

Challenges and possibilities of remote sensing-based Miombo woodland inventories for forest management and REDD

Jonas Franke & Florian Siegert



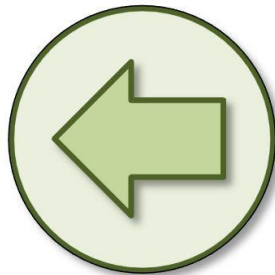
Miombo Network Meeting
Maputo, 24 July 2013

The main role of remote sensing in the context of REDD

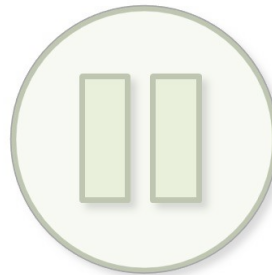


A valuable tool to:

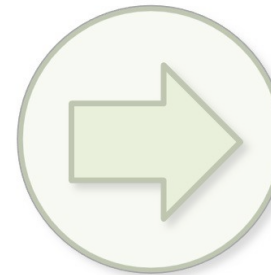
- Establish a reference emission level (REL) through a historical land-/forest cover assessment
- Support monitoring, reporting and verification (MRV)



*Historical Forest
Cover & Carbon Stock*



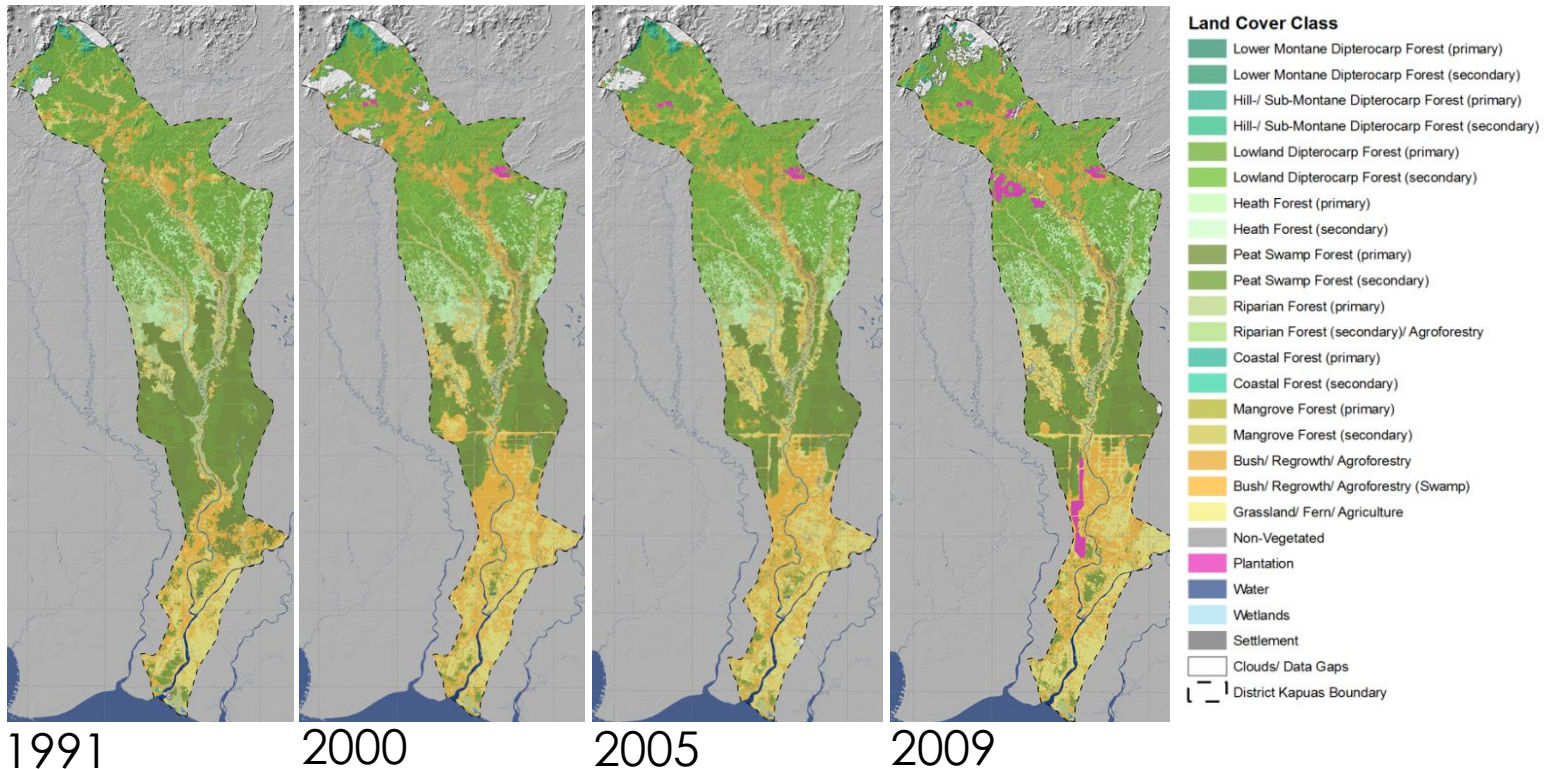
*Current Forest
Benchmarking*



*Future Forest
Monitoring*

Historical baseline assessment

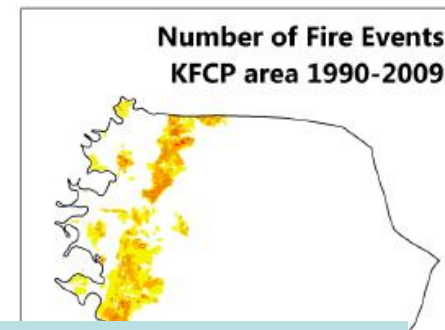
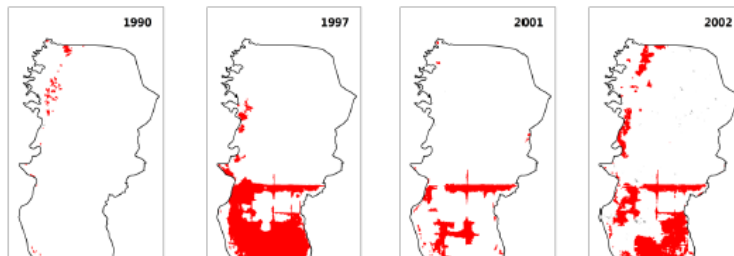
Kapuas district, Central Kalimantan, Indonesia



This historical land cover assessment was conducted by RSS in the framework of the REDD demonstration activities of the Kalimantan Forests and Climate Partnership (KFCP); funded by AusAID

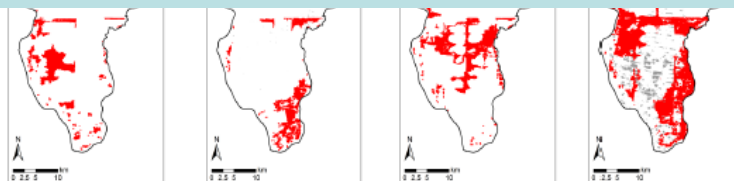
Estimating Emissions from Forest Fires

- Historical assessment of burned areas using Landsat data
- Emission estimates via burned area and burned land cover



VCS methodology: Estimation of greenhouse gas emissions from forest fires and peat fires in Southeast Asia.

This methodology is also applied by RSS for the world's largest VCS-verified REDD project (Rimba Raya Biodiversity Reserve)



Burned area:
5,939ha

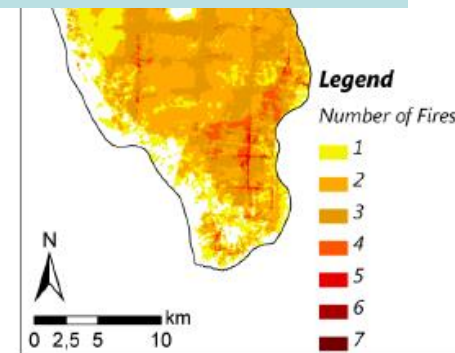
Burned area:
4,522ha

Burned area:
9,075ha

Burned area:
18,793ha

Legend

- Burned Area
- Cloud/Data gaps
- KFCP boundary

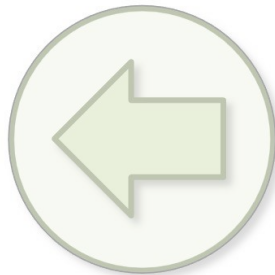


The main role of remote sensing in the context of REDD

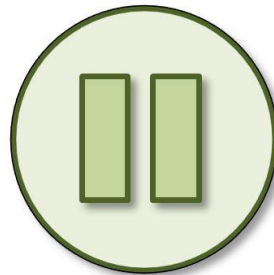


A valuable tool to:

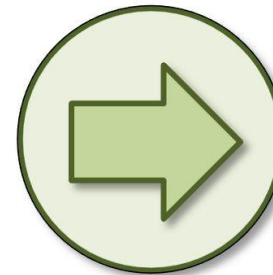
- Establish a reference emission level (REL) through a historical land-/forest cover assessment
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*Historical Forest
Cover & Carbon Stock*



*Current Forest
Benchmarking*



*Future Forest
Monitoring*

Deforestation vs. Forest Degradation



Deforestation:

- Rapid and abrupt land cover transformation through clearing or fire
- Binary transformation from forest (1) to non-forest (0)
- Easy to detect by remote sensing



Forest Degradation:

- Slow and subtle change in forest cover through e.g. selective logging
- Continuous characteristics between forest and non-forest
- Detection by remote sensing is challenging
- Often the initial phase in the process of land cover transformation to complete deforestation



RapidEye – high-resolution satellite data



- 5 satellites
- 5 spectral bands
- 5 m pixel size (ortho-rectified)
- 5.000.000km² per day
- 3000 km per satellite & orbit
- 77km swath (Nadir)



Illustration of the 5 satellites in orbit
Source: RapidEye AG

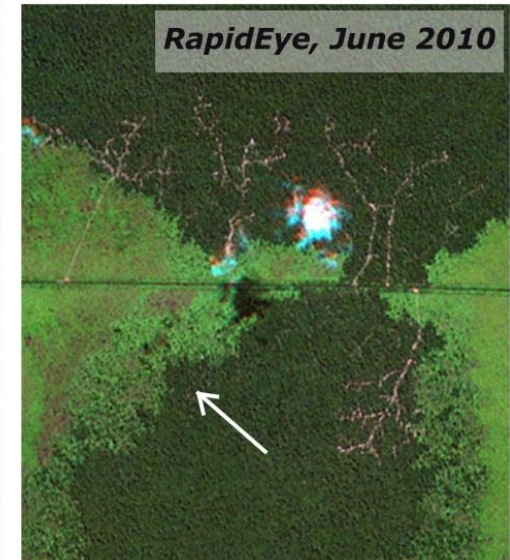
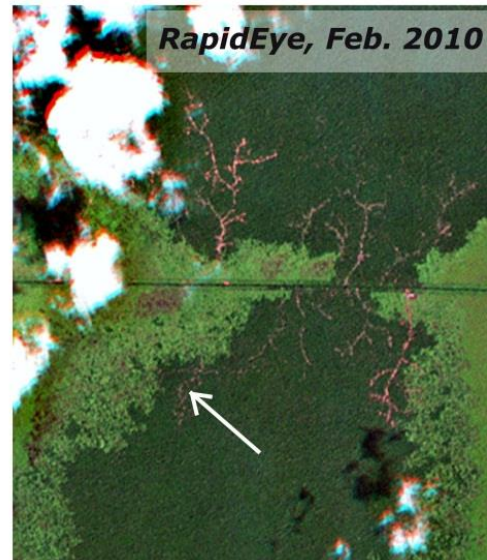
Example: Deforestation



RapidEye 2012

Example: forest degradation

RapidEye time series



RapidEye time series shows the progress of illegal logging.



