K&C Phase 4 – Status report

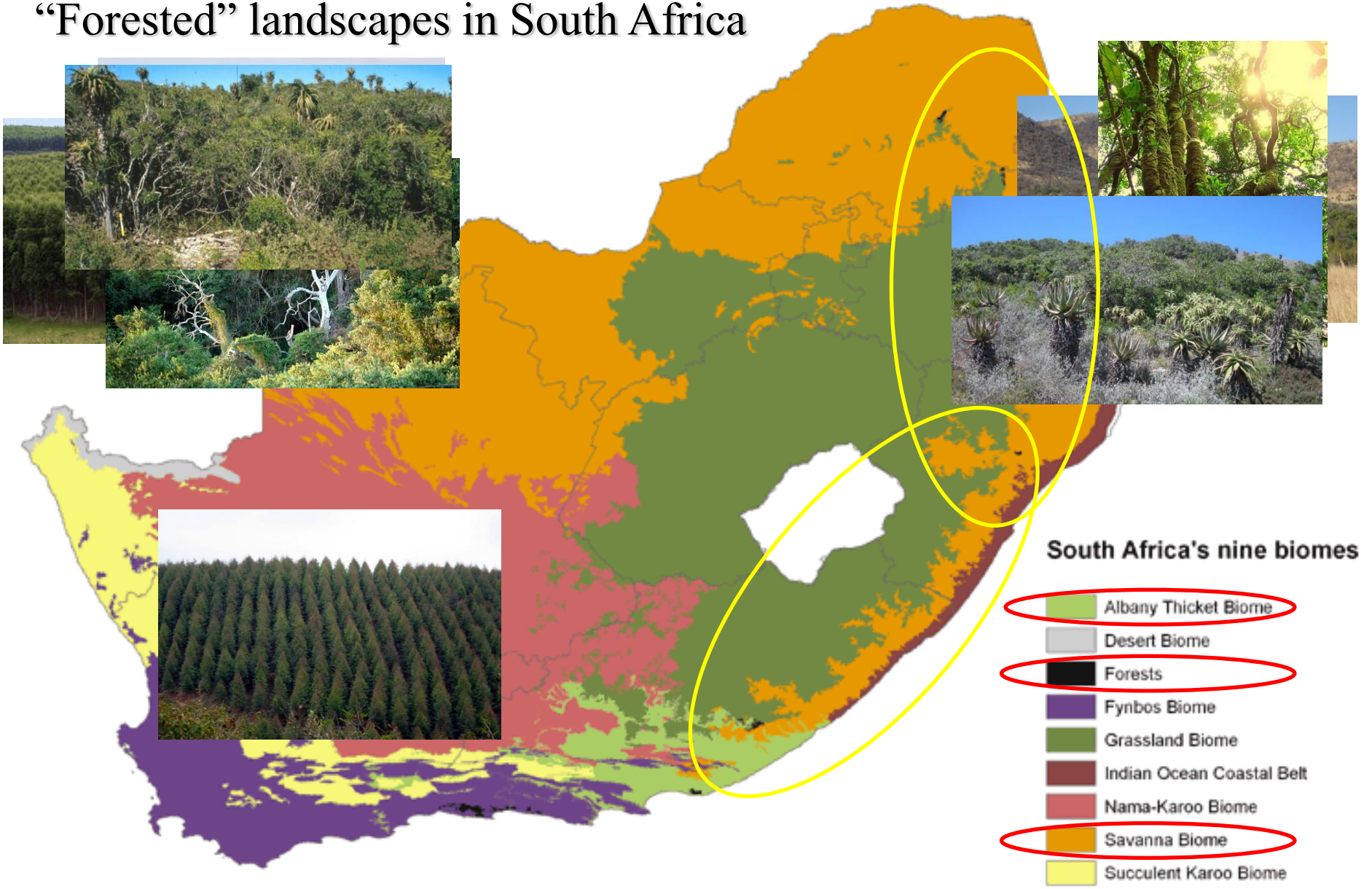
Mapping woody fraction cover and above ground biomass in southern Africa using ALOS-2 PALSAR

Renaud Mathieu, Russell Main, Laven Naidoo
Konrad Wessels

Council of Science and Industrial Research, South Africa

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

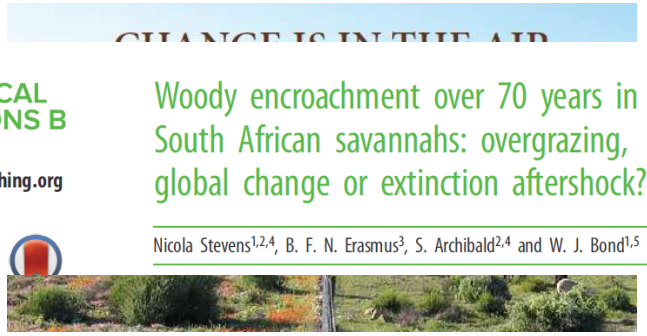
“Forested” landscapes in South Africa



[illegible] succulent trees and shrubs, height < 5m

Vegetation change in South Africa

- Drastic vegetation changes:
  - Bush encroachment (too many trees) affects 10-20 M ha



PHILOSOPHICAL TRANSACTIONS B

rstb.royalsocietypublishing.org

Woody encroachment over 70 years in South African savannahs: overgrazing, global change or extinction aftershock?

Nicola Stevens[1,2,4], B. F. N. Erasmus[3], S. Archibald[2,4] and W. J. Bond[1,5]

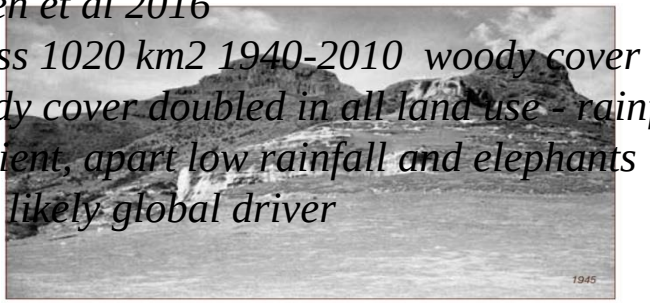
African Journal of Range & Forage Science

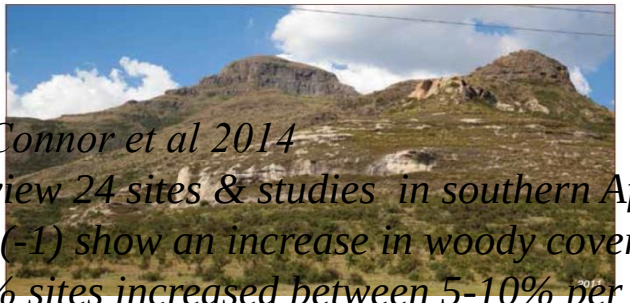
ISSN: 1022-0119 (Print) 1727-9380 (Online) Journal homepage: http://www.tandfonline.com/loi/tarf20

Bush encroachment in southern Africa: changes and causes

Tim G O'Connor, James R Puttick & M Timm Hoffman

Steven et al 2016
Assess 1020 km2 1940-2010 woody cover change
Woody cover doubled in all land use - rainfall gradient, apart low rainfall and elephants
CO2 likely global driver





O'Connor et al 2014
Review 24 sites & studies in southern Africa
All (-1) show an increase in woody cover
50% sites increased between 5-10% per decade

Lower grassland of mountain side,Clarens, Free State

Vegetation change in South Africa

- Drastic vegetation changes:
  - Woody alien invasive (wrong trees) affects additional 10 M ha
- Impacts are not well known, little spatial data
  - Reduce grazing capacity and land productivity (food security), biodiversity, change of hydrological regime

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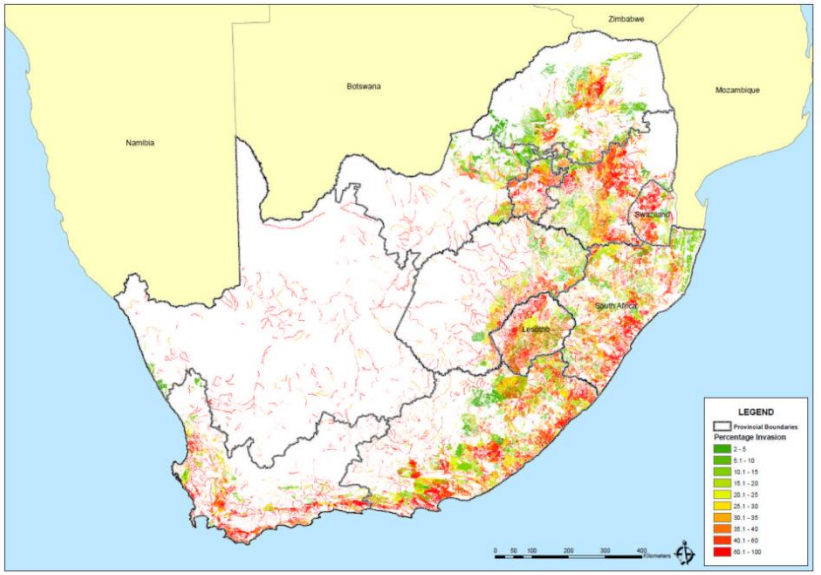
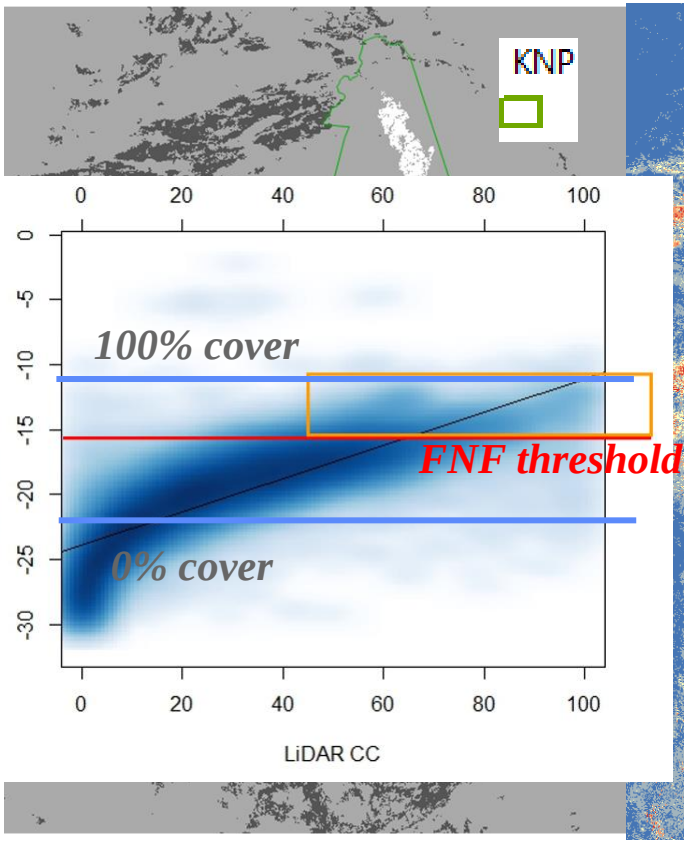
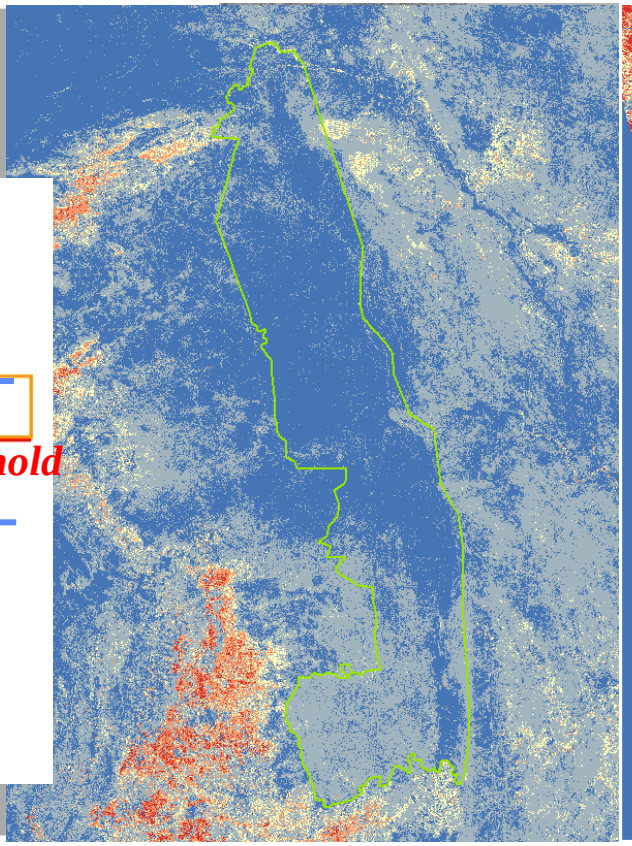
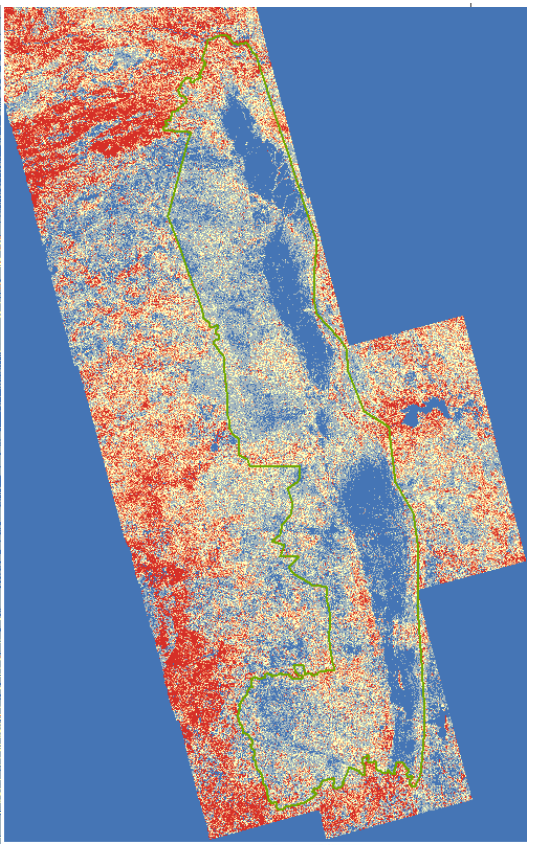


