

LiDAR/SAR-based mapping of woody attributes in savannahs and woodlands in Southern Africa

Renaud Mathieu¹, Konrad Wessels², Russell Main¹, Laven Naidoo¹

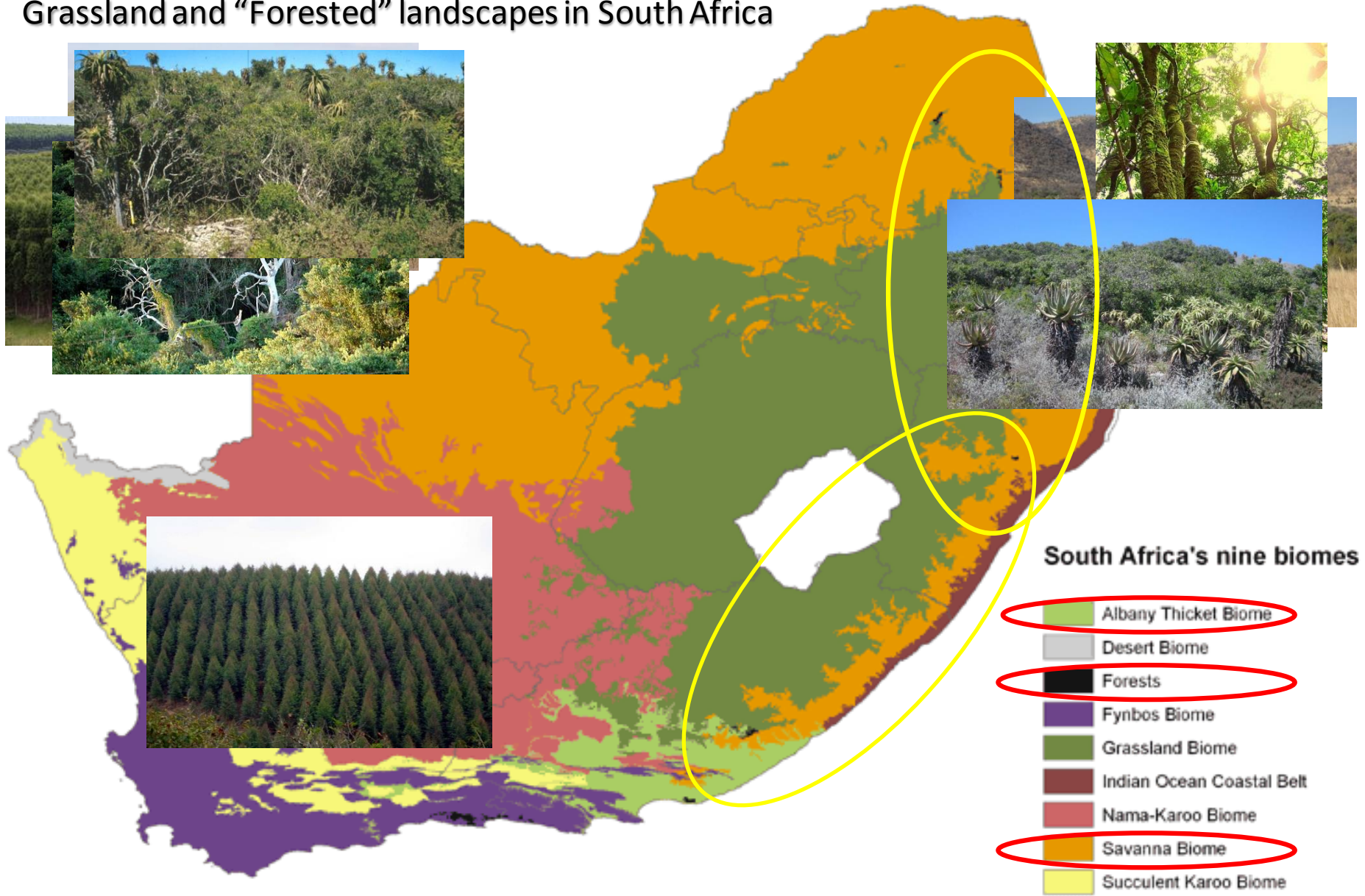


1 Earth Observation Research Group, CSIR-NRE

2 Remote Sensing Research Unit, CSIR-Meraka

Protea Centurion
Pretoria Hotel,
Centurion
June 20-22, 2016

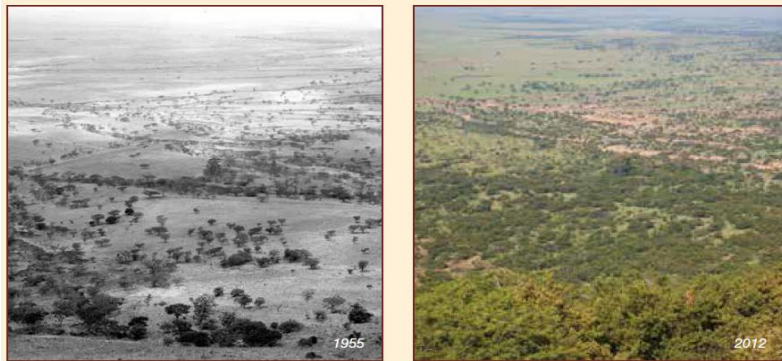
Grassland and "Forested" landscapes in South Africa



Savanna is the most widespread biome (25% of SA land area), but only 10% of the area is forested. It is a mosaic of grassland and trees and shrubs, height < 5m