RS-based benchmark of Miombo forests

Mecuburi Forest Reserve, Mozambique



EC FP7-project REDD-FLAME

In cooperation with (among other partners) Almeida A. Siteo, Faculty of Agronomy and Forestry, Eduardo Mondlane University, Maputo

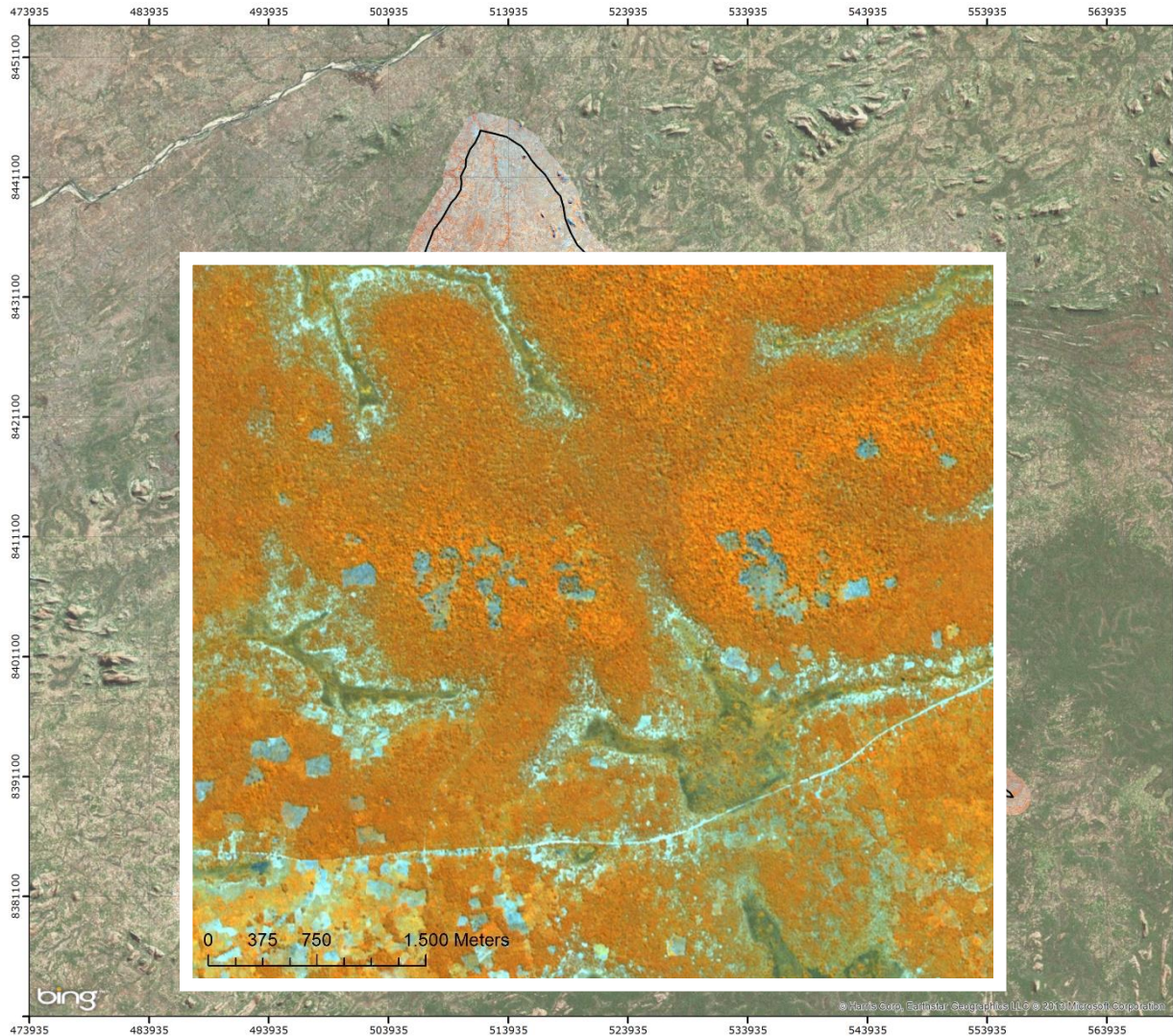
Specific characteristics of Miombo woodland:

- Very complex ecosystem with small-scale land cover patches
- Small agricultural conversions, logging concession, selective logging, fuelwood harvesting and charcoal production
- Fires occur frequently, but it depends on the fire intensity if it affects the forest canopy
- Massive seasonal effects that have to be considered for remote sensing approaches
- Phenological effects such as drop of leaves and fires in the dry season complicates remote sensing monitoring

RapidEye image of the Mecuburi Forest Reserve



Area: 2,500 km²



RapidEye 09/06/2012 Mecuburi, Mozambique

Location Diagram



Legend

- Mecuburi Forest Reserve
- Red: Band_5
- Green: Band_4
- Blue: Band_3

Cartographic Information

0 2 4 8 12 16 Kilometers

Scale : 1 : 300 000

Projection: UTM zone 37 South

Datum: WGS '84



Framework

Data source: (c) RapidEye (2012),

provided under EC/ESA GSC-DA

Spatial resolution: 5 m

Image date: 09/06/2012

Background image: Bing Maps

Created: February 2013

Produced by: RSS GmbH

Produced for: REDD-FLAME project

Reference: www.redd-flame.info

Contact: info@rssgmbh.de

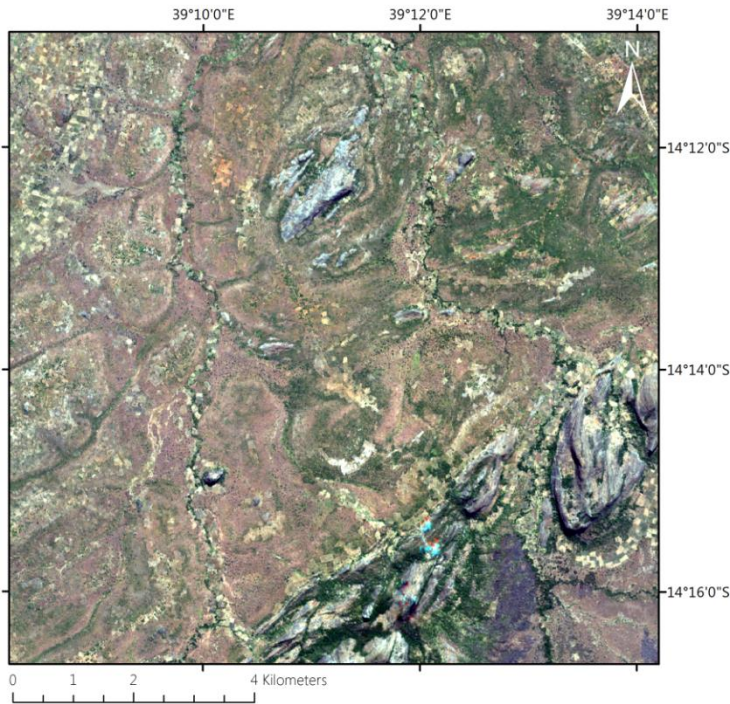


RS-based benchmark of Miombo forests

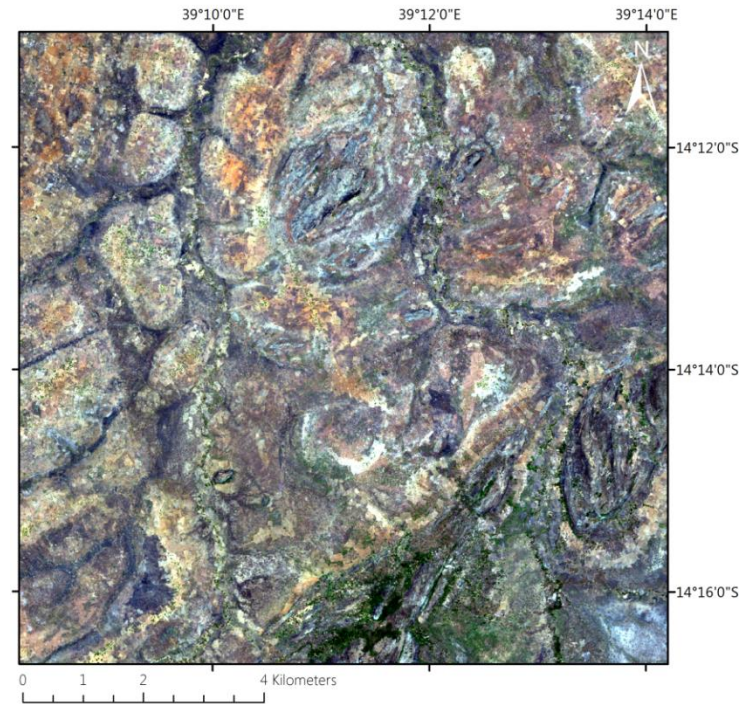
Example for seasonal effects



RapidEye (true color RGB) 26/07/2010



RapidEye (true color RGB) 02/11/2010



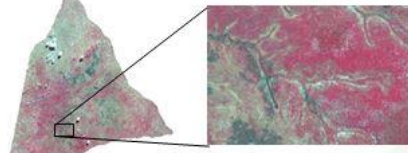


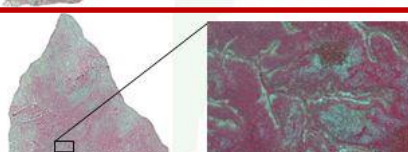


Example for the seasonal effects on remote sensing data.

There is a enormous difference in images between July 2010 and November 2010.

RS-based benchmark of Miombo forests

RapidEye Images and Miombo Phenology



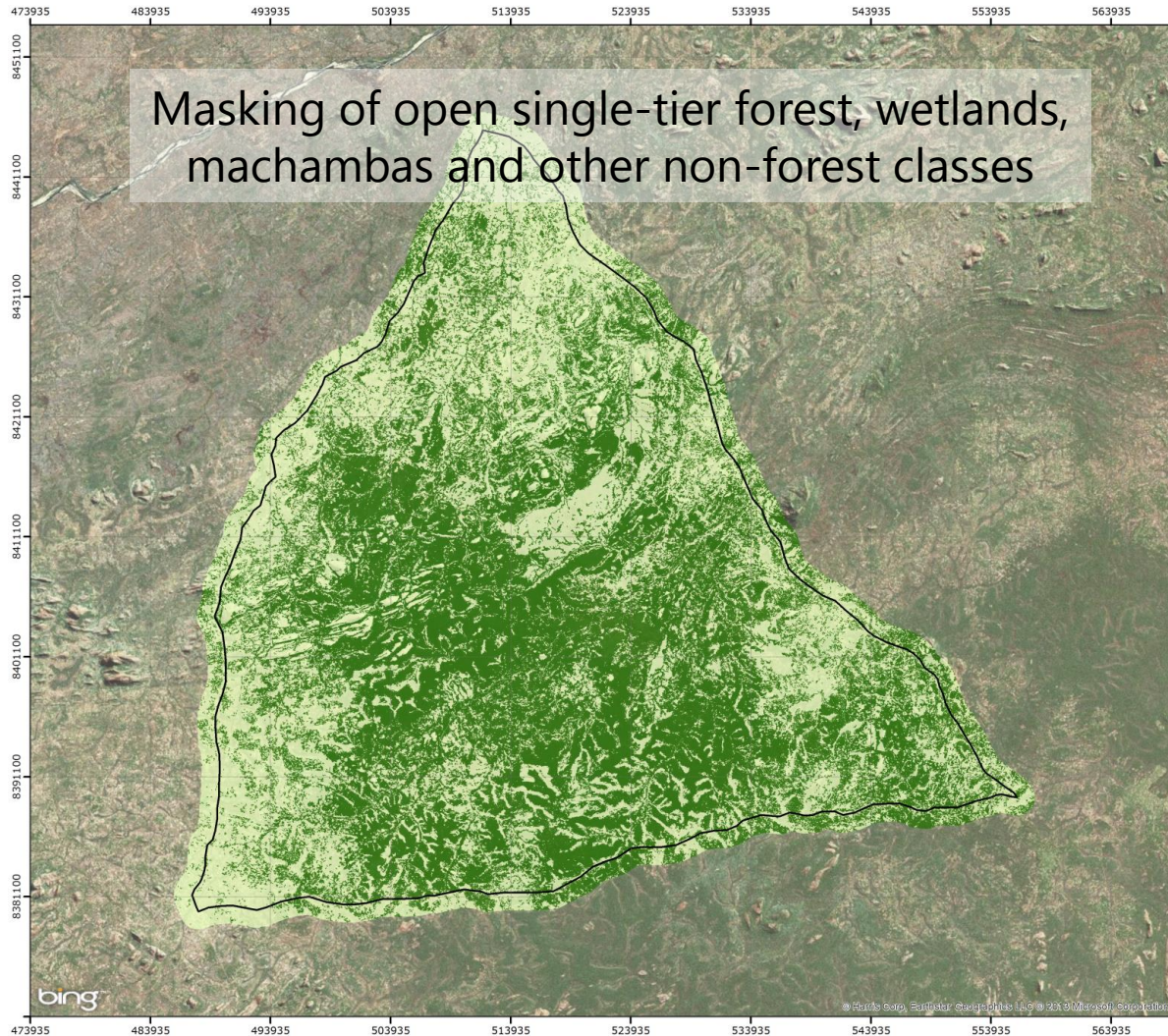
Observation period	Image overview/zoom	Use
07-2010		Not suitable due to seasonal effects
11-2010		Not suitable due to seasonal effects
10-2011		Not suitable due to seasonal effects
06-2012		Forest Benchmark
09-2012		Burned area mapping
04-2013		Refining Forest Benchmark & Forest Cover Change

RS-based benchmark of Miombo forests

Miombo benchmark map 2012

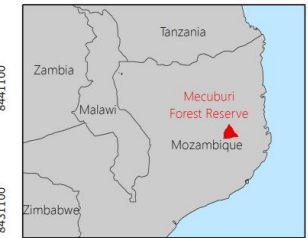


Masking of open single-tier forest, wetlands, machambas and other non-forest classes



Forest Benchmark Map 2012 Mecuburi, Mozambique

Location Diagram



Legend

- Mecuburi Forest Reserve
- Forest/Woodland
- Other land cover

Interpretation

This map shows the forest extent in the Mecuburi Forest Reserve, Mozambique in 2012. The forest area was analyzed using RapidEye imagery. A minimum mapping unit of 0.5 ha was applied to the forest area.