% IAP invasion, ARC, NIAPs, 2010

Savannahs are poorly captured in global EO-based forest products in South Africa







Forest >10% woody cover

Non Forest <10% woody cover

Water

JAXA ALOS PALSAR Forest / Non Forest product

CC (%)

0 - 10

10 - 30

30 - 50

50 - 70

70 - 100

LandSAT WELD VCF

CSIR locally cal/val ALOS PALSAR L-band woody cover product

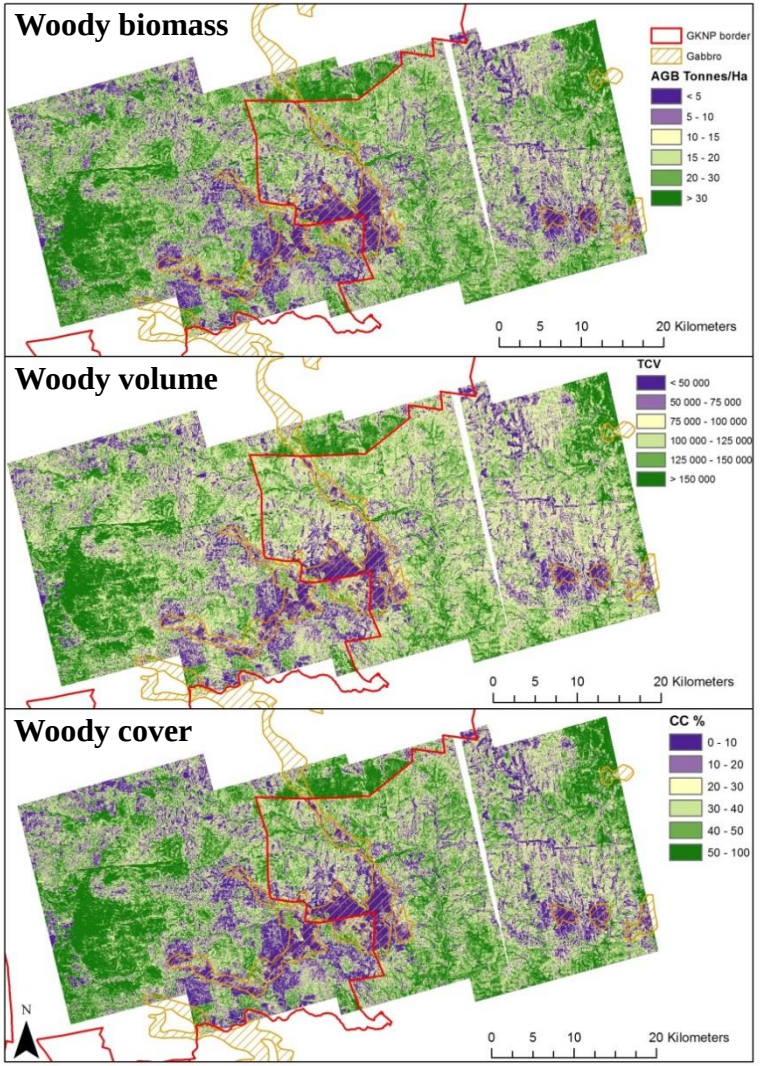
Contents lists available at ScienceDirect

ISPRS Journal of Photogrammetry and Remote Sensing

journal homepage: www.elsevier.com/locate/isprsjprs

Savannah woody structure modelling and mapping using multi-frequency (X-, C- and L-band) Synthetic Aperture Radar data

Laven Naidoo [a,b,*], Renaud Mathieu [a,b], Russell Main [a,b], Waldo Kleynhans [c,f], Konrad Wessels [b,c], Gregory Asner [d], Brigitte Leblon [e]

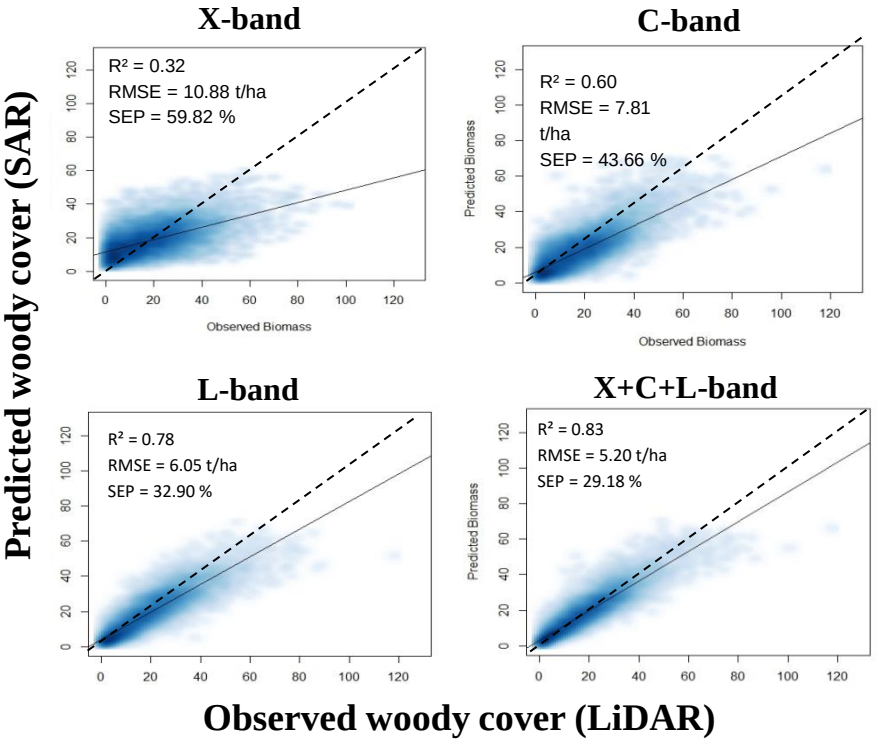


Winter dual-pol datasets

Combined L&C&X-band > L-band (ALOS PALSAR) >> C-band (RADARSAT-2) >>> X-band (TerraSAR-X)

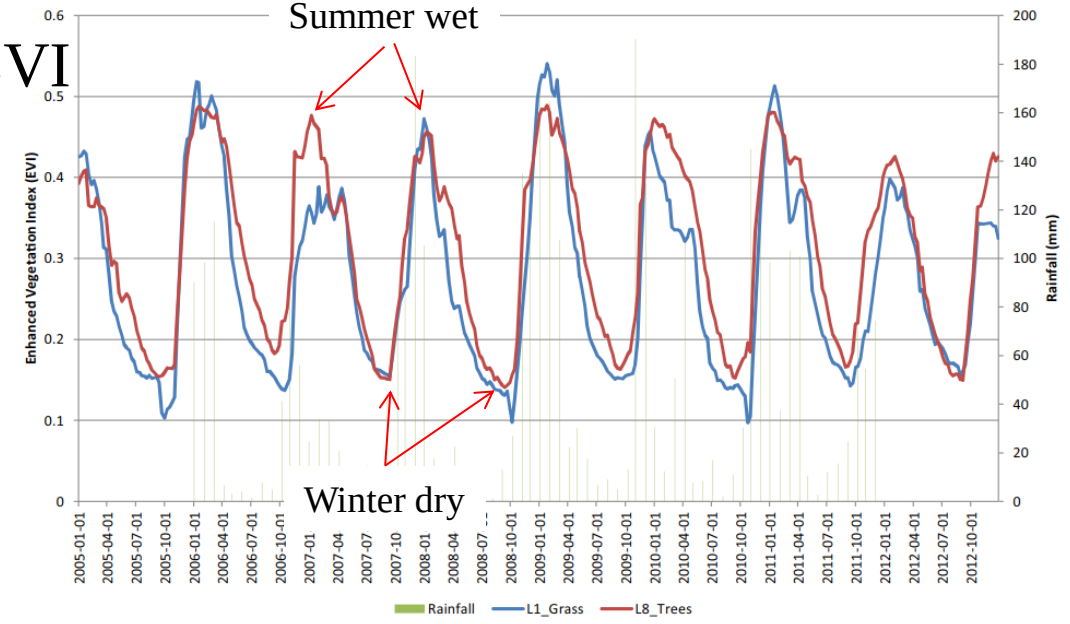
Random forest > ANN > Decision trees > linear regression

SAR better predict woody volume > cover = biomass



Dataset	Season of Imagery		R^2	RMSE (%)	SEP (%)
Individual LandSAT-5 TM	Summer		0.47	12.64	52.02
	Autumn		0.34	13.96	58.46
	Winter		0.32	14.25	58.76
	Winter		0.32	14.10	58.69
	Summer		0.53	11.84	49.24
	Autumn		0.46	12.89	52.64
	Winter		0.37	13.60	56.73
	Spring		0.40	13.19	53.2
	Summer		0.44	12.76	52.86
	Autumn		0.50	12.04	49.6
	Summer		0.64	14.77	46
	Autumn		0.65	13.55	44.43
Multi-seasonal LandSAT-5 TM	All available images	**2007**	0.58	11.27	47.23
	All available images	**2008**	0.64	10.53	43.31
	All available images	**2009**	0.57	11.36	46.92
	All available images	**2010**	0.72	12.84	39.75
SAR	Winter		0.80	7.88	32.08
	Winter		0.81	10.17	33.16