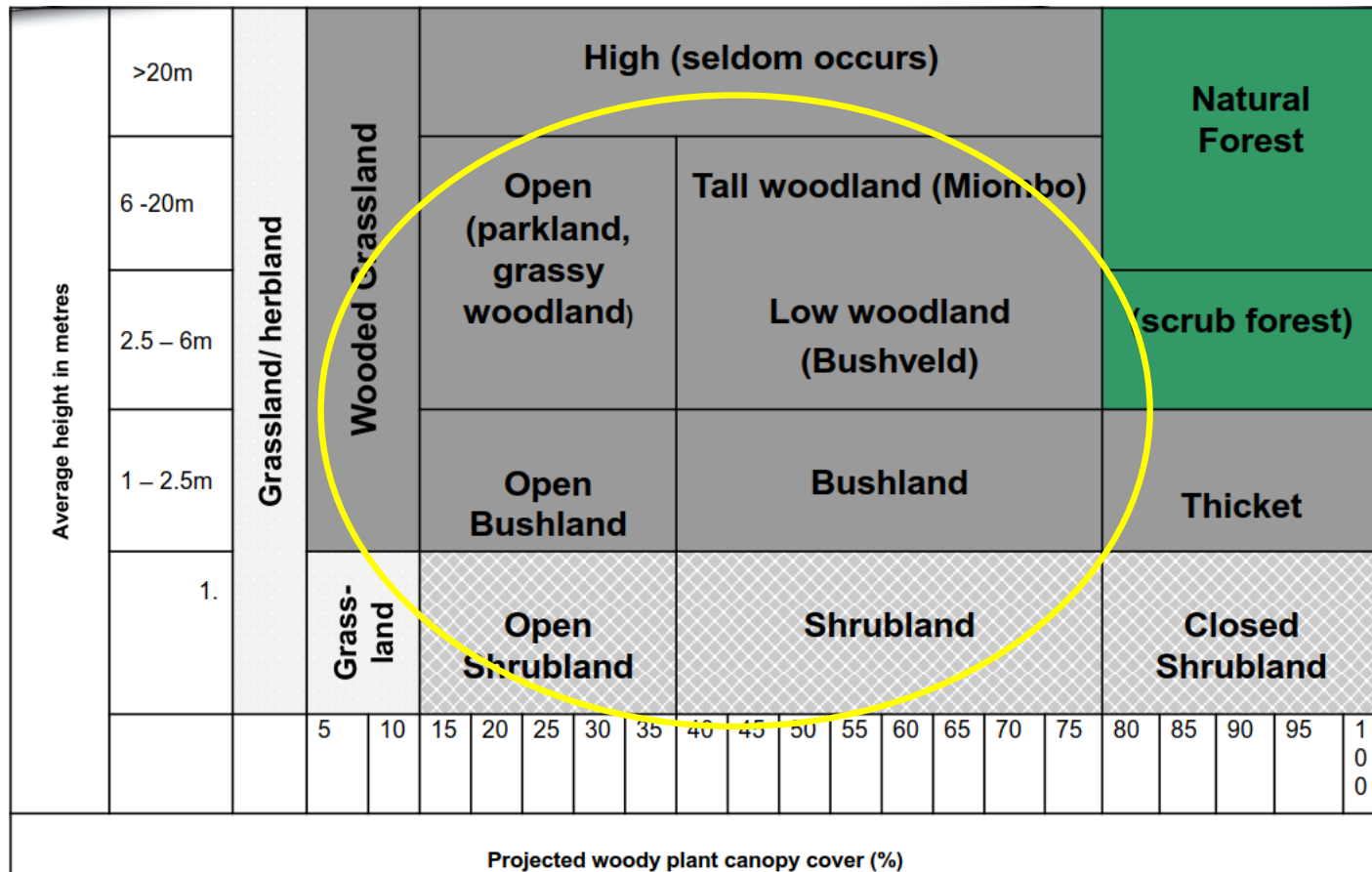
Why information on woody component is important?

- Savannahs:
 - Dominant mixed grass / woody landscape in SA
- Browser vs. grazer, life form competition
- Bush encroachment (densification, expansion into grassland) affects 10-20 M ha in SA, **5-6% tree cover increase per decade** → food security vs. energy security
- Grass information retrieval (or tree retrieval) complicated by small scale mixture of trees and grass



Why information on woody component are important?

- Focus on national mapping of continuous variables
 - Woody cover, height and biomass
 - “Forest types” (and grass resources) largely (but not only) related to woody structure, cover / height



An EO challenge

- Arid-semi arid: 10-50% cover, 60T/ha biomass
- Multi- (and especially fine) scale vertical and horizontal heterogeneity
 - Soil properties & water availability (catenas)
 - Disturbance factors: fire, herbivore, human
- Temporal variability
 - Seasonality and differential tree – grass phenology
 - Mostly gradual changes: drought, fire, human (e.g. bush encroachment, logging)



Geographical context



Aim to approaches scalable at national level

R&D pilot sites (GFOI)

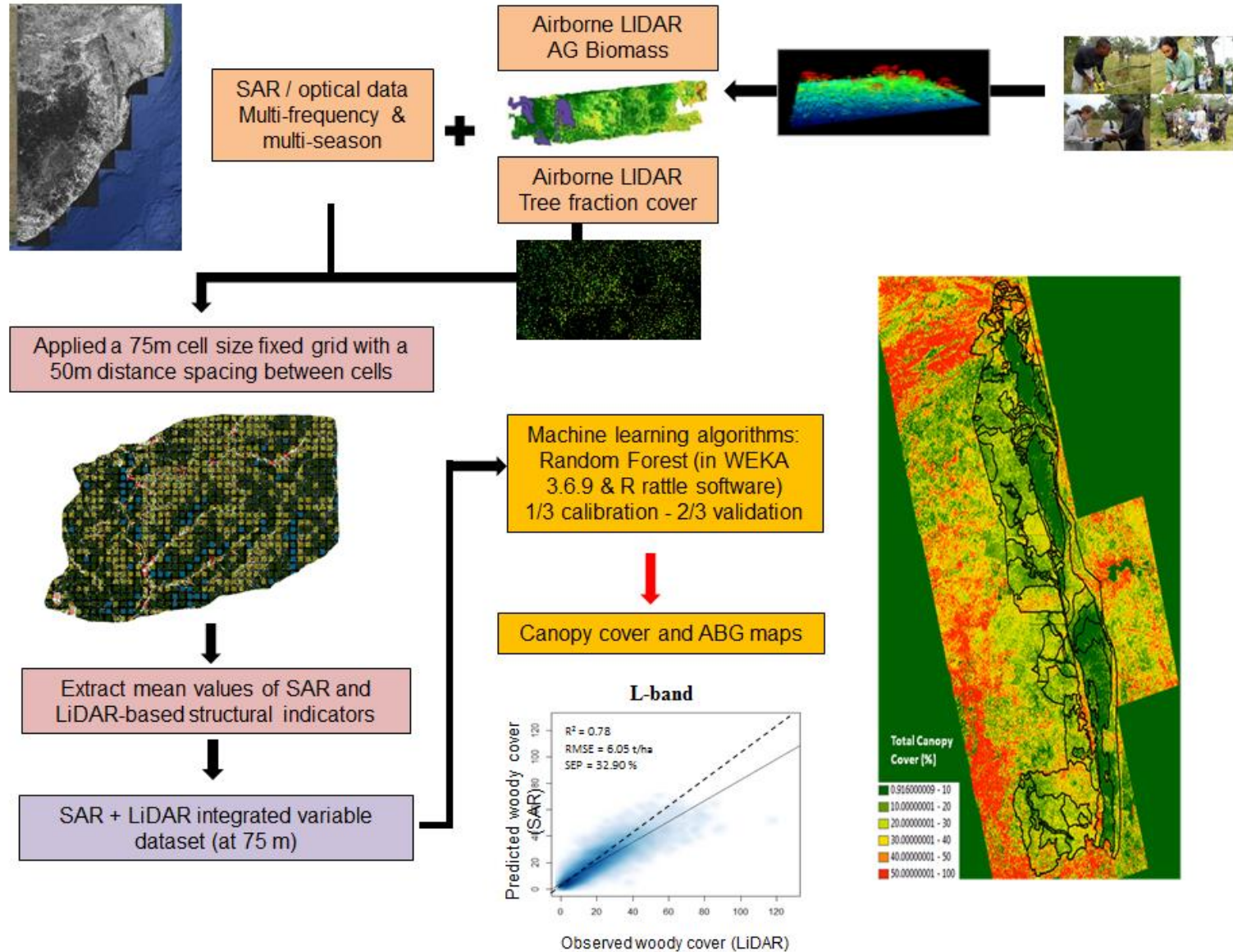
1: **Lowveld, KNP** (Mpumalanga, Limpopo): plantation, mountain forests, savannahs

