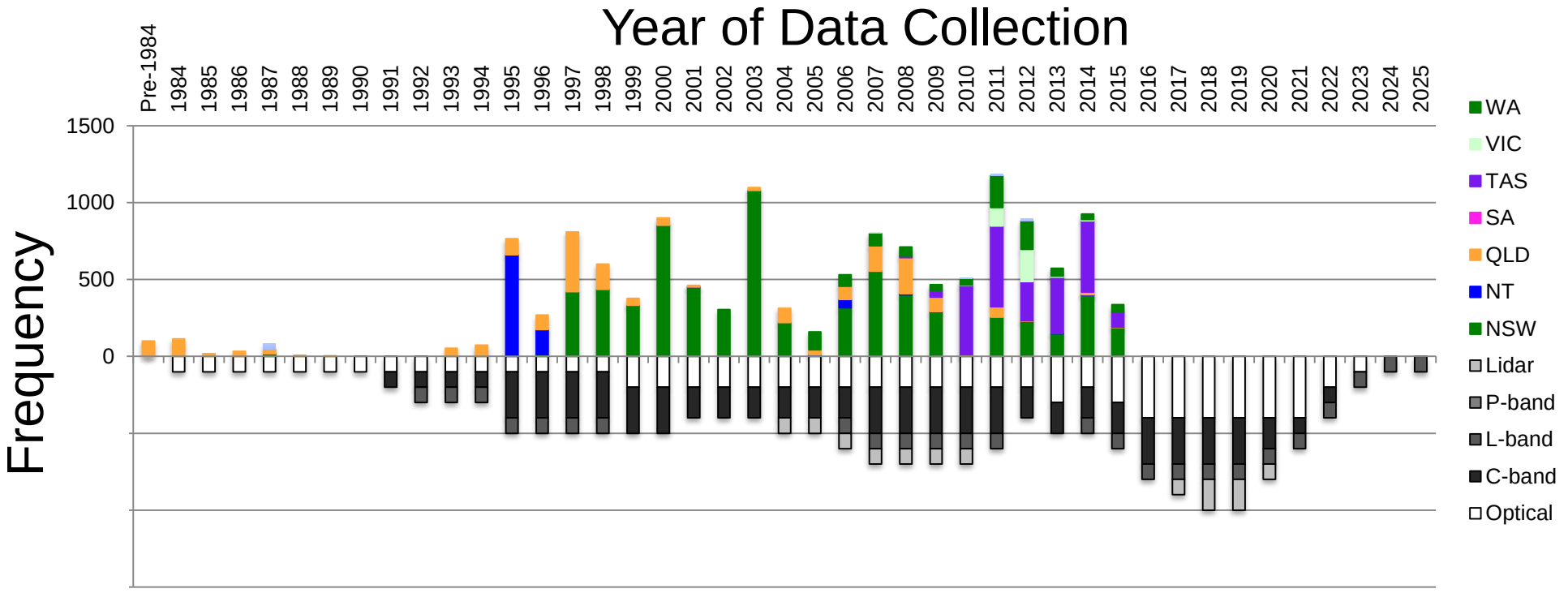
- project: Herbarium - Cali1
- site: Cali1_11
- estsurvey: 1997



Number of satellites supporting regional to global biomass mapping

Optical	C-band	L-band	P-band	Spaceborne lidar
Landsat-7	ERS-1 SAR	JERS-1 SAR	BIOMASS	ICESAT GLAS
Landsat-8	ERS-2 SAR	ALOS PALSAR		ICESAT-2
Sentinel-2	RADARSAT-1	ALOS-2 PALSAR-2		GEDI ON ISS
	RADARSAT-2	SAOCOM CONAE		
	Sentinel-1	NISAR		

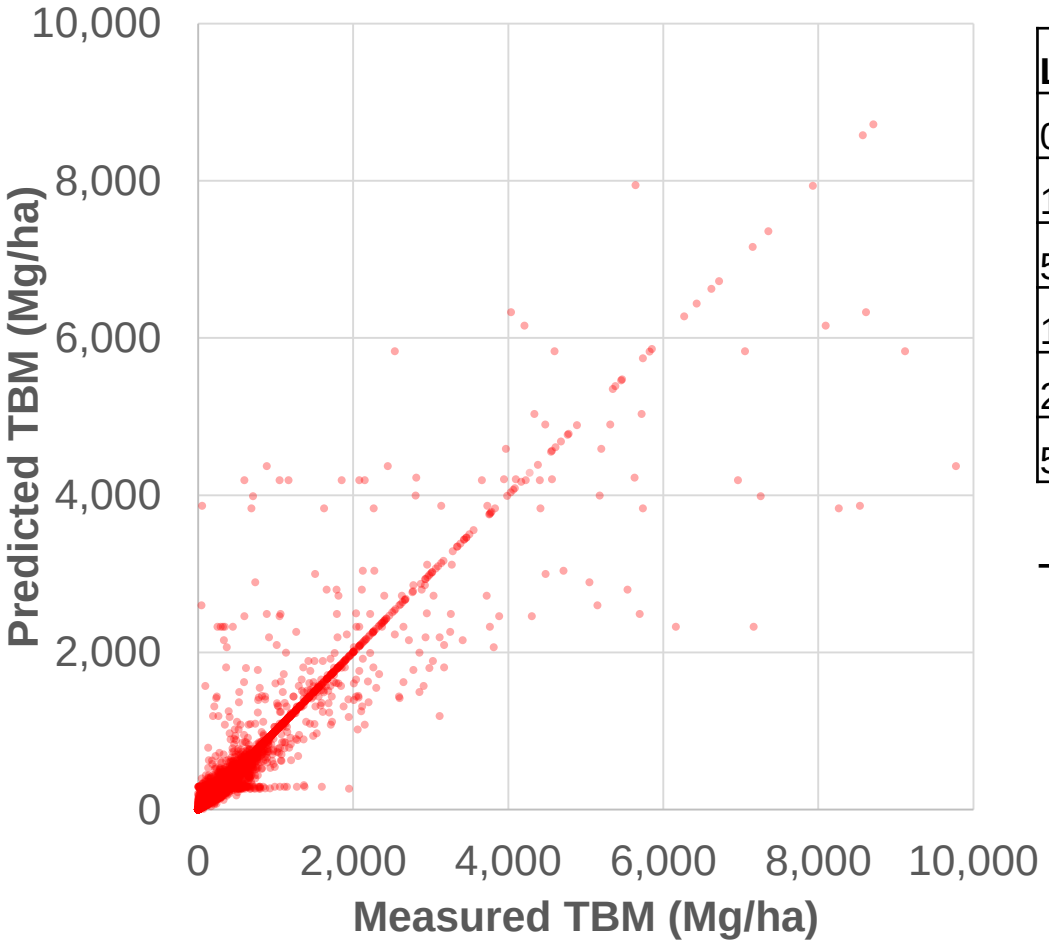
Development of an Australian above ground biomass map

Demonstration using Machine Learning Pipelines

Landsat:
- PG mean
- PG SD

PALSAR:
- HH mean
- HH SD
- HV mean
- HV SD

ICESat:
- ρ_g, ρ_v
- F_{cov} 0-5m
- F_{cov} 5-10m
- F_{cov} 10-30m
- F_{cov} 30m+
- F_{cov}
- RG SD
- $H_{0.25}$
- $H_{0.50}$
- $H_{0.75}$
- $H_{0.95}$
- H_{Mode}



Lower	Upper	RMSE
0	100	85
100	500	81
500	1000	283
1000	2000	420
2000	5000	731
5000	10000	2242