Cartographic Information

0 2 4 8 12 16 Kilometers
Scale: 1 : 300 000
Projection: UTM zone 37 South
Datum: WGS '84

Framework

Data source: (c) RapidEye (2012), provided under EC/ESA GSC-DA.
Spatial Resolution: 5m
Image date: 09/06/2012
Background image: Bing Maps

Created: February 2013
Produced by: RSS GmbH
Produced for: REDD-FLAME project
Reference: www.redd-flame.info
Contact: info@rssgmbh.de

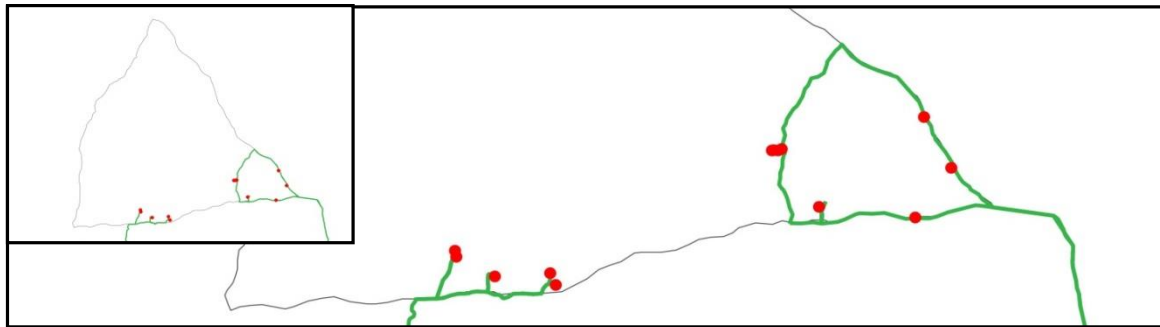


RS-based benchmark of Miombo forests

Accuracy Assessment by field validation



Field evaluation was performed in November 2012 by REDD-FLAME project partner RSAC in the company of Sosdito Mananze of UEM and Aly Awasse, Community Forest & Wildlife Management Unit Coordinator in the Provincial Forest & Wildlife Service, Nampula



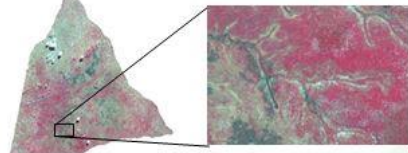


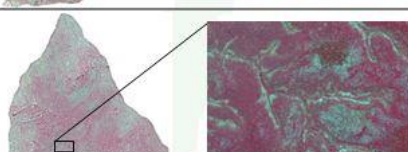


Photos: T. Pearson (RSAC)



RS-based benchmark of Miombo forests

RapidEye Images and Miombo Phenology



Observation period	Image overview/zoom	Use
07-2010		Not suitable due to seasonal effects
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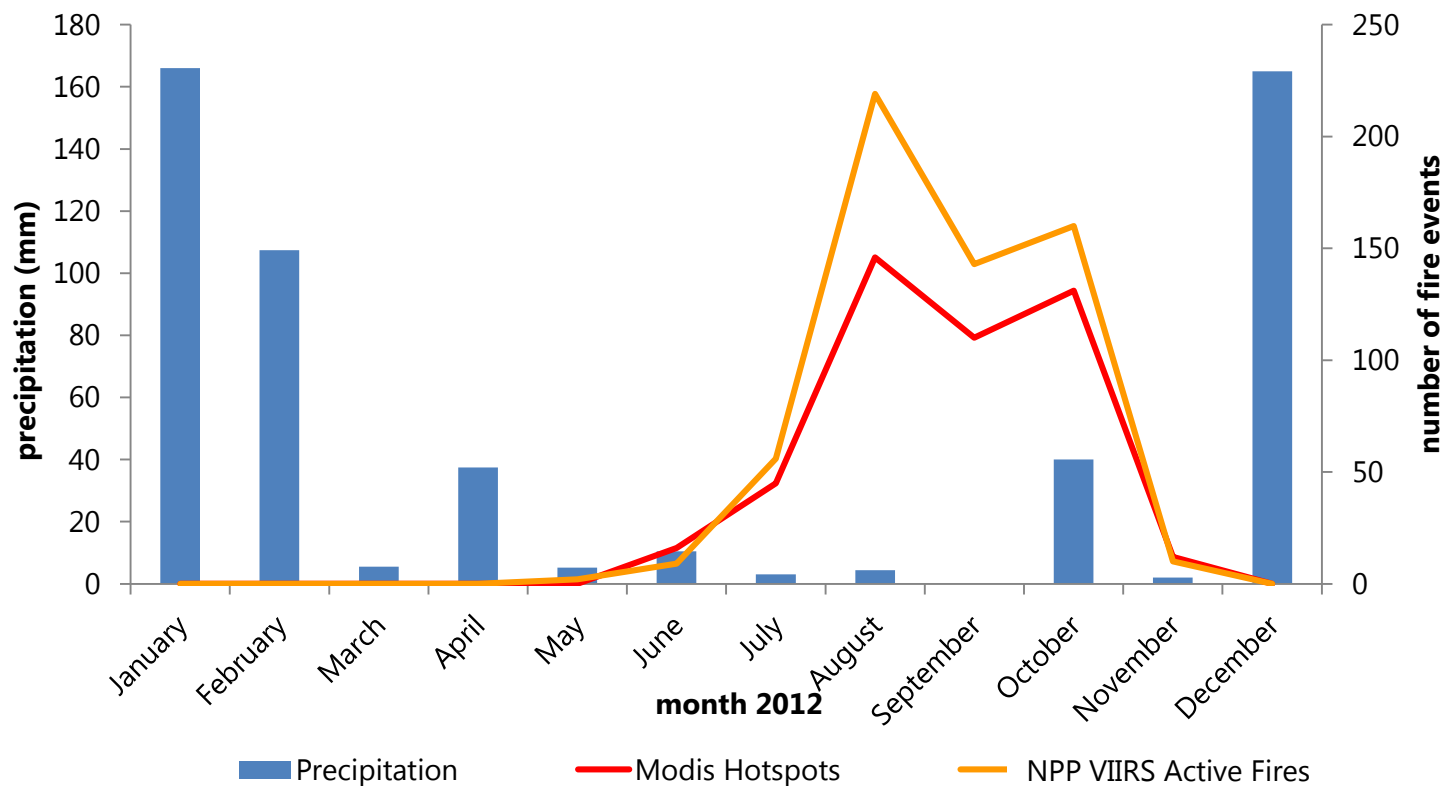
RapidEye-based burned area mapping

