Joint GFOI / GOFC-GOLD / CONABIO / SilvaCarbon R&D Expert and Capacity Building workshop on:

Regional solutions to forest type stratification and characterising the forest state for national forest monitoring and carbon emissions reporting

LiDAR/SAR-based mapping of savannahs forests in Southern Africa

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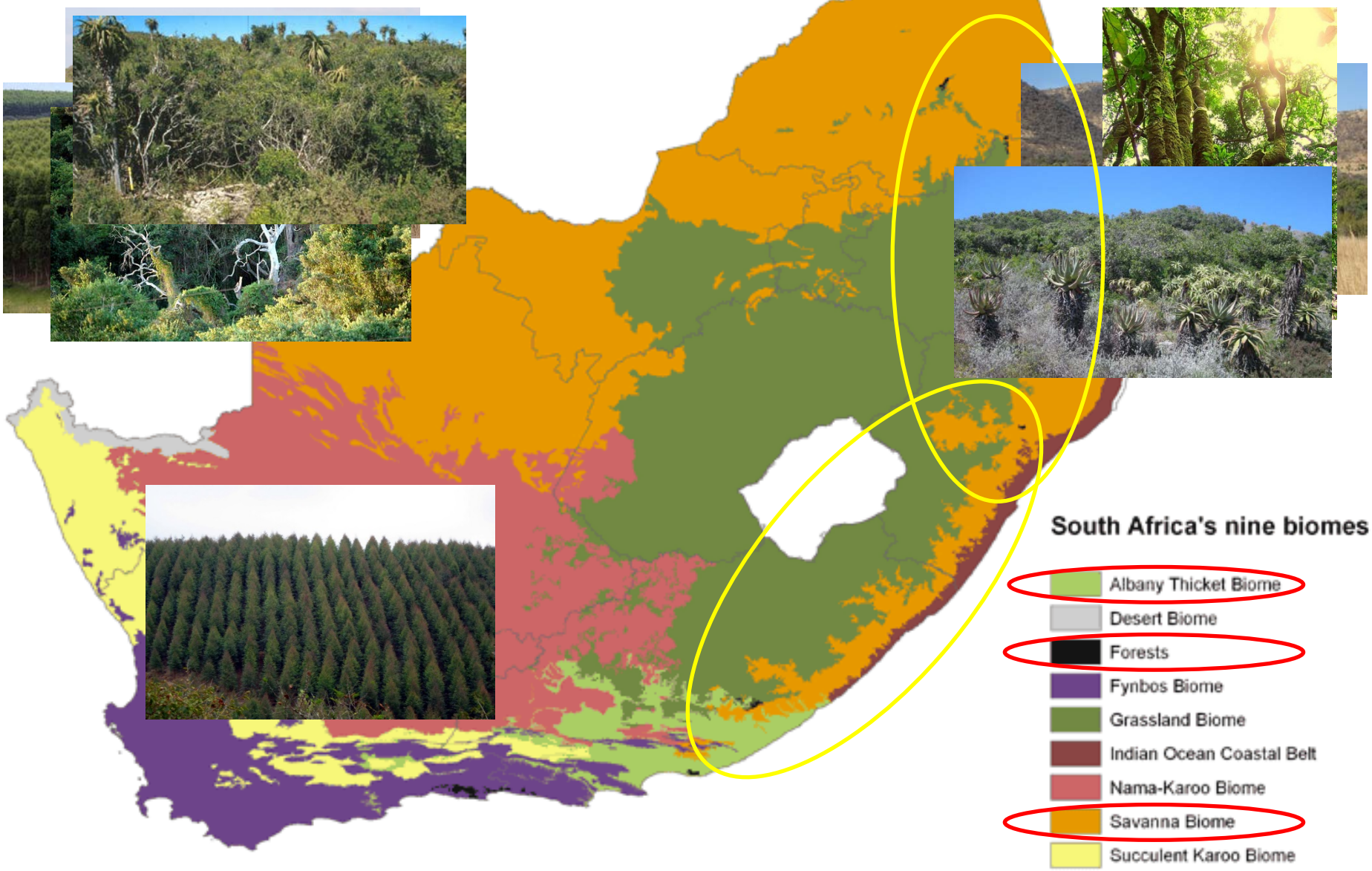
CONABIO, Mexico City
June 7-10, 2016

“Forested” landscapes in South Africa

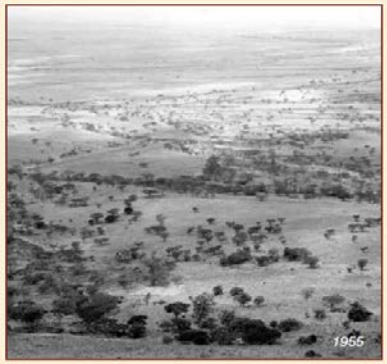


[illegible] $t\ ha^{-1}$

[illegible] < 50T ha^{-1} trees and shrubs, height < 5m

Context: Some information needs

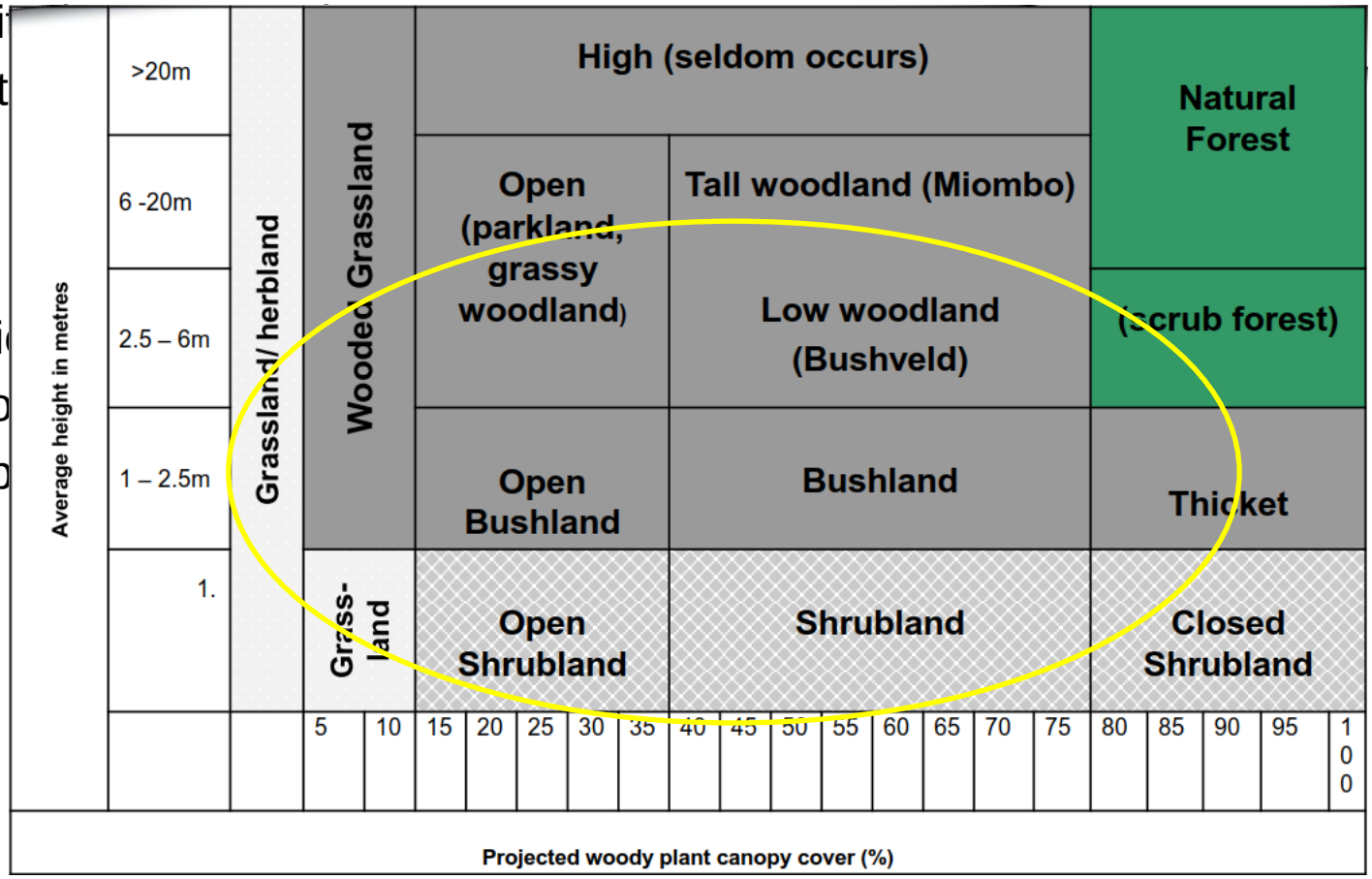
- Drastic vegetation changes: management needs
  - Bush encroachment affects 10-20 M ha in SA, 5-6% tree cover increase per decade → food security vs energy security
  - Woody alien invasive affects additional 10 M ha in SA & Lesotho → land productivity / water security
  - Carbon stock assessment, legal international reporting obligation (UNFCC) → Impact of bush encroachment? (1/3 of C sink in US, (Houghton et al. 1999)
- Lack of national spatial information to man