Total RMSE = 207 Mg/ha

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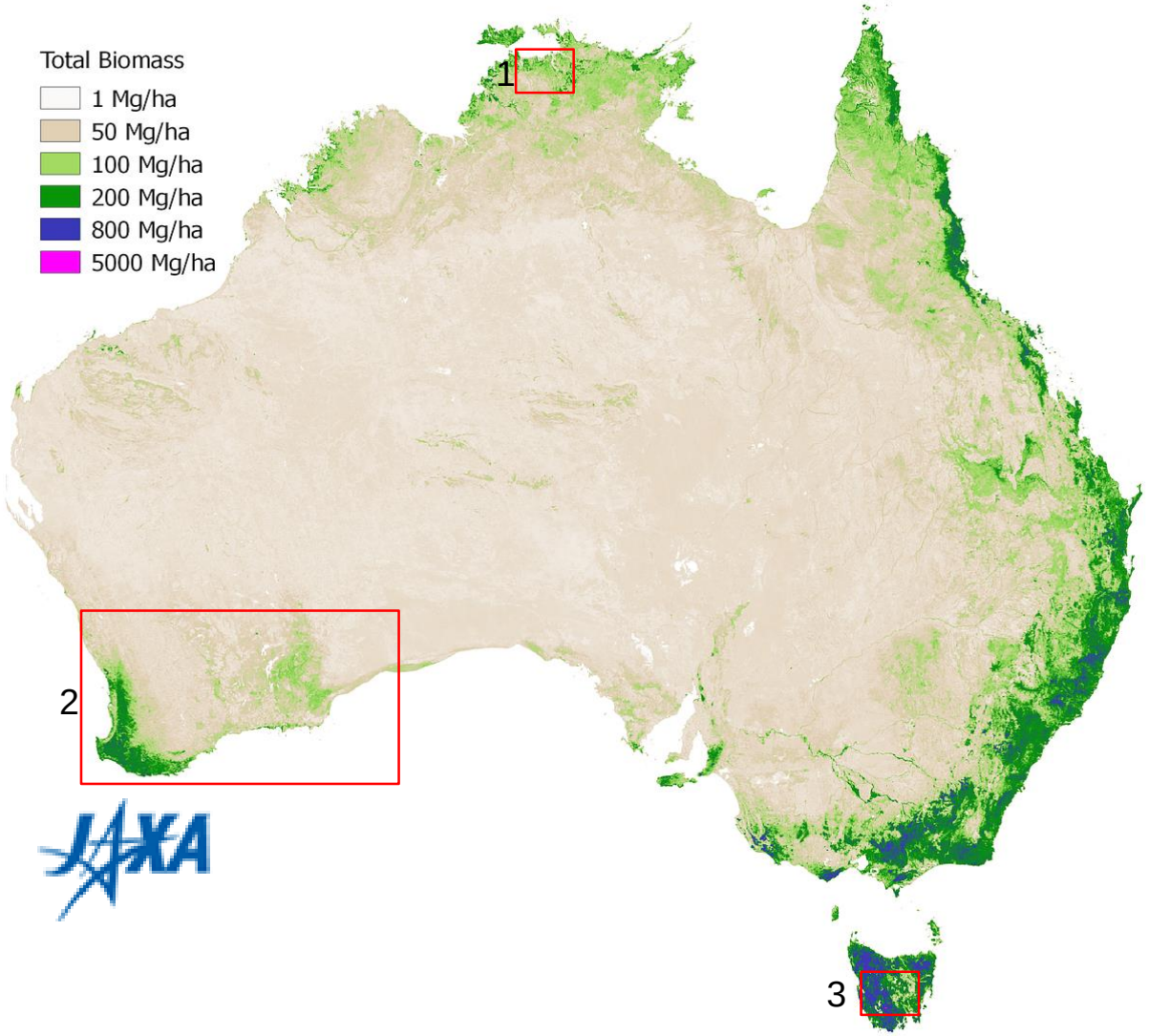
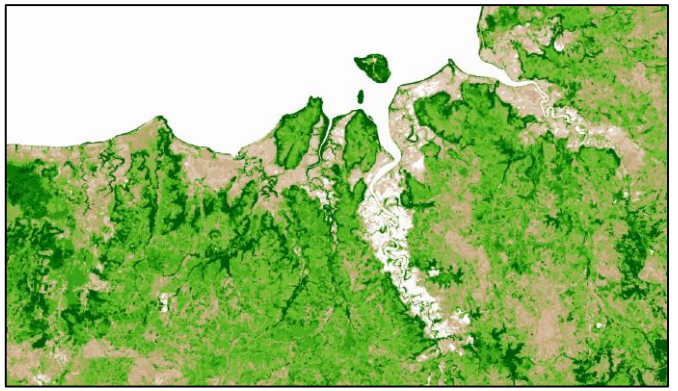
Continental Above Ground Biomass Prediction



JAXA

1



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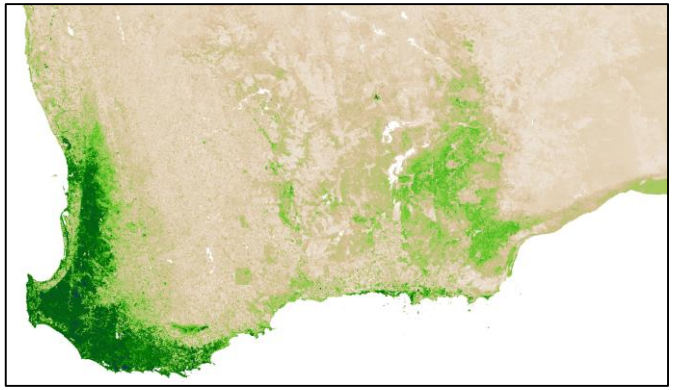

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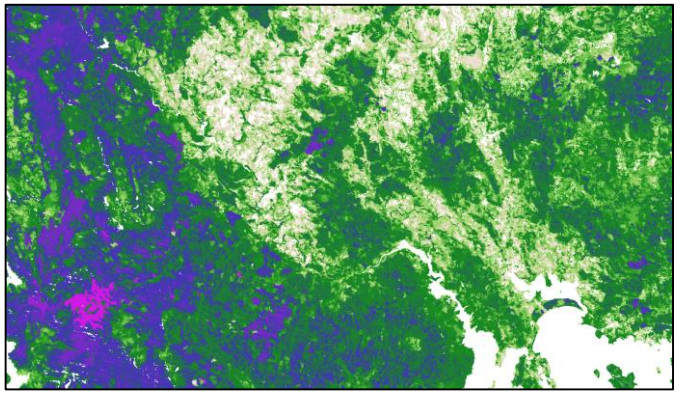

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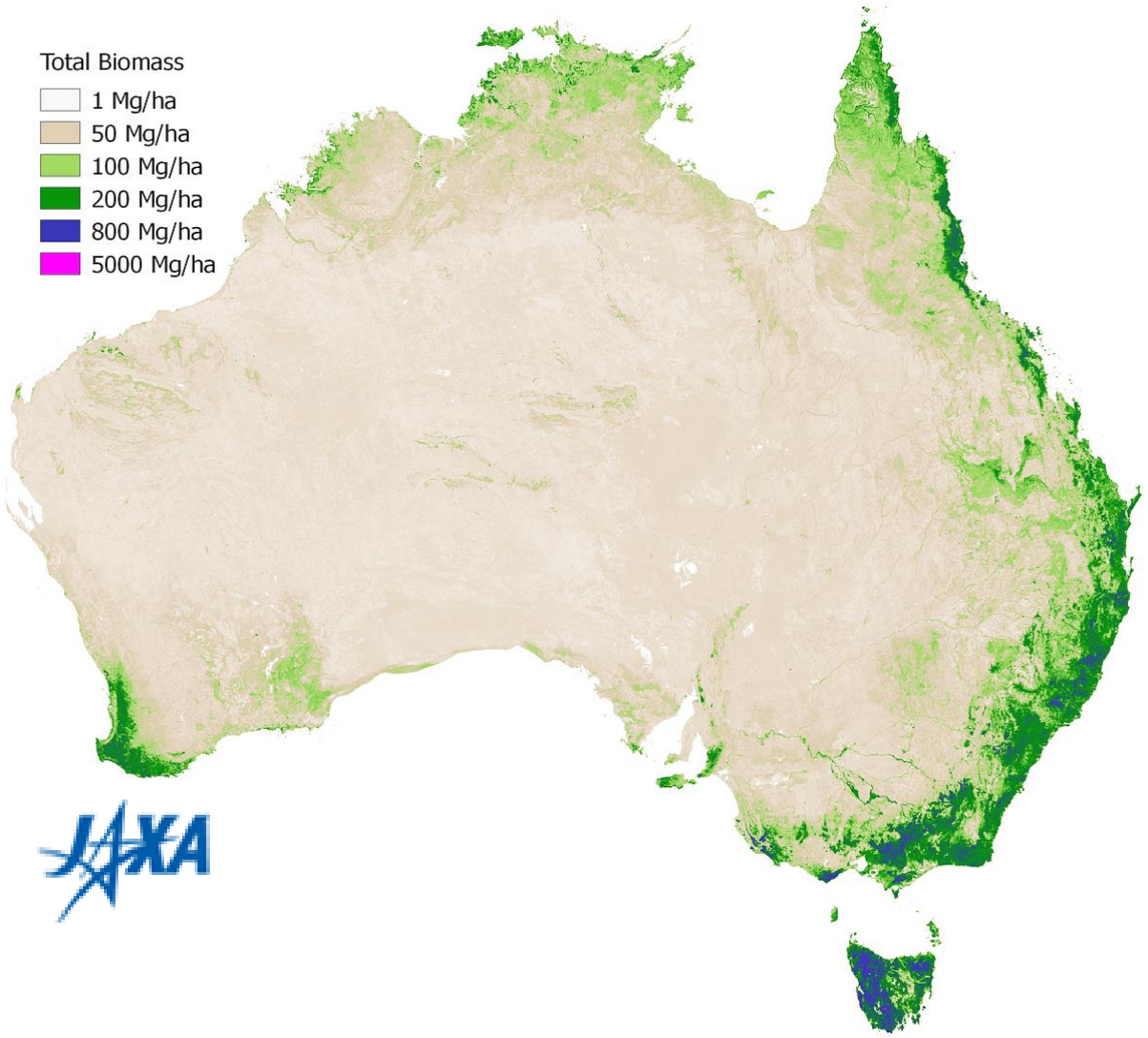
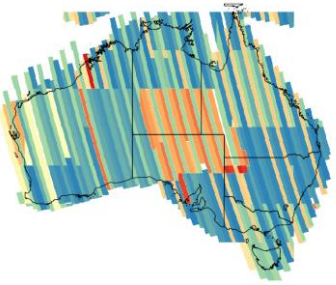
Continental Above Ground Biomass Prediction