Comparison MODIS hotspots & NPP active fires



APPS4GMES

Precipitation and number of active fires 2012
Mecuburi, Mozambique

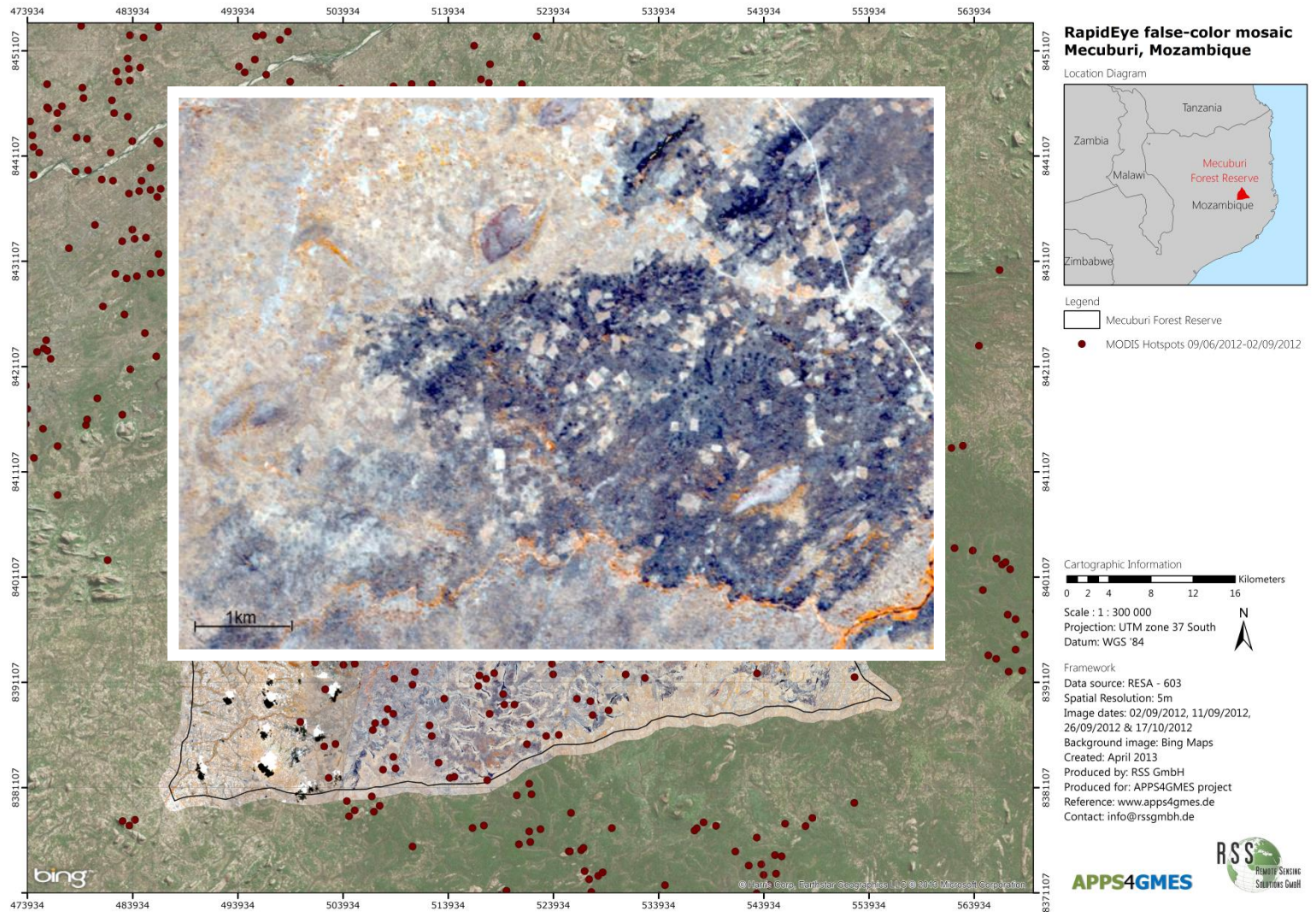


RapidEye-based burned area mapping

RapidEye image and MODIS hotspots



APPS4GMES



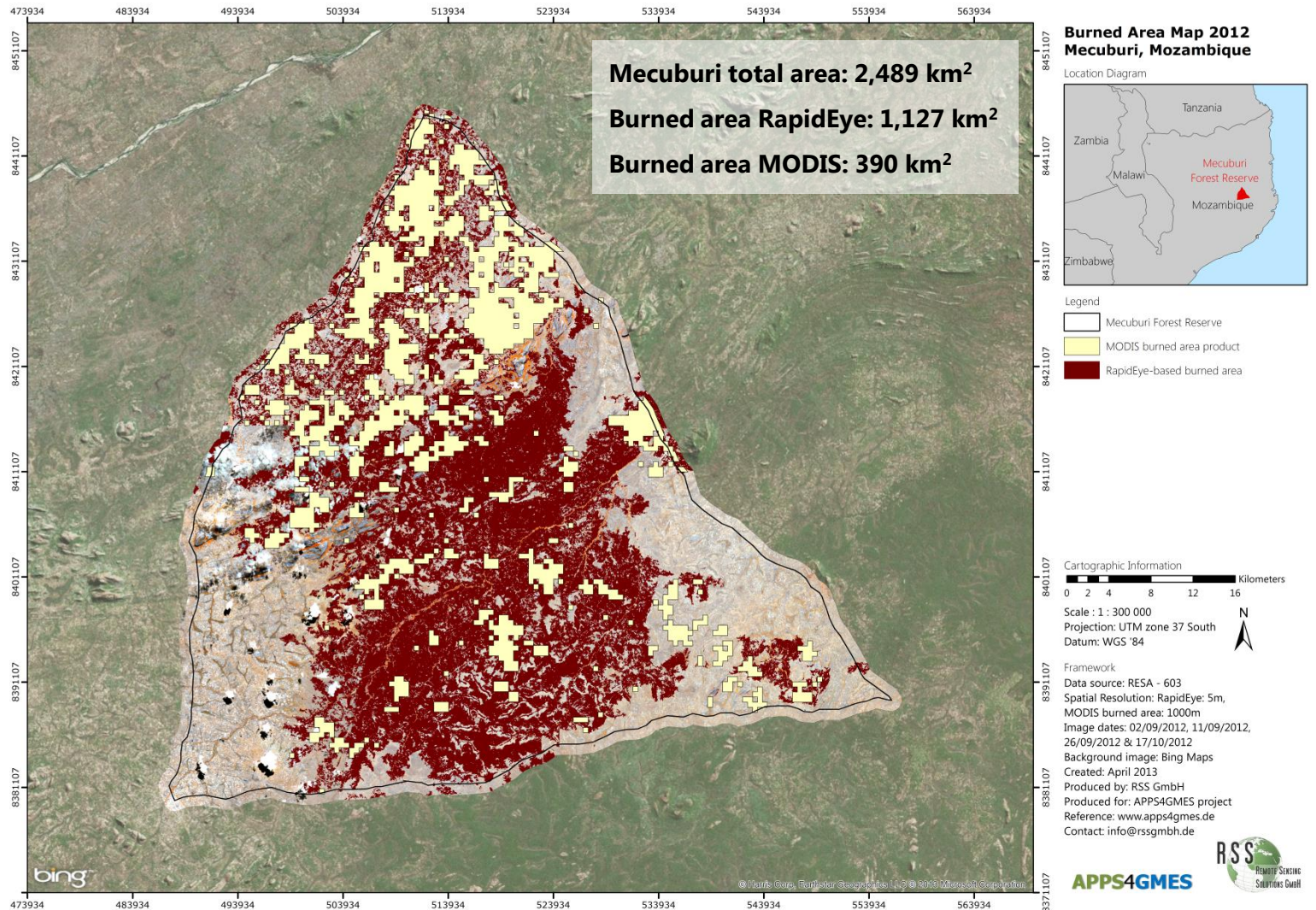
RapidEye-based burned area mapping

Making use of high-resolution data



RapidEye-based burned area and MODIS burned area product

APPS4GMES



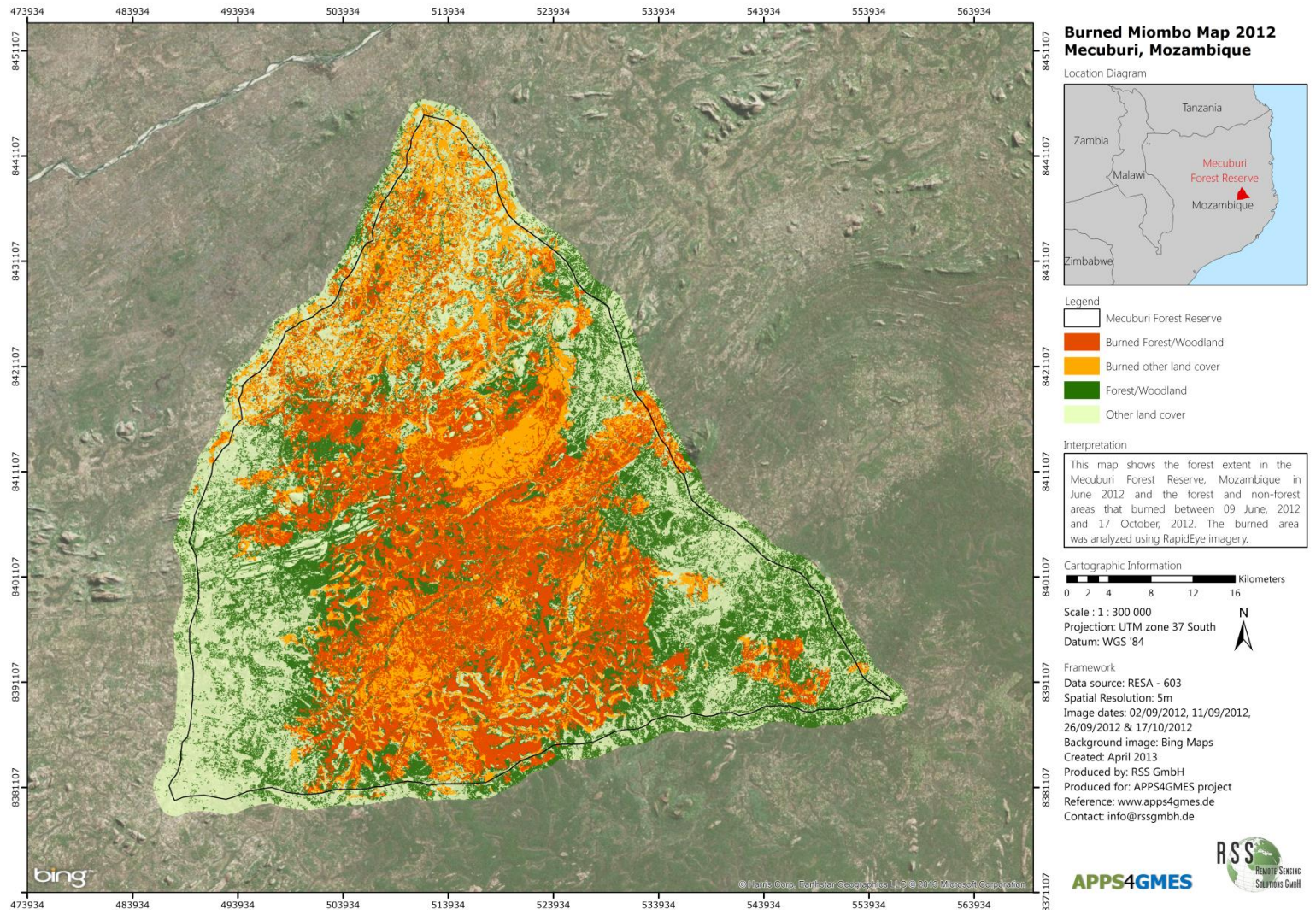
RapidEye-based burned area mapping

Burned Miombo Map 2012



Depends on fire intensity if Miombo forest was affected !

APPS4GMES

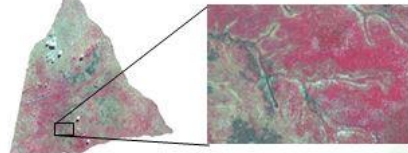
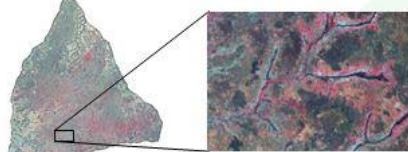
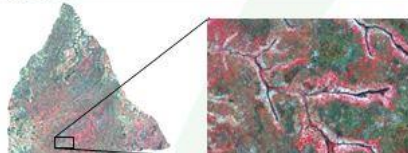
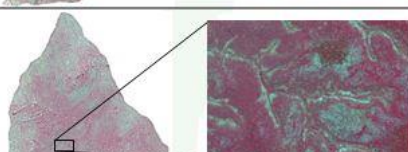




RS-based benchmark of Miombo forests

RapidEye Images and Miombo Phenology



APPS4GMES

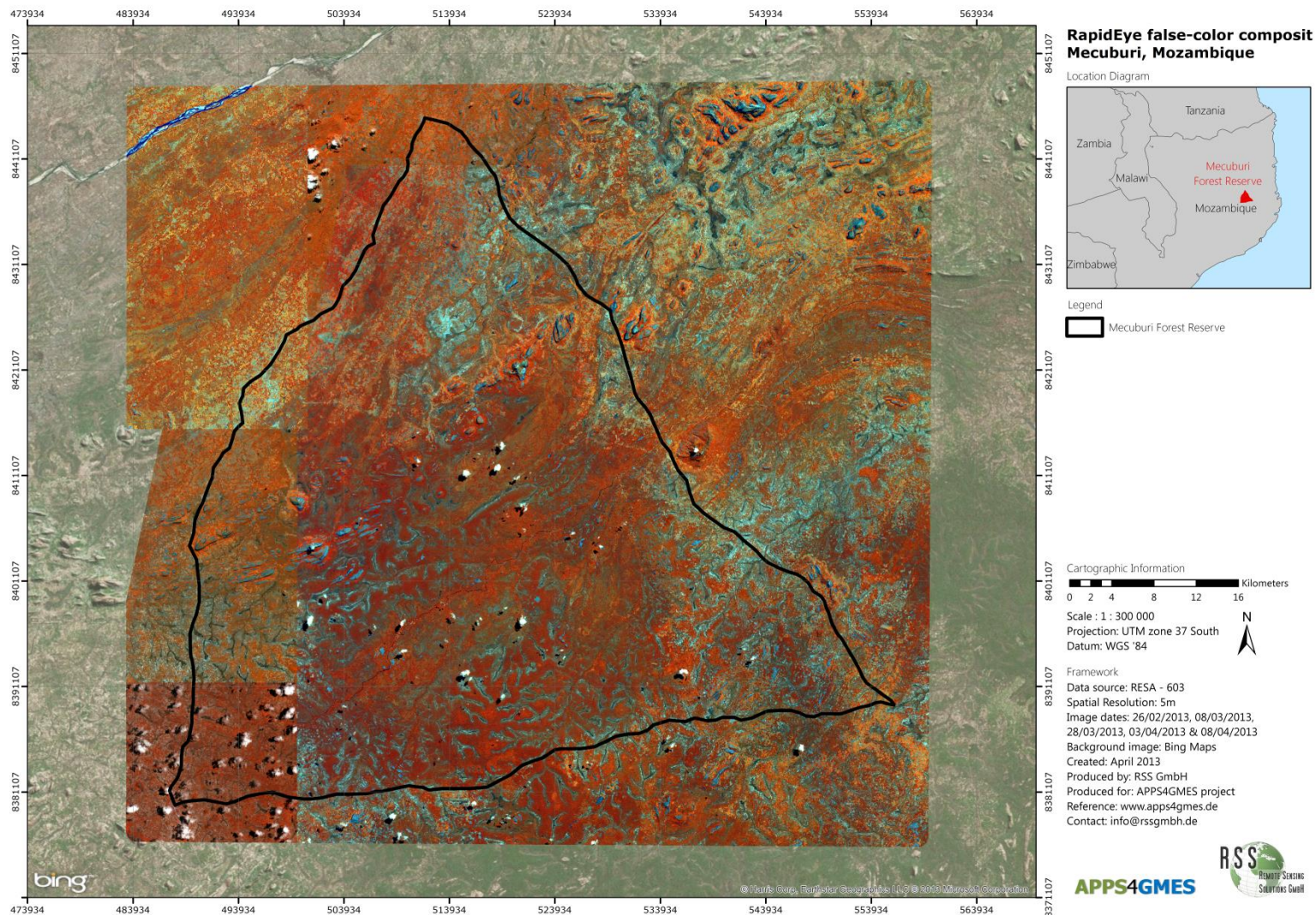
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RapidEye-based burned area mapping

Refining the benchmark and mapping change



RapidEye image mosaic March/April 2013

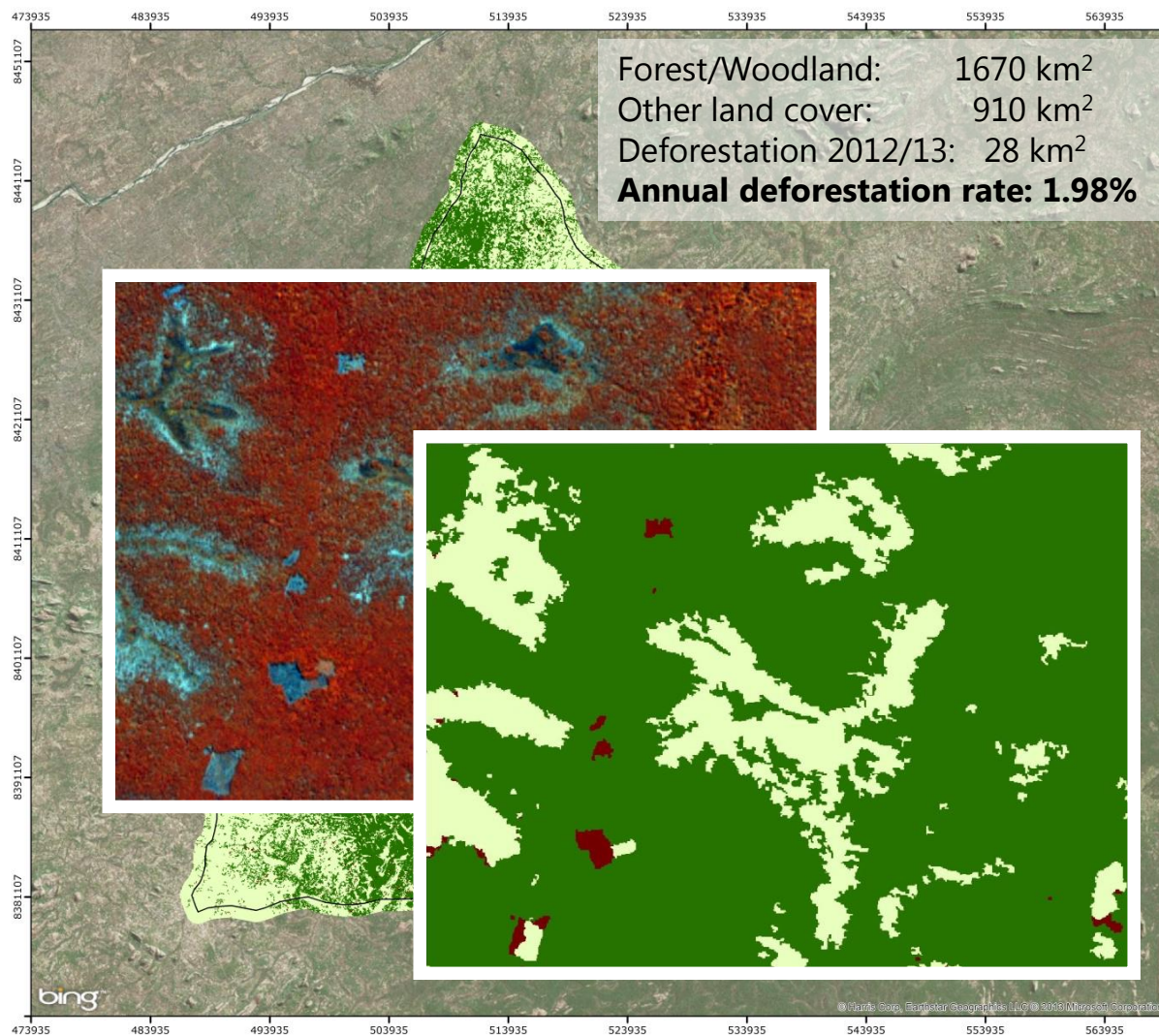


RapidEye-based burned area mapping

Refining the benchmark and mapping change



Deforestation Map 2012-2013



**Deforestation Map 2012-2013
Mecuburi, Mozambique**

Location Diagram



Legend

- Mecuburi Forest Reserve
- Forest/Woodland
- Other land cover
- Deforestation 2012-2013

Interpretation

This map shows the forest extent in the Mecuburi Forest Reserve, Mozambique in April 2013 and areas that experienced deforestation between June, 2012 and April, 2013. The forest cover change was analyzed using RapidEye imagery.