2: **Duku Duku area & iSimangaliso Wetland Park** (KZN): plantation, coastal forests, savannahs, mangrove

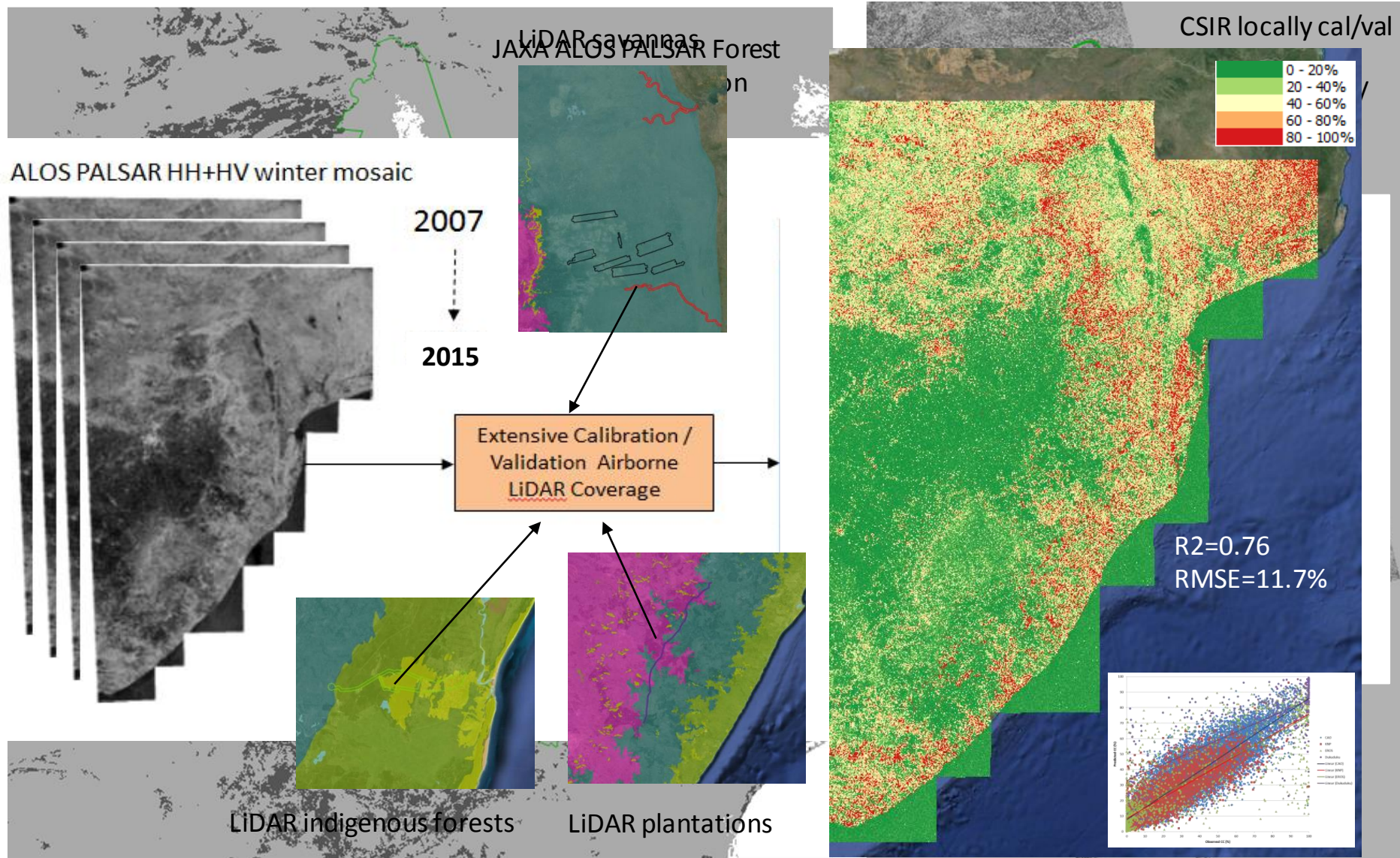
3: **Addo Elephant Park area** (Eastern Cape): thicket

