GEO-FCT Product Development Team
2012 Technical Status Report (v. 1.0)
18 October 2012

GEO FOREST CARBON TRACKING

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1 Introduction

1.1 GEO FCT Product Development – 2012 Progress

The GEO Forest Carbon Tracking (FCT) Task presently comprises eleven National Demonstrator (ND) countries. Mexico, Brazil, Guyana, Cameroon, Tanzania, Indonesia/Kalimantan and Australia/Tasmania, were included in 2009, and Peru, Colombia, D.R. Congo and Indonesia/Sumatra were added in 2010. Finally, Nepal was included as an ND in mid 2011.

This technical report document provides an overview of the satellite data dissemination status and forest information product development progress in the National Demonstrator countries in 2012. It is based on progress reports submitted by the Product Development Teams that have been established within, or in support of, each ND country. At the time of the release of this version of this document [18 October 2012], progress reports have been obtained from nine of the eleven National demonstrators.

During 2012, the FCT product development activities have in some of the more advanced NDs been aimed at the development of national-scale forest information prototype products, in the cases where wall-to-wall satellite image data have been at hand. Some of the NDs are focusing on methodology development on a local-scale over the Validation Sites, while yet some of the recently included NDs are still in their start-up phases.

This report, as well as the FCT PD Team Reports for 2010 and 2011, are available for download at the GEO FCT Document Repository: http://www.geo-fct.org/pd-team-documents

1.2 Prototype products developed in 2012

Summary of forest information prototype products for GEO-FCT in 2012.

ND	2012 FCT prototype products
MEXICO	Horizon 1a (FNF) , Mexican Chiapas prototype [2012], Spot 5 Horizon 1c (FNF) , Mexican Chiapas prototype [2012], Spot 5 Horizon 2, Biomass maps Chiapas prototype [2012], Spot
COLOMBIA	Horizon 1a (FNF)wall-to-wall prototype [2010], Landsat TM/ETM+ Horizon 1b (Forest Change) prototype Tinigua VS (COL-04) [2011] RapidEye MODIS Image Mosaic wall-to-wall [2012] Horizon 1c Amazon [2012], Landsat TM/ETM+
PERU	None reported
BRAZIL	None reported
GUYANA	Forest–Land Cover Change (FLC) Mahdia Test site prototype [2007-2010], PALSAR-LandsatENVISAT ASAR Image Mosaic, wall-to-wall prototype [2010-2011] RadarSAT-2 Image Mosaic, wall-to-wall prototype [2010] PALSAR Image Mosaic, wall-to-wall prototype [2010]
CAMEROON	Horizon 1a Forest Cover Map, prototype Centre Province [2010], RapidEye, Landsat Horizon 1b Forest Cover Change Map, prototype Centre Province [1990-2000], Landsat TM/ETM+ Horizon 1b Forest Cover Change Map, prototype Centre Province [2000-2010], Landsat TM/ETM+ Horizon 2 Biomass map, Adamawa Region prototype [2007-2010], PALSAR Horizon 2 Preliminary Degradation Map, Adamawa Region prototype [2009-2011], RapidEYE, ETM+ Landsat TM/ETM+, RapidEye Image Mosaic, Centre Province [1990, 2000, 2010] PALSAR Image Mosaic Adamawa Region [2007, 2010]
D.R. CONGO	None reported

TANZANIA	Horizon 1a (FNF) TNZ-3 [2009], ALOS PALSAR and ENVISAT ASAR Horizon 1a (FNF) TNZ-2, Amani, Liwale [2007-2009], ALOS PALSAR Horizon 1b (forest change) TNZ-3 and 4, [2007-2009], ALOS PALSAR Horizon 2 (Biomass) Amani, Liwale [2007-2009], ALOS PALSAR
NEPAL	Horizon 1a (FNF) Terai Region [20], RapidEye Horizon 1a (FNF) Sub-national wall-to-wall prototype [2010], Landsat RapidEye Image Mosaic, wall-to-wall [2010-2011] LandSat TM/ETM+ Image Mosaic, wall-to-wall [2010]
INDONESIA (Borneo, Sumatra)	Borneo: Horizon 1c (LC), 1d (LCC) wall-to-wall prototypes [2007-2010] PALSAR Borneo: BOR-3small-scale illegal logging detection prototype [2011], RadarSat-2 Borneo: Horizon 2 Biomass Stratification, wall-to-wall prototype [2008], PALSAR and ICESatGLAS Sumatra: SUM-2Horizon 2 deforestation series prototype [2011-2012], ASAR Borneo: PALSAR, RadarSat Image mosaics, wall-to-wall [2010] Sumatra: ASAR, PALSAR, JERS-1 Image mosaics, wall-to-wall mosaic [2010] Sumatra: Horizon 1a(FNF), wall-to-wall prototype [2007-2010], PALSAR Sumatra: Horizon 1c (LULUCF), Riau Province prototype [2007-2010], PALSAR
AUSTRALIA (Tasmania)	Horizon 1a (FNF), wall-to-wall, annual F/NF time-series prototype [2007-2010], PALSAR Horizon 1b (FC), wall-to-wall, prototype [2010], PALSAR Horizon 1c (LC) ,1d (LCC), 3 verification sites prototype [2009], ASAR and RadarSat-2 PALSAR, ASAR, RadarSat-2 Image mosaics, wall-to-wall prototype [2009-2011]

Horizon 1a: FNF - Forest/Non-Forest

Horizon 1b: FC - Forest Change

Horizon 1c: LC - Land Cover

Horizon 1d: LCC - Land Cover Change

2 Product Development Team Progress Reports

2.1 MEXICO

Report based on the presentation at the 3rd Science and Data Summit, by Michael Schmidt, Sergio Ojeda, Carlos Zermeño, Rainer Ressl, Fernando Paz (Conafor, Conabio, INEGI)

2012 Activity Summary

- Product development progress
  - Horizon 1a (FNF) for Mexican Chiapas 2012
  - Horizon 1c (LC) for Mexican Chiapas 2012
  - Production of Biomass maps in Chiapas

Remote Sensing Science Questions

General focus on Chiapas State 2012, create Carbon Budget models and including satellite data.

- map mosaic deforestation and defuse degradation in Chiapas state using remote sensing high resolution data.
- Within the ReCover Project, to develop beyond state-of-the-art service capabilities to support fighting deforestation and forest degradation in the tropical región.
  - FP7 Theme Space -funded project
  - Duration 3 years starting in November, 2010
  - Consortium of 9 research and industrial partners:
  - (Europe, Latin America), coordinated by VTT, Finland
  - Total budget of 3.5 M€
  - www.recover-redd.eu

Planned activities over the next 6 months

- Field and satellite (radar-optical-lidar) data fusion
- North-South-South cooperation (GEO-SilvaCarbon-CarboNA-CSIRO/DCCEE-etc.)
- Benchmarking (Chiapas) for satellite products validation (South-South)
- Multiscale MRV implementation: community monitoring to national C emissions budget
- Full implementation of Tier 3 (IPCC)
- Full C budget models (CBM, FullCAM, Mexico)

Satellite data obtained during 2012

No data received

Demonstration products generated to date (Oct. 2012)

Thematic Product	Coverage	Spatial resolution	Data source [year]	Validation
Biomass	Chiapas site		SPOT 5 [2004]	
Forest/Non-Forest	Chiapas Site	2.5 m	SPOT 5 [2009]	
Land Cover	Chiapas Site	2.5 m	SPOT 5 [2009]	
Carbon Flux	Chiapas Site	30 m	Landsat TM/ETM+ [1992-2010]	
Image Product	**Coverage**	**Spatial resolution**	**Data source [year]**	**Validation**

Participation at SDS#4 (Australia, Feb, 2013)