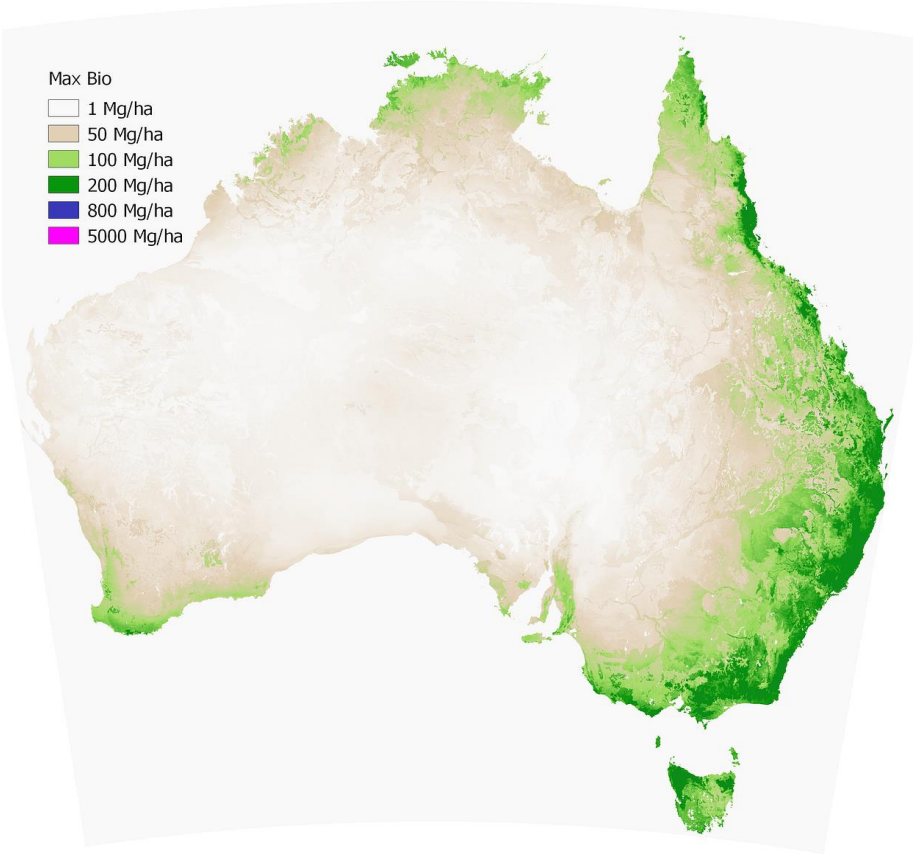
- Demonstration of integrated ecological data science using K&C and TERN data, machine learning, and open source tools
- Vertical structure metrics help biomass estimation
- Field data is more critical than ever when using machine learning

- Add additional attributes as constraints (soil, climate…)
- Improve error propagation in prediction of AGB
- Challenges in implementation with temporally coincident PALSAR-2 and Landsat products

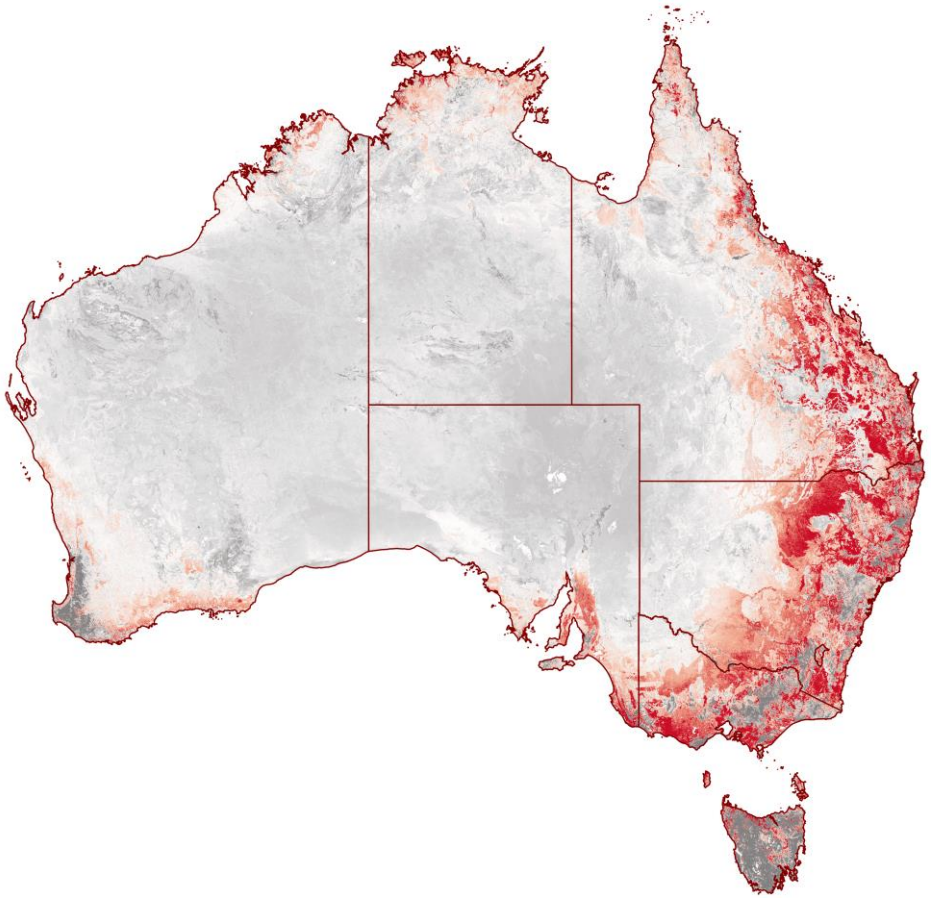


National Carbon Accounting System estimates of Maximum AGB (MaxBio)

The values at which aboveground biomass curves asymptote when modelling natural forest growth.



Modelled MaxBio - EO predicted = Best areas for reforestation?