4: **Alguhas Plains** (Western Cape): alien woody vegetation, fynbos

General methods LiDAR/SAR for mapping structure



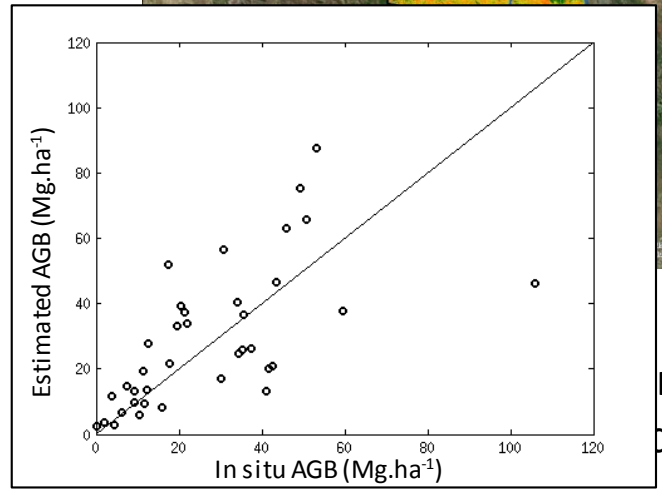
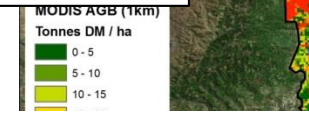
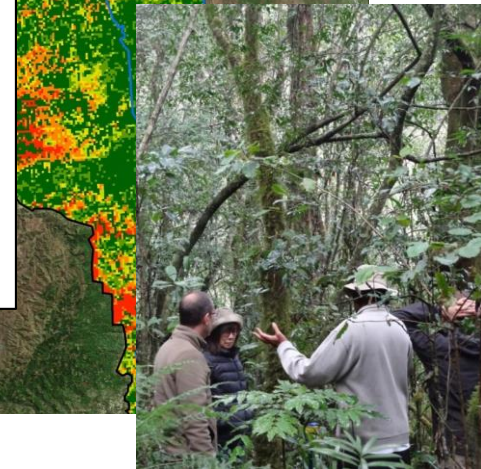
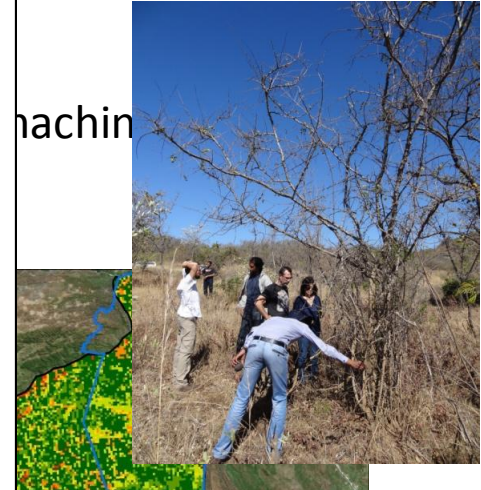
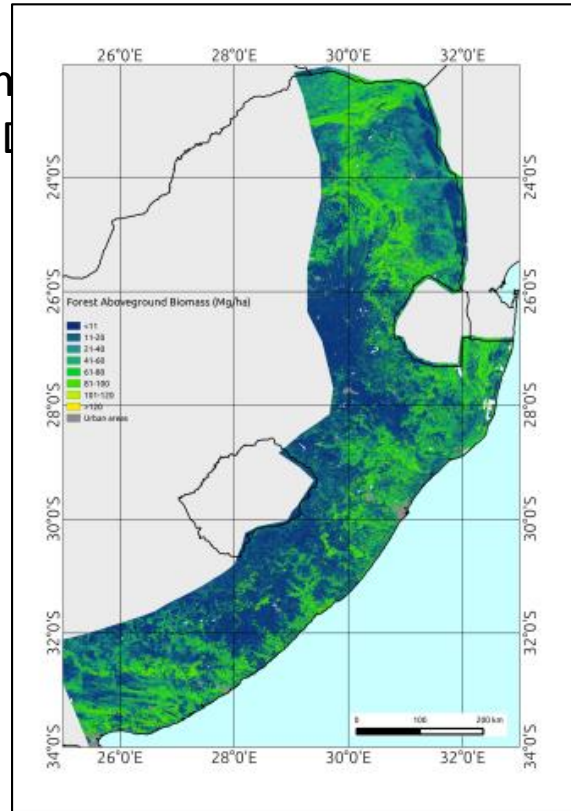
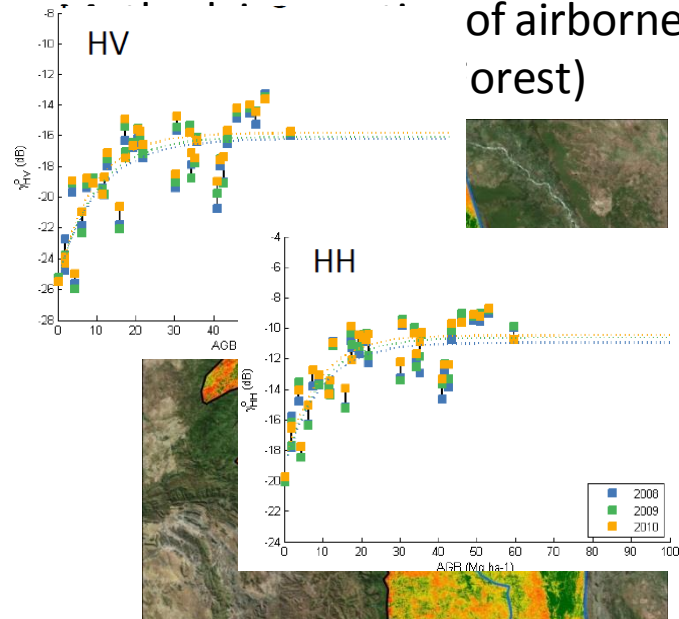
Development of national / regional EO-based woody & forest products



Biomass mapping in South Africa



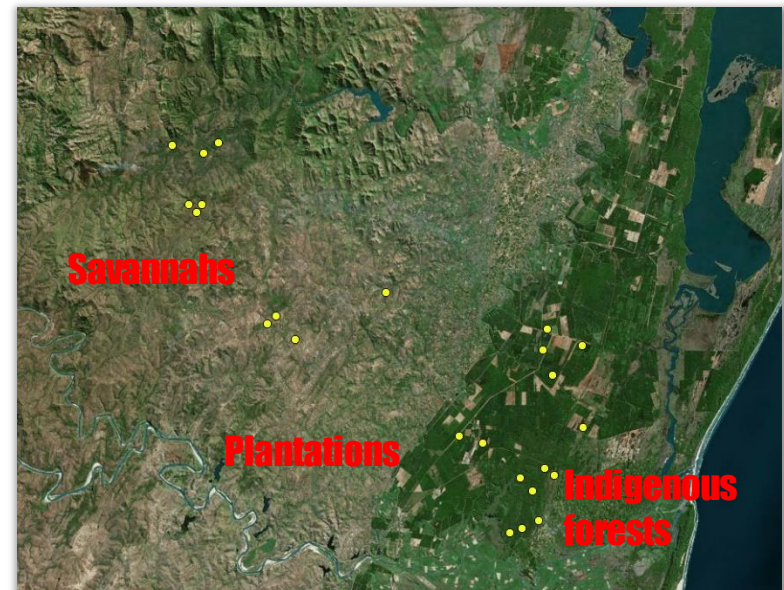
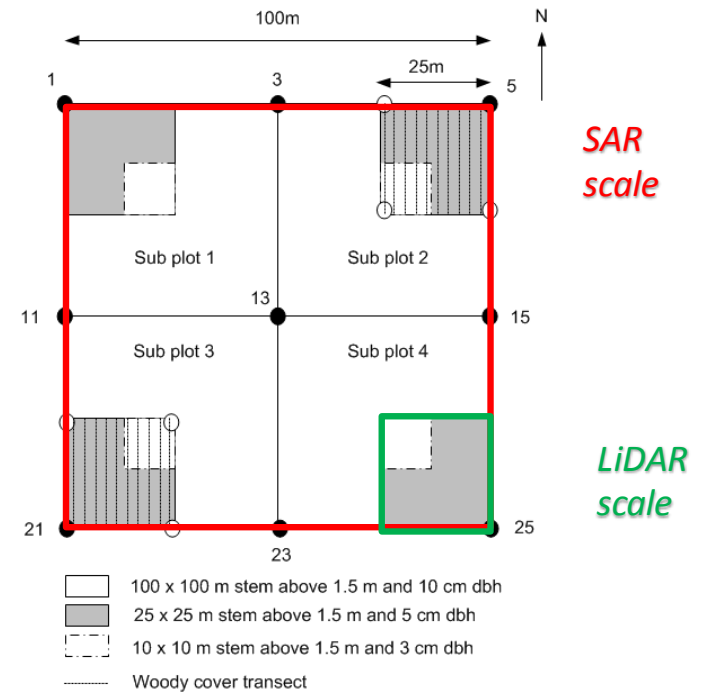
2010 CSIR above ground biomass map of airborne LiDAR (forest)



Le Toan & team
 2005/2010/2015 CESBIO-CSIR above ground biomass map in SA forest belt; method: semi empirical methods, use small number of cal plots, MIPERS SAR simulator (forest/env parameters), water cloud models & Bayesian inversion