"Undertake provincial and national forest resource

Some information needs

- Drastic vegetation changes: management needs
  - Bush encroachment affects 10-20 M ha in SA, 5-6% tree cover increase per decade → food security vs energy security
  - Woody alien invasive affects additional 10 M ha in SA & Lesotho → land productivi
  - Carbon st (UNFCC)
- Focus on nati
  - Woody co
  - Forest typ



Geographical context

Aim to approaches scalable at national level

R&D pilot sites (GFOI)

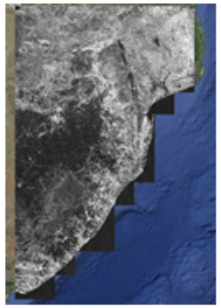
1: Lowveld, KNP (Mpumalanga, Limpopo): plantation, mountain forests, savannahs

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

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

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

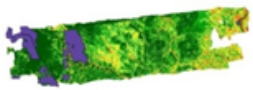
General methods LiDAR/SAR for mapping structure

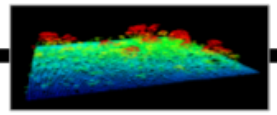


SAR / optical data
Multi-frequency &
multi-season

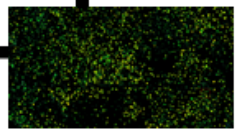
+

Airborne LIDAR
AG Biomass

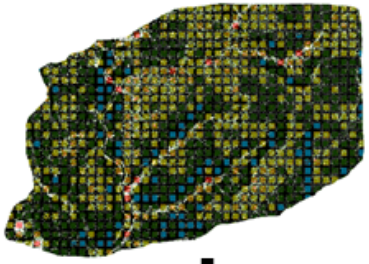




Airborne LIDAR
Tree fraction cover



Applied a 75m cell size fixed grid with a
50m distance spacing between cells

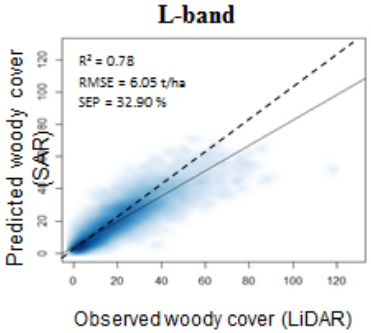


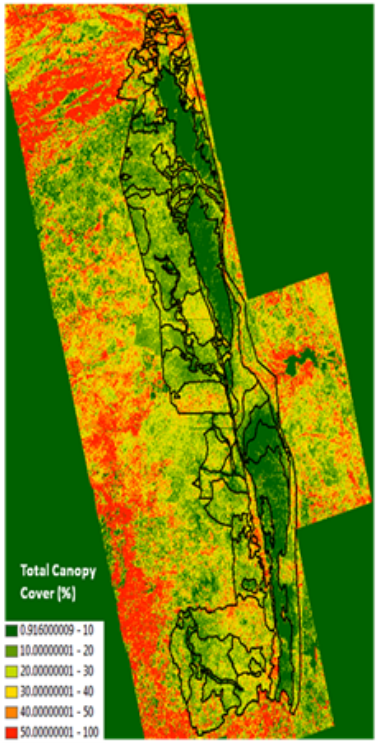
Extract mean values of SAR and
LiDAR-based structural indicators

SAR + LiDAR integrated variable
dataset (at 75 m)

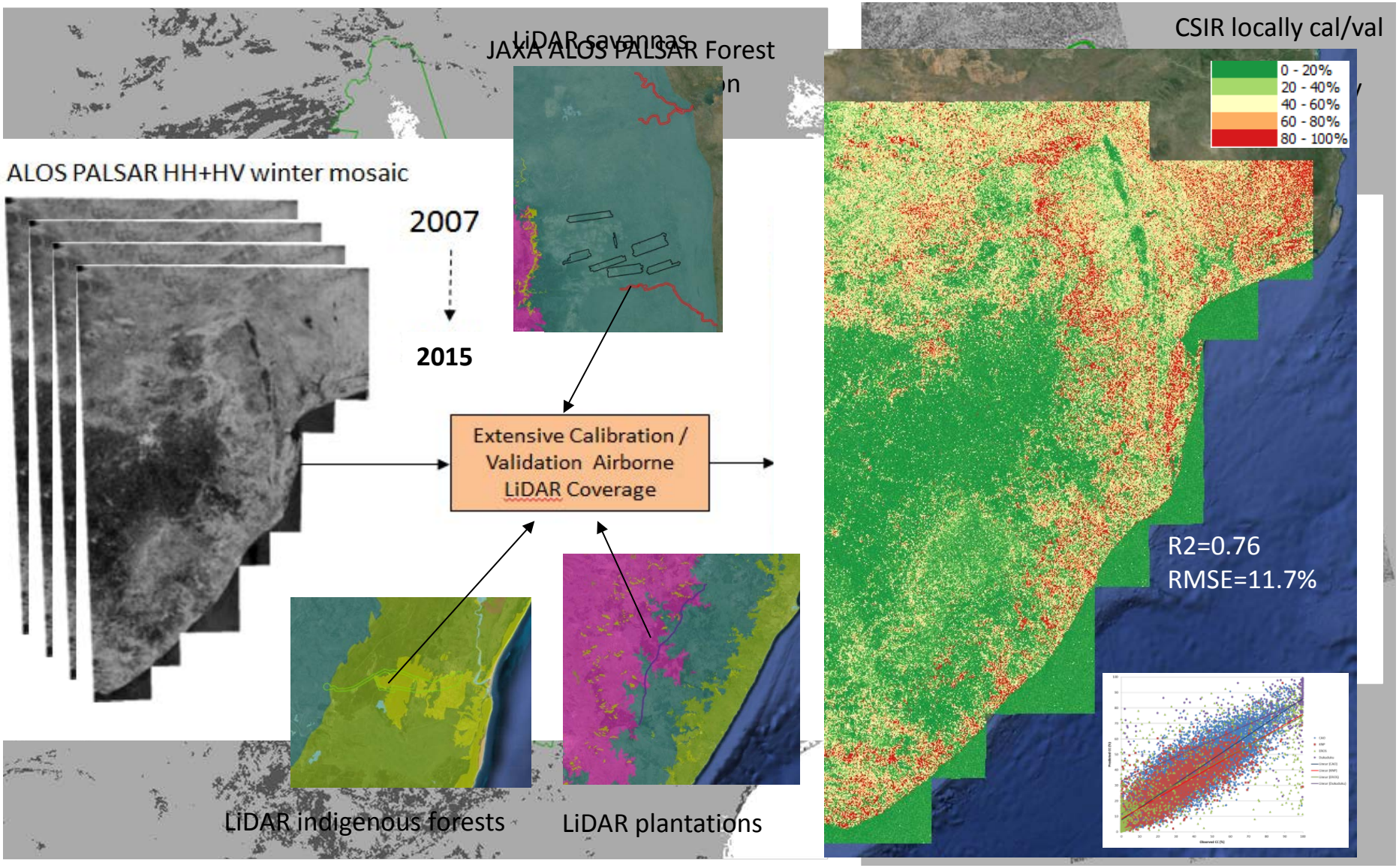
Machine learning algorithms:
Random Forest (in WEKA
3.6.9 & R rattle software)
1/3 calibration - 2/3 validation

Canopy cover and ABG maps





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



Biomass mapping in South Africa

2010 CSIR above ground biomass m

of airborne LiD

orest)