TBC

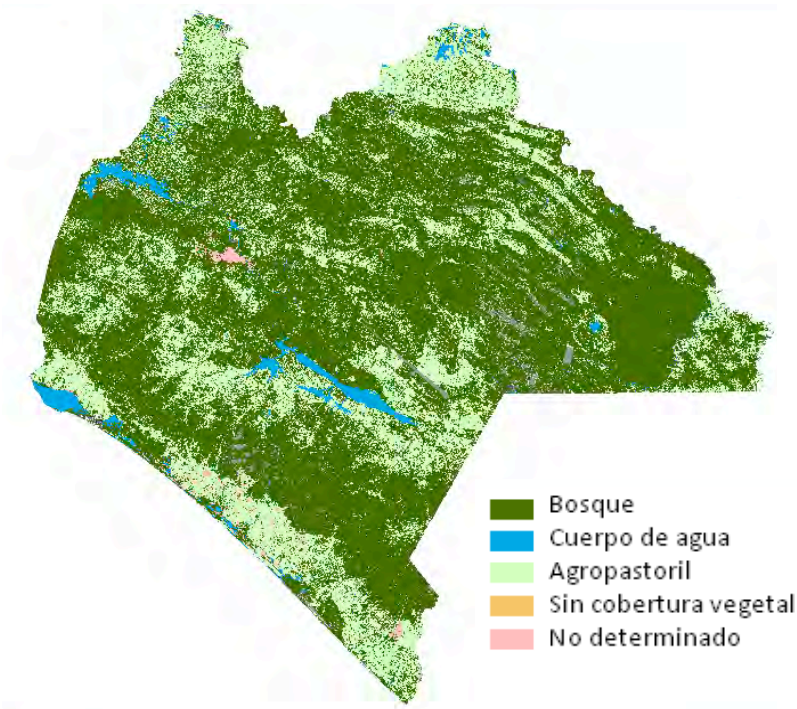


Figure 2.1.1. *Forest- Non Forest classification 2009 for the Chiapas state, with Spot 2.5 meter resolution data*

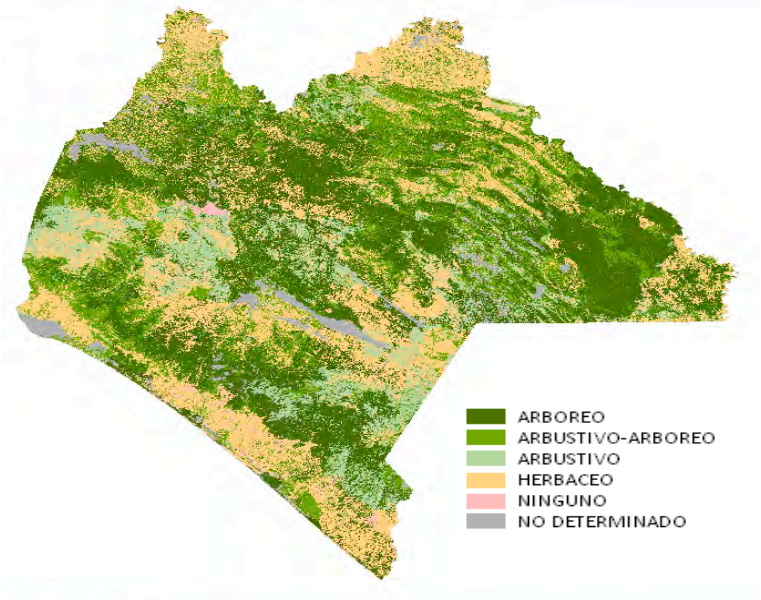


Figure 2.1.2. *Land Cover classification 2009 for the Chiapas state, with Spot 2.5 meter resolution data.*

2.2 COLOMBIA

Reported by Gustavo Galindo / Edersson Cabrera/ Josef Kellndorfer.

2012 Activity Summary

- Product development progress
  - Horizon 1a (FNF) for Colombian Amazon 2012.
  - Early Warning Change prototype using Alos PALSAR ScanSAR images for Tinigua VS.
- Field data collection campaigns
  - Field data collection for verification of TerraSAR-X indicator of change in the Pacific region.
  - 24 0.25 ha plots for Huila-Andes GEO-FCT VS.
- Training courses attended and/or given
  - 4th Technical Americas GEO FCT ND- Regional Forest Monitoring Workshop Topic: Wide-area, Optical and Multi-Frequency SAR data integration and processing for GEO Forest Products. HOST: Colombia-Ideam.
  - 5th Technical Americas GEO FCT ND- Regional Forest Monitoring Workshop Topic: Exchange of Experiences on Forest Degradation Mapping and Monitoring. HOST: Ecuador.
  - 6th Special GEO FCT Global Workshop. Topic: IPCC GPG-compliant Modelling Approaches for National-Scale Land-Surface Carbon Accounting. HOST: Costa Rica.
  - Advanced training in SAR image processing. October4-19. HOST: WHRC.

Remote Sensing Science Questions

Use of ALOS ScanSAR data for an Early Warning system in the Amazon.

- We wanted to explore options to use ALOS PALSAR ScanSAR mode images to detect changes related with deforestation/degradation for an early warning system. In the Eastern Colombian Amazon, where the most important deforestation hotspot of the country is located, we used a ScanSAR HH time series for 2009-2010 that was classified using object oriented e-cognition software. Changes detected with this methodology were compared with the ones detected from a F/NF change detection using Rapid-eye imagery of the same time period. Less than 50% of the changes detected with ScanSAR had coincidence with the ones detected with the high resolution imagery, especially because of variation in vegetation or soil humidity.

Planned activities over the next 6 months

- Degradation VS in the Colombian Amazon: An area in the Colombian Amazon was proposed as a pilot worksite to monitor forest degradation. In it, there is a permanent 25 ha plot that has data for the last 5 years and with SilvaCarbon collaboration, an EDDY flux tower is planned to be constructed there somewhere in the near future. Using the high detail ground info and a dense time series of the Landsat catalogue we plan to evaluate a series of methodologies to monitor forest change.

- Early Warning deforestation system: Using a combination of low cost wide angle ScanSAR images or optical medium or low resolution images we plan to generate alerts at least two times per year for the national hotspots of deforestation. Different methodologies are evaluated, such as MODIS disturbance index or data fusion between MODIS and Landsat data.

- Pre-processing of SAR and Optical data: We want to enhance the country´s capacities to monitor forest by implementing working fluxes for atmospheric and/or topographic normalization and for inter-calibration of SAR imagery.

- Horizon 1a (FNF) for Colombia 2012: For The first semester of 2013 we plan to finish the FNF map of 2012 of the country. SAR images or commercial medium resolution images are required for the areas where there is no reliable Landsat ETM info.

- Validation of Horizon 1a(FNF) 2010.

Satellite data obtained during 2012

Sensor [year]	Coverage	Spatial resolution	Data provider	Obtained through GEO FCT
ALOS ScanSAR, (2009-2010)	VS		JAXA	Yes (pre-processed by WHRC)
Rapideye	30% of the country		Astrium	No (Commercial licence)
Landsat ETM (2012)	Wall-to-Wall		USGS	No

Verification data

- Ground data collected in situ (date of field work)

  Ground plots for VS-Huila (June- 2011)

  Verification for VS-Concosta for TerraSAR-X (May 2011)

Demonstration products generated to date (Oct. 2012)

Thematic Product	Coverage	Spatial resolution	Data source [year]	Validation
Forest/Non-Forest	ND wall-to-wall	30 m	Landsat TM/ETM+ 1987-1993	NO
Forest/Non-Forest	ND wall-to-wall	30 m	Landsat TM/ETM+ 1997-2003	NO
Forest/Non-Forest	ND wall-to-wall	30 m	Landsat TM/ETM+ 2003-2007	NO
Forest/Non-Forest	ND wall-to-wall	30 m	Landsat TM/ETM+ 2009-2010	On going
Forest/Non-Forest Change map	VS Tinigua	5 m	RapidEye 2009-2011	NO
Image Product	**Coverage**	**Spatial resolution**	**Data source [year]**	**Validation**
Satellite image mosaic	ND wall-to-wall	250 m	MODIS MOD09 [2001-2007, 2011, 2012]	N/A