EVI



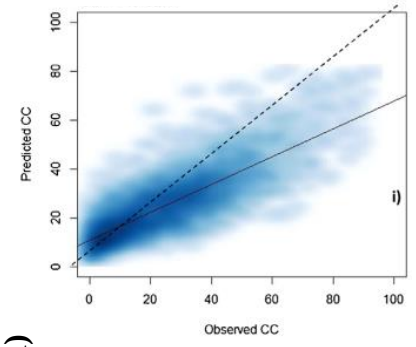
Blue grassland

Red dense woody

Contents lists available at ScienceDirect
International Journal of Applied Earth Observation and Geoinformation
journal homepage: www.elsevier.com/locate/jag

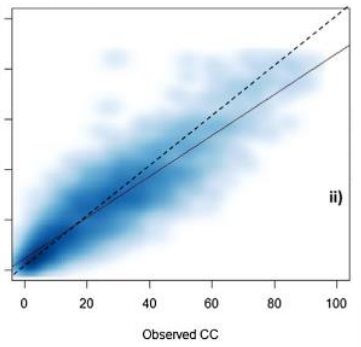
L-band Synthetic Aperture Radar imagery performs better than optical datasets at retrieving woody fractional cover in deciduous, dry savannahs

Laven Naidoo[a,b,*], Renaud Mathieu[a,b], Russell Main[a,b], Konrad Wessels[b,c], Gregory P. Asner[d]

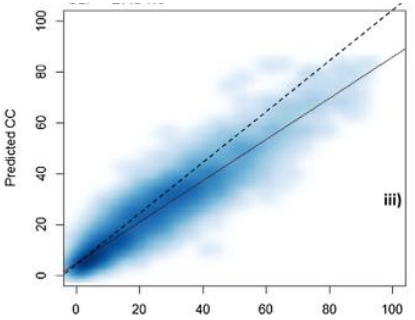


Multi-season Landsat
R2 0.64
RMSE 10.5%

Woody cover (predicted)



Winter single scene ALOS PALSAR
R2 0.8
RMSE 7.8%



Combined Landsat and ALOS PALSAR
R2 0.85
RMSE 6.6%

Woody cover (observed)

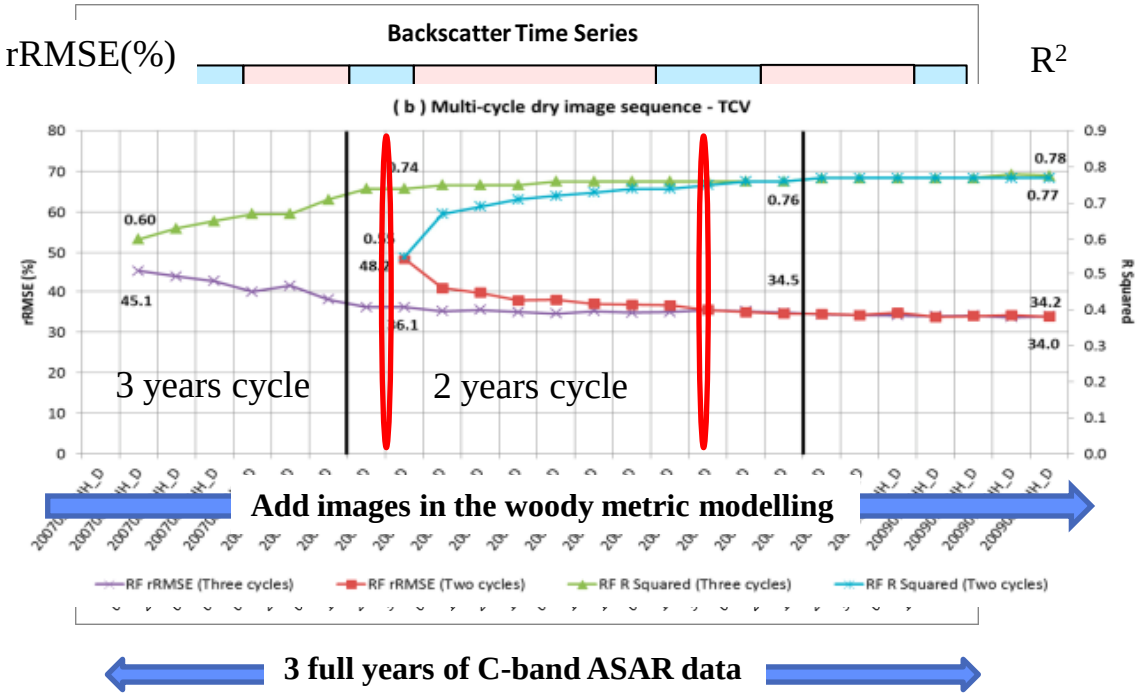
C-band ENVISAT-ASAR Wide Scan: 75 m pixel size, hypertemporal time series HH&VV;

Random Forest ≥ linear regression; temporal filter improves modelling results

ASAR predicts woody volume > woody cover; dry > wet, but both improve modelling results

ASAR C-band produces similar results to ALOS L-band beyond 6-10 images (mostly acquired in winter)

→ Baseline maps for change detection
→ Preparation for free Sentinel-1 A and B with also HV



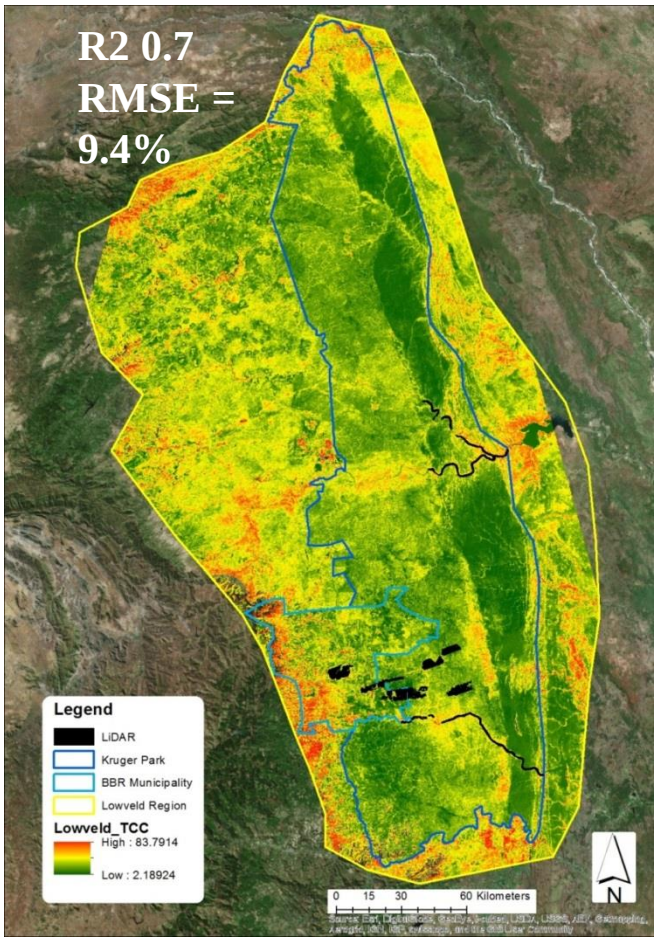
remote sensing
MDPI

Article

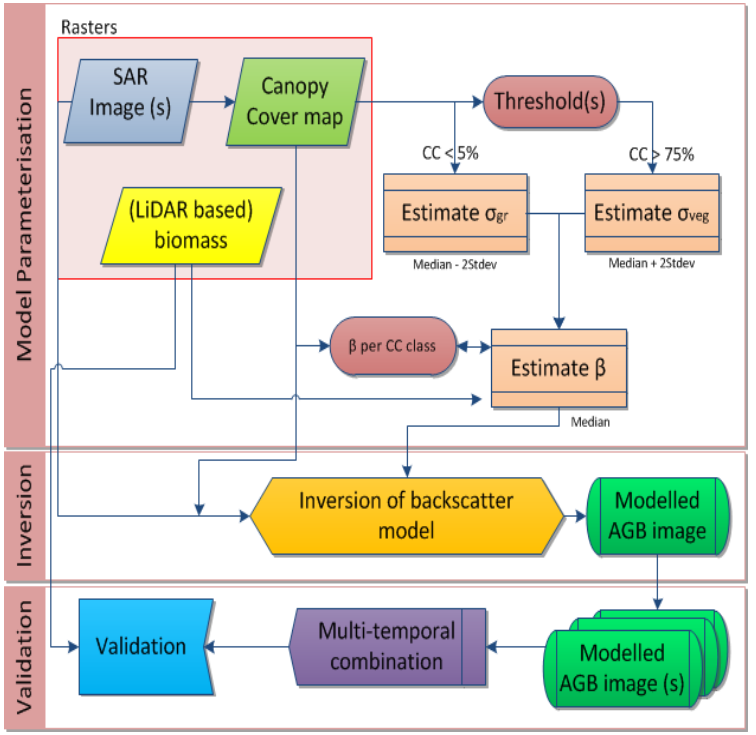
Hyper-Temporal C-Band SAR for Baseline Woody Structural Assessments in Deciduous Savannas

Russell Main [1,2,*], Renaud Mathieu [1,2], Waldo Kleynhans [3,4], Konrad Wessels [2,3], Laven Naidoo [1,2] and Gregory P. Asner [5]

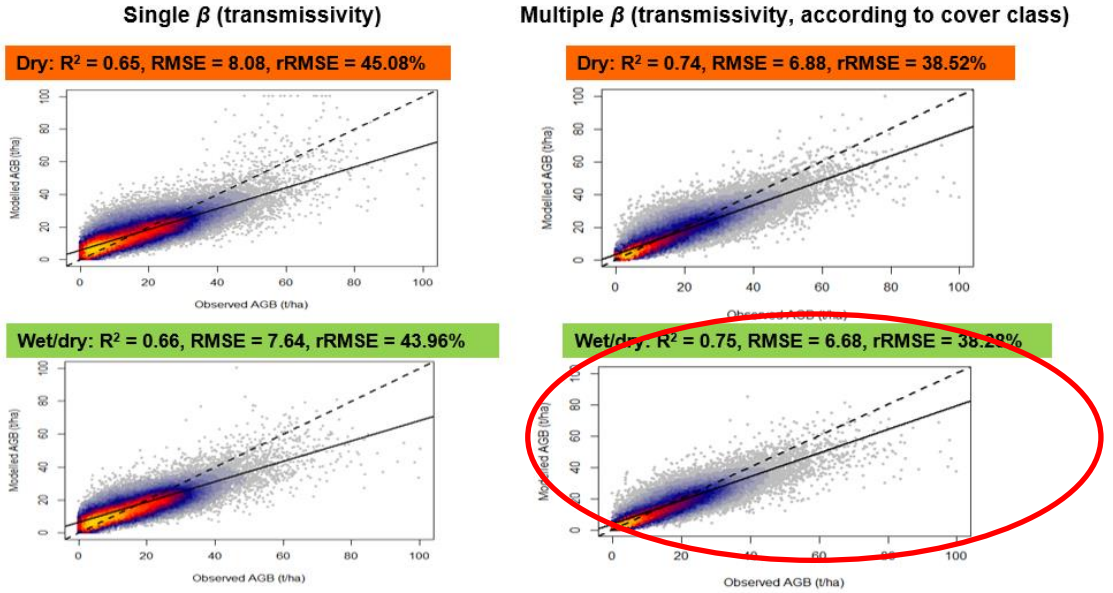
Woody cover map ASAR C-band 10 winter summer images