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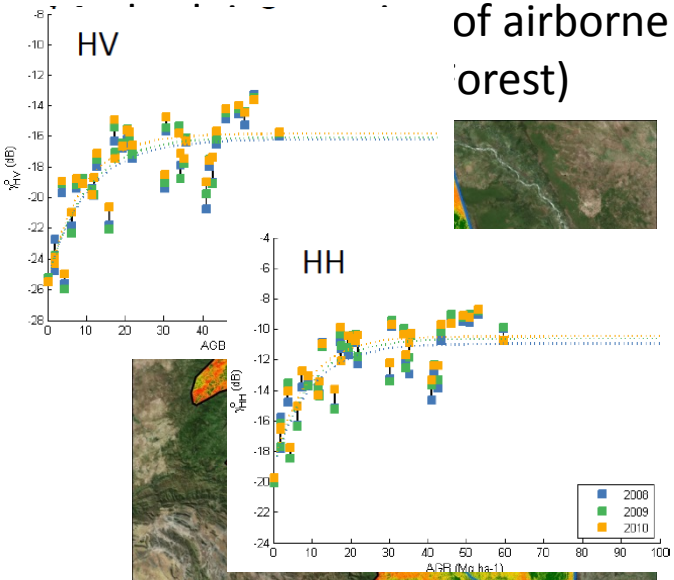

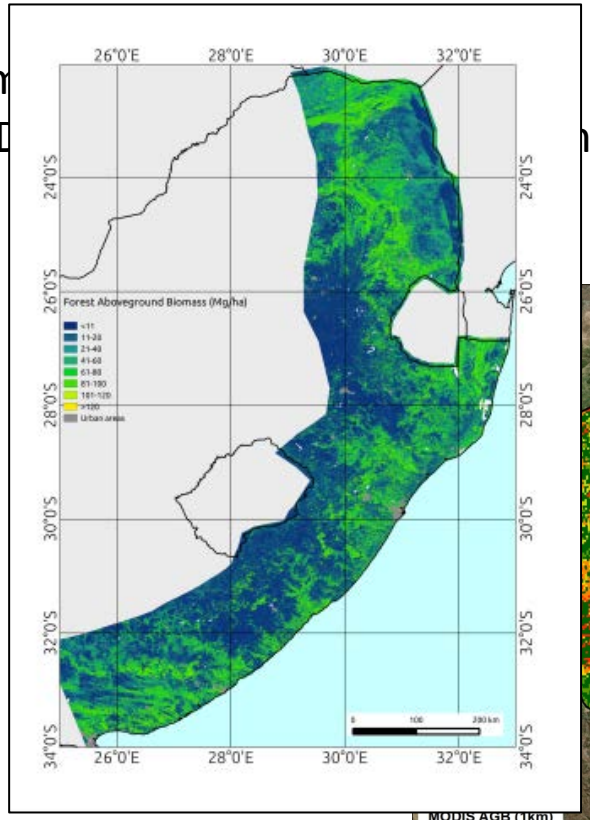

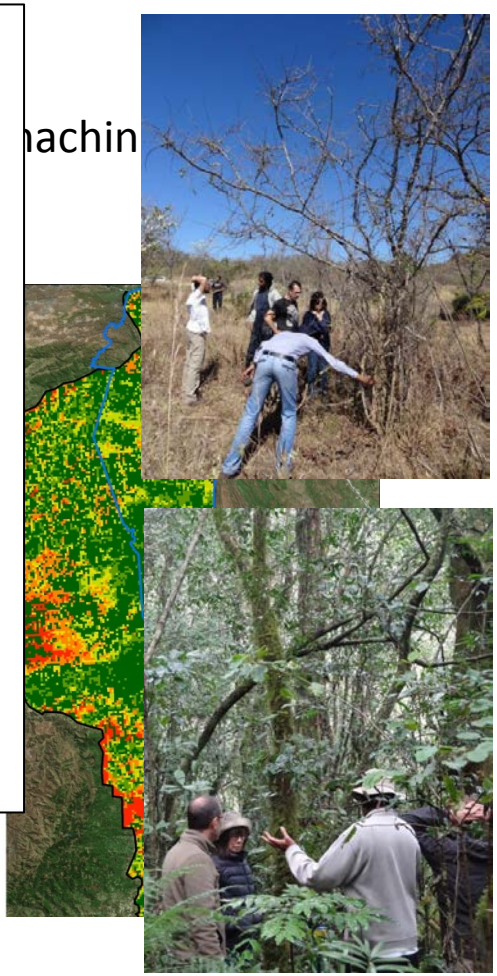

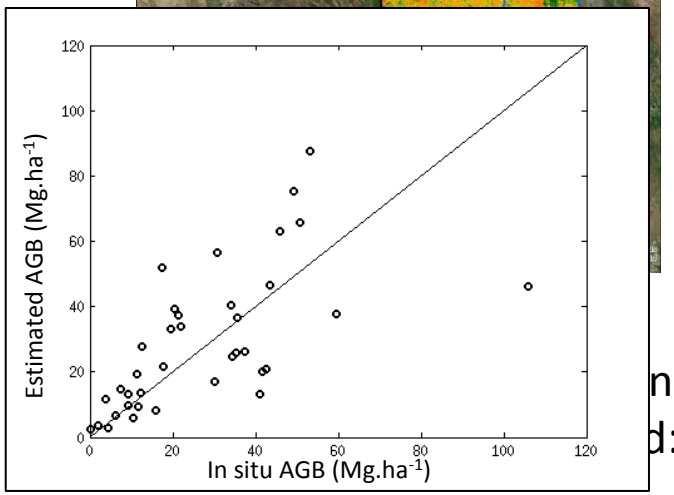

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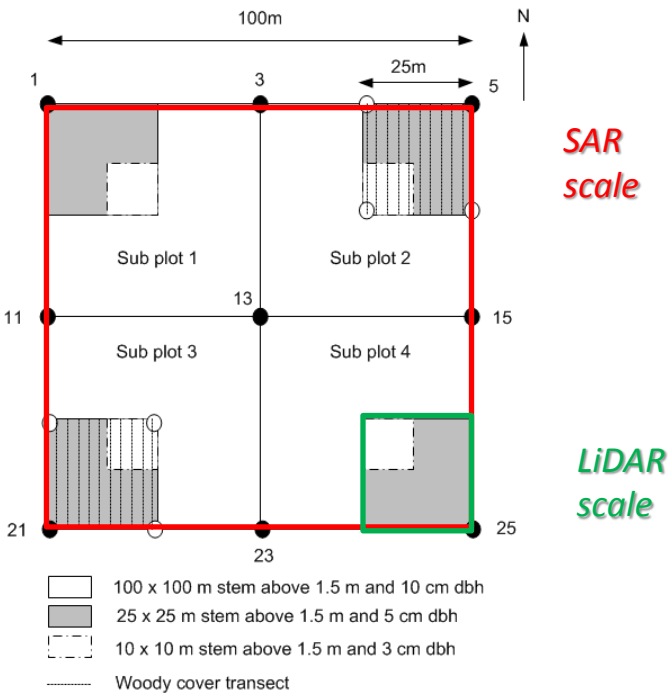
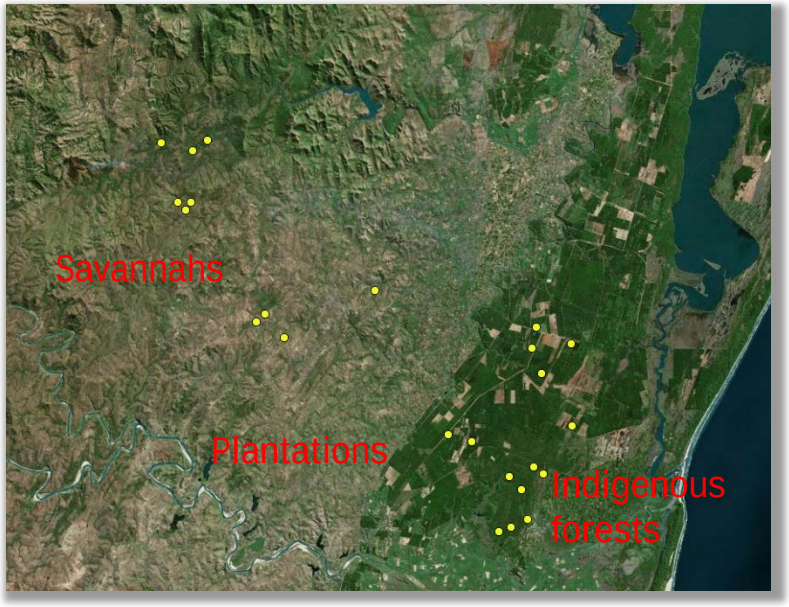
Le Toan & team