On-going product generation for CEOS Plenary, GEO Ministerial, COP-18 and/or SDS#4

Product/topic	Coverage	Data source [year]	Target
Land Cover	Amazon	Landsat TM/ETM+ [2012]	GEO-9
Forest Cover Change	ND wall-to-wall	Landsat TM/ETM+ [2012]	June 2013
Degradation	Degradation VS	Landsat TM/ETM+ [2000-2012]	June 2013
Degradation	Tinigua VS	Alos Palsar [2007-2010]	-
Forest Carbon Stocks	VS	GEO SAR/ALOS PALSAR/Landsat	June 2013

Participation at SDS#4 (Australia, Feb, 2013)

Yes

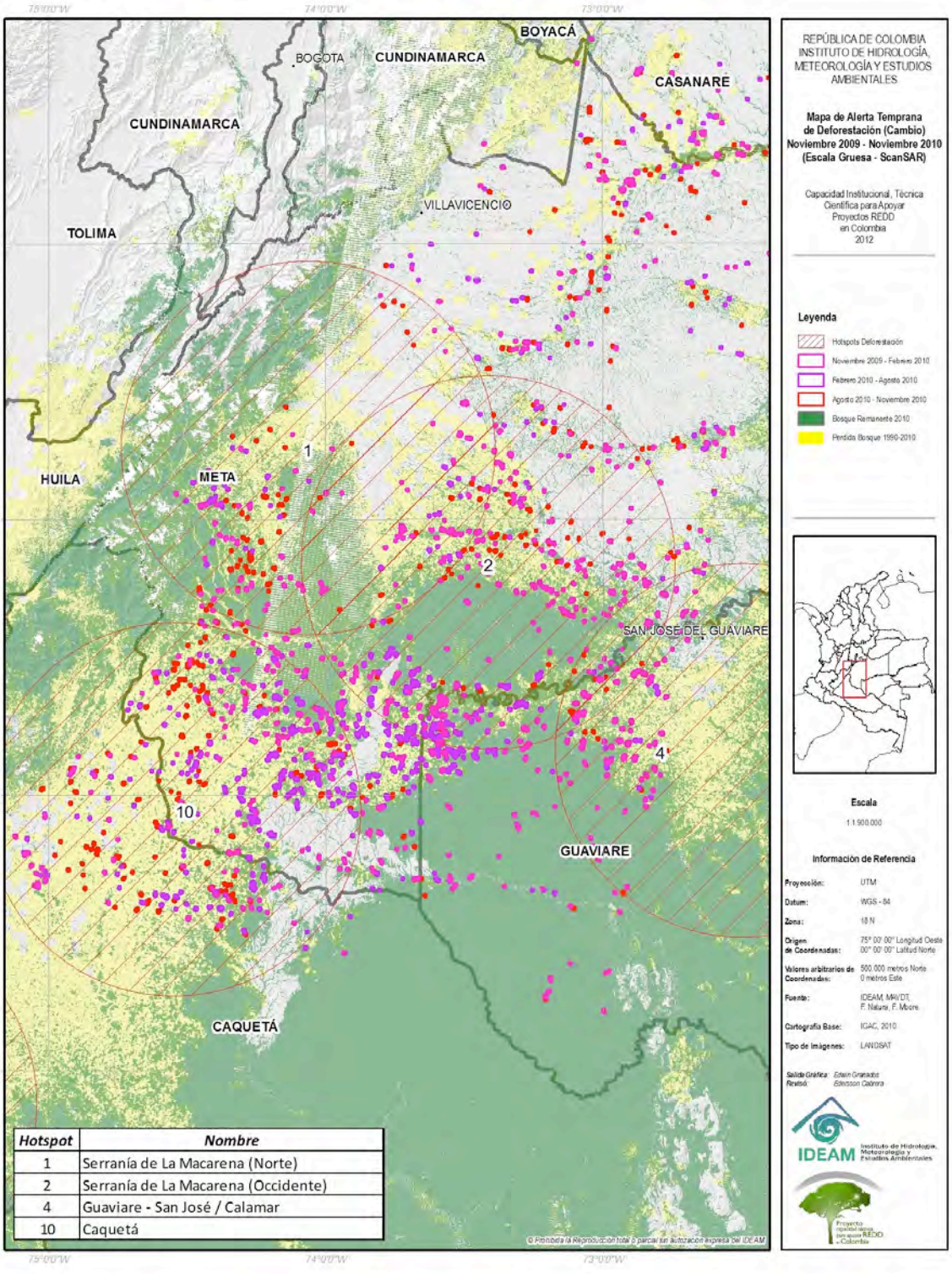


Figure 2.2.1. *Changes (2009-2010) detected using ALOS PALSAR ScanSAR data.*

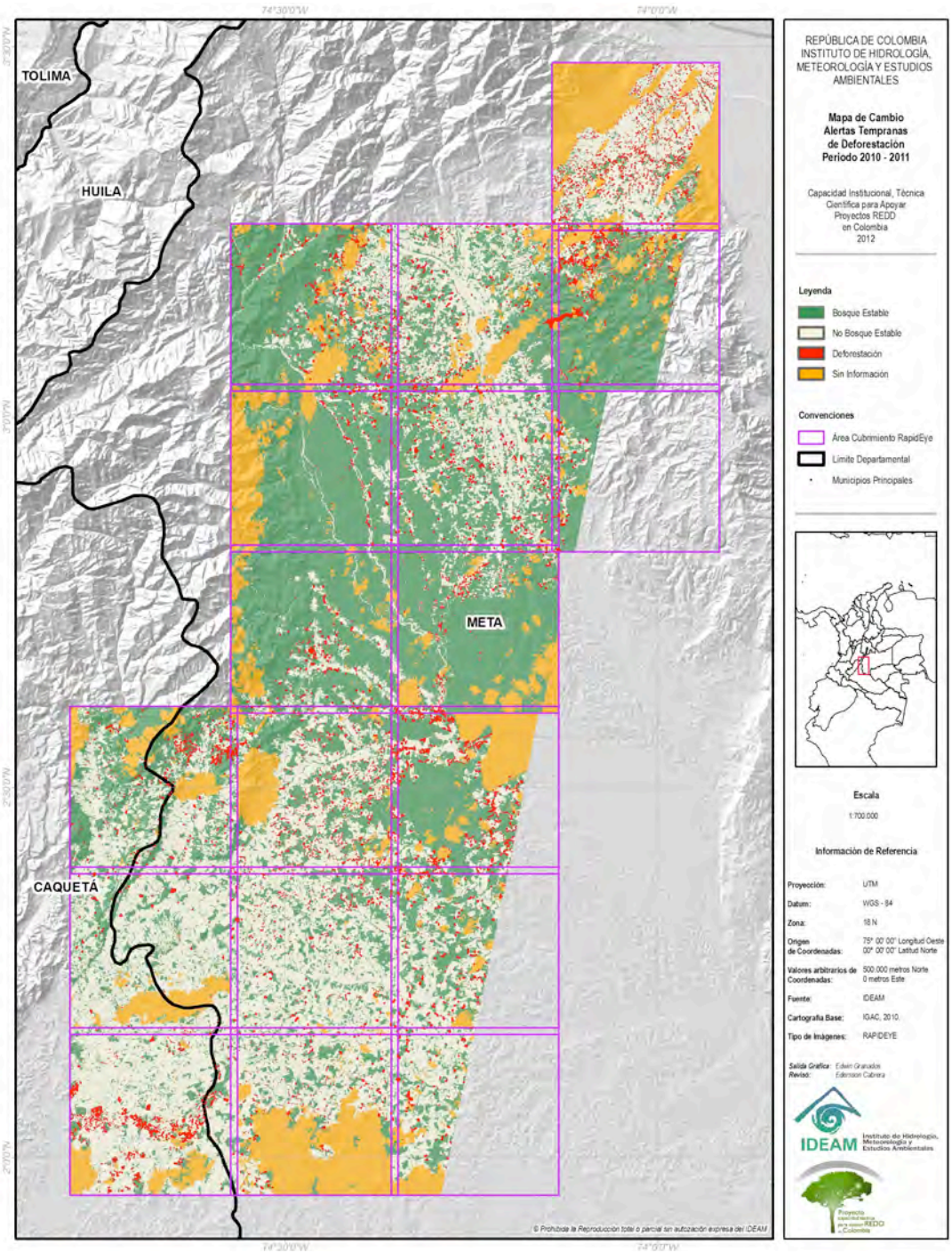


Figure 2.2.2. *Forest Change detection using Rapid eye 2009-2010 images.*

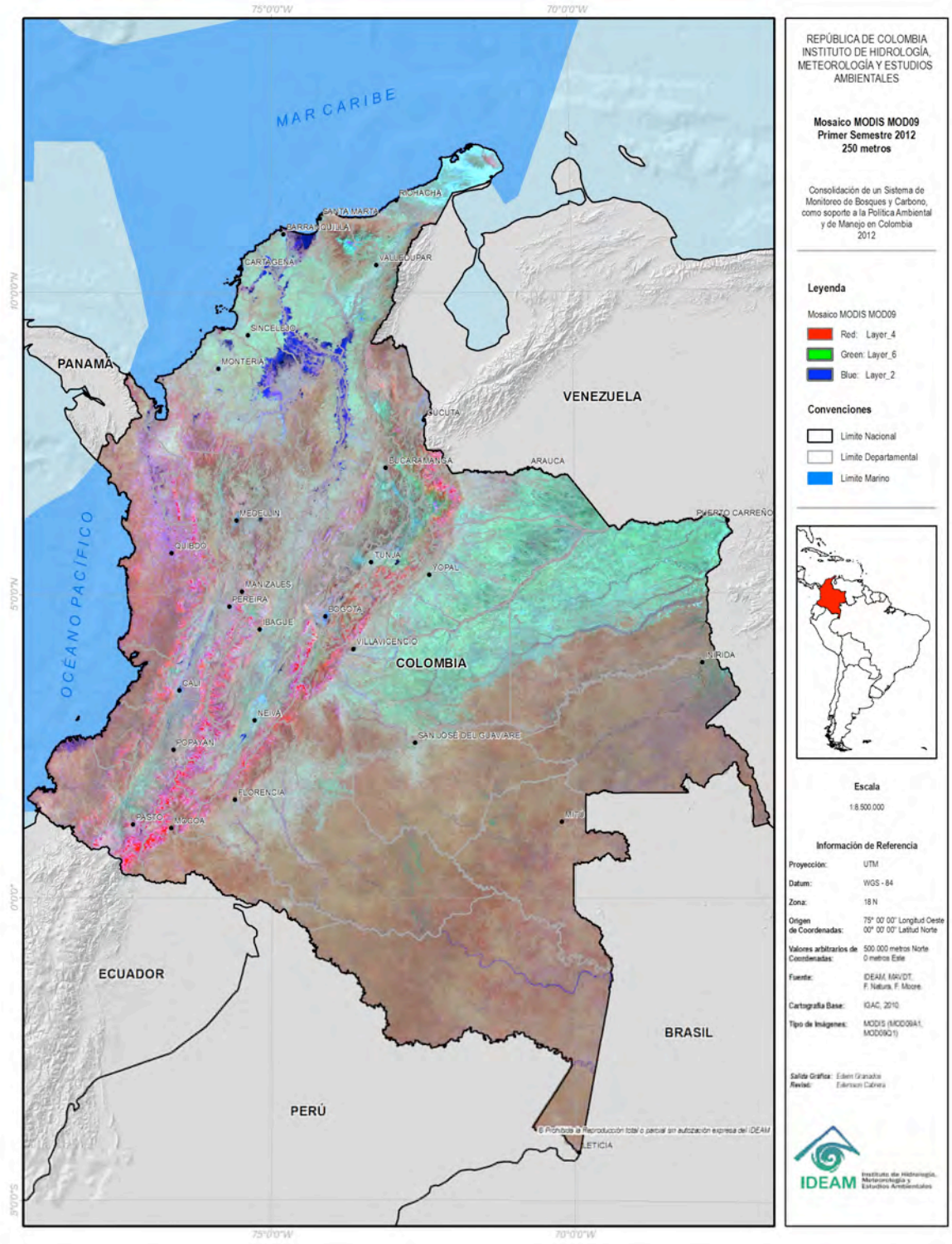


Figure 2.2.3. *MOD09 Composite for the first semester of 2012. RGB-261*

2.3 PERU

Work on data evaluation in the VS and country scale mapping activities is now progressing in Peru and will be reported upon in the next reporting cycle.

2.4 BRAZIL

Report from the Brazil National Demonstrator is expected shortly. It will be included in the next revision of this report, scheduled to be released prior to the 2012 GEO Plenary.

2.5 GUYANA

Reported by Dirk Hoekman (Univ. Wageningen)

2012 Activity Summary

- Product development activities in Guyana still on hold due to lack of funding for the PD development team.
- SarVision/Wageningen University took care of the pre-processing of all available GEO-FCT ASAR and RS-2 data of Guyana and shipped them to the Guyana Forestry Commission. (Even though financial support was not available)
- A Wageningen University PhD study includes activities in Guyana (focus on GUY-1 and GUY-2) using, amongst others, GEO-FCT and K&C data. It is funded primarily by the EU Recover project and will be completed early 2015.
- A progress meeting with the GFC was held early November 2011, in Georgetown.