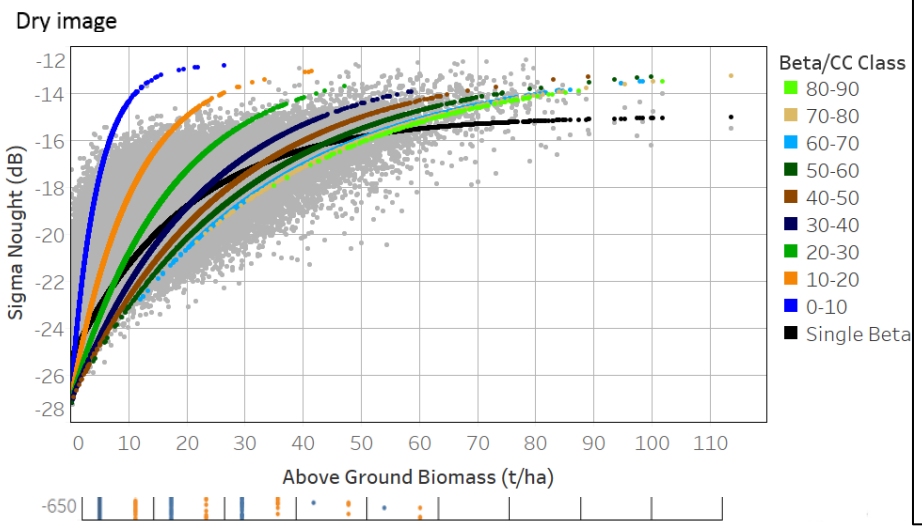


Water cloud model with multi-temporal C-band Sentinel-1 (Main et al)



$$\sigma^o_{for} = \sigma^o_{gr} e^{-\beta V} + \sigma^o_{veg}\left(1 - e^{-\beta V}\right)$$



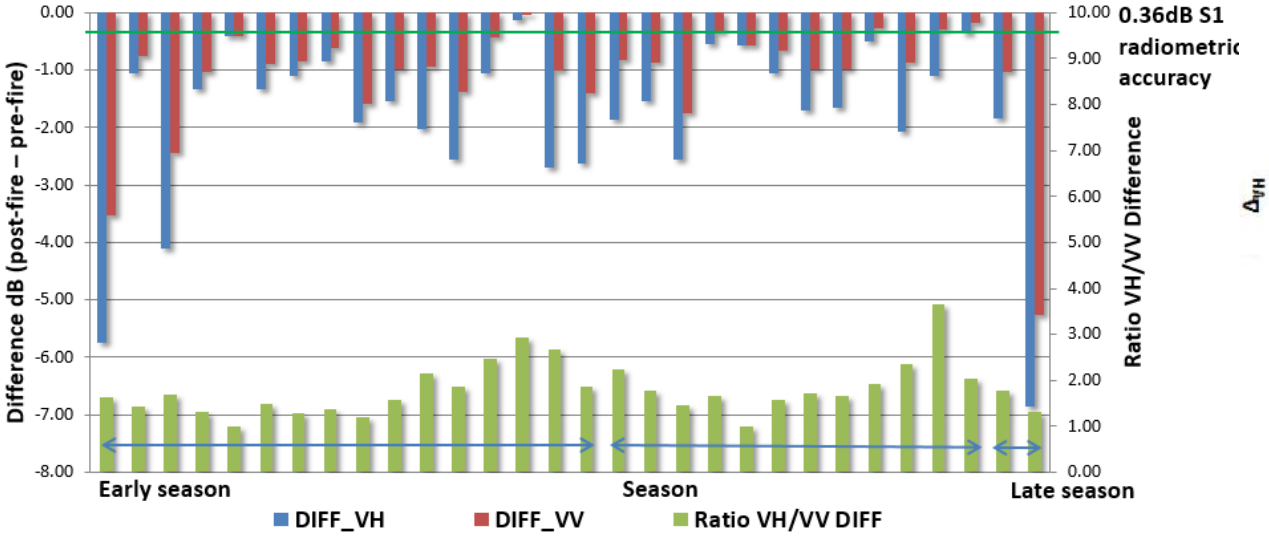


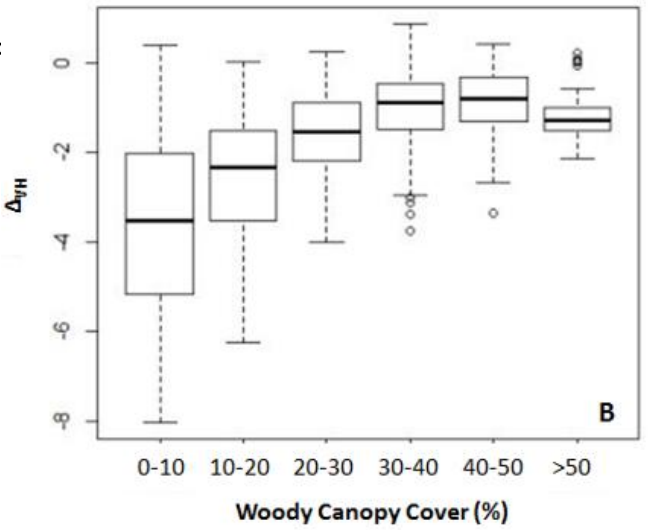
SAR: 14 Dual-pol IW Sentinel-1 images 2015 (VH-pol Images)
LiDAR biomass maps: ~54 000 ha CAO data (2012)

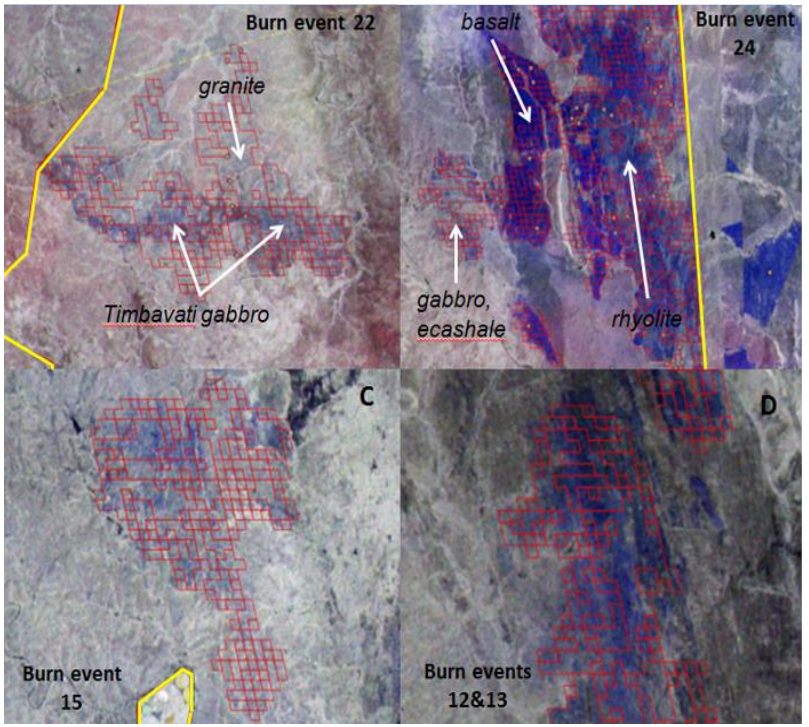
Dry
Usi
Mul
red
Imp
appl

Empirical RF regression (Naidoo et al., 2015)

SAR frequency	AGB (tonnes per hectare)	
	R^2	RMSE (SEP%)
X-band only	0.32	10.88 (59.82)
C-band only	0.60	7.81 (43.66)
L-band only	0.78	6.05 (32.90)





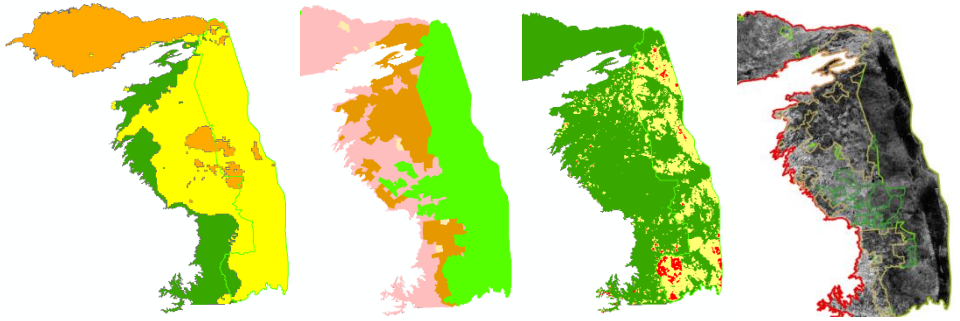


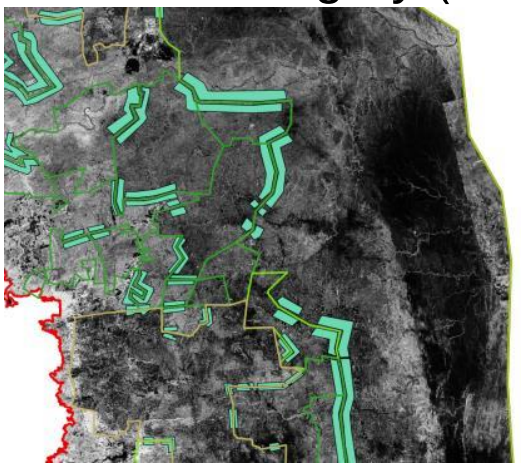
Kruger National Park
30 burned events in 2015, 18 Sentinel-1 pairs,
Compared to MODIS burned area maps

Systematic decrease of backscatter > 0.36 dB
→ grass removal and moisture (soil/grass) decrease
HV twice more sensitive than
Sensitivity decreases with woody cover

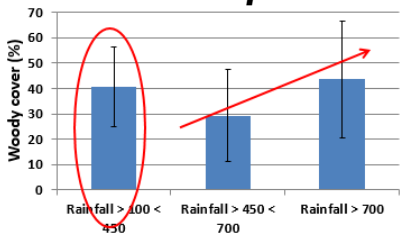
Detection of burned areas in southern African savannahs using time series of C-band Sentinel-1 data (Mathieu et al)

Woody resources and land management in the South African Lowveld with L-band SAR and LiDAR imagery (Mathieu et al)