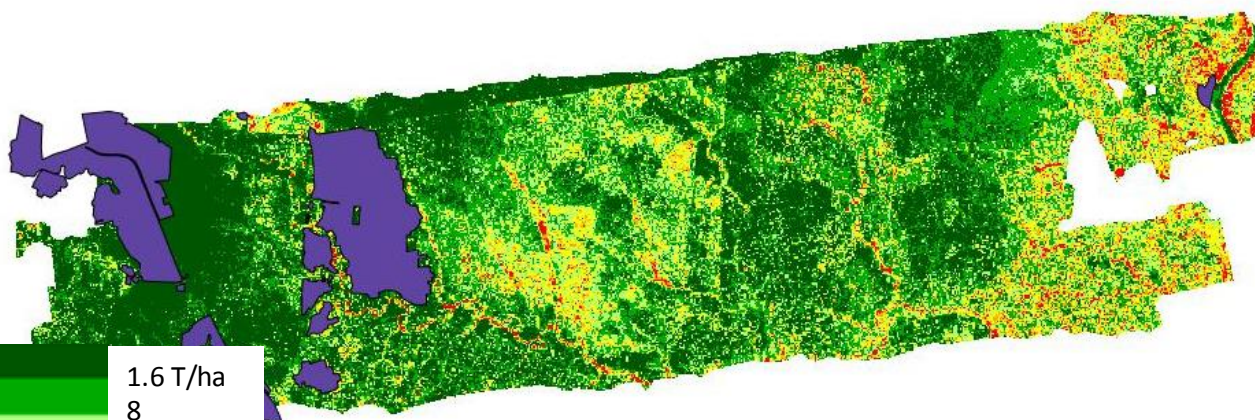
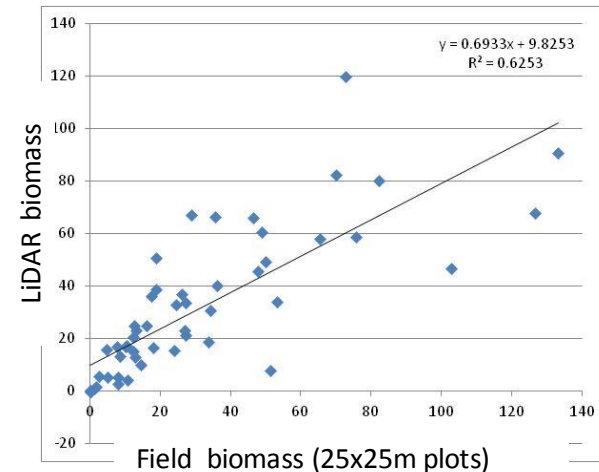
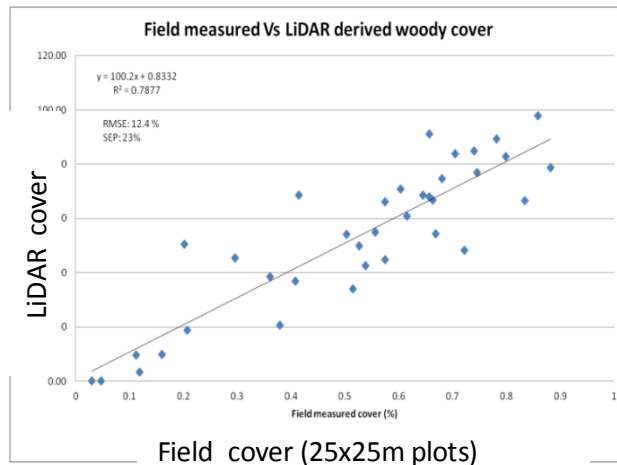
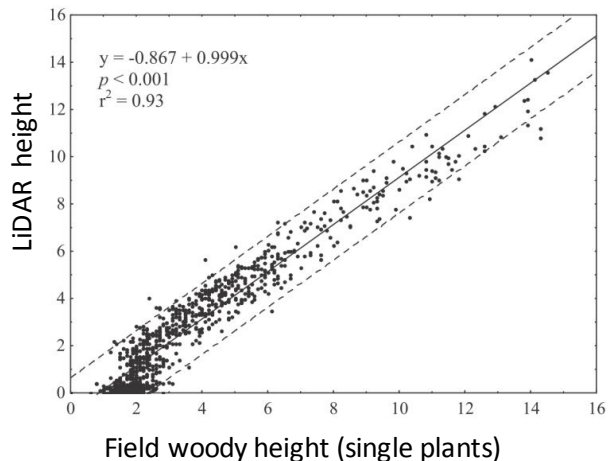
Field sampling effort – above ground biomass

- 1 ha square plots (cal/val LiDAR & SAR)
 - Height & DBH
 - Species
- ~ 100 plots over various veg types
- Allometric equations



LiDAR cal/val & product development

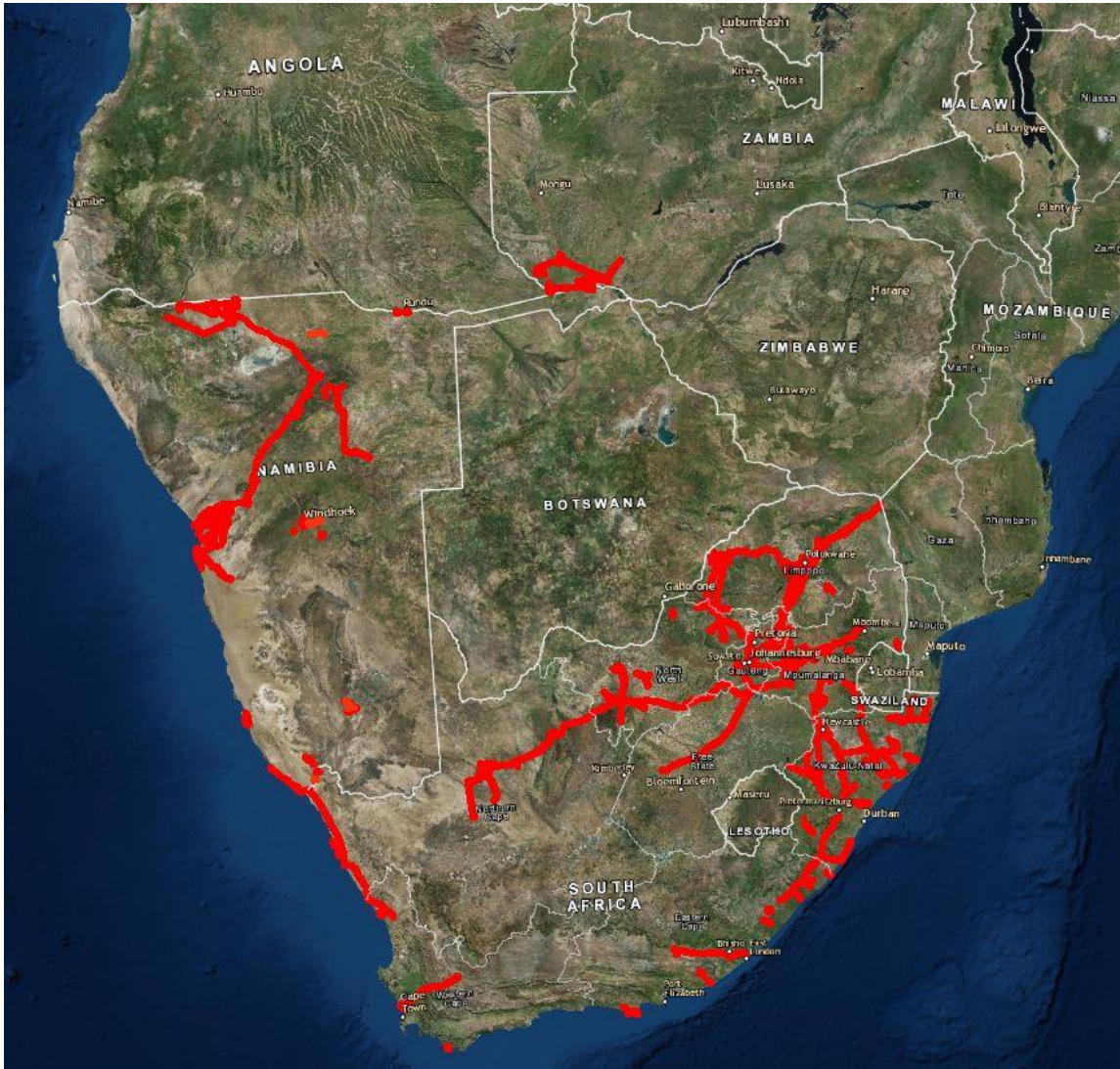
Assessment of accuracy of LiDAR products, development and validation of above ground woody biomass products – SAR upscaling