Cartographic Information

Scale : 1 : 300 000
Projection: UTM zone 37 South
Datum: WGS '84

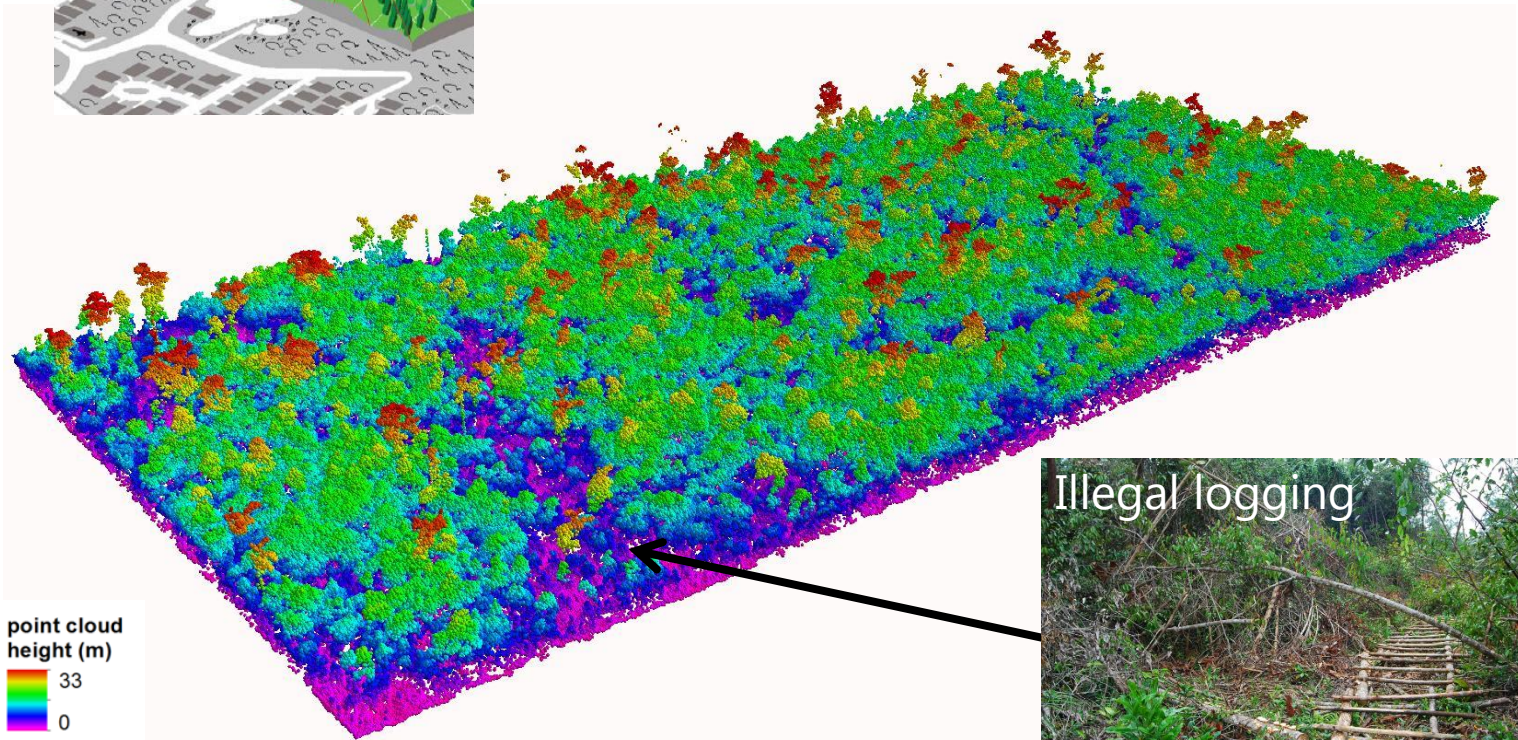
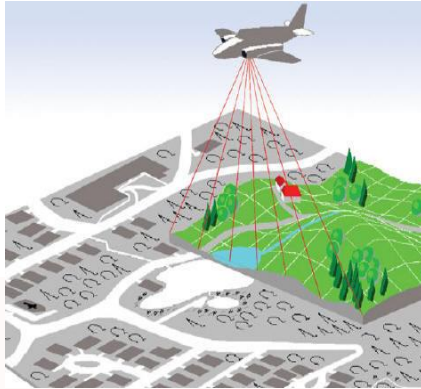
Framework

Data source: RESA - 603
Spatial Resolution: RapidEye: 5m,
Image dates: 26/02/2013, 28/03/2013
03/04/2013 & 08/04/2013
Background image: Bing Maps
Created: April 2013
Produced by: RSS GmbH
Produced for: APPS4GMES project
Reference: www.apps4gmes.de
Contact: info@rssgmbh.de

APPS4GMES

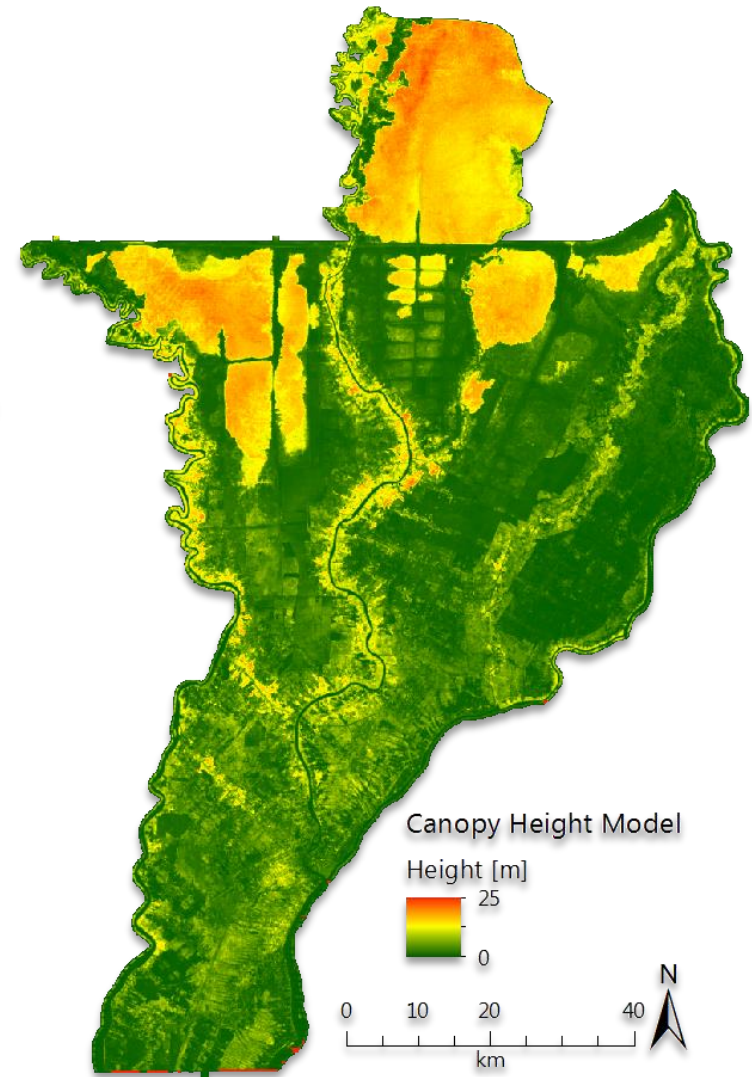
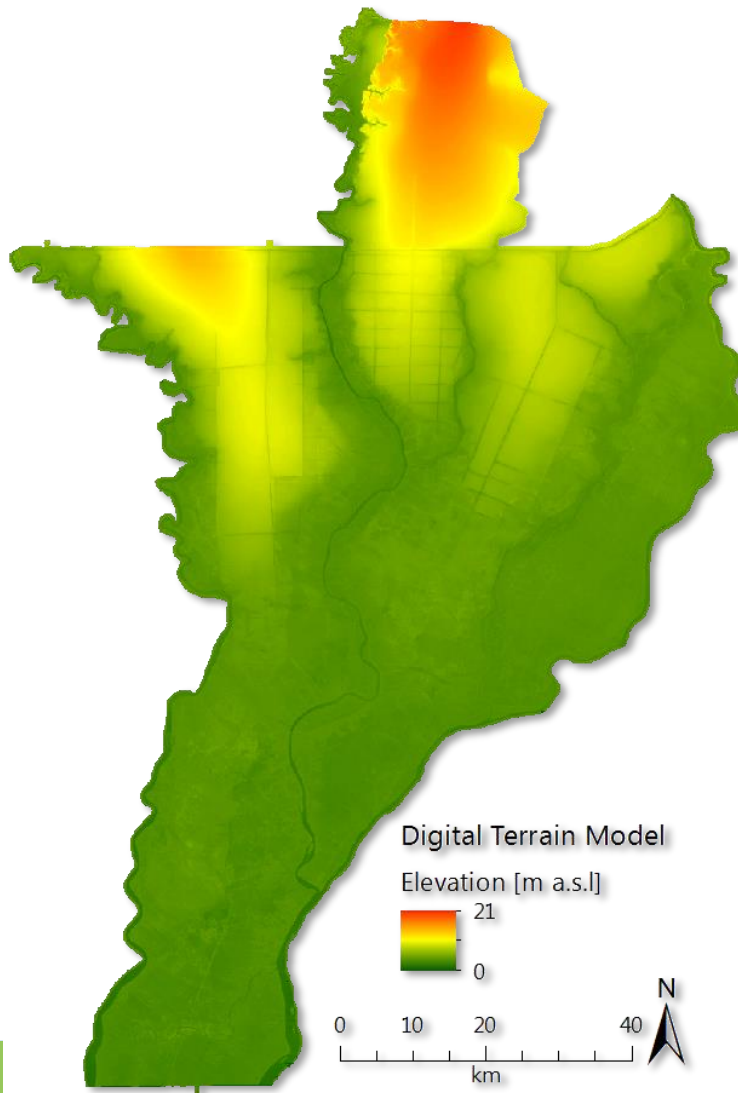
LiDAR (Light Detection and Ranging)

Applications for forest monitoring



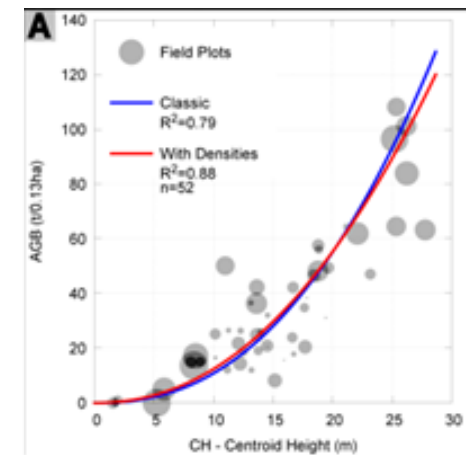
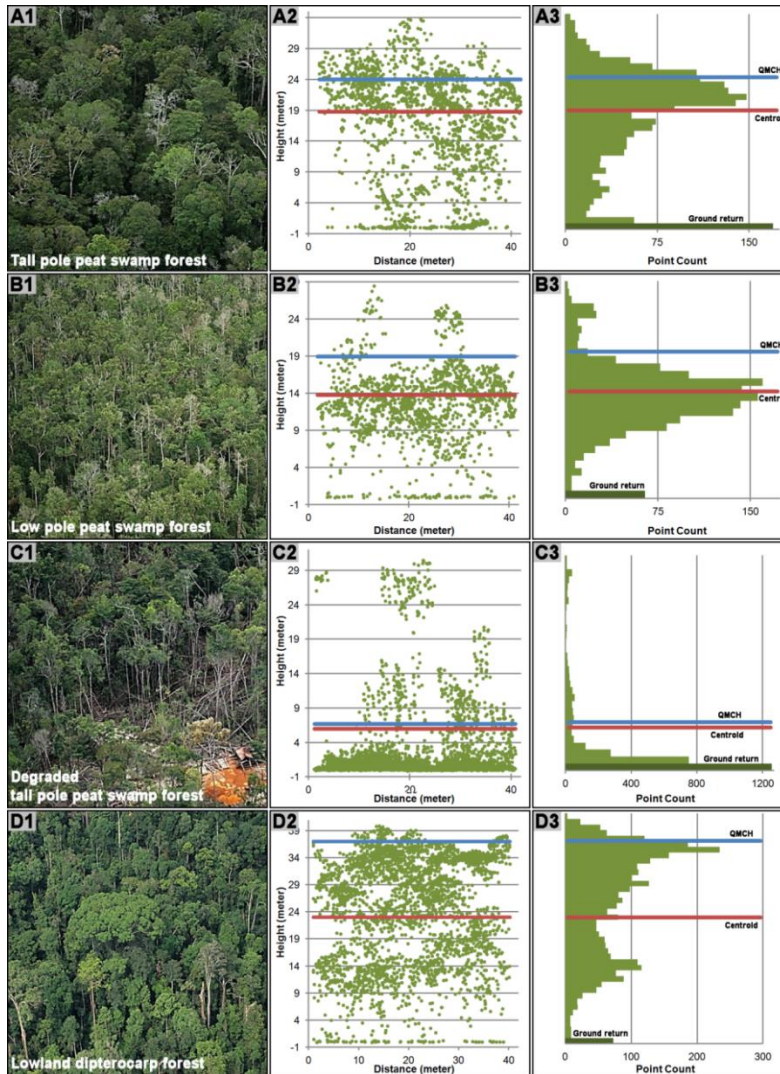
LiDAR (Light Detection and Ranging)

DTM and canopy height model



LiDAR (Light Detection and Ranging)

Height metrics for forest characterization



Jubanski et al. 2012

Conclusion



- Remote sensing is an integral part of REDD+ MRV (Measurement, Reporting and Verification) systems
- Historical baseline, current benchmark and future monitoring of forest cover and carbon stock is possible
- Ground-based forest inventories are very important for RS-based monitoring
- Low resolution fire products are very helpful for identifying fire clusters
- High-resolution data provide more reliable assessments of patterns of fire occurrence
- High resolution RapidEye data proofed to be very suitable to monitor Miombo forest and its changes at small spatial scales
- The period for acquiring satellite data is most crucial due to seasonal effects of Miombo forest (phenology, fire occurrence and fast regrowth)
- „End-of-wet-season-imagery“ is required for Miombo forest/woodland mapping (benchmark and change monitoring) and „end-of-dry-season-imagery“ is required for detailed burned land cover mapping
- LiDAR can provide precise measures of forest structure and estimates of carbon stock
- An upscaling approach using field plots, LiDAR transects and large-area coverage of satellite data is recommended

Thank you for your attention...