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

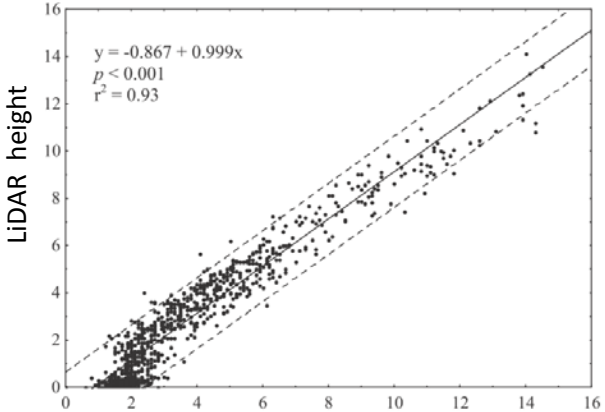
- 1 ha square plots (cal/val LiDAR & SAR)
  - Height & DBH
  - Species
- ~ 100 plots over various veg types
- Allometric equations



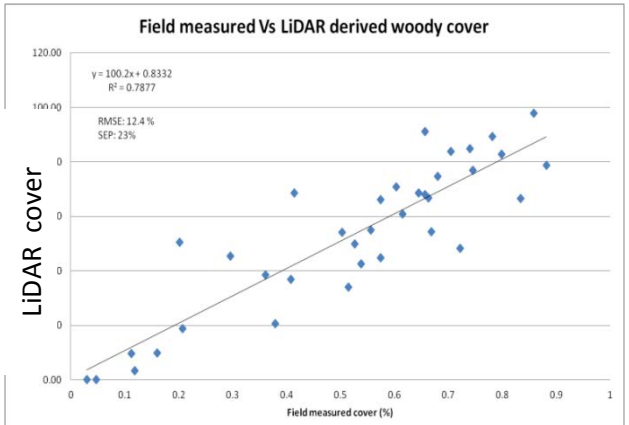


LiDAR cal/val & product development

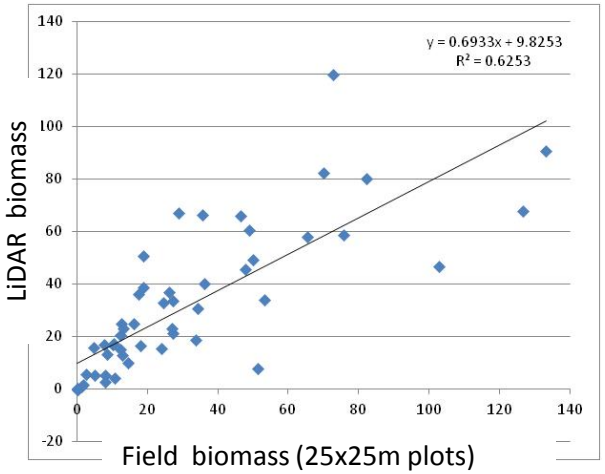
Assessment of accuracy of LiDAR products, development and validation of above ground woody biomass products – SAR upscaling



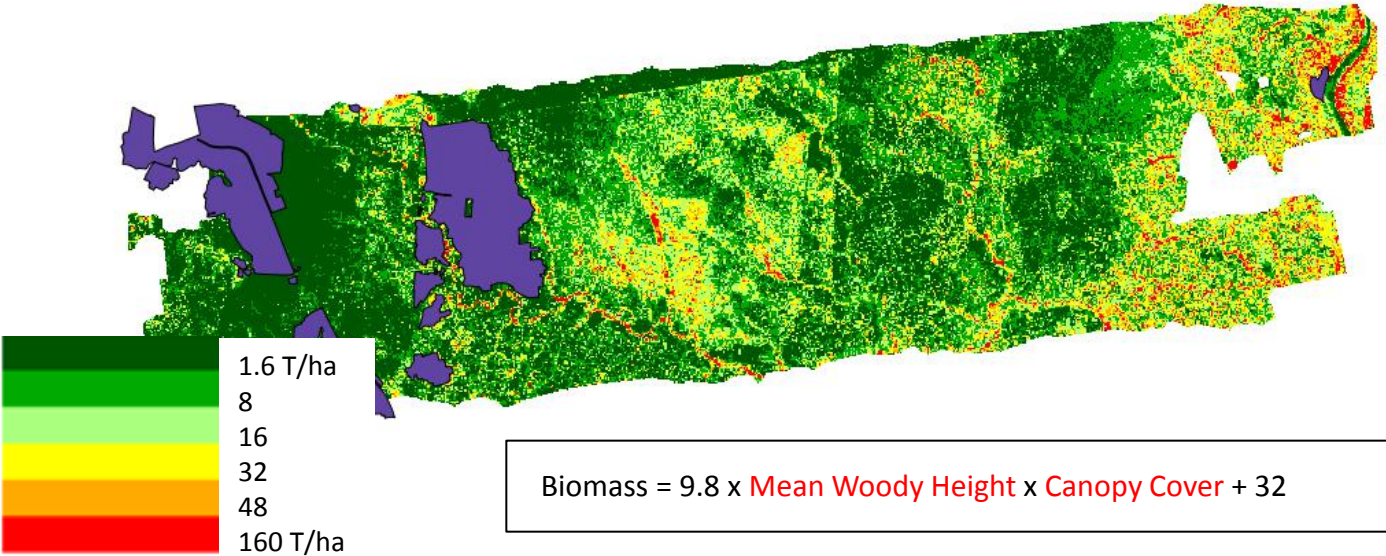
Field woody height (single plants)



Field cover (25x25m plots)



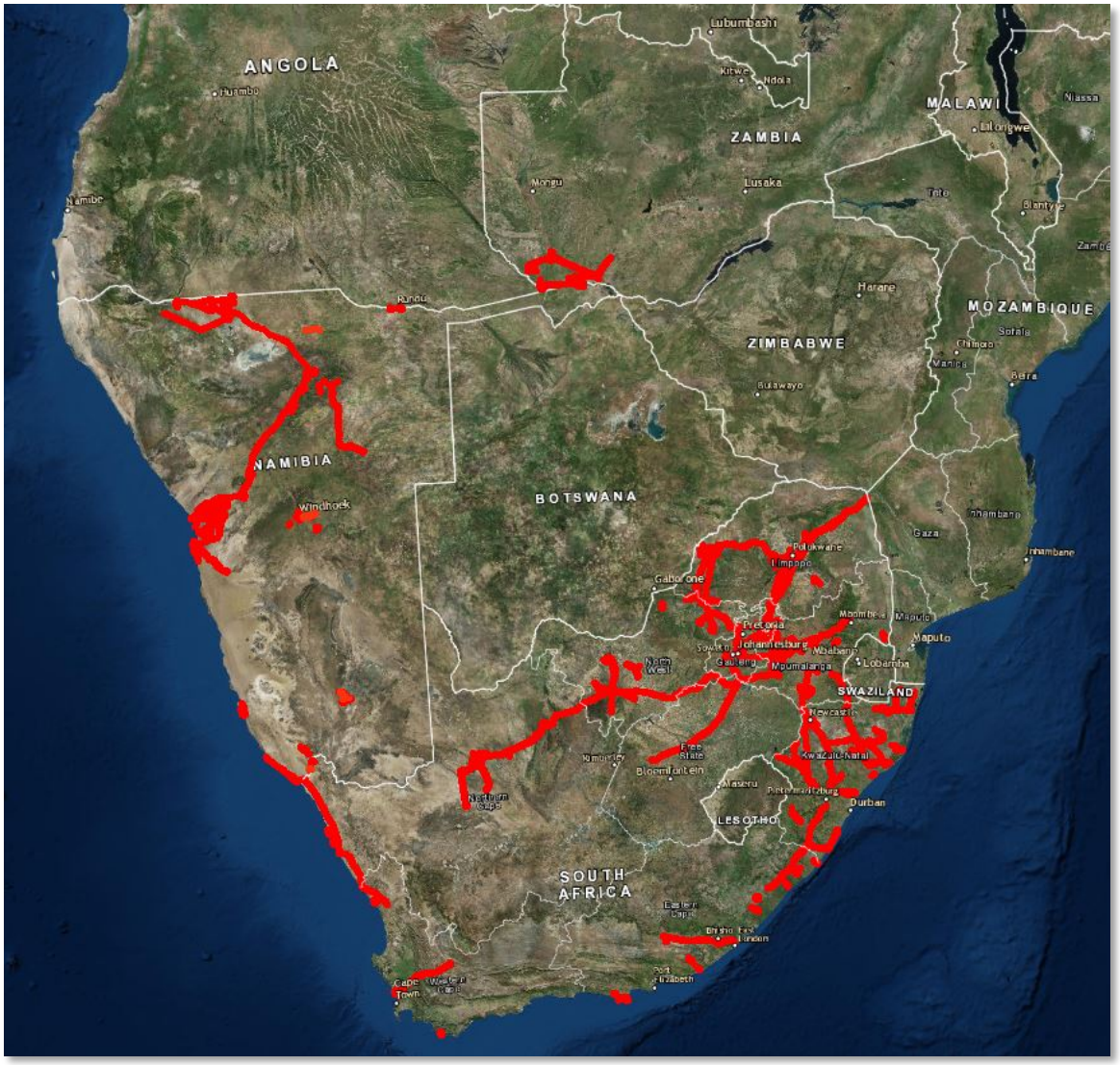
Field biomass (25x25m plots)