Biomass = 9.8 x Mean Woody Height x Canopy Cover + 32

LiDAR-based biomass allometric equations

National (and SADC) LiDAR database development



- LiDAR inventory, storage and processing
- 2006+
- Main stream discrete LiDAR instruments are available (Southern Mapping Company)
- Many datasets are collected in SA (and Namibia, Zambia)
 - Power utilities
 - Plantation company
 - National and provincial parks
 - Cities, mines
 - Etc.

Multi-temporal, polarimetric C-band RADARSAT-2 & L-band PALSAR & woody cover in savannahs

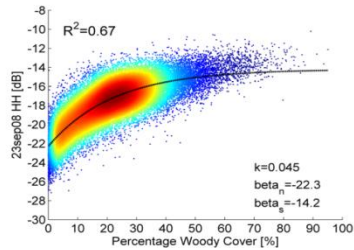
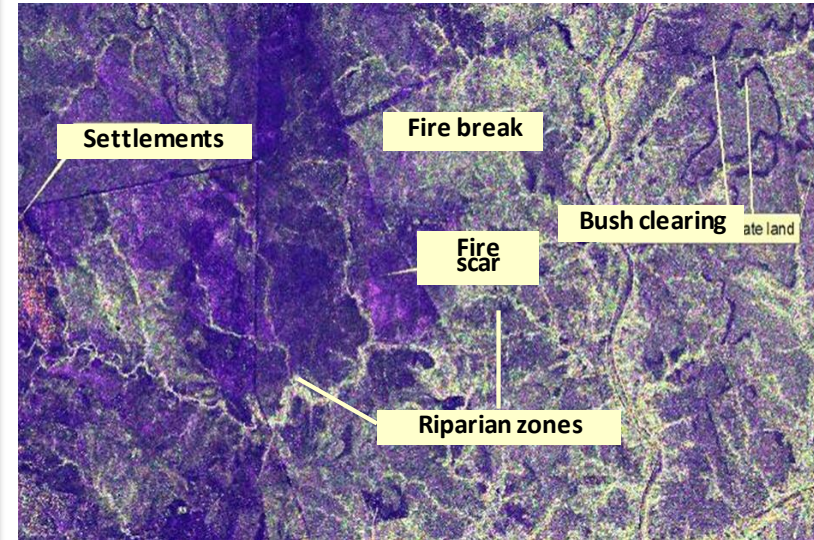
Season: Winter >> summer > autumn, multi-season improves slightly the model

Polarization: HV & HH during dry season, HV during wet season

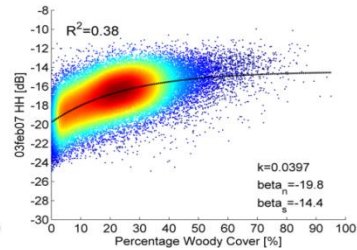
Scale: optimum around 0.25-1ha (50-100m)

Polarimetric decomposition (Freeman, Van Zyl): volume component does not improve on co-pol HV