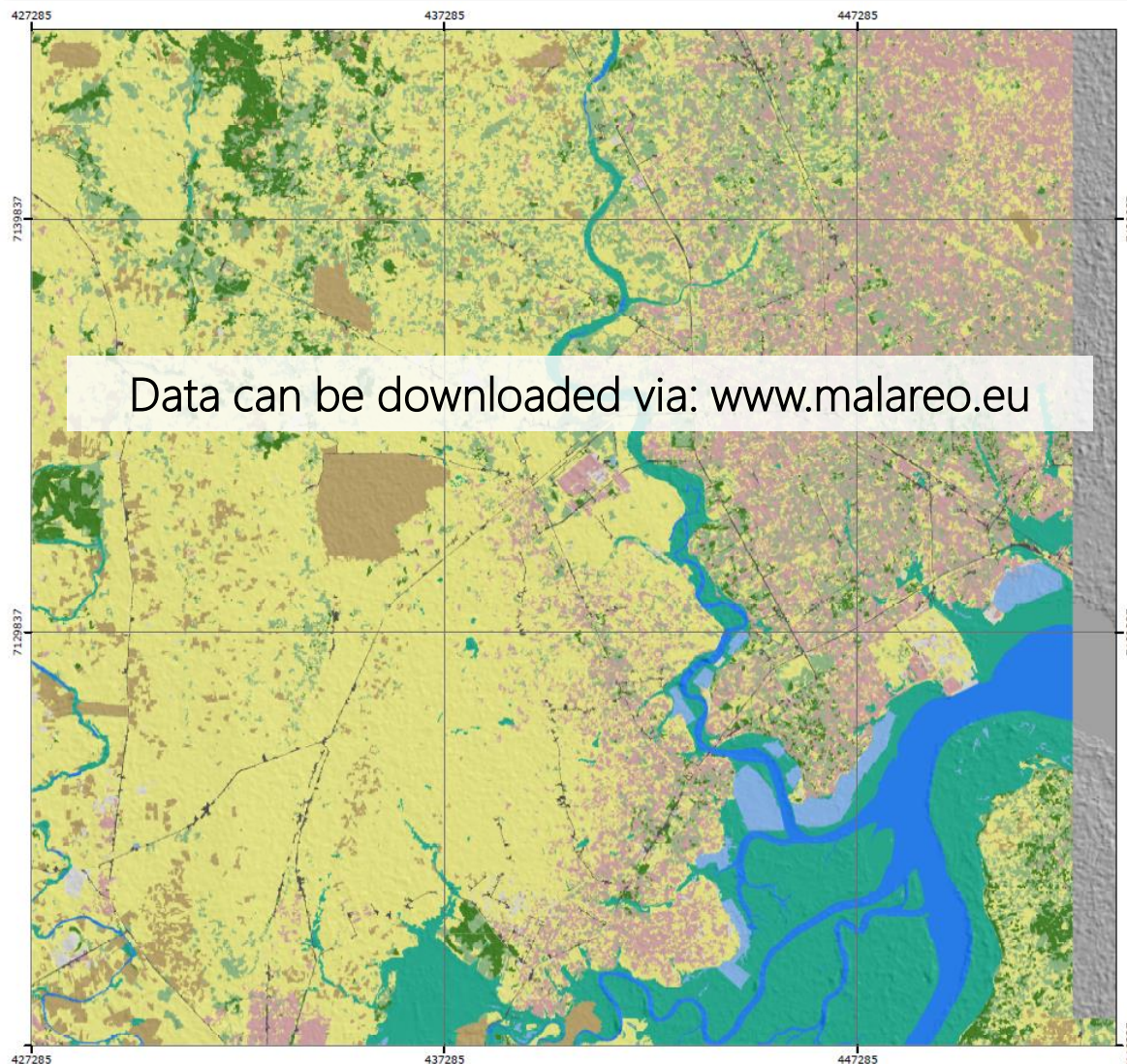


RSS - Remote Sensing Solutions GmbH
Isarstrasse 3
82065 Baierbrunn (Munich)

franke@rssgmbh.de
siegert@rssgmbh.de
www.rssgmbh.de

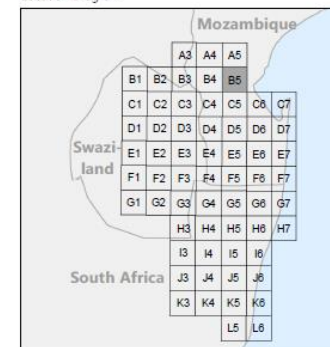
RS-based benchmark of other forests

Forest extent mapped with RapidEye (2011)



MALAREO Land Cover Map Matola

Location Diagram



Legend

- Forest/Woodland
- Bush-/Shrubland
- Grassland/Savanna
- Wetland
- Large-scale Agriculture
- Subsistence Farming
- Flowing Water
- Standing Water
- Roads/Tracks
- Bare Soil/Rock
- Settlement/Infrastructure

Cartographic Information

0 5,000 Meters

Map scale: 1:90,000
Projection: UTM zone 36 South
Datum: WGS '84

Framework

Data sources: (d) RapidEye (2011), provided under EC/ESA GSC-DA.
Spatial resolution: 5 m
Background image: Hillshade 30m
Created: September 2012
Produced by: RSS GmbH, EUROSENSE & MRC
Produced for: MALAREO project
Reference: www.malareo.eu
Contact: info@rssgmbh.de

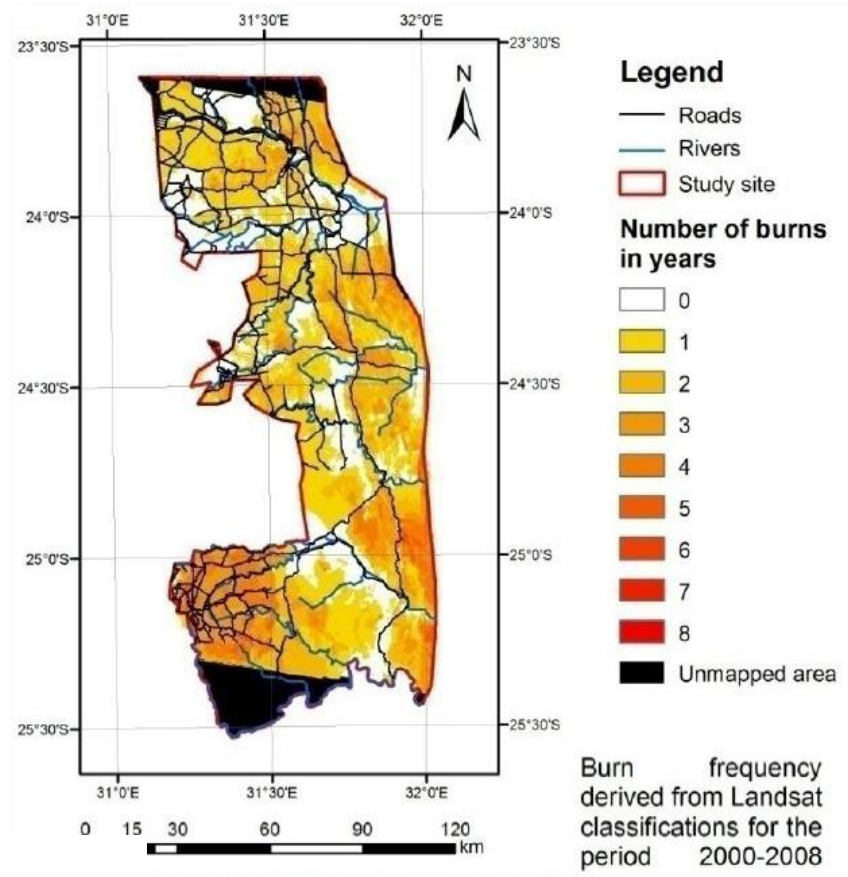


WIFI - WildFire Impact Evaluation by RS

(Kruger National Park, South Africa)



- Landsat-based fire history (classification of 21 LS scenes)
- In cooperation with Navashni Govender (Program Manager: Fire Ecology & Biogeochemistry)



RapidEye-based burned area mapping

Temporal monitoring aspects



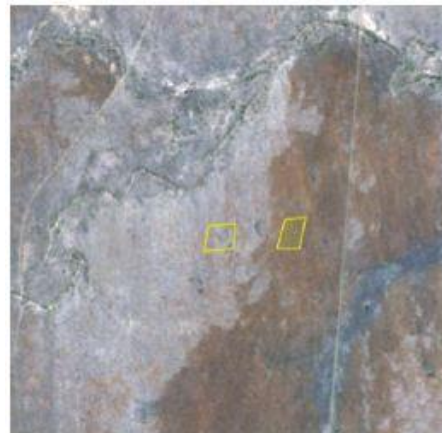
Very fast regrowth in wet season

Example 1

Example 2

Example 3

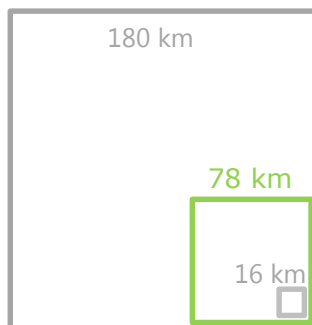
Aug.
2010



Dec.
2010



Selected satellite sensors suitable for REDD+



Resolution and coverage	Mission	Number of bands	Spatial Resolution	Swath Width	Revisit time
Very high resolution Small spatial coverage	WorldView-2	9 bands	PAN: 0,46 m MS: 1,84 m	16,4 km	1-6 days
	Ikonos-2	5 bands	Pan :1m MS: 4 m	11 km	
	GeoEye	5 bands	PAN: 0,41 m MS: 1,65 m	15.2 km	
	QuickBird	5 bands	PAN: 0,61 m MS: 2,44 m	16,5 km	
	Pleiades	5 bands	PAN: 0.5 m MS: 2 m	20 km	
High resolution Moderate spatial coverage	RapidEye	5 bands	6.5 m	78 km	daily
	SPOT 5 / 6	4 bands	Pan: 5 m (2.5) MS: 10 m	60 km	2-3 days
Medium resolution Large spatial coverage	Landsat 7ETM+/ 8	7-11 bands	PAN: 15 m, MS: 30 m	185 km	16 days

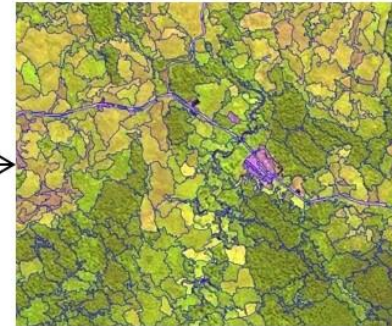
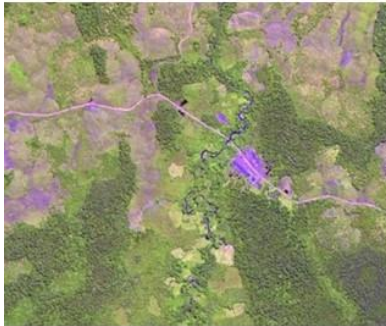
Forest Benchmark Mapping

From image to information

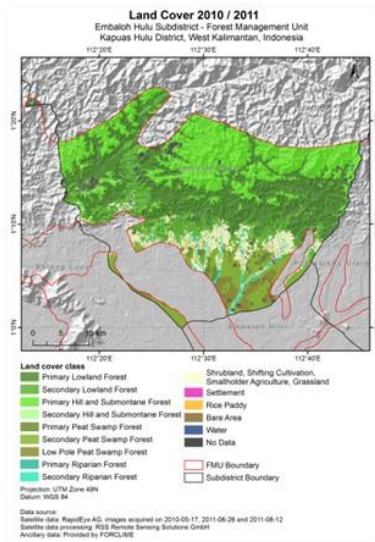


Atmospheric correction

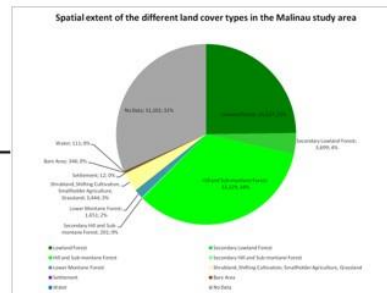
Image segmentation



Ruleset classification

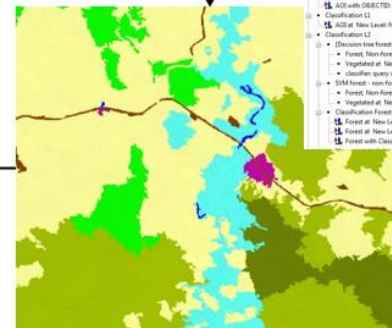


Spatial analysis



```

Segmentation
  70 (shapefile compact 0.5) creating 'New Level'
  Export objects for sample generation
  at New Level: export object shapes to samples_random_non-forest
  (Forest, Non-forest) at Samples_Forest, Non-Forest: export object shape
  Assign samples
  with Class_name samples = 'Forest' at New Level: Forest
  with Class_name samples = 'Non-forest' at New Level: Non-Forest
  Define AOI
  unclassified with OBJECTID >= 2 at New Level: AOI
  AOI with OBJECTID >= 2 and Non-forest = 0 at New Level: No Data
  Classification 1
  AOI at New Level: Non-vegetated, Vegetated
  Classification 1.2
  [Decision tree forest - non-forest]
  Forest, Non-forest at New Level: classifier: train decision tree using
  Vegetated at New Level: classifier: apply
  classifier: query decision tree
  SGM forest - non-forest
  Forest, Non-forest at New Level: classifier: train svm using SVM11
  Vegetated at New Level: classifier: apply
  Classification Forest types
  Forest at New Level: Hill and Submontane Forest, Lower Montane F
  Forest at New Level: Swamp Forest
  Forest with Classified as Swamp Forest = 0 at New Level: Lowland F
  