LiDAR-based biomass allometric equations

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

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 & woody cover in savannahs

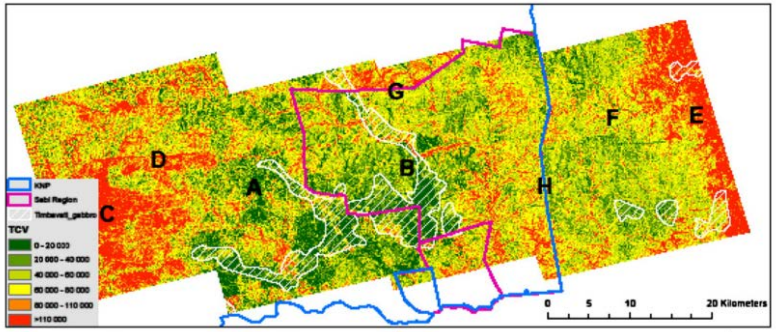
Season: Winter >> summer > autumn, multi-season improves slightly the model

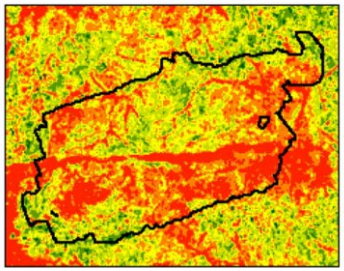
Polarization: HV (best)

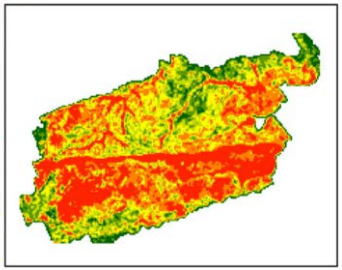
Scale: optimum around 1ha (100m)

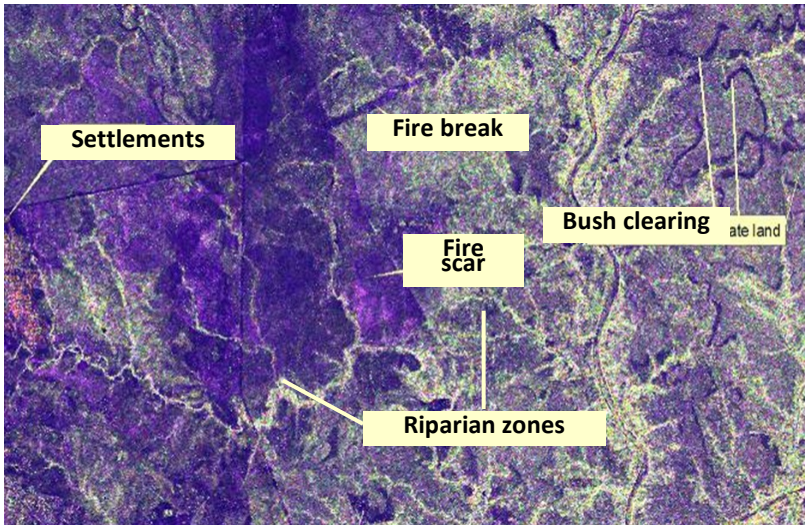
Polarimetric decomposition (Freeman, Van Zyl): volume component does not improve on co-pol HV

SAR better predict woody volume > cover

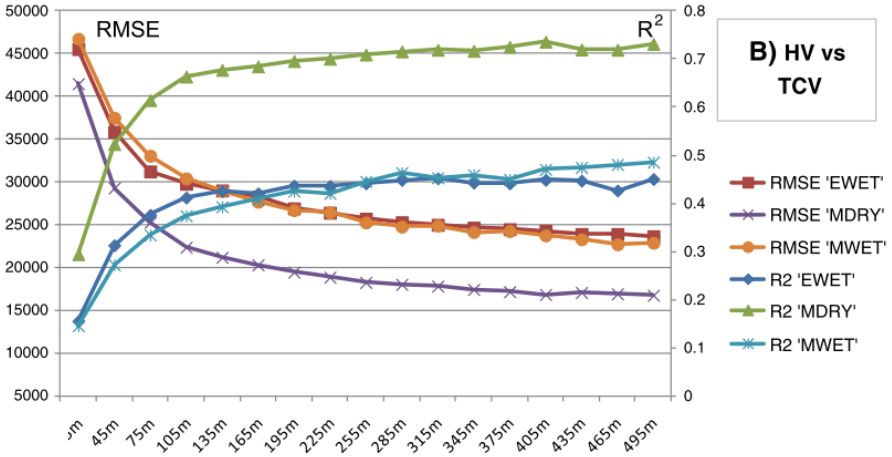








Mathieu et al. 2013, Remote Sensing of the Environment



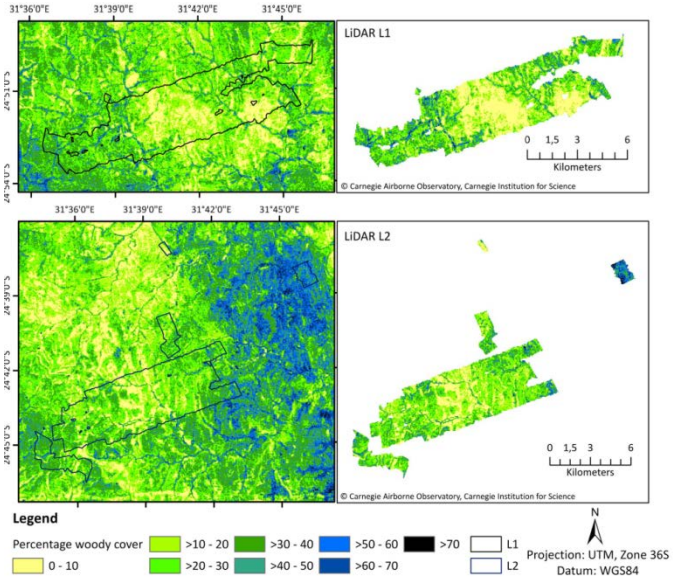
Multi-temporal, polarimetric L-band PALSAR & woody cover in savannahs

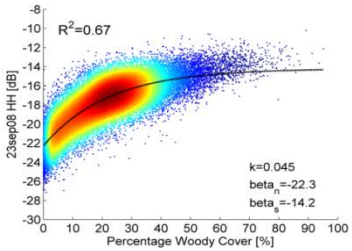
Season: Winter >> summer > autumn

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

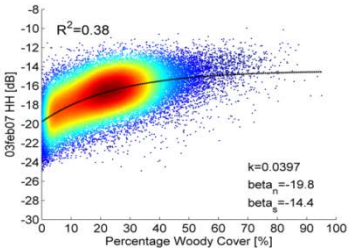
Scale: optimum around 0.25-1ha (50-100m)