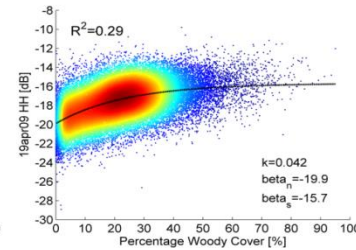
SAR better predict woody volume > cover



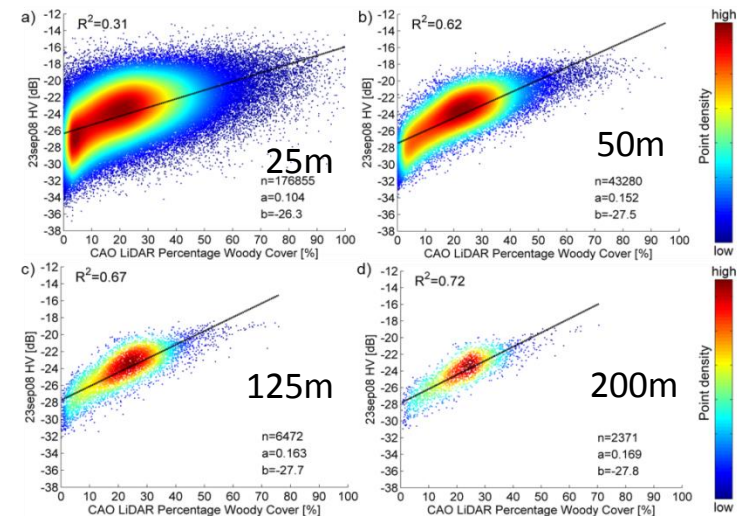
Winter: tree leaf-off, dry grass



Summer: tree leaf-on, green grass

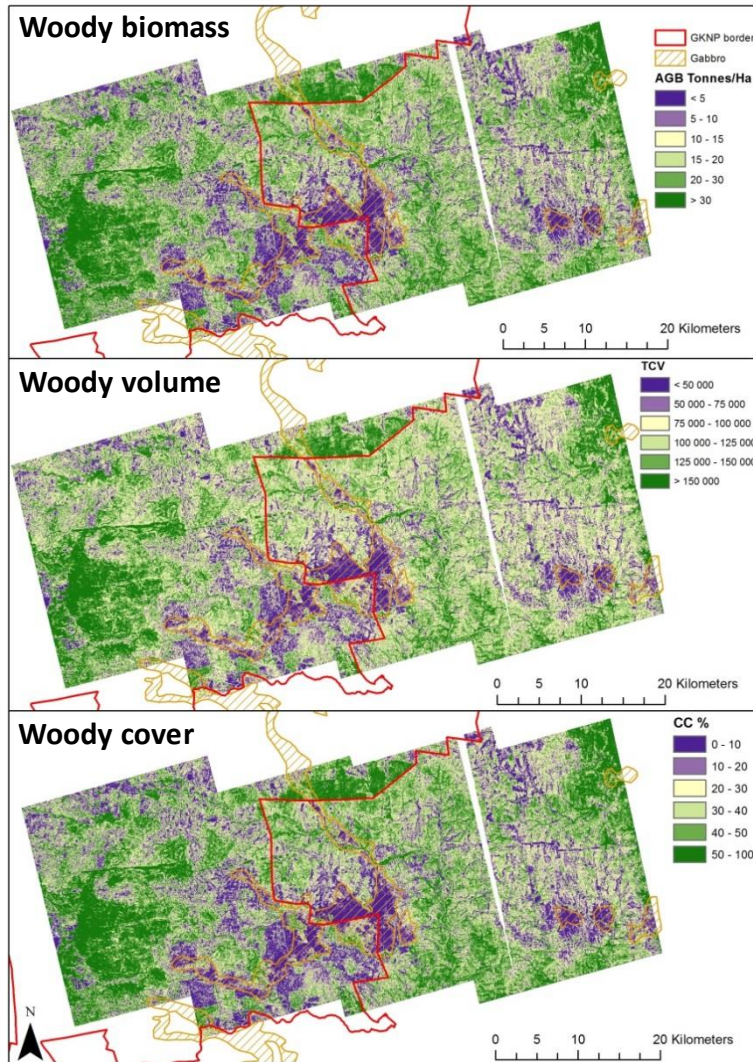


Autumn: tree leaf-on, dry grass



Mathieu et al. 2013, Remote Sensing of the Environment
 Urbazaev et al. 2015, Remote Sensing of the Environment

Multi-frequency SAR (X, C, L) modelling of woody cover, biomass, and volume in savannahs

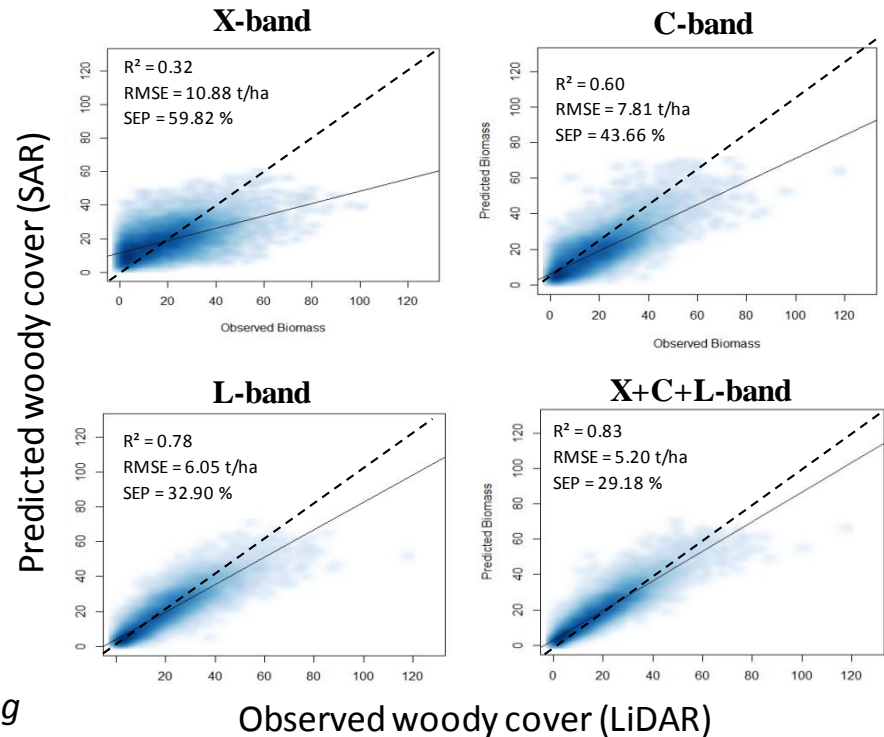


Winter dual-pol datasets

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

Random forest > ANN > Decision trees > linear reg

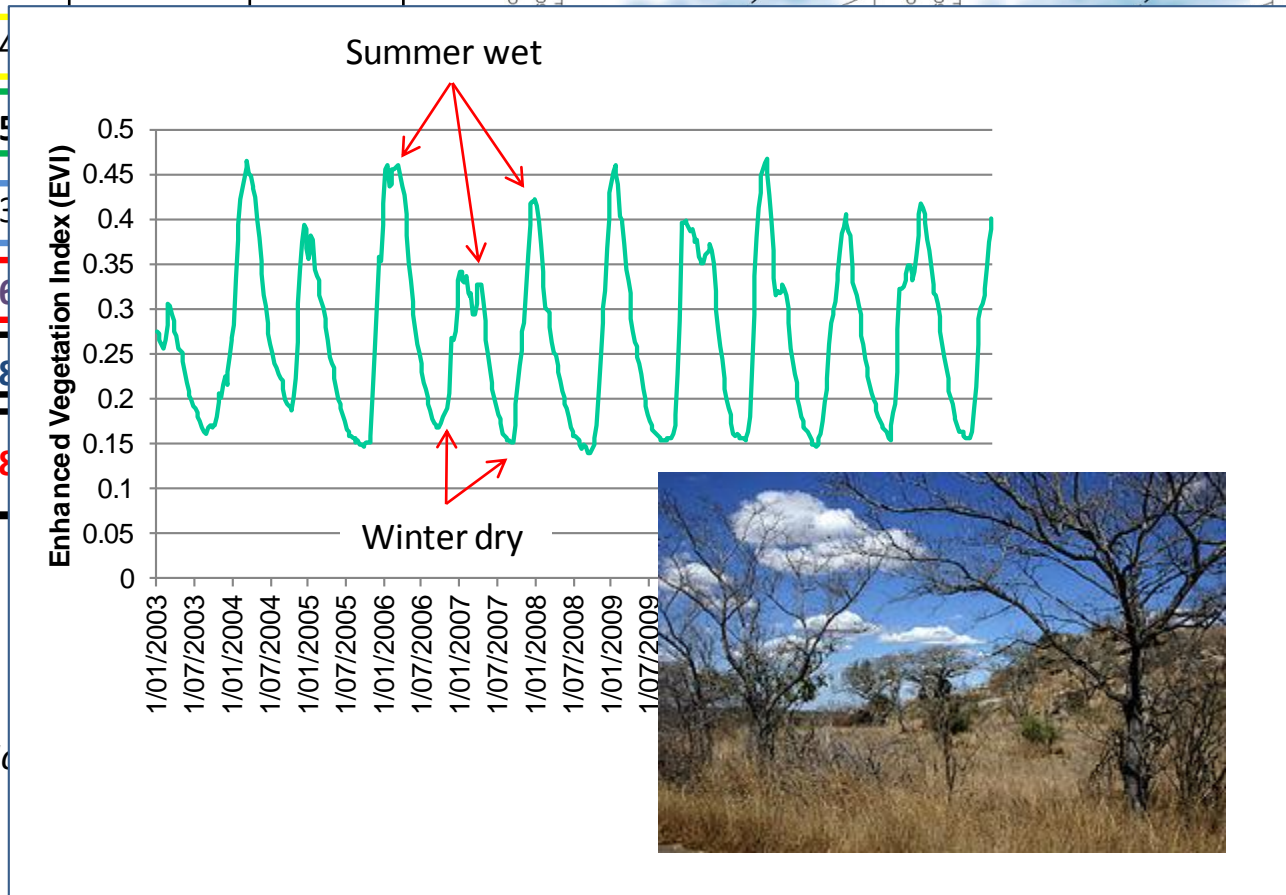
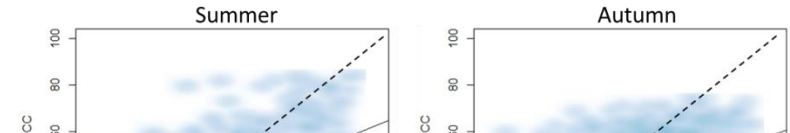
SAR better predict woody volume > cover = biomass