Objective 2

Determine if changes in woody structure due to processes of clearing, regeneration, fire and thickening may be detected using combined Landsat and PALSAR-1 and PALSAR-2 time-series

1. Quantifying and understanding the response of terrestrial ecosystems to change
   - Injune Landscape Collaborative Project (ILCP)
2. Quantifying regrowth structure and AGB following clearing
   - Queensland and NSW SLATS (Qld DSITI and NSW OEH)
   - Evaluation of the use of Synthetic Aperture Radar (SAR) data for mapping woody regrowth in New South Wales
3. Impact of fire management on vegetation structure and fuel loads
   - Landscape scale fire experiment (Kapalga Station, Northern Territory)

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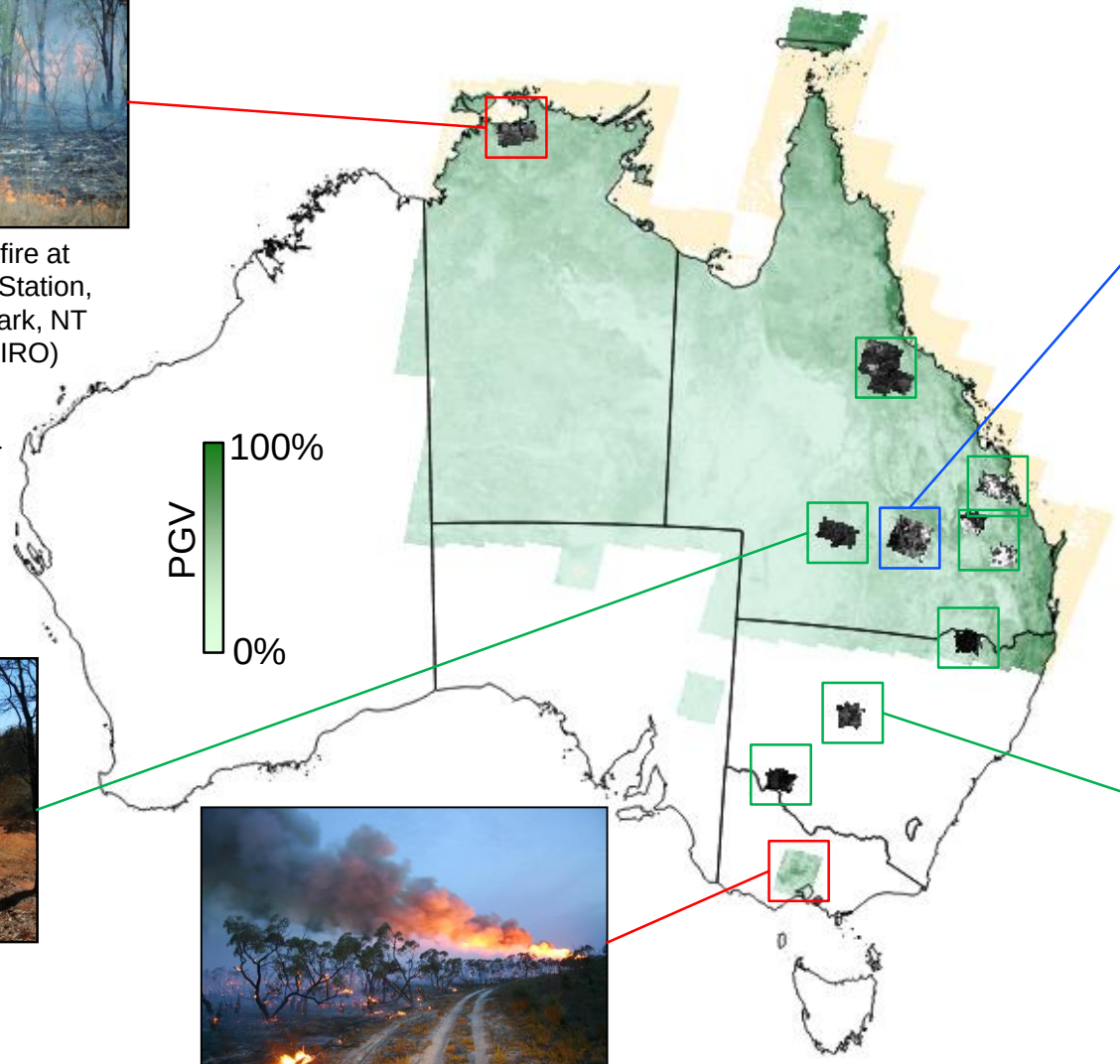
Original Pilot Study Locations

Early-dry season fire at Kapalga Research Station, Kakadu National Park, NT (B. McKaige, CSIRO)

Injune Landscape Collaborative Project Queensland (DSITI, 2015)

Processed ALOS-2 L1.1 data

- Impacts of fire management
- Quantifying woody regrowth
- ILCP ecosystem change



Mulga regrowth harvesting, Queensland (DSITI, 2014)

Controlled burning at Lillimur, Victoria (DELWP, 2007)

Cobar Peneplain Cypress Pine, NSW (Daryl Green, 2013)

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Revised Pilot Study Locations

Early-dry season fire at Kapalga Research Station, Kakadu National Park, NT (B. McKaige, CSIRO)

Processed ALOS-2 L1.1 data

- Impacts of fire management
- Quantifying woody regrowth
- ILCP ecosystem change

PGV 100% 0%

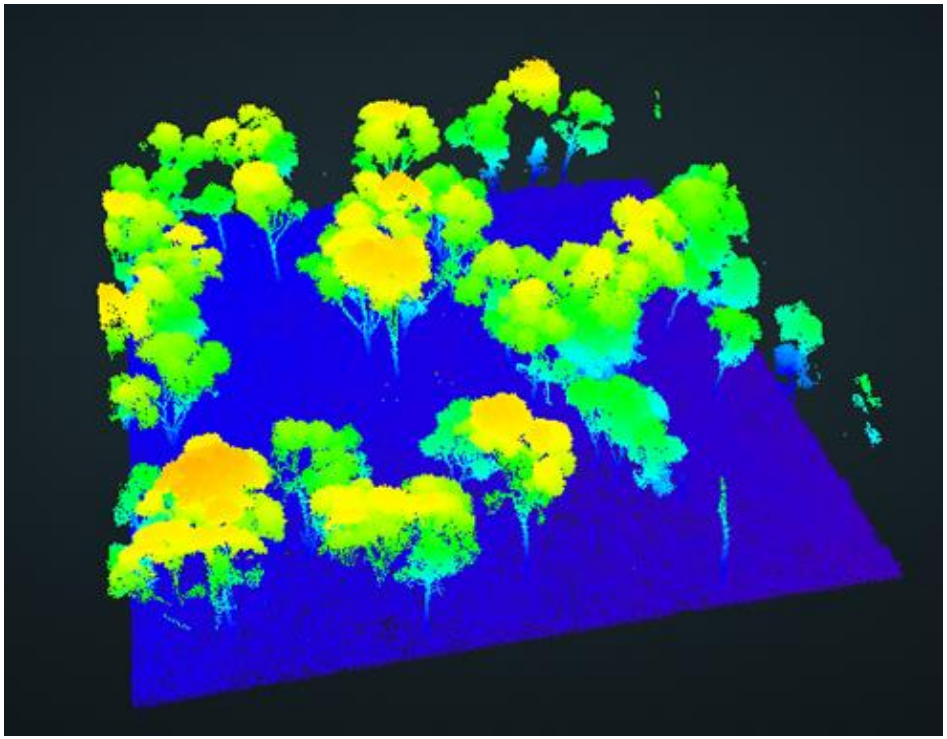
Injune Landscape Collaborative Project Queensland (DSITI, 2015)

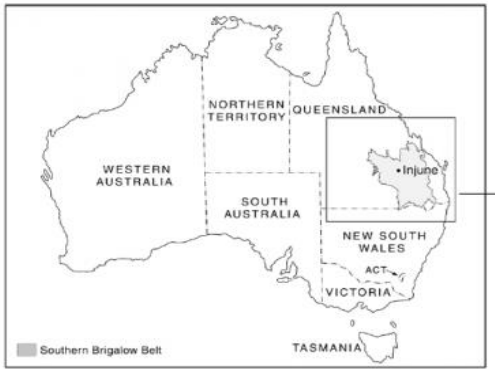
Brigalow Belt South Bioregion (NSW OEH)

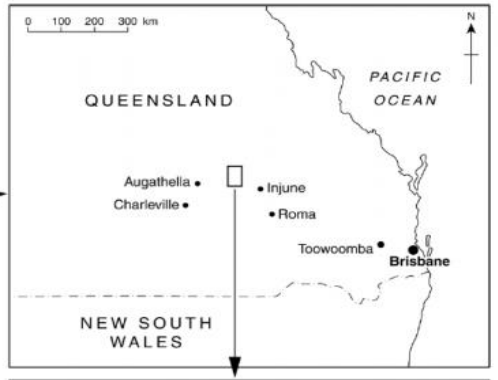
South Western Slopes Bioregion (NSW OEH)

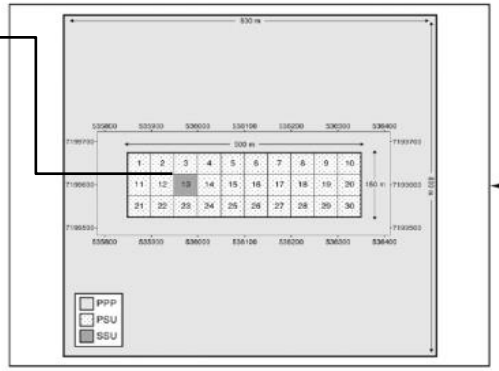
Mulga regrowth harvesting, Queensland (DSITI, 2014)