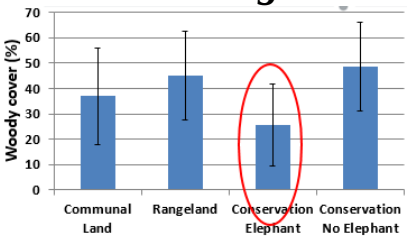


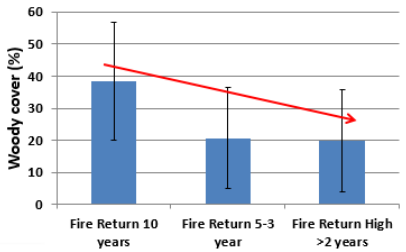


Rainfall

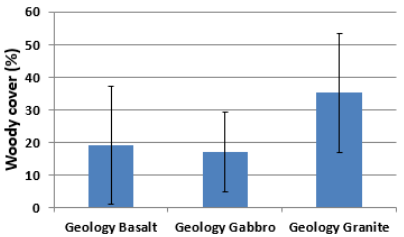


Land management

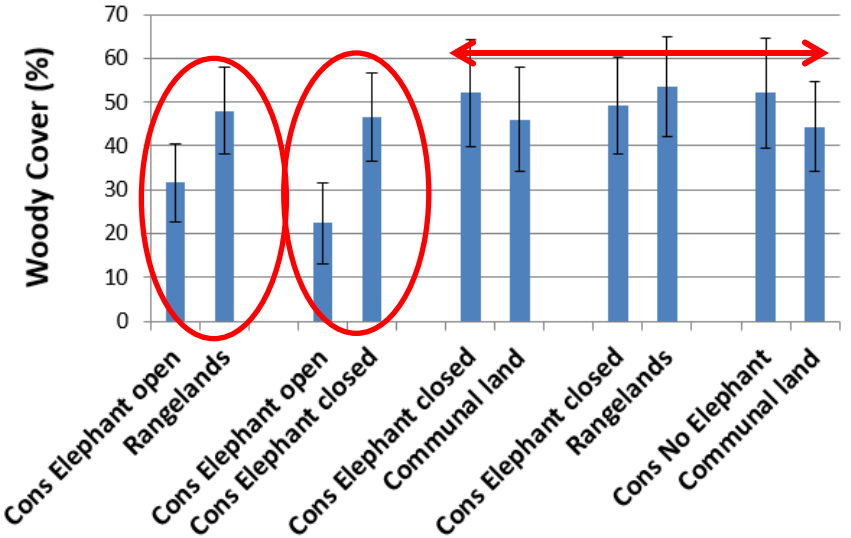


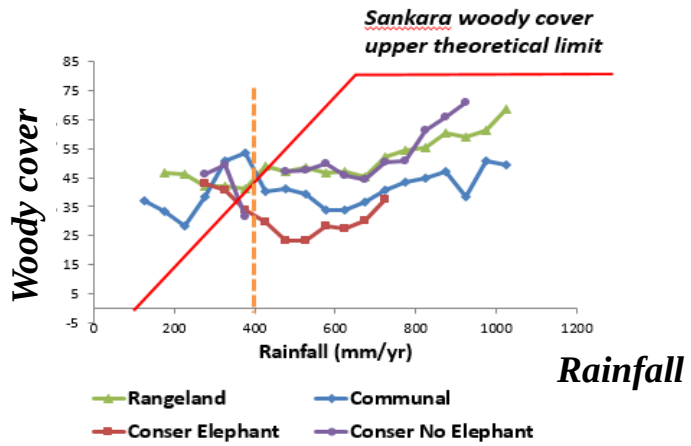


Fire return



Geology





Rainfall

Greater Lowveld: conservation, communal land (subsistence agriculture / ranching), commercial rangelands

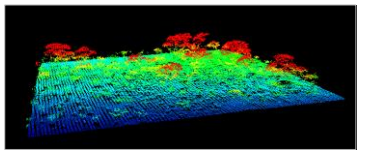
National woody vegetation mapping

Satellite imagery layers: SAR, optical (Landsat, Sentinel-2)

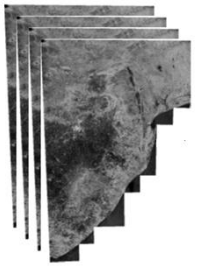
Field plots

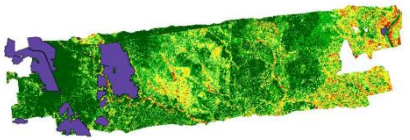
LiDAR data
Woody cover &
height metrics

Regression tree models



2010 / 2015
ALOS
PALSAR
global
mosaics,
HH, HV,
texture





LiDAR biomass
maps

DEM,
slope,
aspect

Rainfall

Temp.

Training
samples:
n = 30 000
X 10 folds

Training
data

Regression tree models

Train
regression
trees
(bagging)