- A first field visit to the Mahdia area took place during the second half of October 2011. During 2013 more field visits may follow (in the framework of the PhD study funded by the EU Recover project).
- Demonstration change products (for the Mahdia test site, a gold mining hot spot area) based on a combination of PALSAR and Landsat (radar/optical integration/synergy) were made (in the framework of the PhD study). Note that change refers to deforestation as well as forest degradation!
- Other relevant information: The progress made in Borneo/Sumatra is also relevant for Guyana. In principle, the systems (and training courses) developed in/for Indonesia, could be introduced very quickly in Guyana, and brought to operational level, with only minor modifications needed. The PD team has ample experience in Guyana from previous radar studies since 1990.

Remote Sensing Science Questions

- We would like to study the dense RS-2 time series (in FB-QP mode) collected for GUY-1 and GUY-2, however did not receive them (yet).

Planned activities over the next 6 months

- Study of dense PALSAR time series and PALSAR polarimetric data over selected sites

- Demonstration products for GEO-IX Ministerial and SDS#4
    - Deforestation/degradation product over Mahdia test site based on a combination of PALSAR and LANDSAT data [Fig.1].

Satellite data obtained during 2012

Sensor [year]	Coverage	Spatial resolution	Data provider	Obtained through GEO FCT
Landsat TM/ETM+ [2011-2012]	partly	25m (full)		No
ALOS PALSAR [2007-2010]	VS GUY-1; GUY-2 Dense time series	SLC	JAXA	Yes (no cost)
ALOS PALSAR [FBD single year]	wall-to-wall	Strip (w2w) 25 m	JAXA	No (K&C)
ENVISAT ASAR [2011]	Guyana	SLC	ESA	Yes (no cost)
RapidEye	Mahdia test site	6 m		No

Verification data

Field data collected in October 2011 during GFC supported filed trip to Mahdia area.