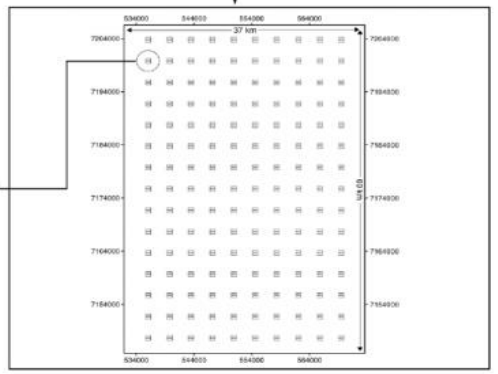
Injune Landscape Collaborative Project Study Site



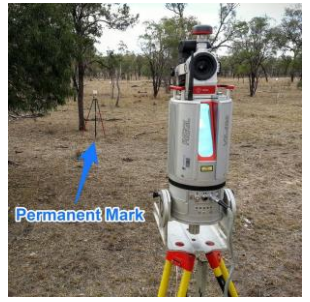








1. **Airborne data acquisitions -** 2000, 2009 and 2015 (Lidar, HS, AIRSAR)
2. **Spaceborne data -** C-/L-band SAR/optical/ICESat
3. **Ground data -** 2000, 2004, 2006, 2009, 2015



ALOS

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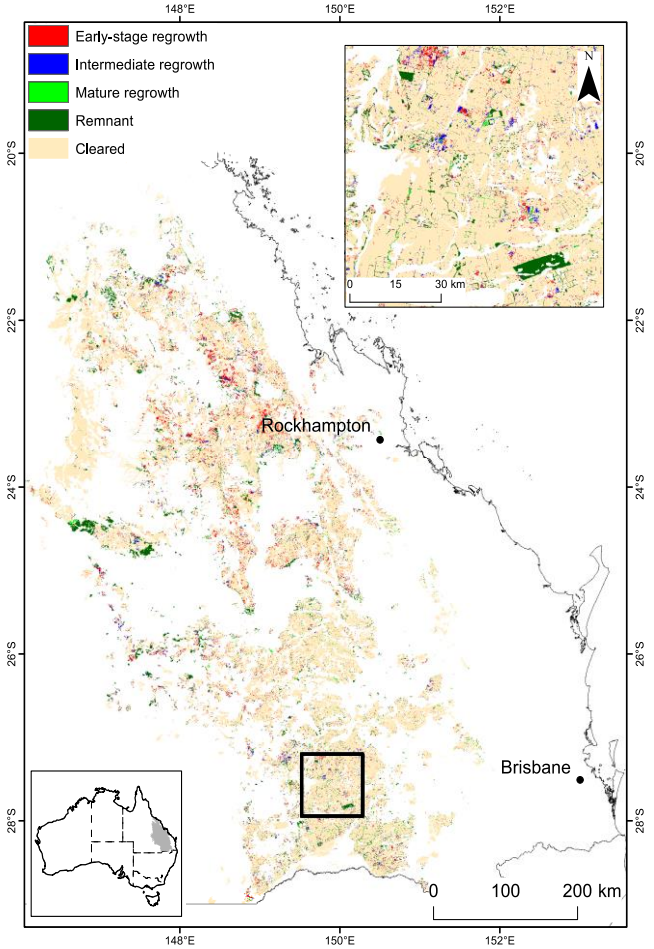
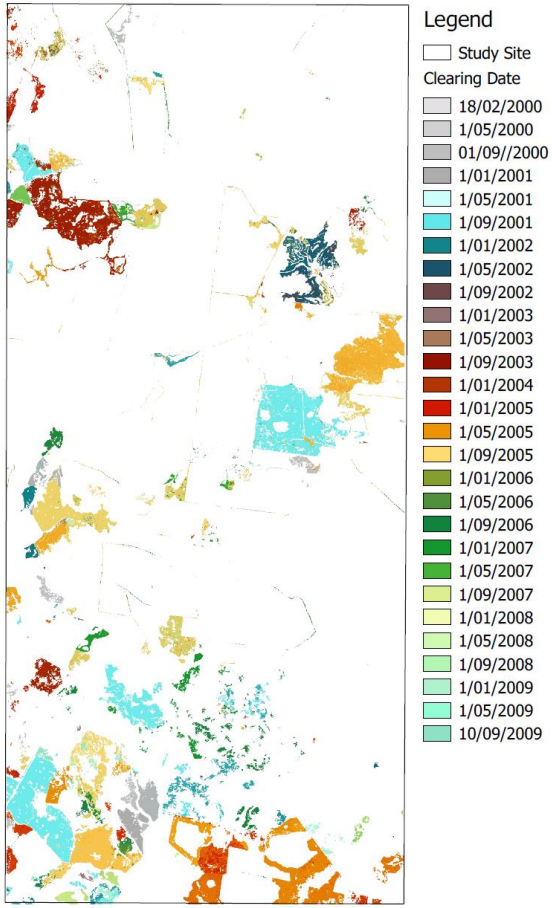
Quantifying regrowth structure and AGB following clearing

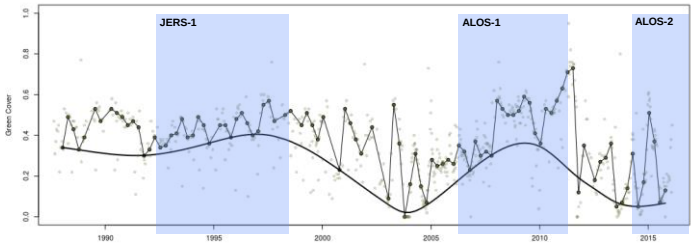


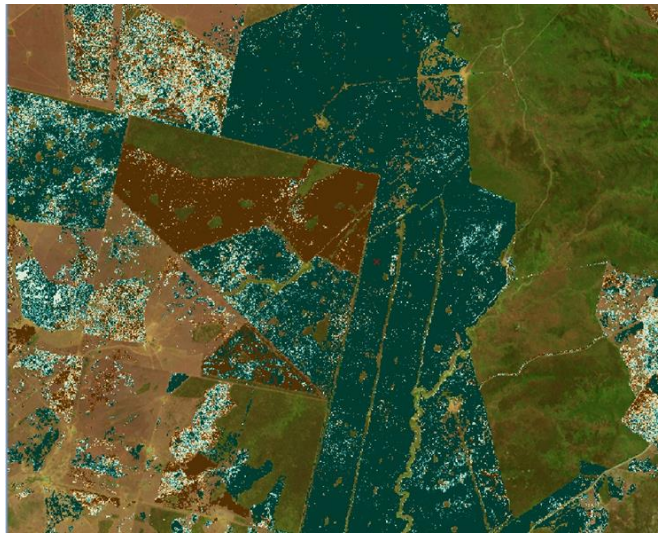
Lucas et al. (2014) RSE



Schmidt et al. (2015) RSE

PGV/SAR time-series





Trends in persistent green vegetation following clearing

Quantifying regrowth structure and AGB following clearing

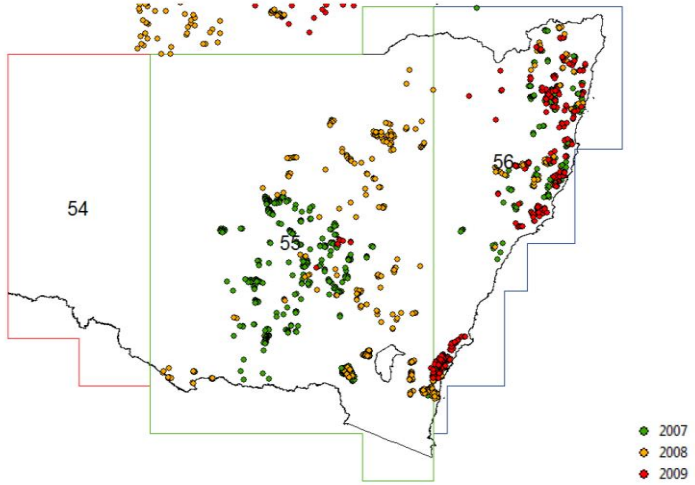
Evaluation of the potential of L-band SAR for mapping areas of increasing woody cover in NSW (i.e. regrowth in previously cleared areas and new growth)