Apply RF
models to
input data

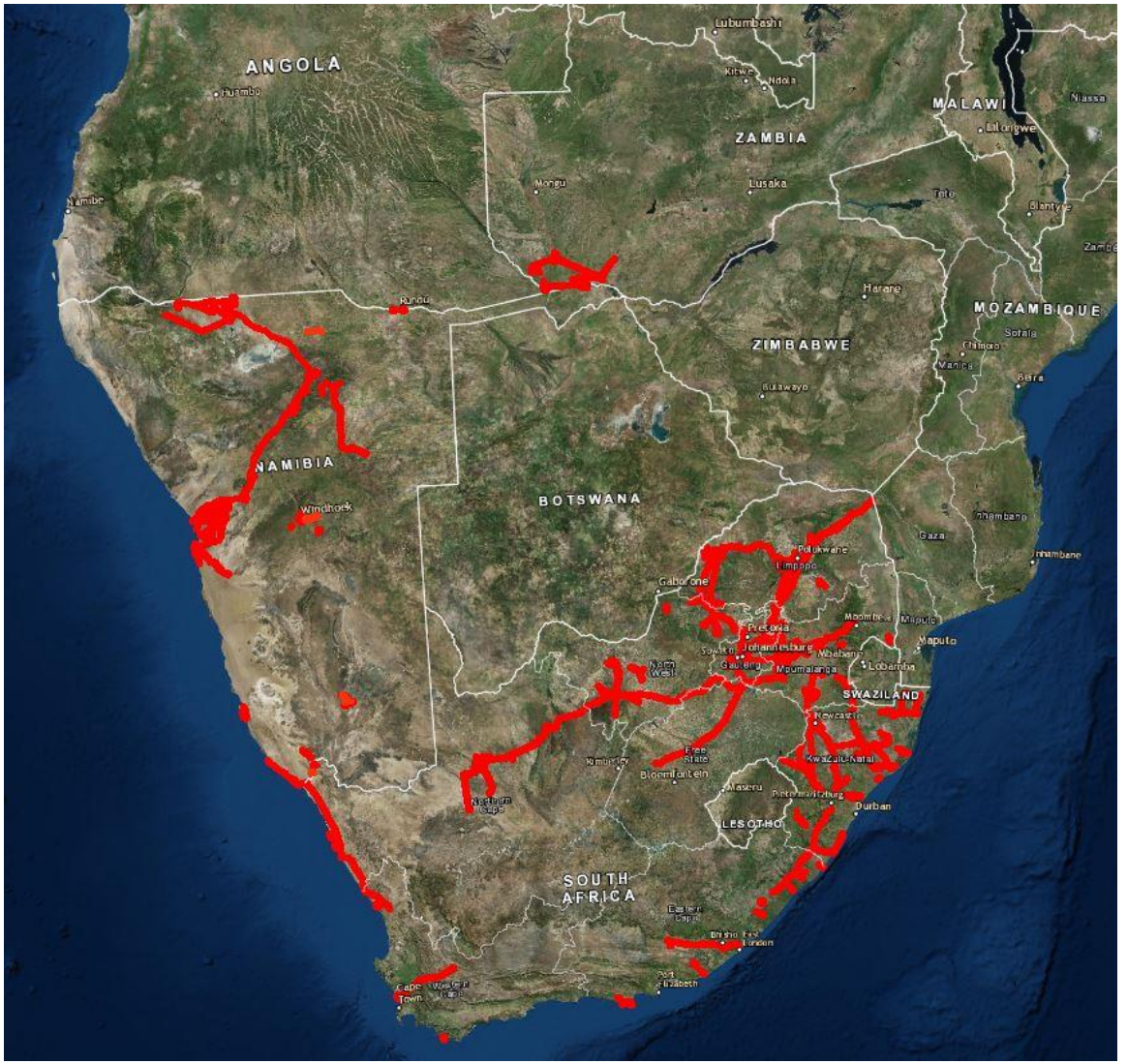
Outputs:
Woody
vegetation CC,
biomass

Validation

Explanatory variables
- input data

Calibration / Validation

Regional LiDAR database development

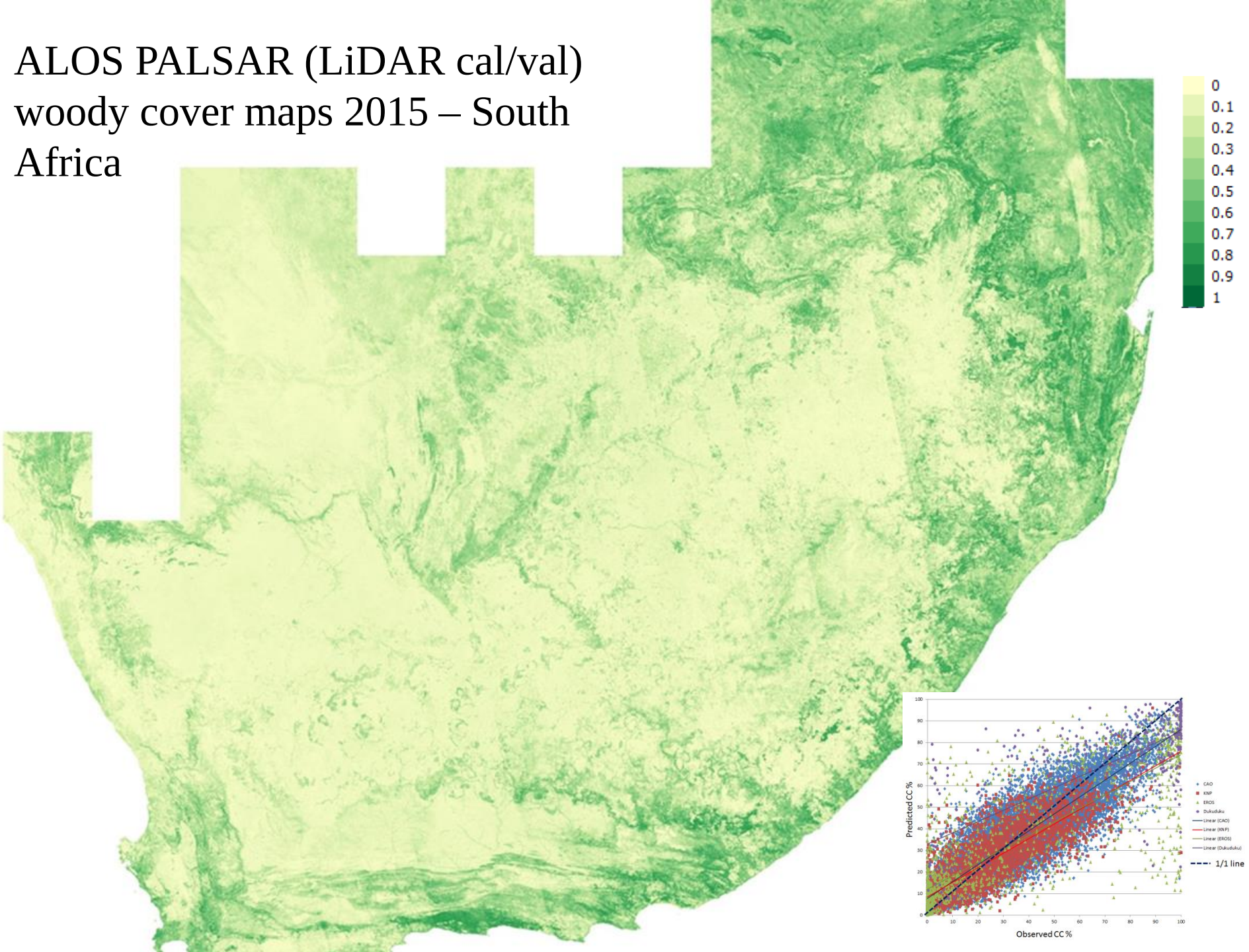


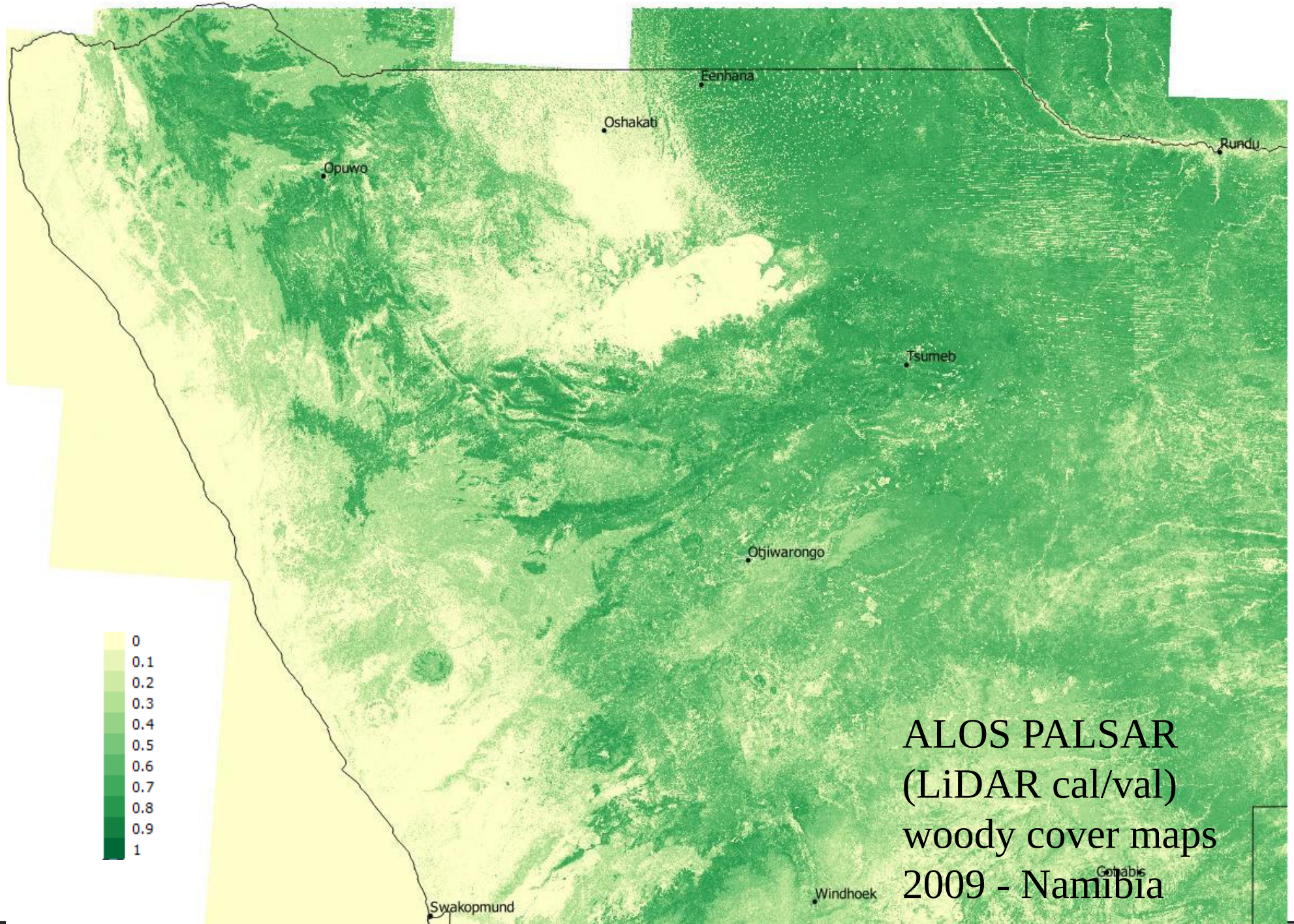
- LiDAR inventory, storage and processing; large volume of data
- 2006+, keep increasing fast
- Discrete LiDAR systems
- Datasets collected in SA, Namibia, Zambia
  - Power utilities
  - Plantation company
  - National and provincial parks
  - Cities, mines