Auxiliary map data provided by the GFC GIS department

Demonstration products generated to date (Oct. 2012)

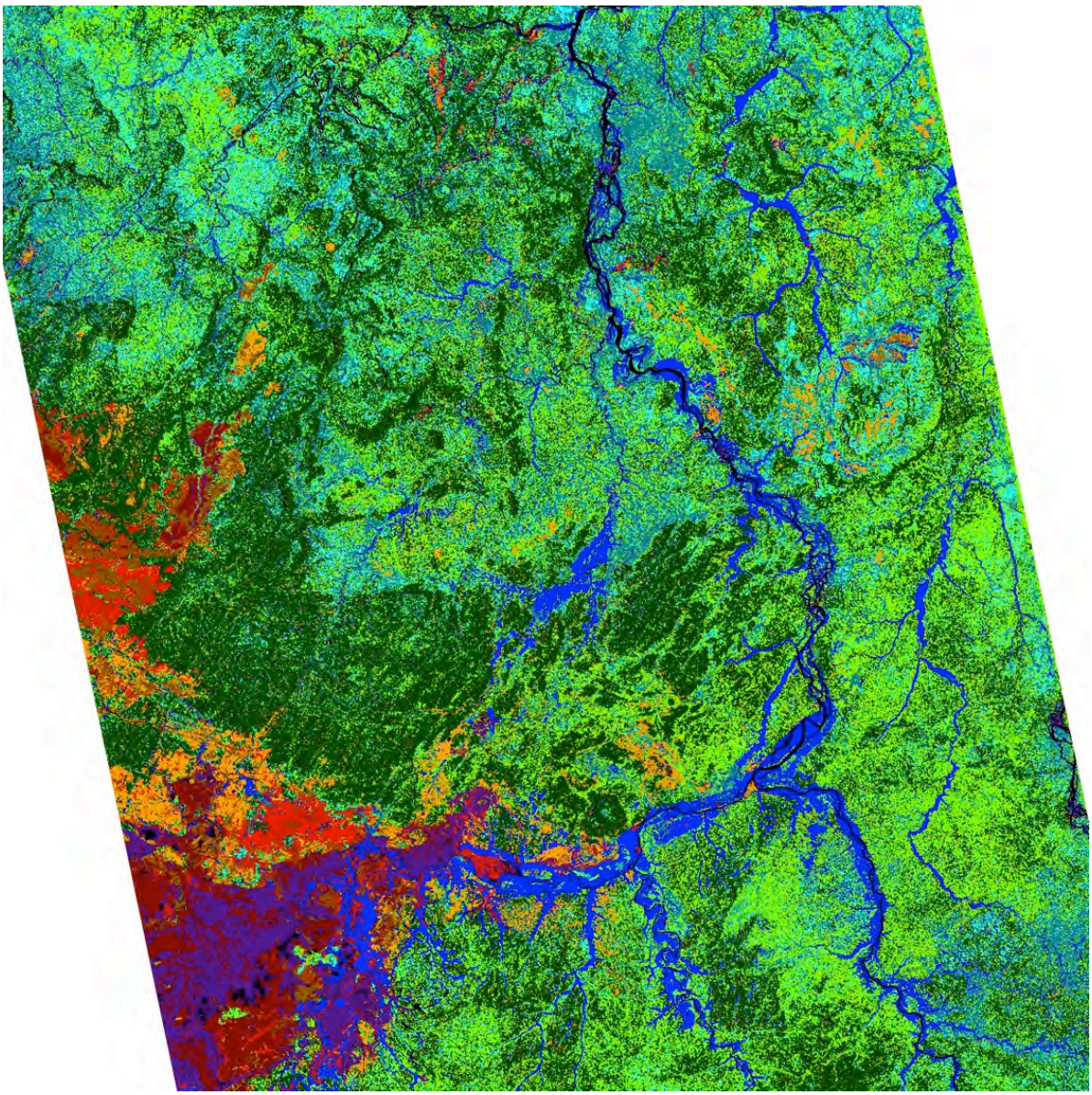
Thematic Product	Coverage	Spatial resolution	Data source [year]	Validation
PALSAR-Landsat Forest - Land Cover (FLC) change map 2007-2010 [Fig.1]	Mahdia test site	25 m	2007-2010	Yes [fieldwork and RapidEye]
Biomass stratification	Iwokrama	50 m	PALSAR FB	Yes [fieldwork]
Image Product	**Coverage**	**Spatial resolution**	**Data source [year]**	**Validation**
PALSAR w2w mosaic 2010	ND wall-to-wall	50 m	PALSAR FBS-FBD strip data [2010]	N/A
ASAR w2w mosaics 2010 and 2011	ND wall-to-wall	25 m	ENVISAT ASAR [2010-2011]	N/A
RS-2 w2w mosaic 2010	ND wall-to-wall	25 m	RS-2 [2010]	N/A

On-going product generation for CEOS Plenary, GEO Ministerial, COP-18 and/or SDS#4

Product/topic	Coverage	Data source [year]	Target
Biomass stratification map Iwokrama (Central Guyana)	Iwokrama	PALSAR [2007-2009]	2013
Dense time series analysis	GUY-1 and GUY-2	ASAR [2007-2011] PALSAR FBS-FBD [2007-2010]	2013 (Part of PhD-thesis)
Dense time series analysis	GUY-1 and GUY-2	RS-2 (FB-QP) (tbc) [2010-2013] Cosmo-SkyMed (tbc) [2011-2013]	2013 (Part of PhD-thesis)

Participation at SDS#4 (Australia, Feb, 2012)

Yes (supposing funding will be available)



Forest type	color
Mountain high forest	
Lowland High Forest	
Riparian high Forest	
Swamp forest 1	
Swamp forest 2	
Woodlands 1	
Woodlands 2	
Shrublands 1	
Shrubs in savanas	