```

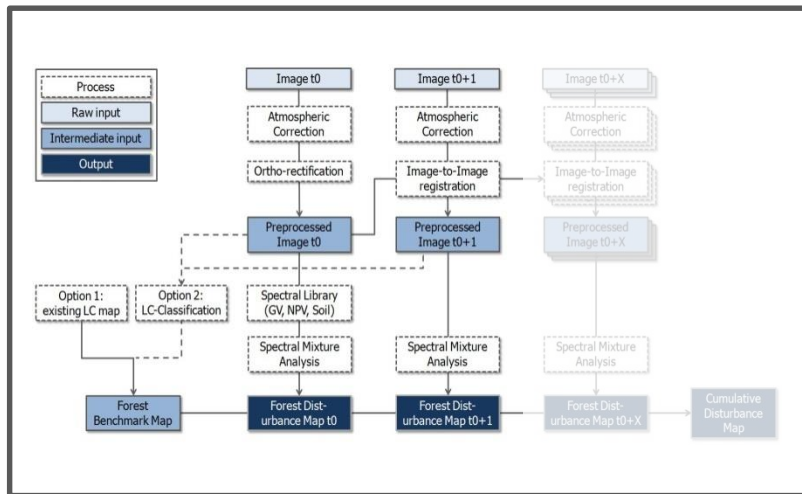


Monitoring fire and selective logging activities

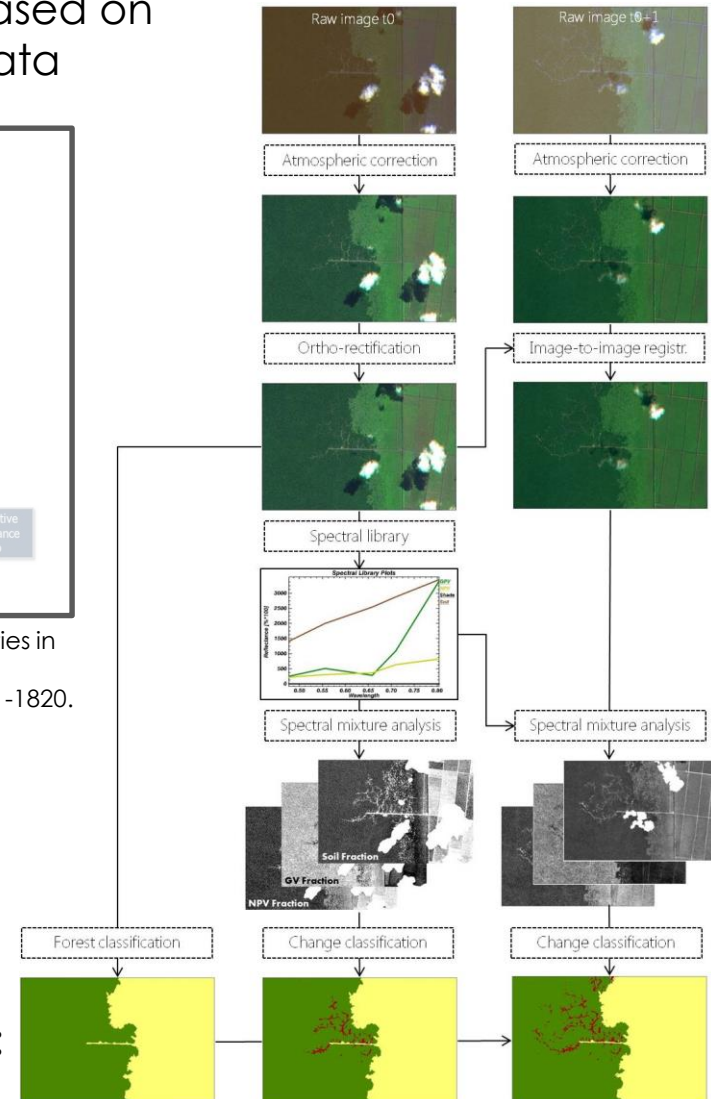
RapidEye time series analysis



Forest change detection system based on optical high-resolution RapidEye data



Franke et al. (2012): Monitoring fire and selective logging activities in tropical peat swamp forests. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 5(6), 1811-1820.

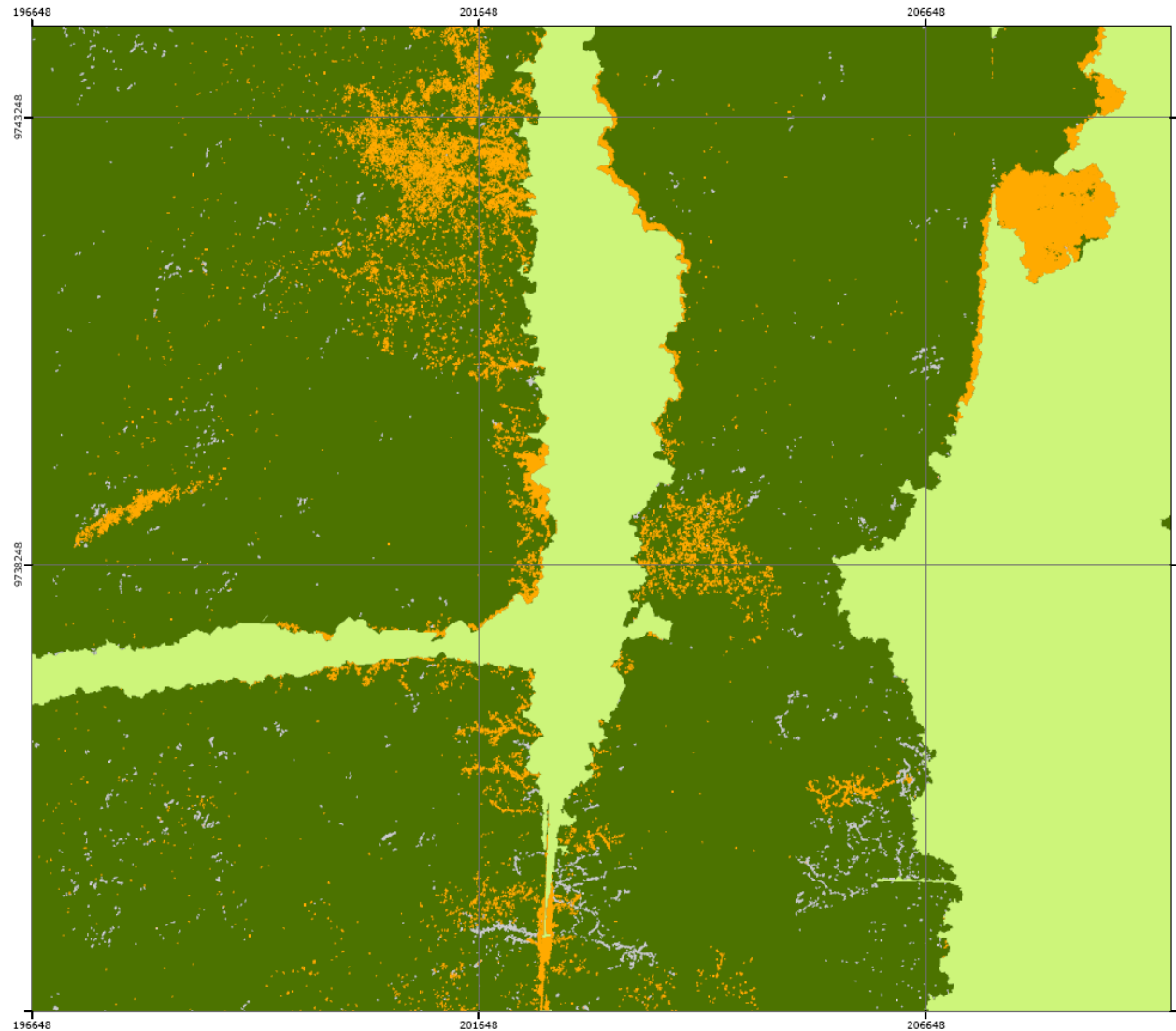


Activity data on D&D:



Monitoring fire and selective logging activities

RapidEye time series analysis



Deforestation and Forest Degradation Block B, Central Kalimantan, Indonesia, 2009-2012

Location Diagram



Legend

- Deforestation & Degradation 2010-2012
- Deforestation & Degradation 2009-2010
- Other Land Cover
- Forest Area in 2009 (Benchmark)

Interpretation

This map shows the forest extent in the Mawas area, Central Kalimantan, Indonesia as in May 2009 and the deforestation and forest degradation in 2010 and 2012. The forest area was analyzed using multitemporal RapidEye imagery. The map shows small-scale forest disturbances through illegal logging and fire.

Cartographic Information

0 1.740
Meters

Map scale: 1:40.000

Projection: UTM zone 50 South

Datum: WGS '84

Framework

Data sources: (c) RapidEye (2009-2012), provided under EC/ESA GSC-DA.

Spatial resolution: 5 m

Image dates: 22/05/2009, 21/06/2010

29/07/2012

Created: September 2012

Produced by: RSS GmbH

Produced for: REDD-FLAME project

Reference: www.redd-flame.info

Contact: info@rssgmbh.de



Monitoring fire and selective logging activities

Example REDD demonstration site in Brazil



Sete de Setembro Indigenous Land, Mato Grosso, Brazil
Forest Monitoring 2009 - present

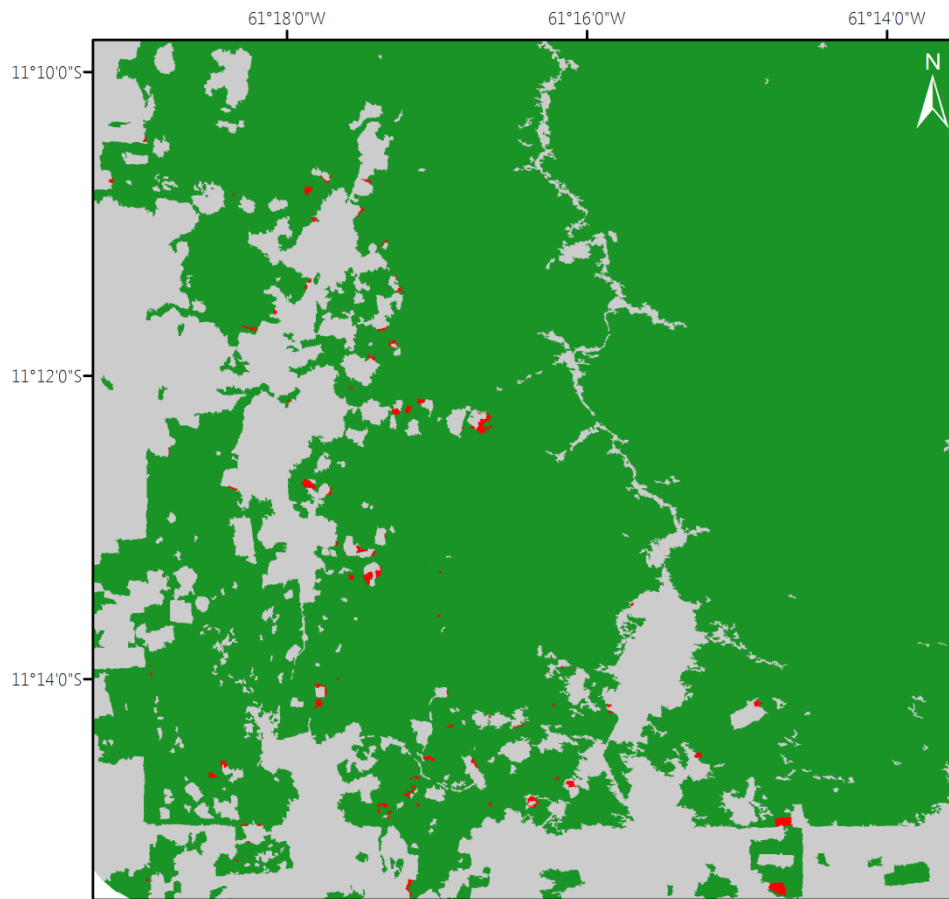


Monitoring fire and selective logging activities

Example REDD demonstration site in Brazil



Sete de Setembro Indigenous Land, Mato Grosso, Brazil
Forest Monitoring 2009 - present