- The availability of ALOS-1/2 PALSAR imagery over NSW at moderate (25 m) and finer (~12.5 m) resolutions provides an opportunity to assess their performance in retrieving the AGB and detecting change in woody vegetation
- Aim was to establish a relationship between L-band backscatter and above ground biomass (AGB) and invert this to model AGB for two time periods - relating the increase in biomass to an increase in woody vegetation cover

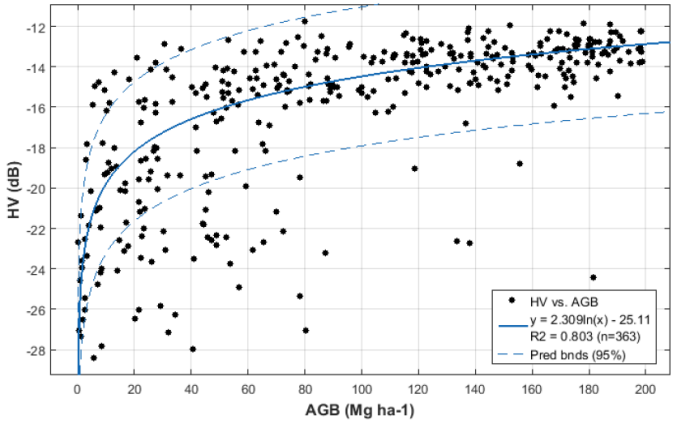
Mitchell, A.L. (2017). Evaluation of the use of Synthetic Aperture Radar (SAR) data for mapping regrowth in NSW. Report submitted to NSW Office of Environment and Heritage.

Relationship between L-band backscatter and above ground biomass (AGB)

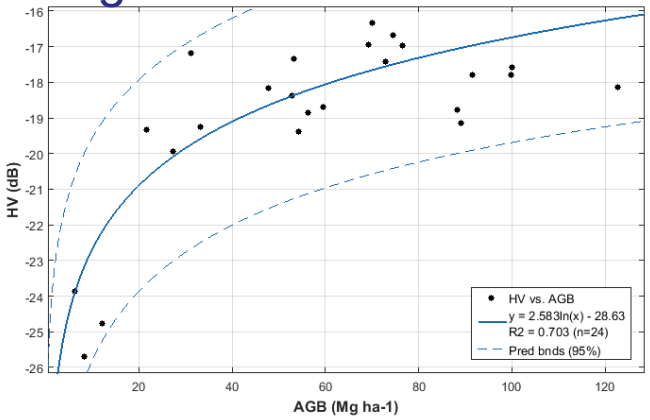
Australian Plant Biomass Library



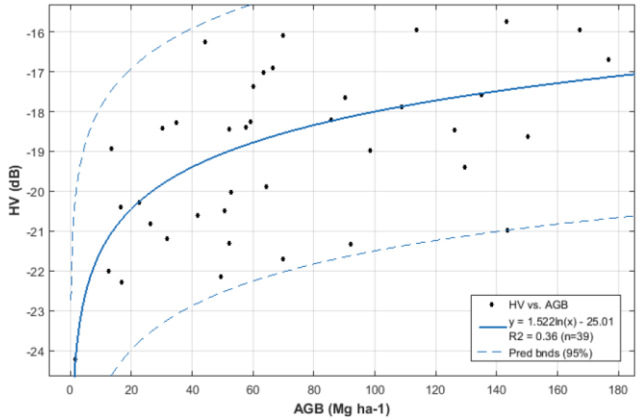
Statewide Model



Brigalow Belt South Model



South Western Slopes



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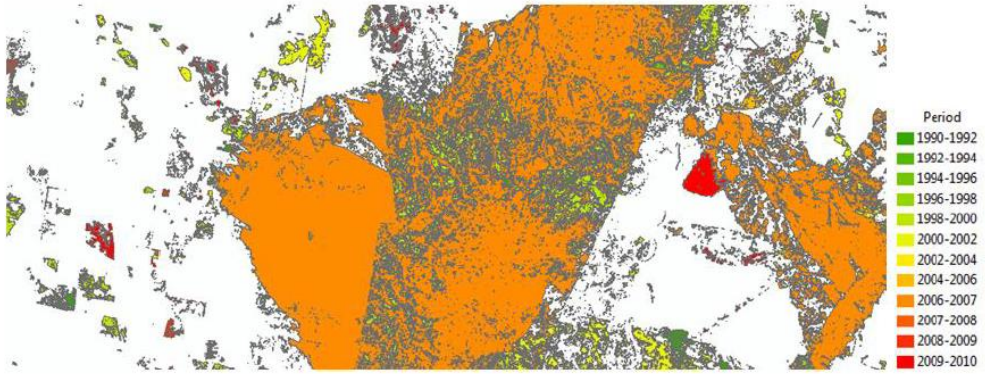
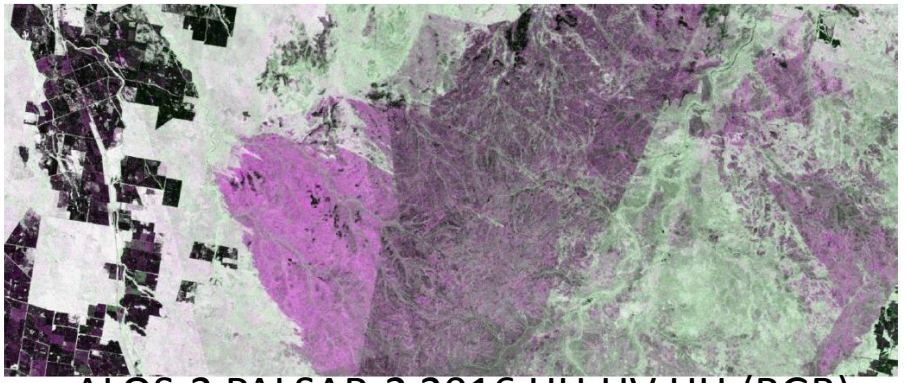
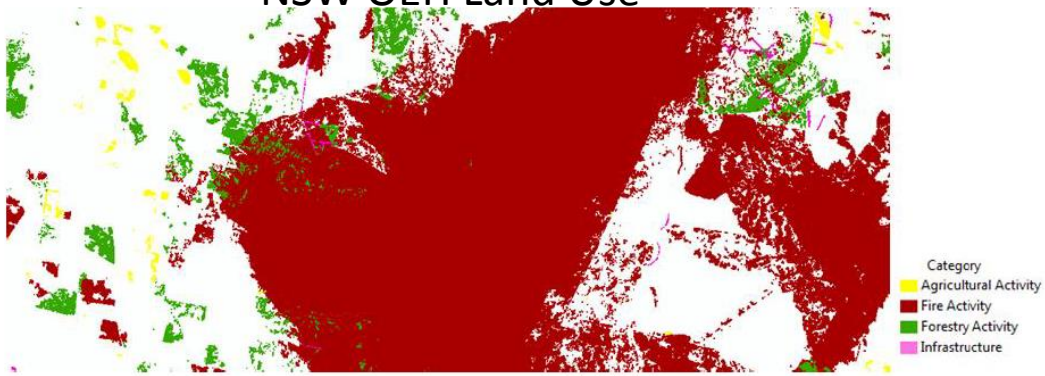
NSW OEH Clearing History



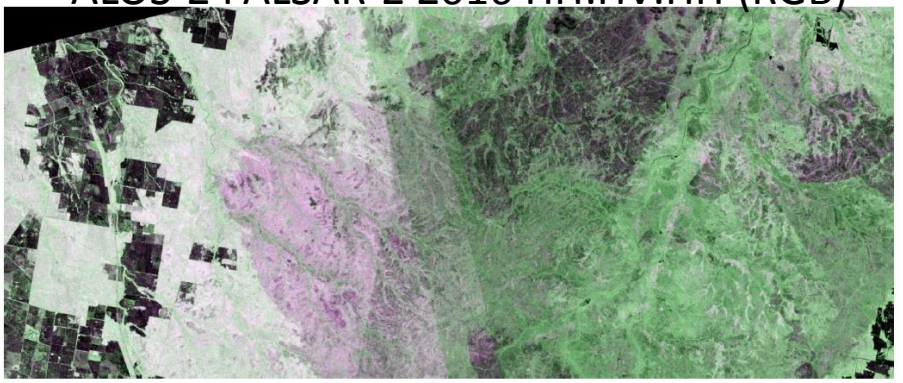
ALOS PALSAR 2008 HH:HV:HH (RGB)