Figure 2.5.1. *Update ALOS PALSAR forest map for Iwokrama (North Rupununi) area*

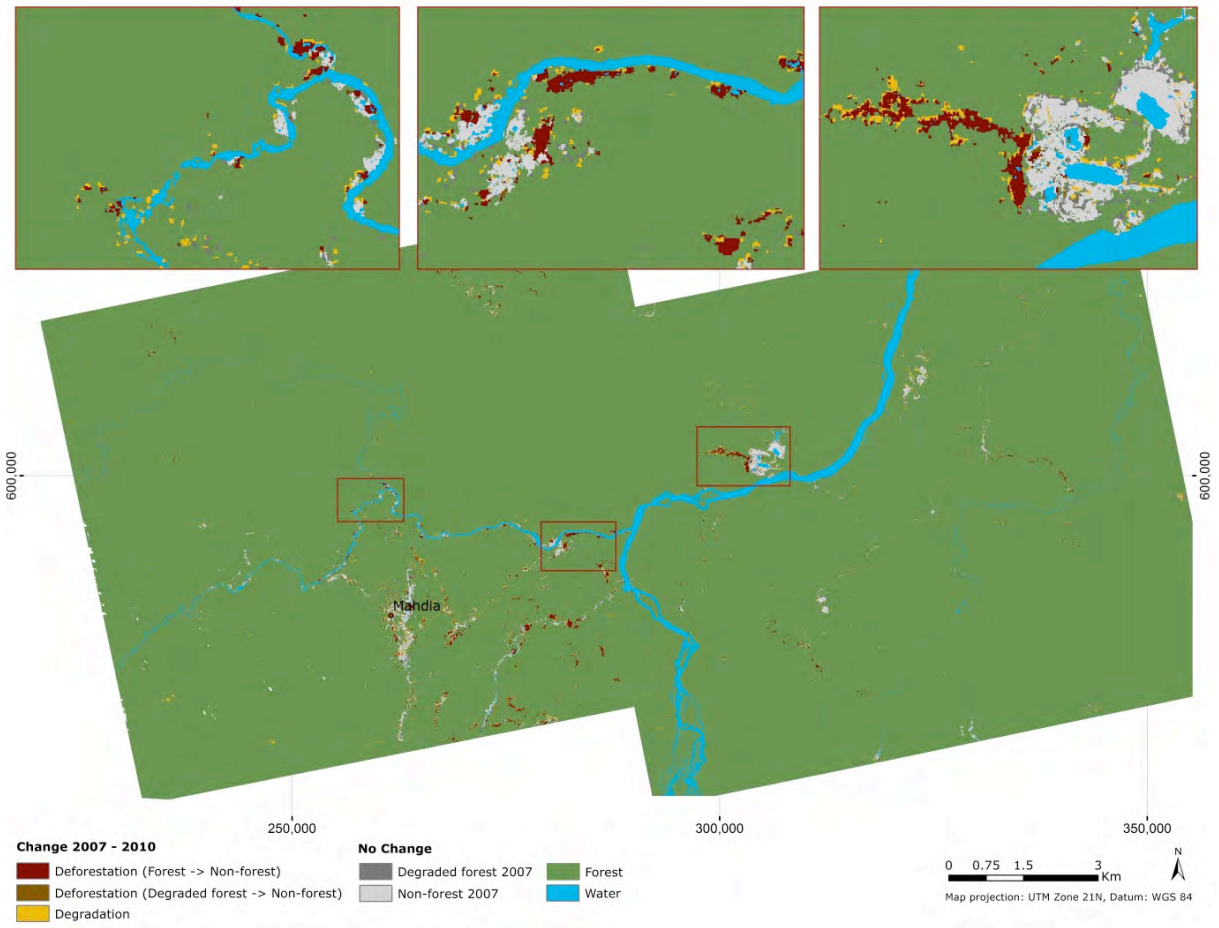


Figure 2.5.2. *ALOS PALSAR-Landsat Forest - Land Cover (FLC) change map 2007-2010 of the Mahdia mining district (central Guyana), including three map details (red boxes).*
Source: Reiche, Souza, Hoekman, Verbesselt, Persaud, and Herold, 2012; Feature level fusion of multi-temporal ALOS PALSAR and Landsat data for mapping and monitoring of tropical deforestation and forest degradation (accepted, IEEE-JSTARS)

2.6 CAMEROON

Reported by G. Ramminger (GAF AG) with contributions from R. Siwe (GAF), T. LeToan and S. Mermoz (CESBIO), Christophe Sannier (SIRS)

2012 Activity Summary

- Product development progress
    - Deforestation Mapping (FP7 project REDDAF)
        - The main objective in the first half of 2012 was to finalise the production of EO optical based Forest Cover/Forest Cover Change Maps and to optimise the classification of IPCC compliant land cover classes (within forest change areas).
        - The production of Forest Cover Maps for 1990, 2000 and 2010 in the Centre Province of Cameroon has been jointly finalised by GAF and SIRS in May 2012. The produced maps (1 ha MMU) are based on the classification of historic Landsat (TM, ETM) and current RapidEye data provided by the ESA managed GSC-DA, funded under ESA – EC agreement on the Implementation of the Space Component of Global Monitoring for Environment and Security (GMES). Accuracy Assessment and Quality Assurance has been finalised for the Forest Cover Maps. The accuracy assessment of the Forest Cover Change maps is foreseen for Phase 2 of REDDAF (end of 2012 to 2013).
        - Further improvements are foreseen with respect to the classification of Dry forest areas (where more than 1 dataset per epoch would be optimal to overcome the problem of misclassification due to non-foliated trees during dry season).
    - Degradation Mapping (FP7 project REDDAF)
        - The main objective in 2012 was to develop and implement viable methods for mapping degradation by overcoming the technical restrictions related to frequent cloud cover as well as complex degradation patterns in tropical forest areas.
        - A methodology has been developed jointly by GAF and SIRS. This methodology is using multi-temporal optical data. An algorithm based on NDVI comparison has been developed in order to detect disturbed area. The pre-processing of the EO data (multi-temporal, at least two different points in time) is comparable to the previous presented processing chain including geometric and radiometric adjustments of the used images, cloud and haze detection and mosaicking. Afterwards the NDVI is calculated for the different mosaics (her two mosaics based on data from 2009/2010 and 2011. A histogram match of each NDVI and a re-classification are the next

processing steps. After the subtraction of the reclassified NDVIs between the two points in time, the results are aggregated to 1 ha cells.

- Further improvements of the algorithm is necessary to achieve stable results as well as transfer the method to also detect other kind of forest disturbance

- Direct Biomass Mapping (FP7 project REDDAF)
  - The continuous development of methodologies/algorithms for direct biomass assessment using Cameroon prototype test site data is on-going. In particular, a significant result is the development of an approach to combine a physical model and experimental data in an inversion model. This is particularly adapted to regions where not much extensive in situ data are available. For example, for the test region in Cameroon, an approach has been developed that consists in selecting a small number of plot data (SAR and in situ) for calibrating the model. The rest of the plot data are then used for validating the result. New inversion approaches (Bayes, Support Vector Regression) have also been tested. The accuracy assessment of the generated biomass map is in progress. This task will be achieved after the finalization of the quality assessment.
  - The objective of the activity is to develop and test methods to directly assess biomass in African tropical forest landscapes (low biomass regions) using EO data. The work is based on existing efforts conducted by CESBIO; a processing chain has been implemented in Cameroon based on current satellite data, and available in situ (Field mission in January/February 2012 in Cameroon) and ancillary data. The activity in 2012 included the following:
    - Collection of in-situ data in Cameroon
    - Development and refinement methodologies/algorithms for direct biomass assessment over the Adamawa Cameroon test site (15000 km2) based on derived in-situ data
    - Determine the requirements of in situ data for calibration and validation of the retrieval methods using PALSAR data

- Field data collection campaigns
  - Field Survey for EO-Direct Biomass Measurement was carried out in the Adamawa region. The objective of the fieldwork was to conduct terrestrial AGB measurements to provide data for calibration and validation of direct biomass assessments and to obtain ground truth data and ancillary information from the field to facilitate the interpretation of the satellite images and support the verification of the classified products.

- Training courses attended and/or given
    - In the scope of REDDAF a training session was organised in Yaoundé from the August 8th-19th 2012. 17 participants attended, comprising technical staff from government administrations; the Ministry of Environment, Nature Protection and Sustainable Development (MINEPDED), Ministry of Forestry and Wildlife (MINFOF); academic institutions, University of Yaoundé, IITA and Non-governmental organisations; Centre of Environment and Development (CED). The training material comprised lectures and practical exercises using open source software for satellite image processing. Participants received instructions on how and where to download freely available satellite images. It should be noted that freely available data does not necessarily guarantee access due to the slow internet transmission in the ND country. SPRING was used to provide practical exercises on satellite image interpretation: calculation of vegetation indices, forest/non-forest classification, and accuracy assessment; and GIS exercises were performed using Quantum GIS.
    - A final 2-week training is envisaged in the scope of REDDAF and will focus on presenting the REDDAF final results and discuss its utility for the REDD national process.

- Level of involvement with ND country members (at management level vs. at technical level)
    - The GEO-FCT Focal Point and the UNFCCC Focal Point main counterparts. Cameroon has recently submitted the first draft of its R-PP which outlines the REDD MRV road map. Some of the REDDAF trainees directly participated in the elaboration of this document. It is worthwhile to mention that institutional and infrastructural capacity building is fundamental for an active involvement of the ND. Consequently, there is no direct involvement of the ND country in the technical implementation of the REDDAF and/or GEO-FCT project activities. An effective involvement should consider procuring the necessary software and hardware as well as build on the trainings that have been implemented in the framework of this project.
    - At a management level, the focal points have been informed of the objectives of the project and they facilitate all in-country activities (training workshops, field missions etc.) related to the project.

- Organisation within the ND that is involved in the product generation
    - As aforementioned, the ND is not involved in product generation due to lack of capacity: infrastructure (hardware and software).

- Validation efforts and results
    - A separate field mission has been conducted in January 2012 to get field samples as basis to improve the model for direct Biomass Mapping based on ALOS PALSAR as well as validate the results.