Combined L-band SAR and optical Landsat datasets

- Green woody canopy, dry grass
- Green woody canopy, green grass
- Leaf-off woody canopy, dry grass

Scenarios	R ²	RMSE (%)	SEP (%)
Autumn	0.46	12.82	52.44
Spring	0.4		
Summer	0.5		
Winter	0.3		
All Four Seasons	0.6		
L-band SAR only	0.8		
L-band SAR and Summer Reflectance	0.8		



Hypertemporal C-band time series

C-band ENVISAT-ASAR WS: 75 m, HH; preparation for Sentinel-1 (free, already large database)

Random Forest \pm = linear regression; temporal filter improves modelling results

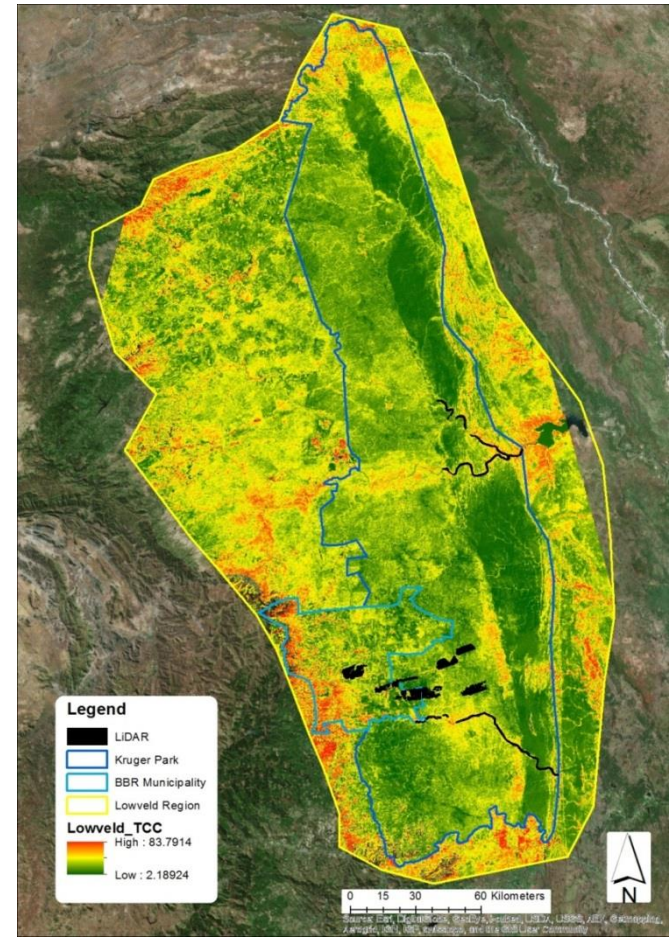
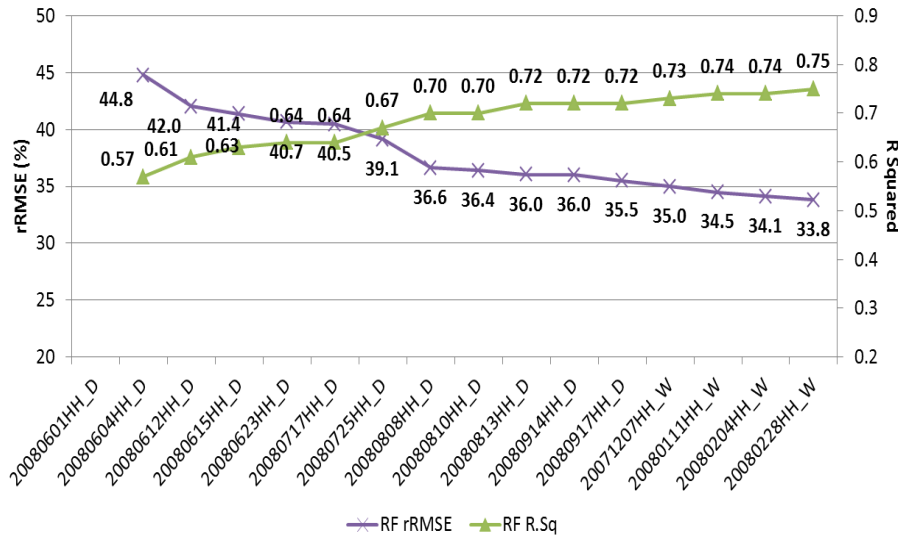
ASAR predicts woody volume > woody cover; dry > wet, but both improve modelling results

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

Main et al 2014, IGARSS

Woody cover map ASAR C-band 20 winter summer images

c) 2007 / 2008 Cycle - TCC



Current and future efforts

- Development of systems, robust upscaling methods at national / regional scales (automation of processes LiDAR –SAR integration with large datasets)
- Biomass mapping and change detection
- Uncertainty assessment (error propagation)
- Development of long term cal/val infrastructure
 - Field, drone, airborne; pilot sites in main ecosystems (Lowveld, Saint Lucia / Duku area, Addo Elephant Park area)
 - Extension of calibration/validation datasets, robustness of LiDAR-based models in various vegetation types (thickets, indigenous forest, plantations)

Acknowledgement