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

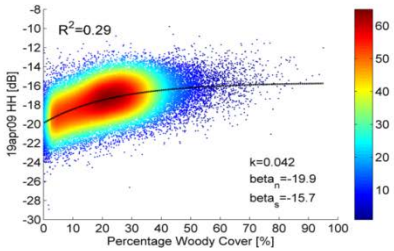




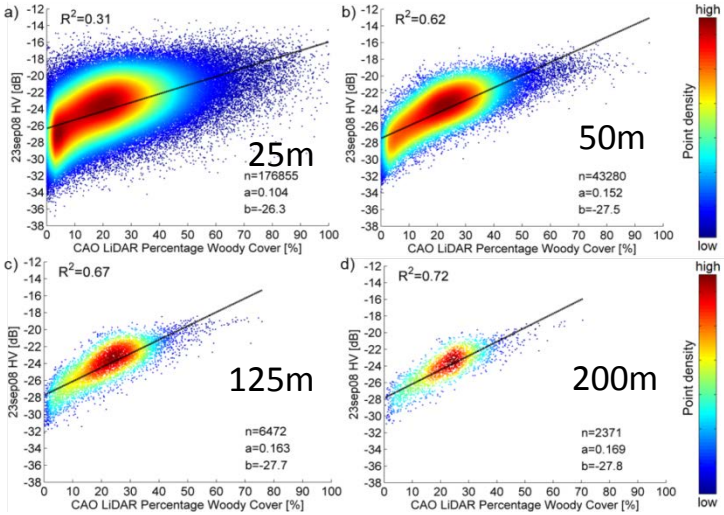
Winter: tree leaf-off, dry grass



Summer: tree leaf-on, green grass

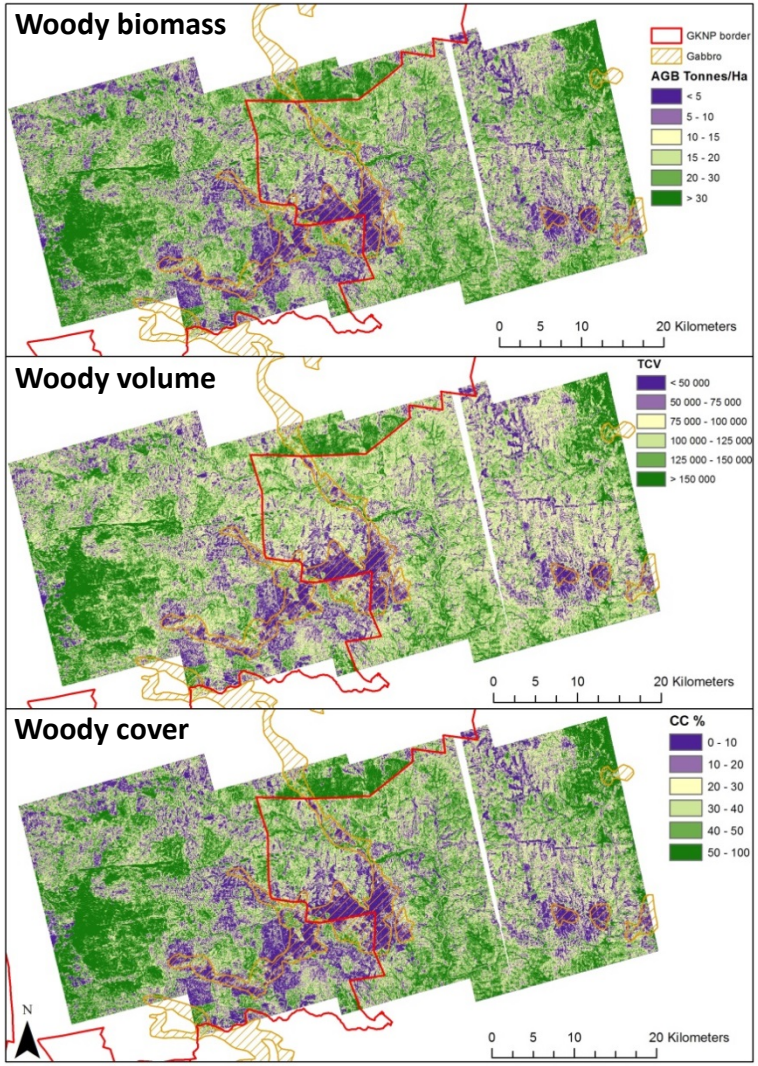


Autumn: tree leaf-on, dry grass



Urbazaev et al. 2015, Remote Sensing of the Environment

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

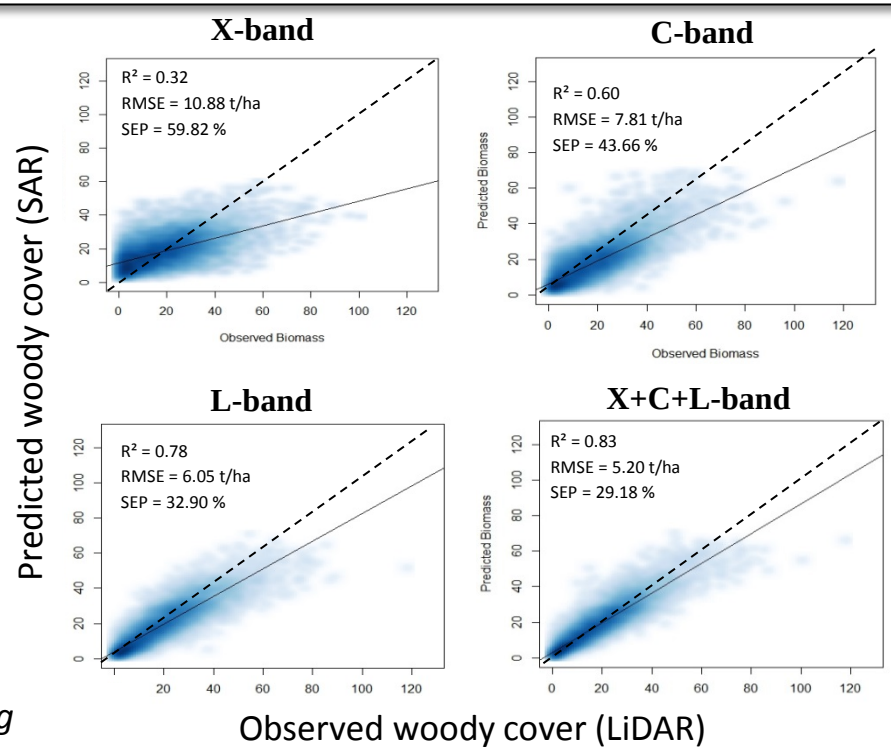


Winter dual-pol datasets

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



Naidoo et al, 2014, IS Photogrammetry & Remote Sensing

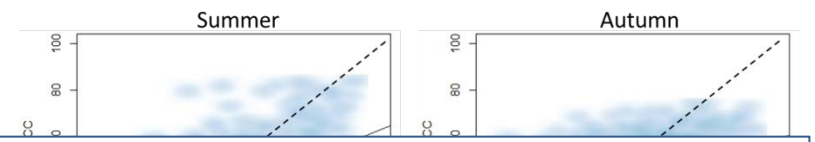
Combined L-band SAR and optical Landsat datasets