Legend

- Deforestation/Degradation 2009-2010
- Forest
- Other land cover

Data Source:
RapidEye, acquired on
14/05/2010 and 17/05/2010

(c) RapidEye (2011), provided
under EC/ESA GSC-DA

Projection:
WGS 1984, UTM Zone 20S

Processing:
Project: REDD-FLAME
Production: Remote Sensing Solutions GmbH

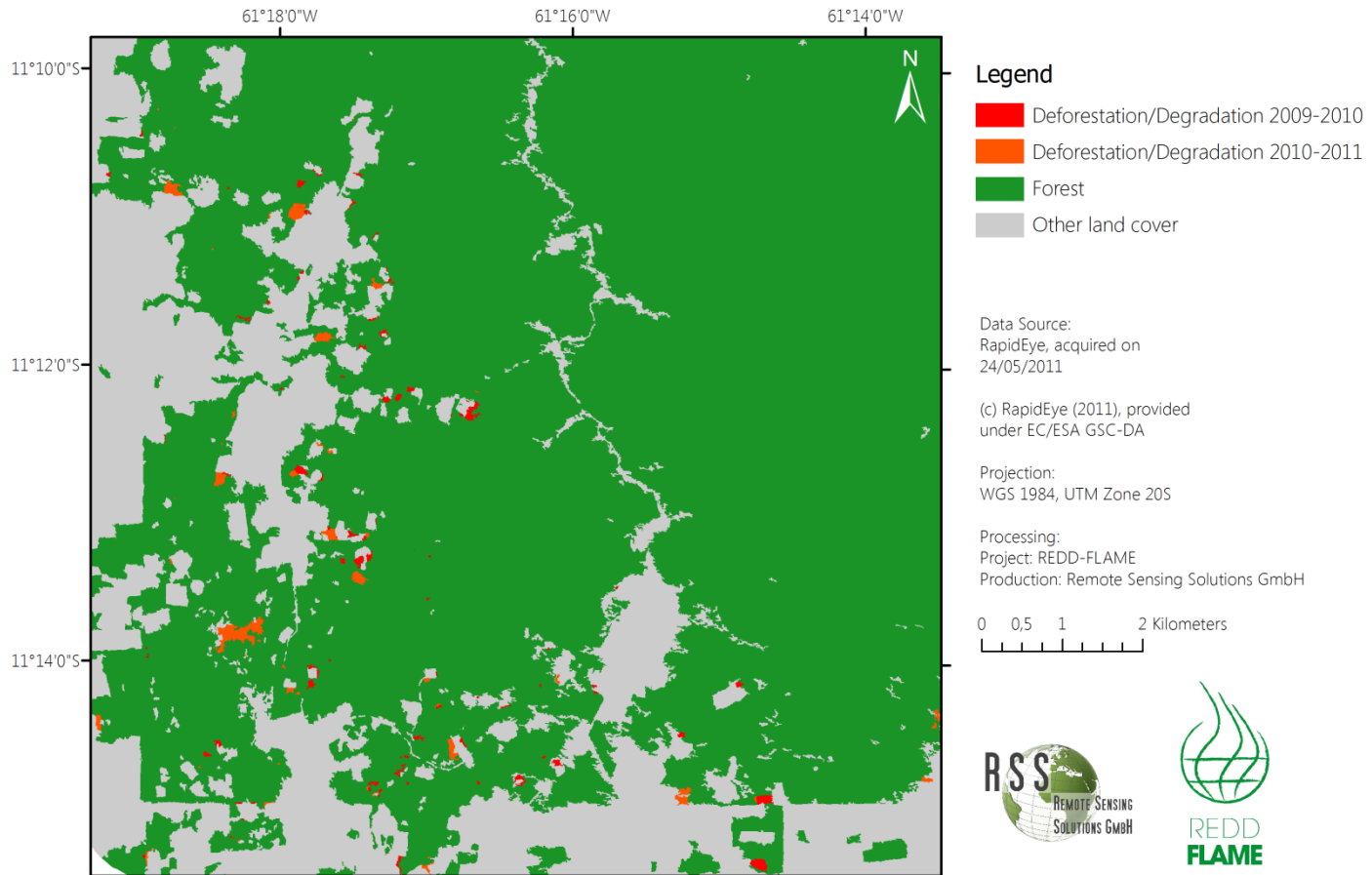
0 0,5 1 2 Kilometers

Monitoring fire and selective logging activities

Example REDD demonstration site in Brazil



Sete de Setembro Indigenous Land, Mato Grosso, Brazil
Forest Monitoring 2009 - present

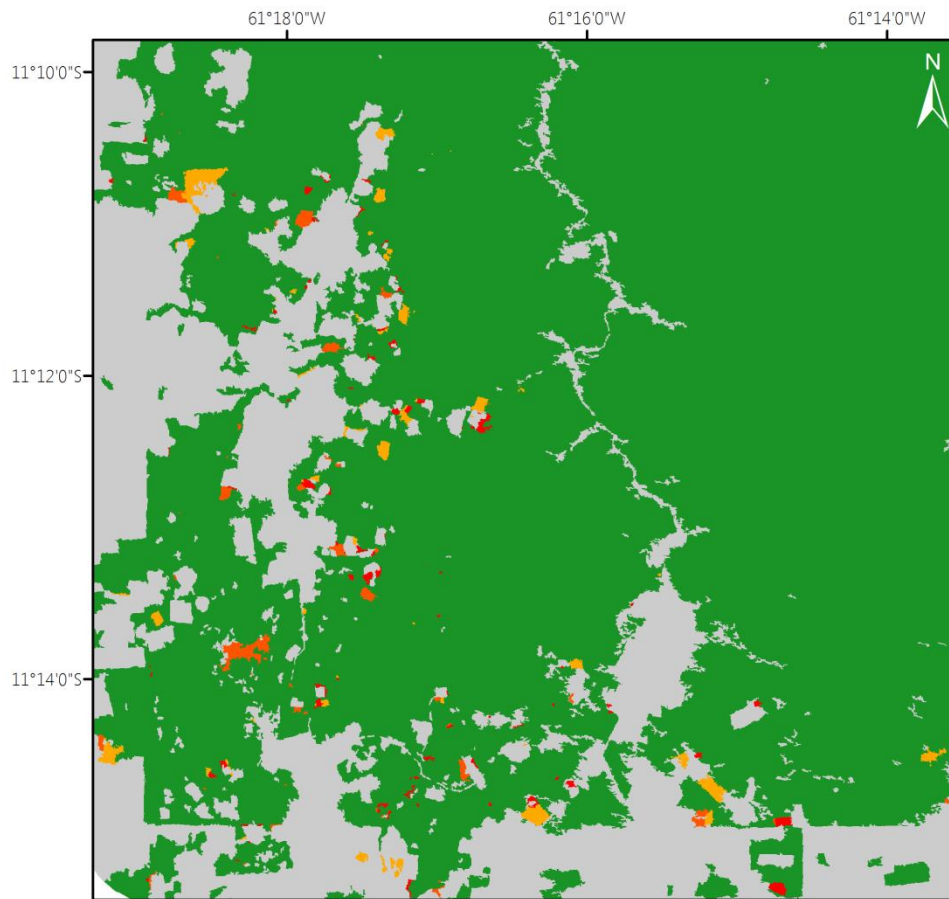


Monitoring fire and selective logging activities

Example REDD demonstration site in Brazil



Sete de Setembro Indigenous Land, Mato Grosso, Brazil
Forest Monitoring 2009 - present



Legend

- Deforestation/Degradation 2009-2010
- Deforestation/Degradation 2010-2011
- Deforestation/Degradation 2011-2012
- Forest
- Other land cover

Data Source:
RapidEye, acquired on
01/06/2012

(c) RapidEye (2011), provided
under EC/ESA GSC-DA

Projection:
WGS 1984, UTM Zone 20S

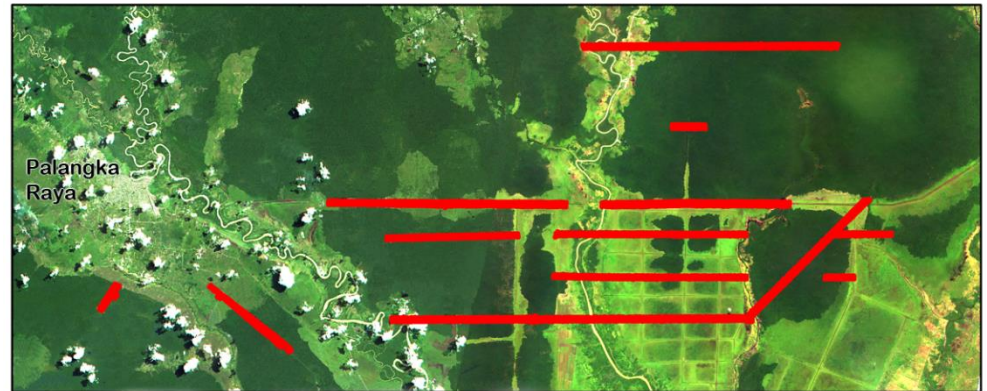
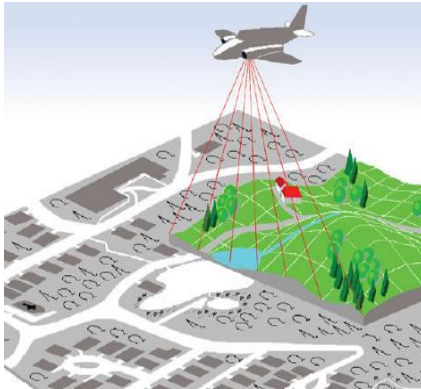
Processing:
Project: REDD-FLAME
Production: Remote Sensing Solutions GmbH

0 0,5 1 2 Kilometers

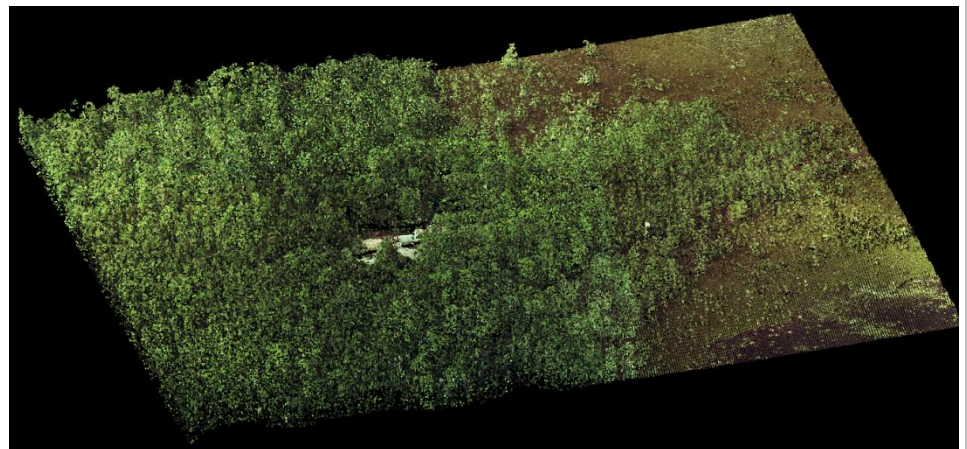
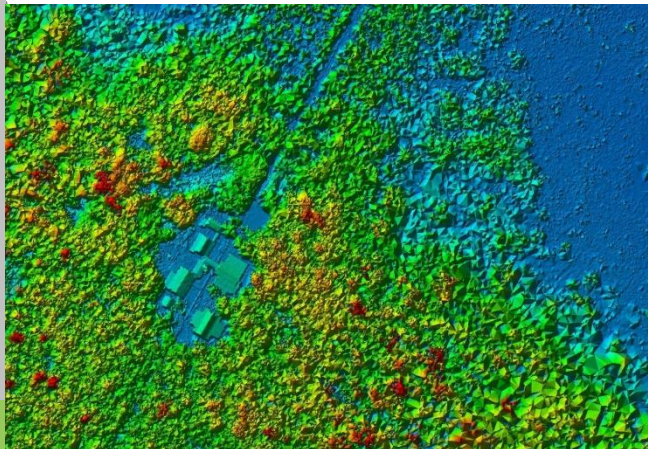
Forest structure and biomass estimation using LiDAR



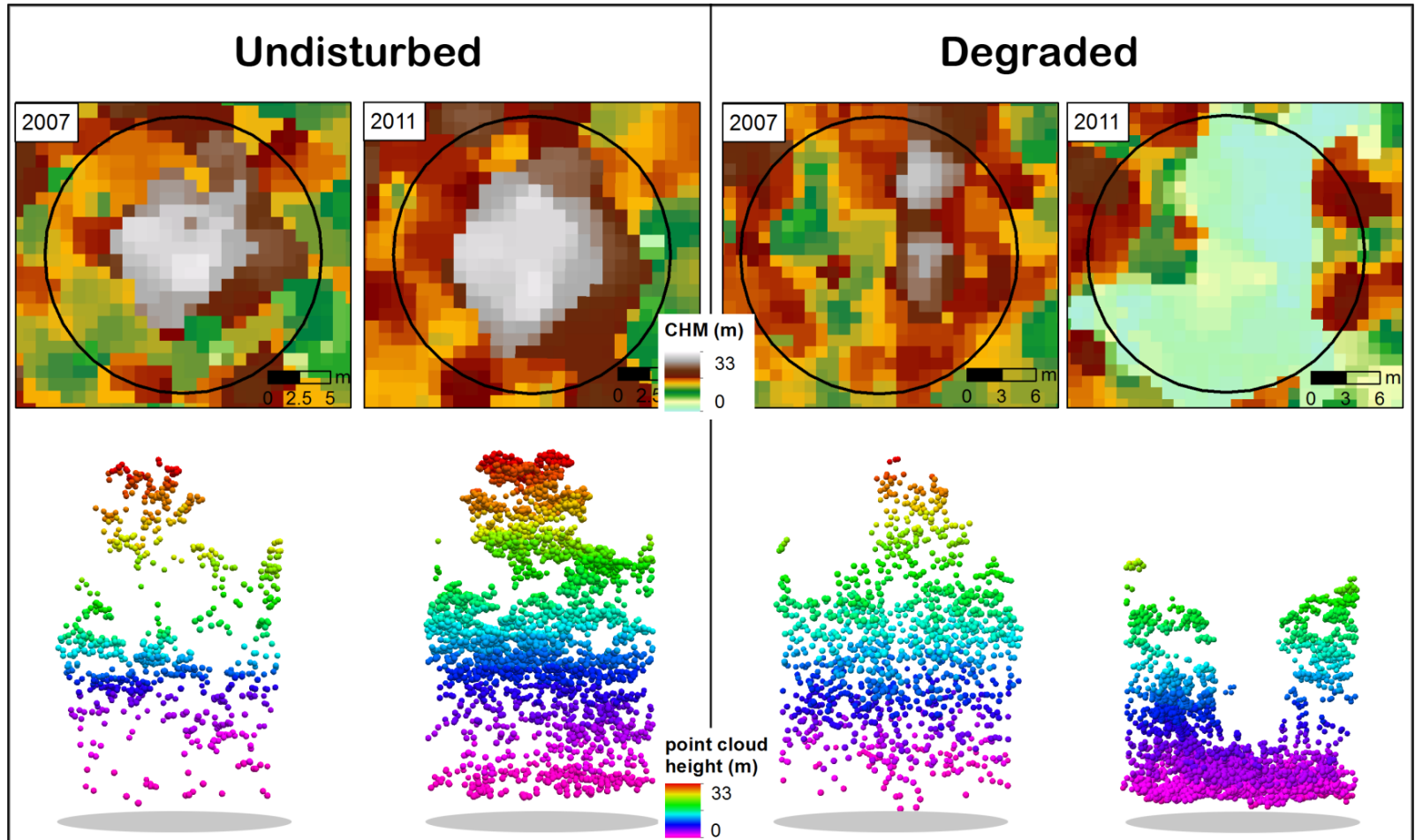
Extensive data sets have been analyzed of 2007 and 2011



0 250 500 1,000 km



Small scale forest degradation



LiDAR



Absolute tree heights derived from LiDAR