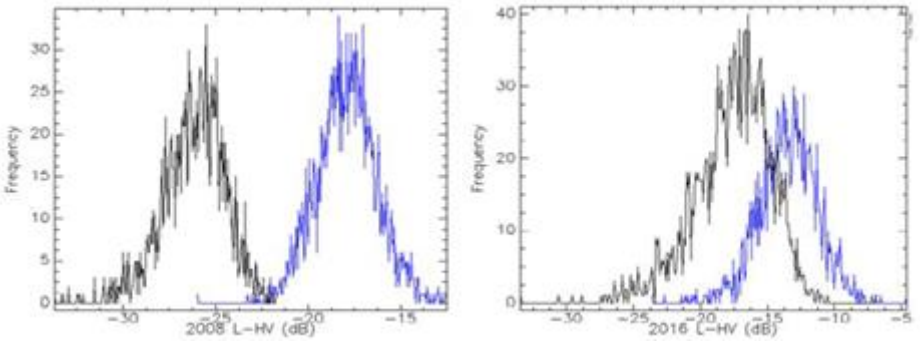
NSW OEH Land Use



ALOS-2 PALSAR-2 2016 HH:HV:HH (RGB)



Mean difference in dB between 0.3 and 1.7 dB, with 13-100% difference in AGB predictions



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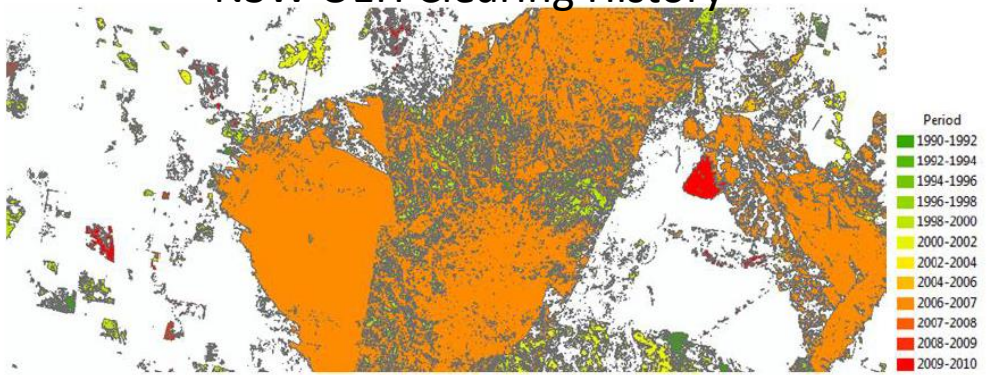
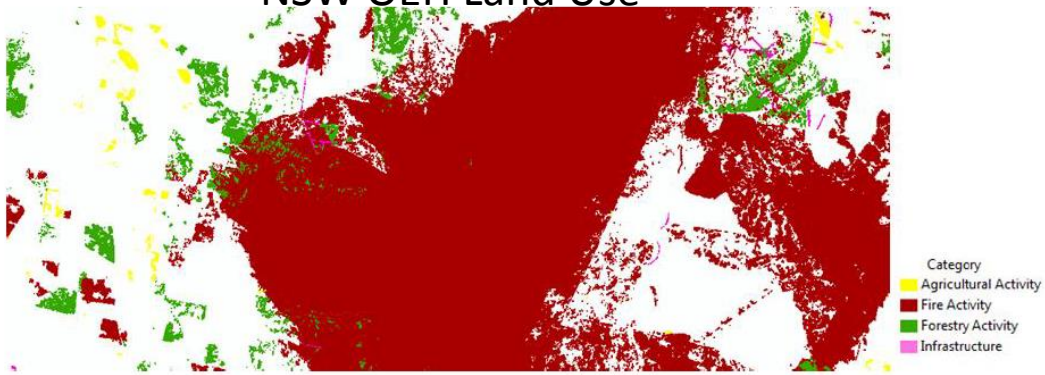
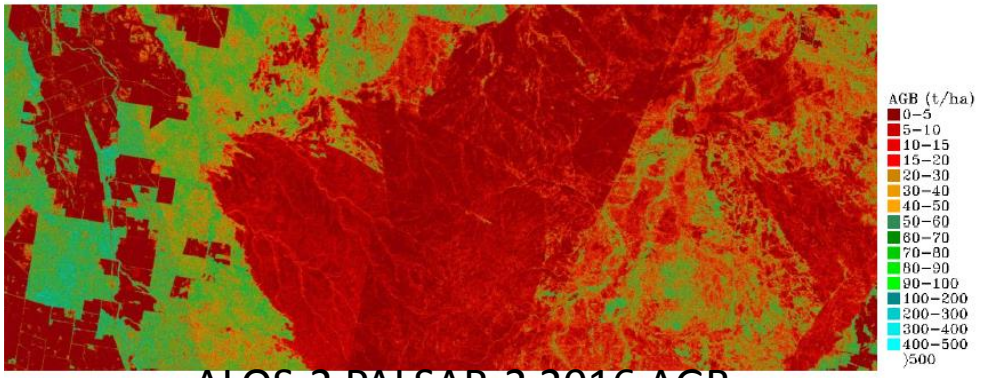
NSW OEH Clearing History



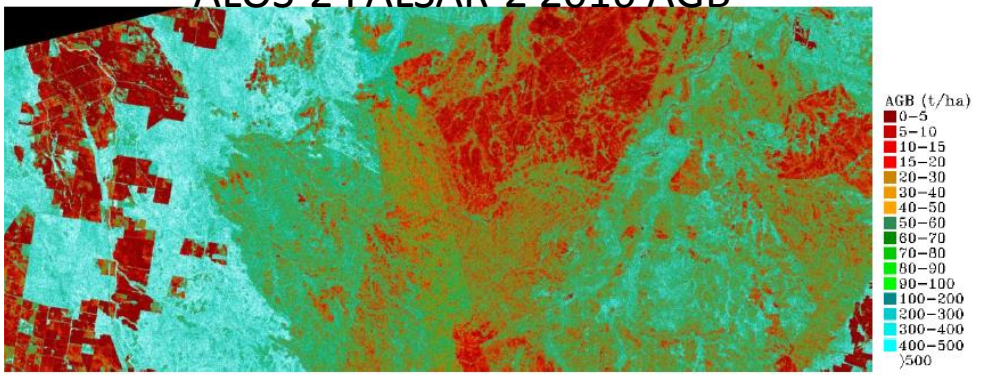
NSW OEH Land Use



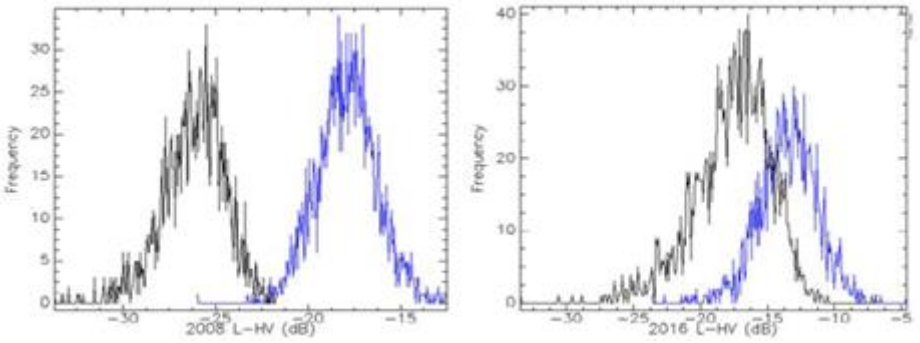
ALOS PALSAR 2008 AGB



ALOS-2 PALSAR-2 2016 AGB

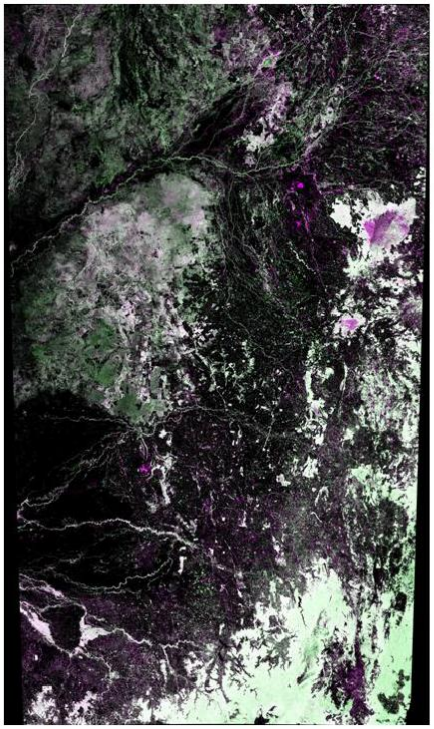


Mean difference in dB between 0.3 and 1.7 dB, with 13-100% difference in AGB predictions