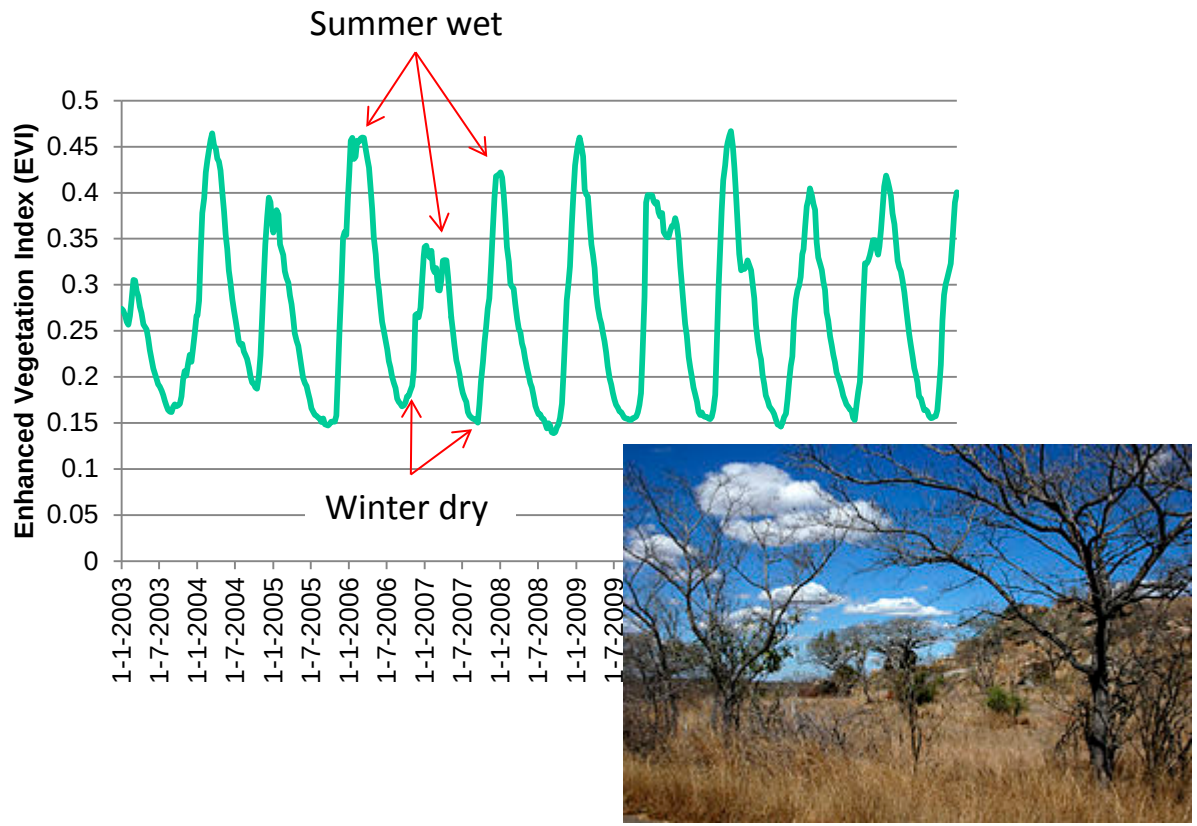
Green woody canopy, dry grass

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**		





Naidoo et al, in Press, International Jo
Observation and Geoinformation

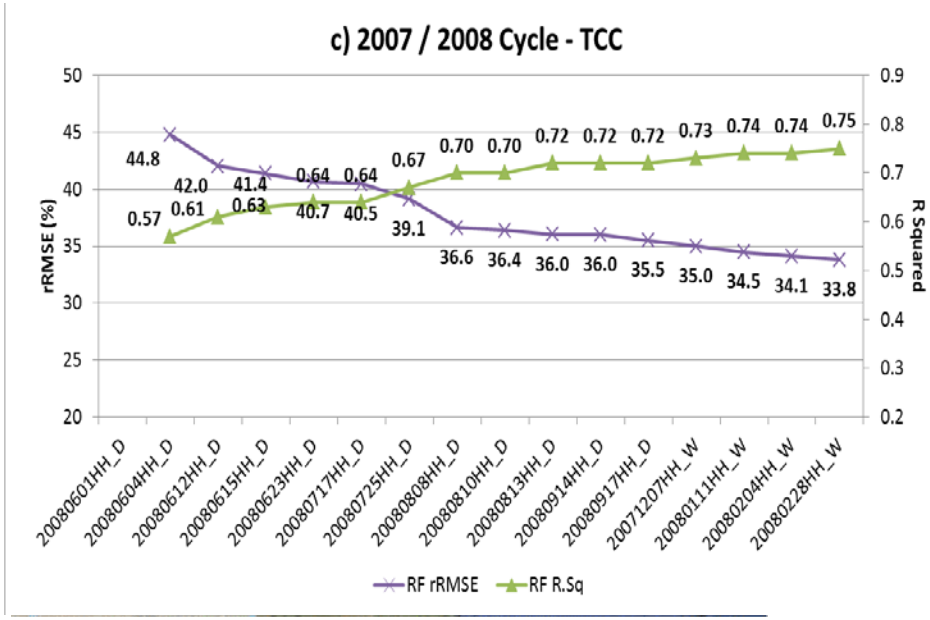
Hypertemporal C-band time series

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

Random Forest ± = linear regression; temporal filter improves modelling results

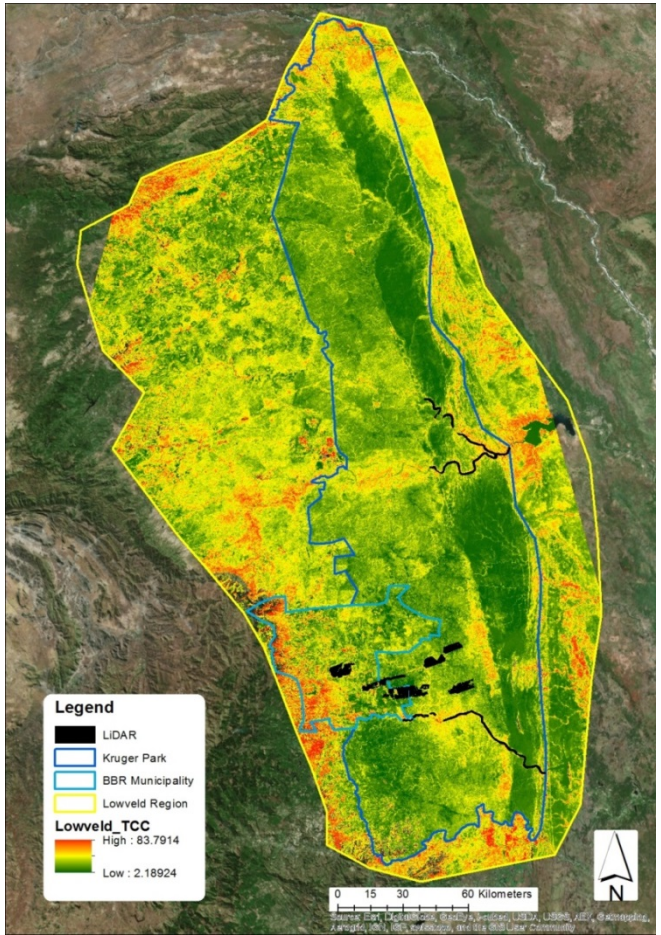
ASAR predicts woody volume > woody cover; dry > wet, but both improve modelling results

ASAR C-band 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



Update database (QGIS)

Attribute (QGIS)

Shape file (LAS Tool)
Manual quality check

1

Optimal parameter for classification
Processing according to general landscape classes:
Flat, hilly, mountain, urban

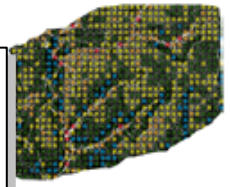
Standard projection
(Albers eq. area, WGS84)
1m resolution

System design: national woody cover map V02

Grid building

3

Basic products



System development, critical for large scale applications

- *Large datasets (spatial & temporal), need maximize automation of processing*
- *Framework for testing methodological approach and developing research question (e.g. model, sample selection)*

ENVISAT ASAR

Orthorectification and georeferencing (DEM selection)

4

:ract dependent and
ependent variables,
% canopy cover
canopy volume
SAR predictors
Environmental variables

Ancillary data
(stratification)
Biome (veg map)
DEM (slope, aspect)

Calibration / validation sample
Criteria selection (e.g.):
1) > 90% area of grid include LiDAR
2) building area < 10%
3) date difference SAR - LiDAR

5

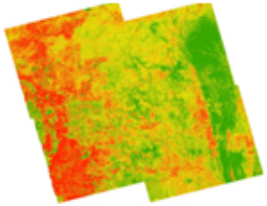
Model SAR + LIDAR
Model selection
Random forest

LiDAR data storage
1 folder / dataset
Naming convention? <date><centroid_latlong>
link to QGIS database

Non processed LiDAR
- las file
Processed
- Classified las cloud point
- Canopy height model (tile, virtual raster)
- Digital elevation model (tile, virtual raster)
- VOXEL