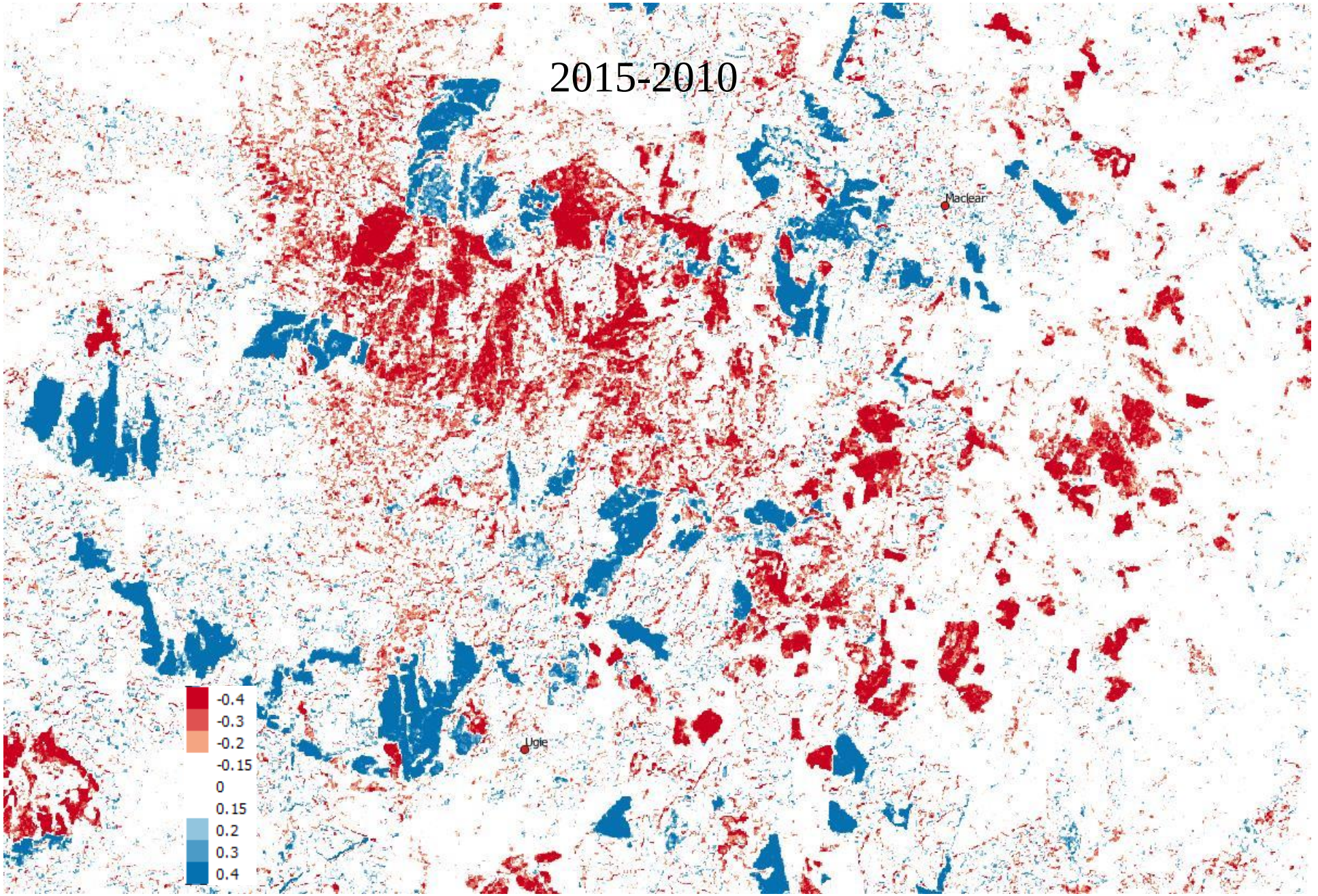
Eskom

SOUTHERN MAPPING COMPANY

ALOS PALSAR (LiDAR cal/val) woody cover maps 2015 – South Africa

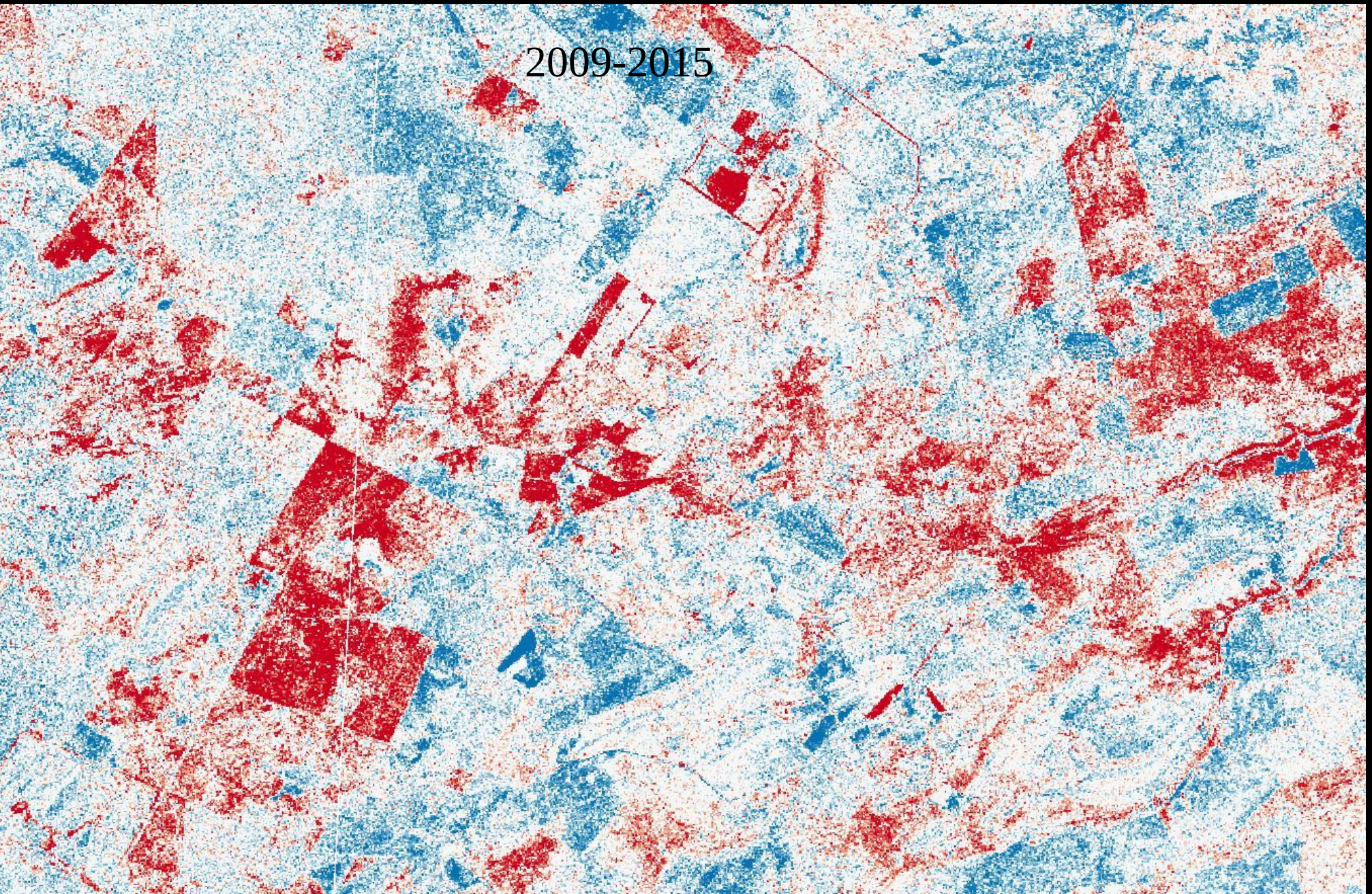


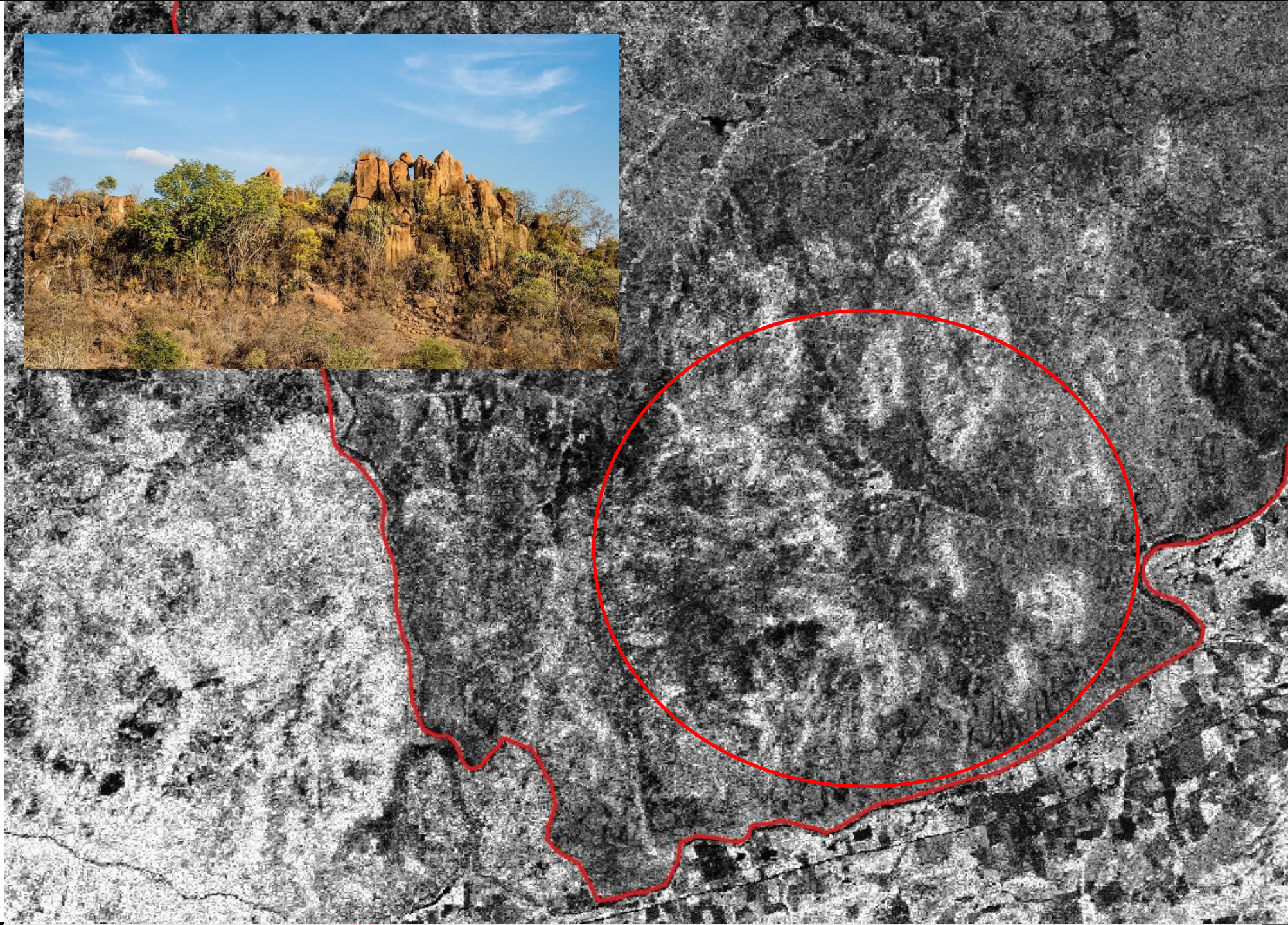

Eenhana
Oshakati
Rundu
Opuwo
Tsumeb
Otjiwarongo
Swakopmund
Windhoek
Gobabis
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
ALOS PALSAR
(LiDAR cal/val)
woody cover maps
2009 - Namibia


2015-2010
Maclear
Ugie
-0.4
-0.3
-0.2
-0.15
0
0.15
0.2
0.3
0.4

2009-2015

O kaupapuka


2009-2015

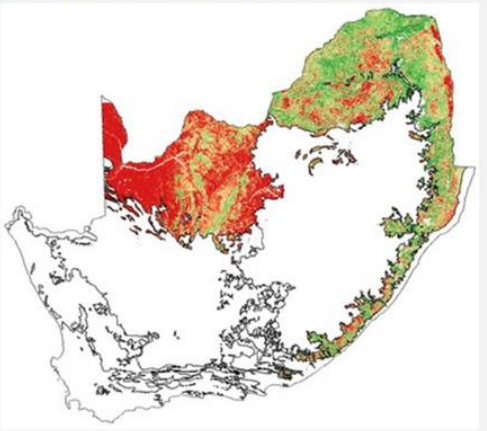


environmental affairs
Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

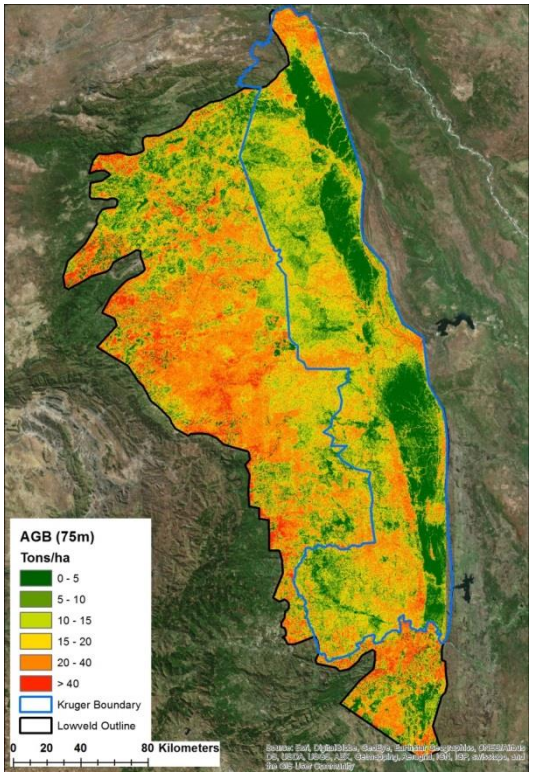
SA Carbon Sinks Atlas

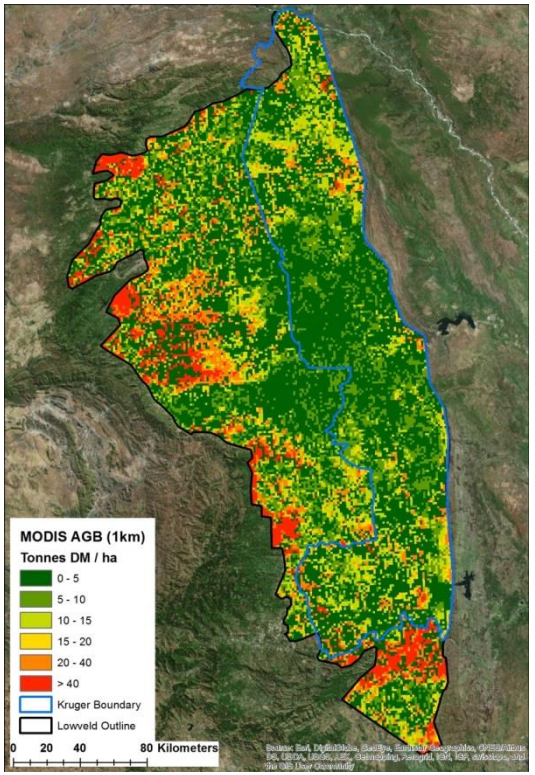
Home | Model | Data Layers | Statistics | Atlas | Download | Documents | Links

Savanna Above Ground Woody Biomass (tonnes/ha)



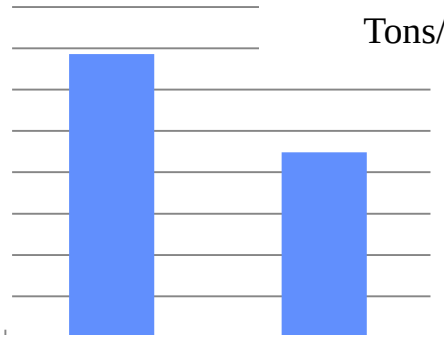
Left 2010 CSIR above ground biomass map in Lowveld (75m)
Method: integration of airborne LiDAR and ALOS PALSAR using machine learning algorithm (Random Forest)





+53%
68.6 M Tons dry biomass
Mean 16.85 Tons/ha

44.8 M Tons dry biomass
Mean 11.02 Tons/ha



SAR estimates | MODIS/GLAS estimates

Right - SA National Carbon Atlas above ground biomass map in Lowveld (75m)
Method: Combination of global GLAS LiDAR and MODIS VCF products

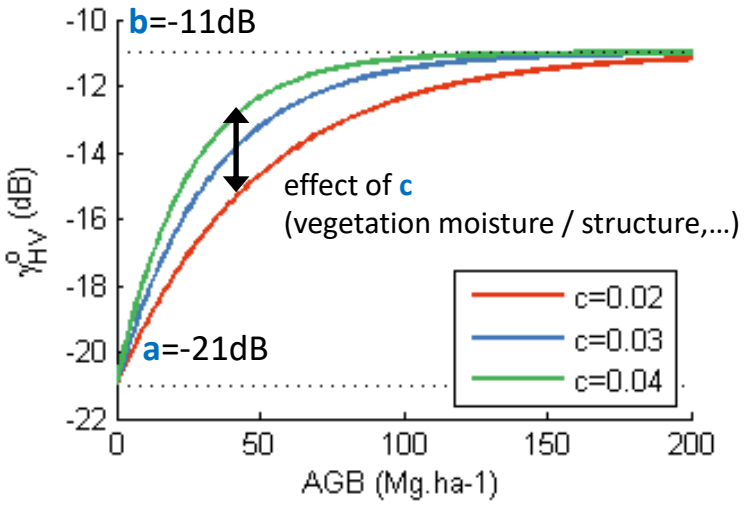
Total above ground biomass in Lowveld, Total area 4M ha

GLOBBIOMASS South Africa

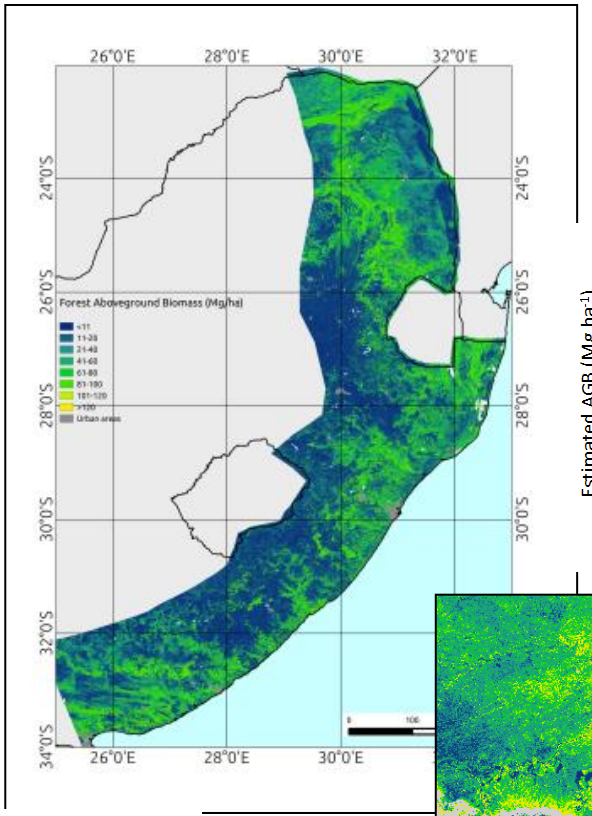
2015-2017, http://globbiomass.org/

Simplified Water Cloud Model (WCM):