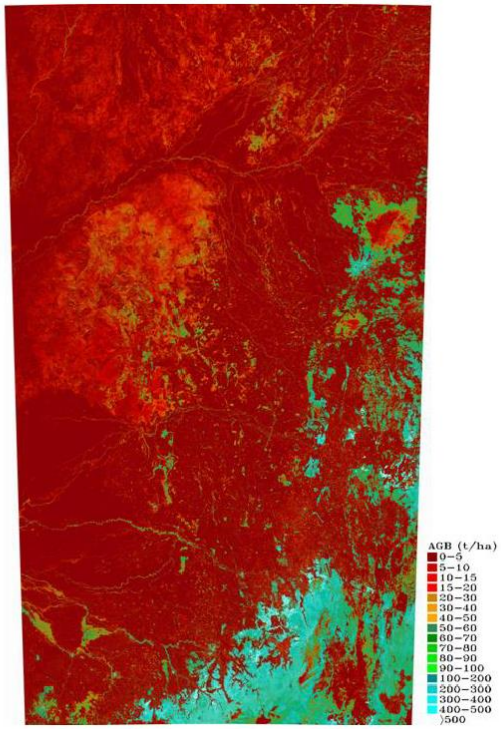


Comparison of ALOS PALSAR and ALOS-2 PALSAR-2 Mosaics

HH:HV:HH (RGB)

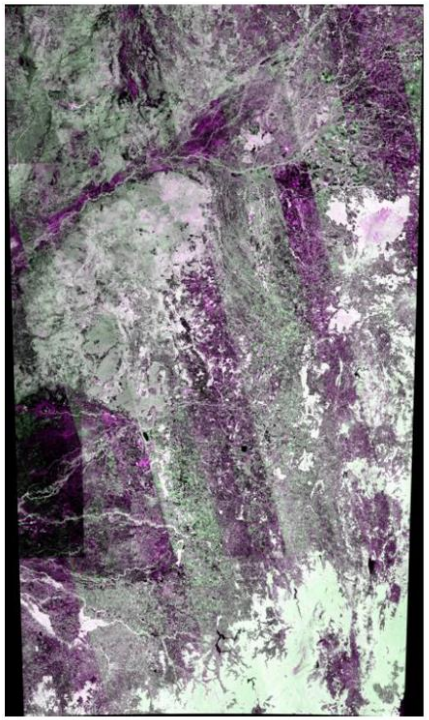


AGBD (Mg/ha)

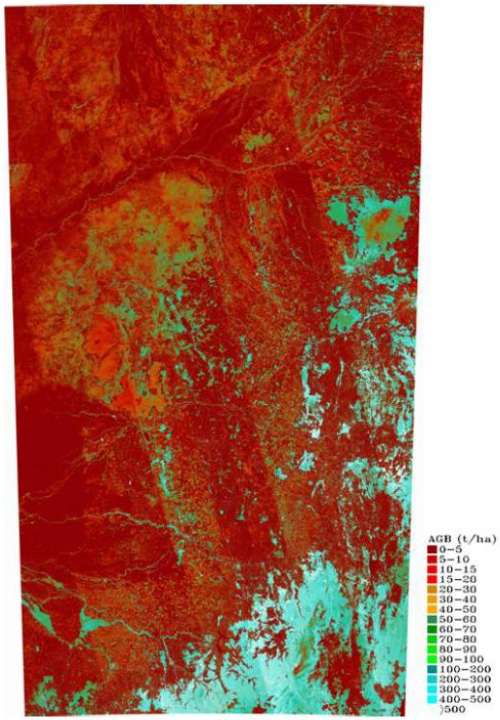


ALOS PALSAR 2008

HH:HV:HH (RGB)



AGBD (Mg/ha)



ALOS-2 PALSAR-2 2016

ALOS

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Evaluation of the use of Synthetic Aperture Radar (SAR) data for mapping woody regrowth in New South Wales

Limitations:

- Effects of surface moisture variation on the observed backscatter in ALOS-1/2 PALSAR FBD and mosaic products
- Change analysis using FBD images detected a high number of false positives due to surface moisture conditions
- The lack of forest type information associated with biomass plot measurements, lack of uniformity in data collection, small plot size, temporal range and under-representation of forest types
- Lack of independent data for validation

Recommendations:

- Evaluate improvements in biomass estimation following normalization of L-band SAR against moisture content variation between swaths
- Compare the use of lidar to calibrate SAR images vs. modelling biomass using SAR alone for retrieval of AGB in regrowth forests
- Detecting new woody growth and regrowth in existing areas using multi-date SAR data

ALOS-2 PALSAR Fine Beam Dual (FBD) polarisation coverage (327 scenes) for NSW acquired between September and November 2016.

PALSAR/PALSAR-2 data access

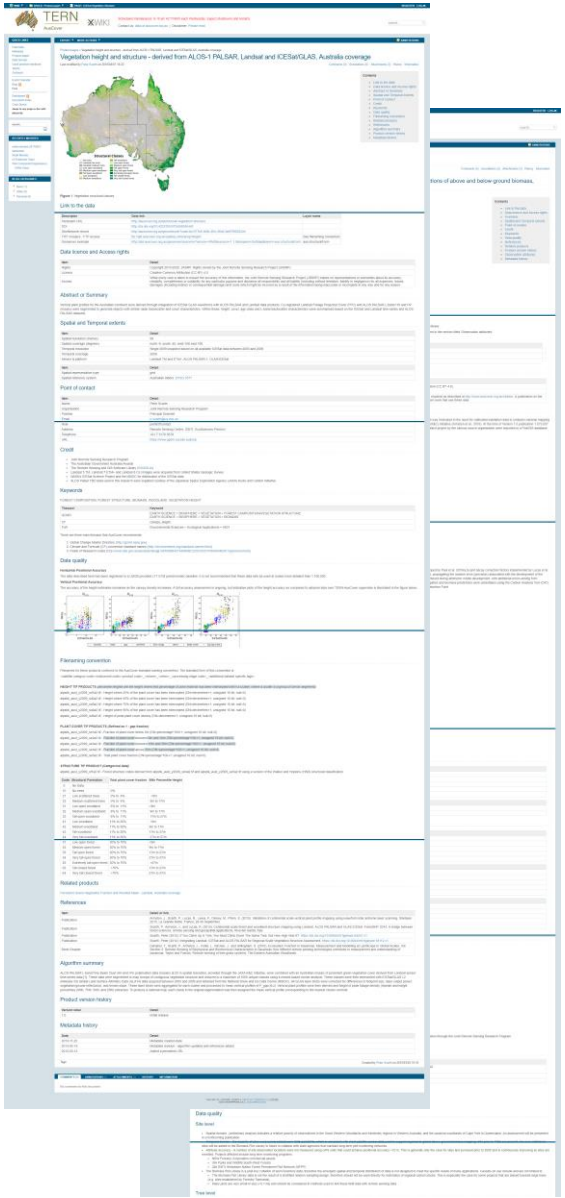
- ALOS-2 PALSAR-2 mosaics for Australia
  - ALOS-2 PALSAR-2 strip data for Queensland / NSW in case of extension?
- Fine Beam Dual (FBD) data over selected case study sites
  - ALOS PALSAR and ALOS-2 PALSAR-2
  - Extend PALSAR-2 time-series to March 2019 in case of extension
- PALSAR/PALSAR-2 ScanSAR mosaics not required

Deliverables / Milestones

- Australian vertical profile metric maps (Complete)
- Australian Plant Biomass Library (Complete)
- Australian above ground biomass map (April 2018)

Additional deliverables by March 2019

- Above ground biomass and woody regrowth maps change maps using PALSAR-1/2 and Landsat/Sentinel time-series at Queensland and New South Wales sites
- Regional application of selected case study results – Queensland and New South Wales
- Validation of above ground biomass maps at nominated reference sites using TERN AusCover airborne lidar
- Journal publication (submit to K&C Special Issue in *Remote Sensing* – titles TBD)



K&C Phase 4 – Status report

Detection of Biomass and Structural Change using Japanese L-band SAR, Australia

John Armston[1,2,5], Richard Lucas[1,3,6], Peter Scarth[1,2], Anthea Mitchell[3,7]
Peter Bunting[6], Stephen Roxburgh[4], Keryn Paul[4], Stuart Phinn[1]

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[7]NSW Office of Environment and Heritage

Science Team meeting #24
Tokyo, Japan, January 29-31, 2018