Planned activities over the next 6 months

- Deforestation Mapping (FP7 project REDDAF):
  - Introduction of new classes (Dry Forest, Plantations,...)
  - Improve the classification accuracy in areas with Dry Forest (use of multi-temporal time series)
  - Finalisation of Forest Cover and Forest Cover Change Mapping in the demonstration site (Centre Province of Cameroon) using ALOS PALSAR data to fill existing cloud gaps and further enhance the classification in areas with Dry Forest
  - Verification and Validation of Forest Cover Change Maps

- Degradation Mapping (FP7 project REDDAF):
  - Further improvement of the preliminary degradation map

- Direct Biomass Assessment (FP7 project REDDAF):
  - Validation of the generated biomass map and refinement of the methods
  - Proposition of viable processing chains for the biomass assessment that can be implemented in Cameroon

Satellite data obtained during 2012

Sensor [year]	Coverage	Spatial resolution	Data provider	Obtained through GEO FCT
ALOS PALSAR [2007, 2008, 2009,2010]	ND wall-to-wall	SLC (full)	JAXA (K&C)	No
RapidEye	VS Pallisco (Eastern Province)	6,5m (full)	RapidEye	Yes
Geoeye/Worldview	Centre province (REDDAF demonstration site)	MS and PAN (full)	ESA	No (GMES GSCDA for FP7 projects)

Verification data

- In situ date collected during field missions
  - Field Survey for EO-Direct Biomass Measurement, carried out in the Adamawa region. The objective of the fieldwork was to conduct terrestrial AGB measurements to provide data for calibration and validation of direct biomass assessments in forest-savannah transition regions based on ALOS PALSAR L-band full polarization data.
  - Field Survey for Training Site information: The main objective of the field mission was to obtain ground truth data and ancillary information to facilitate

the interpretation of the satellite images and to support the verification of the classified products:

- Other data sets (specify)
  - **DEM:** Terrain heights for the Ortho-Image production were taken from the standard 3 arcsec SRTM DEM (SRTM = Shuttle Radar Topography Mission), providing a ground spatial resolution of 90m x 90m. The height accuracy is specified to be 6m relative and 16m absolute.
  - **WRI – Interactive Forestry Atlas:** The Interactive Forestry Atlas of Cameroon was produced by a collaborative effort between the World Resources Institute's (WRI) Global Forest Watch (GFW), the Cameroon Ministry of Forestry and Wildlife (MINFOF), the Limbe Botanical and Zoological Gardens (LBZG), and Cameroon Environmental Watch (CEW). The Version 2.0 has been used as support data for the production process.
  - **GADM database of Global Administrative Areas:** "GADM is a spatial database of the location of the world's administrative areas (or administrative boundaries) for use in GIS and similar software.

Demonstration products generated to date (Oct. 2012)

Thematic Product	Coverage	Spatial resolution	Data source [year]	Validation
Forest Cover Map 1990	Centre Province of Cameroon wall-to-wall	20 m (1 ha MMU)	Landsat TM/ETM+ [1984-1990]	Yes (independent re-interpretation of Landsat data, no historic VHR available)
Forest Cover Map 2000	Centre Province of Cameroon wall-to-wall	20 m (1 ha MMU)	Landsat TM/ETM+ [1998-2003]	Yes (independent re-interpretation of Landsat data, no historic VHR available)
Forest Cover Map 2010	Centre Province of Cameroon wall-to-wall	10 m (1 ha MMU)	RapidEye, ETM+ [2009-2011]	Preliminary (independent re-interpretation of RapidEye data). Acquisition of VHR data to do proper accuracy assessment (planned in near future)
Forest Cover Change Map 1990 to 2000	Centre Province of Cameroon wall-to-wall	20 m (1 ha MMU)	Landsat TM/ETM+ [1984-2003]	On-going

Forest Cover Change Map 2000 to 2010	Centre Province of Cameroon wall-to-wall	10/20 m (1 ha MMU)	Landsat TM/ETM+ [1998-2011]	On-going
Biomass map	ND VS (Adamawa region)	25 m	ALOS PALSAR [2007-2010]	On-going
Preliminary Degradation Map	ND VS (Pallisco site in Eastern Province)	10m	RapidEye, ETM+ [2009-2011]	TBD
Image Product	**Coverage**	**Spatial resolution**	**Data source [year]**	**Validation**
Satellite image mosaic	ND wall-to-wall for Centre Province (REDDAF demonstration area)	20 m/10 m	Landsat TM/ETM+ [1990, 2000], Rapideye [2010]	N/A
Radar satellite image mosaic (ALOS PALSAR)	ND VS (Adamawa region)	25 m	ALOS PALSAR [2007, 2010]	N/A

On-going product generation for CEOS Plenary, GEO Ministerial, COP-18 and/or SDS#4

Product/topic	Coverage	Data source [year]	Target
Degradation Map (improved Version 2)	ND VS (Pallisco site in Eastern Province)	RapidEye [2009/2010/2011]	SDS#4

Participation at SDS#4 (Australia, Feb, 2013)

To be decided at a later stage

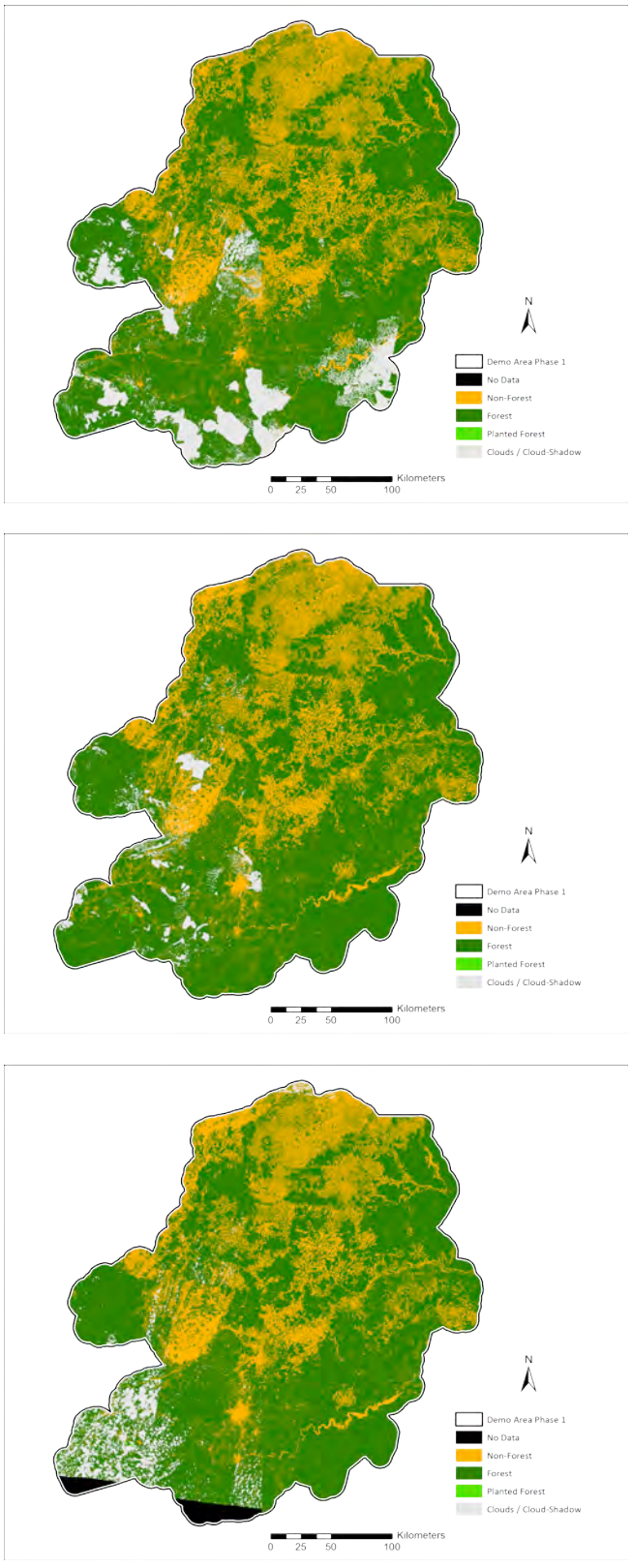


Fig 2.6.1. *Deforestation Mapping- During phase 1 of REDDAF Forest Cover & Forest Change Maps (incl. classification of changes into IPCC compliant Land use classes) were produced for the epochs 1990 (top), 2000 (middle) and 2010 (bottom). HR optical satellite data (Landsat TM4/TM5/ETM+ , RapidEye, Deimos) – Demonstration area Centre Province of Cameroon (~68.000 km²)*

In phase 2 it is planned to focus on the improvement of the produced maps by closing existing cloud gaps in 2010 using additional SAR data (e.g. ALOS PALSAR), introducing new thematic classes (e.g. Dry Forest, Plantations) and developing a robust approach for the accuracy assessment of Change areas.