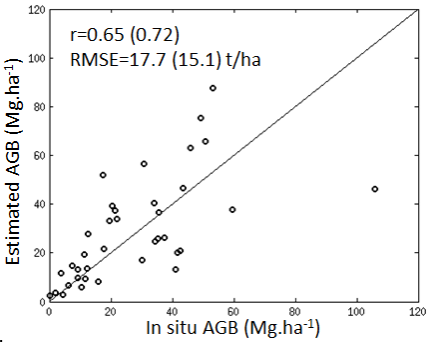
$\gamma^0 = \gamma^0_{ground}.e^{-c.AGB} + \gamma^0_{veg}.(1-e^{-c.AGB}) = \mathbf{a}e^{-c.AGB} + \mathbf{b}(1-e^{-c.AGB})$

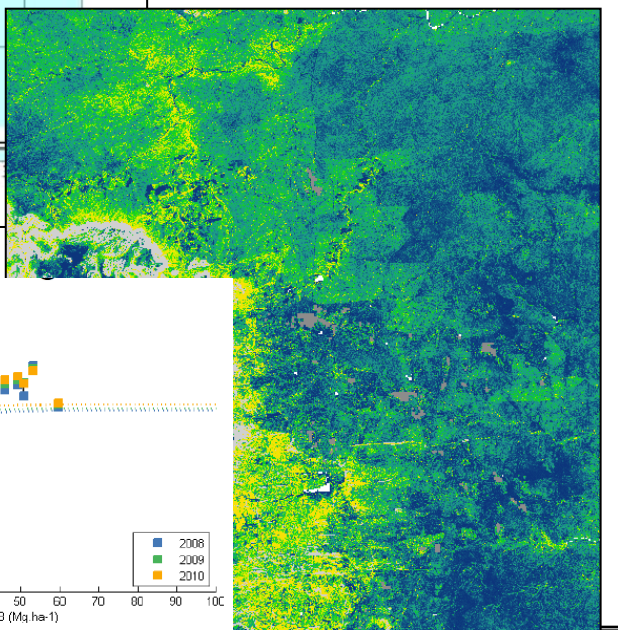


Le Toan & team



2010 CESBIO/CSIR AGB map (25m) in SA forest belt

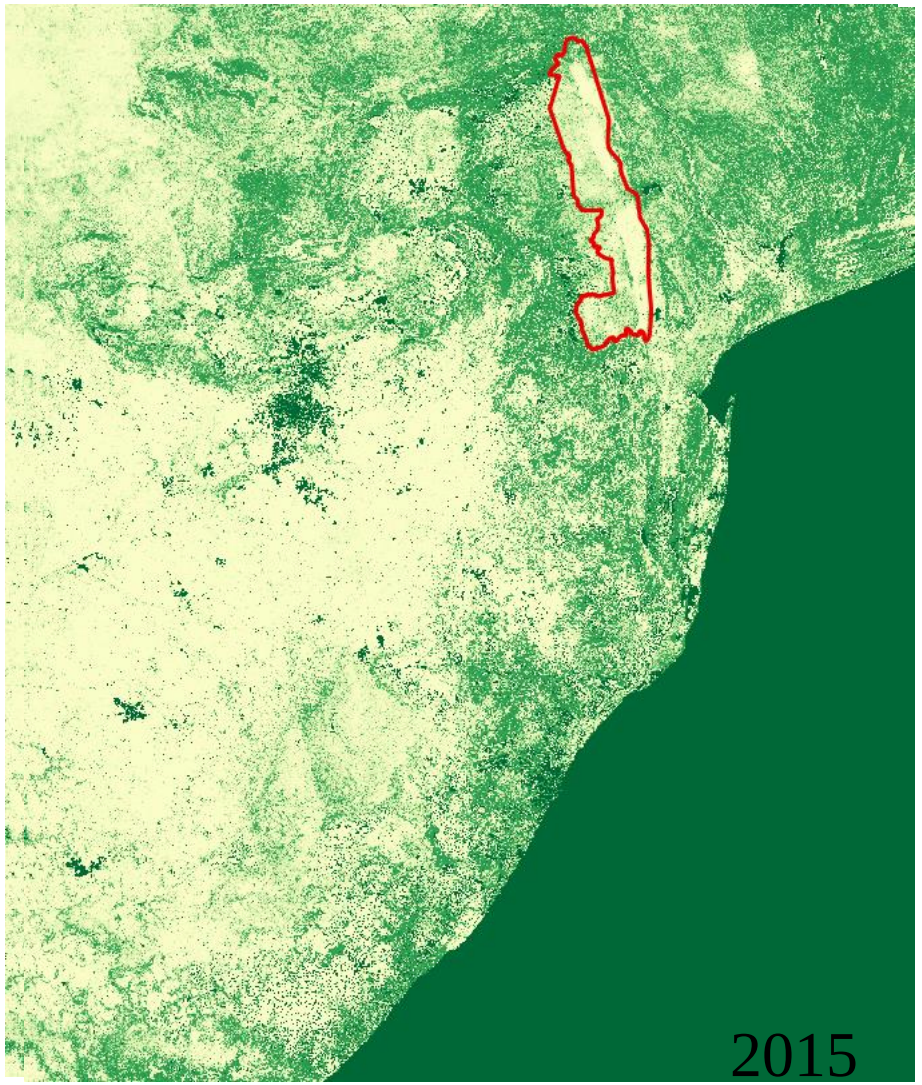


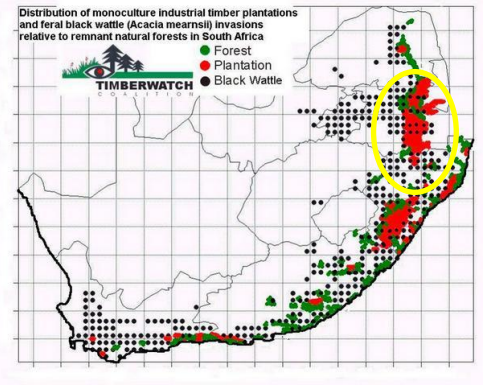


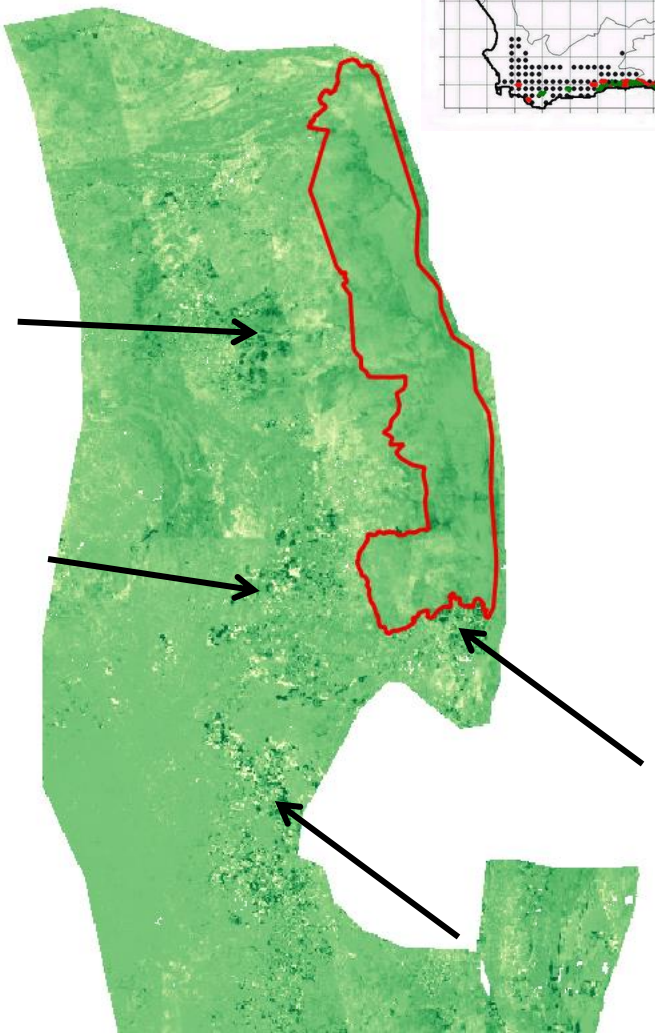
Regional biomass stock and change maps with better spatial resolution than the global reference map **(50 – 150 m)** and with a multi temporal approach comprising three epochs: 2000 or **2005, 2010** (reference year), and **2015**. The regional maps will aim for an overall accuracy of **>80%**:

AGBiomass t/ha

0.000000
25.000000
50.000000
75.000000
100.000000







-40.000000
-20.000000
0.000000
20.000000
40.000000

Project milestones

- List the project milestones until March 2018.
  - National mapping system based on LiDAR / ALOS operational (cover/biomass)
  - Assessment of ALOS FNF product in Southern Africa
  - Maps of cover produced for Namibia and South Africa for 2010/2015
  - Map of biomass produced for savannah biome in SA for 2010
  - Extension of calibration/validation datasets, robustness of models in various vegetation types (thickets, indigenous forest, plantations), on-going LiDAR and field campaign
  - Maps of biomass for other biomes (1990s → JERS-1; 2016-17 → ALOS-2)
  - Formal change assessment (error propagation and analysis)
  - Zambian / Mozambique mapping

Savannah woody structure modelling and mapping using multi-frequency (X-, C- and L-band) Synthetic Aperture Radar data

Laven Naidoo [a,b,*], Renaud Mathieu [a,b], Russell Main [a,b], Waldo Kleynhans [c,f], Konrad Wessels [b,c], Gregory Asner [d], Brigitte Leblon [e]

L-band Synthetic Aperture Radar imagery performs better than optical datasets at retrieving woody fractional cover in deciduous, dry savannahs

Laven Naidoo [a,b,*], Renaud Mathieu [a,b], Russell Main [a,b], Konrad Wessels [b,c], Gregory P. Asner [d]

An above-ground biomass map of African savannahs and woodlands at 25 m resolution derived from ALOS PALSAR

Alexandre Bouvet [a,*], Stéphane Mermoz [a], Thuy Le Toan [a], Ludovic Villard [a], Renaud Mathieu [b], Laven Naidoo [b], Gregory P. Asner [c]

Deliverables

- Project deliverables until march 2018
  - 2 papers published (multi-frequency cover mapping in SA savannahs, contribution of L-band & optical for SA tree cover mapping)
  - 1 collaborative paper with CESBIO (African savannah AGB mapping)
  - Developed a comprehensive LiDAR database for the region
  - National mapping system based on LiDAR / ALOS operational (cover/biomass)
  - Maps cover produced for Namibia and South Africa for 2010/2015
  - Maps biomass produced for savannah biome in SA
- In case of a 1-year extension, additional deliverables by March 2019
  - Three papers in prep using ALOS (Namibian change detection, land management drivers of woody resources, assessment of global forest mapping product in southern African savannahs)
  - Complete national 3 epoch biomass mapping in SA

PALSAR/PALSAR-2 data access

Acquisition currently focused on

1) Annual coverage FDB of SA pilot sites (winter): various veg types, savannahs, plantations, thicket, indigenous dense forests
2) Annual mosaics SA/Namibia/Zambia
3) No current plan for ScanSAR mosaics

Acknowledgement