Masks
Water, Urban&settlement, Croplands

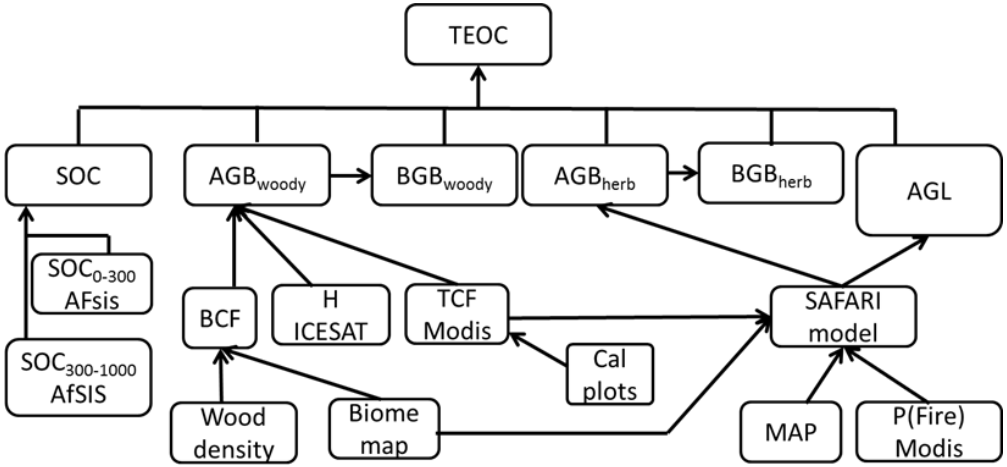
Maps

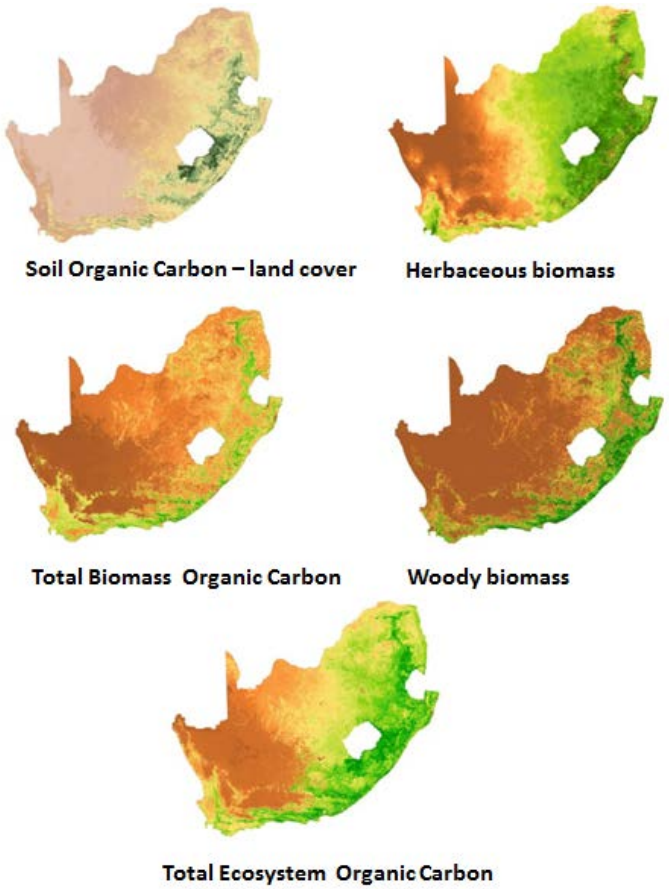


SA Carbon Sink Atlas

Home | Model Description | Carbon Data Layers | Summary Statistics | Online Atlas | Download Data | Documents & Reports | How to Use This Site | Important

- 1 km of carbon stocks and flux modelled with uncertainty / GIS & remote sensing data





CSIR our future through science

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of the Federal Republic of Germany

environmental affairs Department: Environmental Affairs REPUBLIC OF SOUTH AFRICA

Scholes, Wessels, et al.

1. Satellite data requirements
   - Firstly L-band SAR, dual pol, single scene
   - Systematic acquisition of winter season
   - Complement with Landsat / Sentinel-2
   - Sentinel-1 time series
2. Operational status of the existing technology (R&D, pre-operational, operational)
   - Woody cover: pre-operational
   - Above ground biomass: R&D
   - Woody height: R&D
3. Are your IT/infrastructure needs met?
   - Combined commercial software (GAMMA), and developed script
   - High computing environment

1. Describe the obstacles to “operational use” (challenges)
   - Reduce errors in low biomass & cover environment
   - Mapping gradual change / uncertainty assessment (error propagation, field-to-satellite and changes)
   - Development (funding) of long-term calibration / validation infrastructure
   - Deal with variable phenological status
   - Species mapping
   - Last not least: institutional support
2. Indicate the nature of the R&D required to advance the methods to operational use
   - Interferometry – coherence analysis (height assessment and biomass)
   - LiDAR-based AGB modelling
3. What are the timelines for completing the R&D?
   - 3-5 years
4. Describe your satellite data needs for R&D
   1. Data for height estimates, interferometry?
   2. Long term access to L-band data

Int. Symposium of Remote Sensing of Environment – May 2017 Pretoria

ISRSE-37 Call for Papers

The South African National Space Agency, the International Centre for Remote Sensing of Environment (ICRSE) and the International Committee on Remote Sensing of Environment (ICORSE) take pleasure in issuing this call for papers for ISRSE-37 under the overarching theme of "Earth Observation for Development and Adaptation to a Changing World".

Papers are sought on diverse applications of remote sensing to understand and sustainably manage the environment and natural resources in the light of global change. We encourage contributions along the full value chain of Earth Observation, from fundamental research on earth system processes to operational applications, innovative techniques and future missions, as well as international programmes. The Symposium will be particularly, though not exclusively, organised along broad 14 thematic areas described below. The ISRSE-37 Technical Programme Committee will consider and evaluate all abstracts received for inclusion in oral or poster sessions.

Abstracts (max. 300 words) submitted should focus on one of the following themes with subtopics given as examples of topics of sessions:

1 **Biodiversity and Ecosystems** Savannahs and woodlands; wetlands; land cover monitoring; maintaining ecosystem services; land surface dynamics, sustainable management, wildfires and biodiversity conservation; wild life monitoring

2 **Disasters Resilience:** Understanding disasters including fire, earthquakes, hurricanes and floods; preparedness in high risk regions, real-time alerting and mitigation; reducing loss of life and property from natural and human-induced disasters; humanitarian support, subsidence

3 **Energy and Mineral Resources Management:** Exploration and exploitation of non-renewable energy resources and minerals, renewable energy; sustainable use of energy resources; mitigating impacts

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9 **Marine and Coastal Environment, Resources and Dynamics:** Understanding and monitoring marine and coastal environment and resources; ocean state and dynamics including wind, waves, currents, salinity and temperature; ship traffic, offshore operations and marine pollution monitoring

10 **Forests and Carbon Cycle:** Measurement, reporting and verification for REDD+; carbon stocks and fluxes; forest characterisation and biomass estimation; data model integration for estimating emissions; monitoring of deforestation and forest degradation; forest restoration; climate change impacts on forests; data interoperability and time series analysis

11 **Data and Information Systems and Spatial Data Infrastructure:** Systems to manage, process, store and distribute Earth observation data and products; standards, interfaces and systems for spatial data; computationally intensive data processing, big data analytics and visualisation, real-time operational systems; crowd sourcing; topography; digital elevation models; Digital Earth

12 **Airborne Platforms, Sensors, In-situ Measurements and Innovative Techniques:** Airborne platforms and campaigns; novel manned or autonomous aerial vehicles; novel sensors; multi-sensors techniques and interoperability; in-situ observing systems and measurements; citizen observatories

13 **International Regional and National EO Programmes, Education and Outreach:** Progress and impact of international programmes , e.g. CEOS, GEO, AfriGEOSS; Earth observation of sustainable development goal indicators; mainstreaming EO into governments; socio-economic impacts of EO; education and outreach

14 **Current and Future EO Missions and Programmes:** Status and planning of the latest and future Earth observation missions and programmes; nano-satellites

Conference venue and Exhibition

1 **Biodiversity and Ecosystems** Savannahs and woodlands; wetlands; land cover monitoring; maintaining ecosystem services; land surface dynamics, sustainable management, wildfires an biodiversity conservation; wild life monitoring

and monitoring human settlements and urbanisation; socio-economic development; spatial development and planning; cultural heritage monitoring and preservation; archaeology; Smart Cities; border security monitoring; support for planning, monitoring and management of infrastructure (dams, roads, rail, ports, and pipelines) and transportation (air, land and sea)

Abstract Submission System opens	June 2016
Deadline for Abstract and Workshop Proposal Submission	End September 2016
Abstract Acceptance Notification, Call for full Paper	End November 2016

10 **Forests and Carbon Cycle:** Measurement, reporting and verification for REDD+; carbon stocks and fluxes; forest characterisation and biomass estimation; data model integration for estimating emissions; monitoring of deforestation and forest degradation; forest restoration; climate change impacts on forests; data interoperability and time series analysis

Invitation for special session on forest / carbon applications

Suggestion welcome

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Acknowledgement

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