Fig is providing results of the Forest Cover Change Map product showing an area in the North-Western part of the Centre Province (Cameroon) with deforestation between the epochs 2000 and 2010.

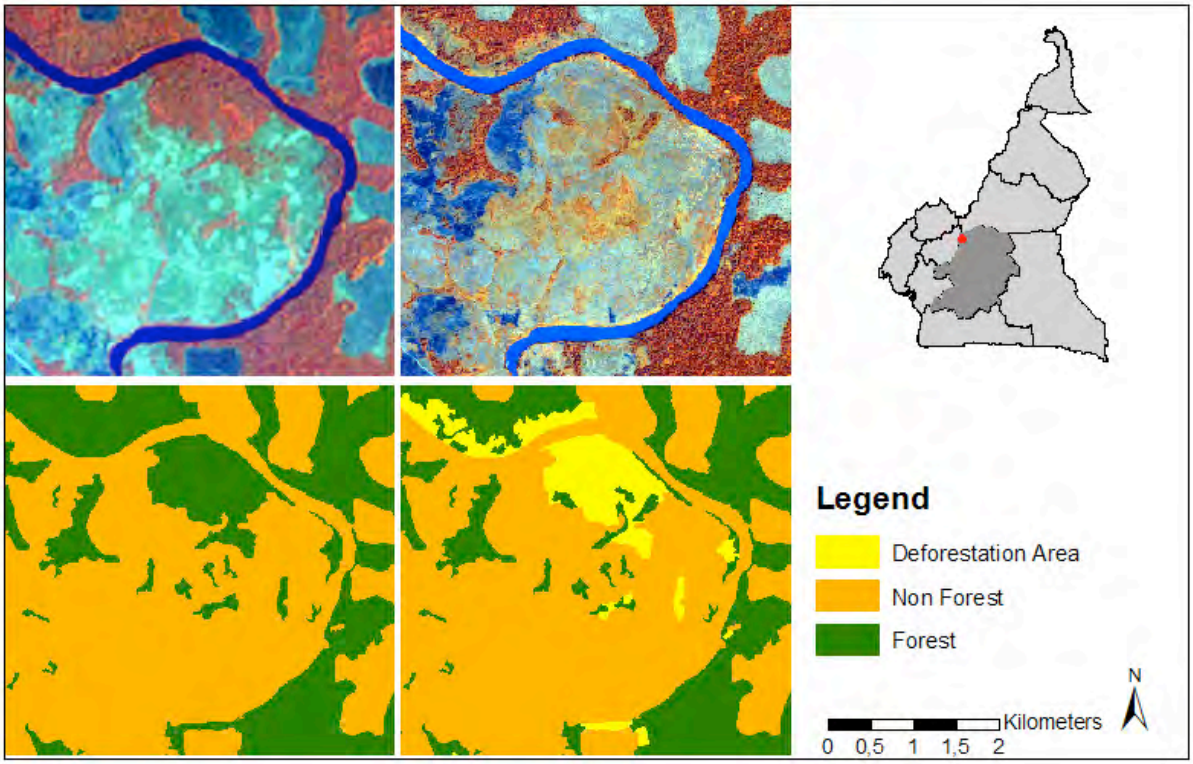


Figure 2.6.2. *Forest Cover Change between 2000 (Landsat ETM) and 2010 (RapidEye), north of the Centre Province in Cameroon*

Degradation Mapping (FP7 project REDDAF):

The methodology being developed by both service providers GAF and SIRS has been used to calculate the degree of degradation and regeneration in a demonstration area of about 10.000 km² located in the Eastern Province of Cameroon (near Forest Concession of Pallisco). Selective logging is the main reason for degradation in this area. Figure 2.6.2 below is providing first results of the method showing an area with new logging activities, which have taken place in 2010/2011.

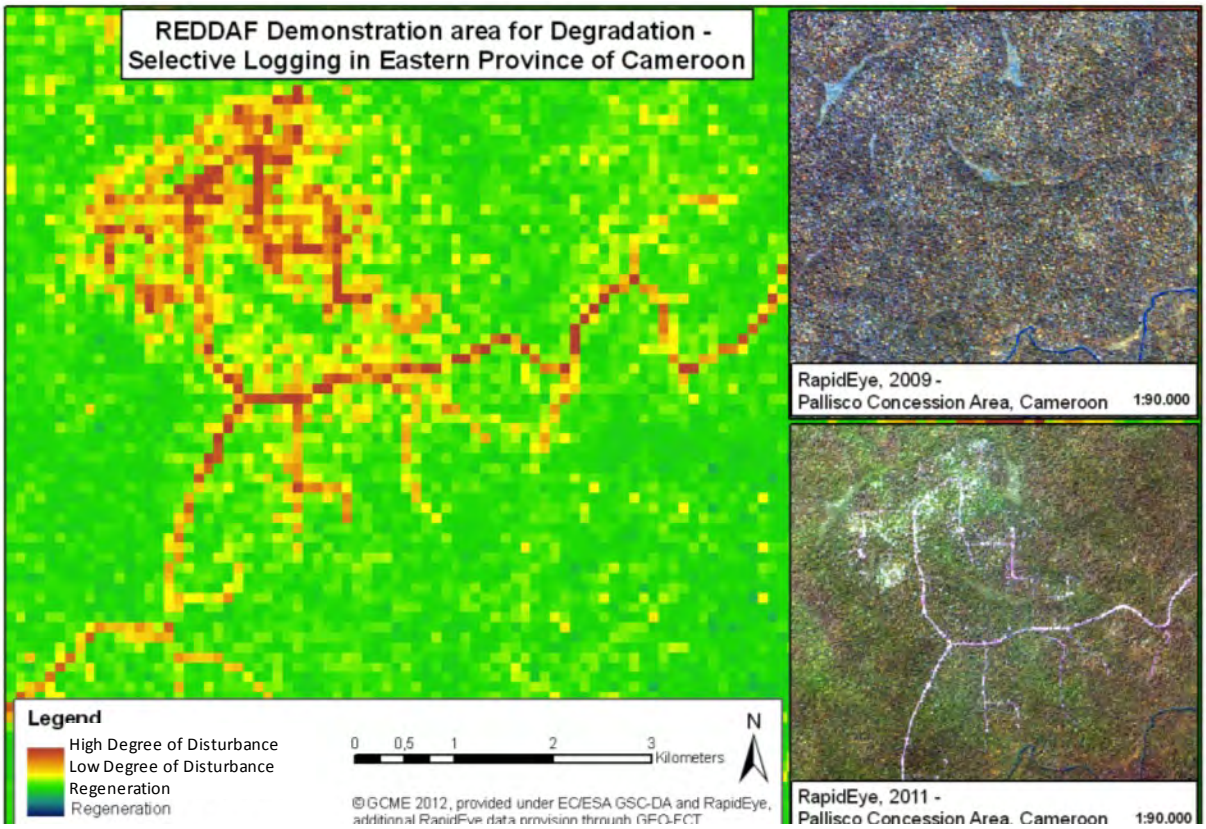


Figure 2.6.2. *Preliminary degradation product based on NDVI and multi-temporal data (RapidEye data from 2009 to 2011). The results are showing different degrees of degradation due to selective logging calculated in 1 by 1 ha units with (Eastern province of Cameroon).*

The differences between the images 2009 and 2010/2011 are clearly visible. New logging roads have been built up and in some areas, logging activities have already been finalised. The results are providing different degree of disturbance based on a 1 by 1 ha grid. In phase 2 of REDDAF it is foreseen to further improve the methodology.

Fig below is showing degraded as well as forest areas with new regeneration.

Direct Biomass Assessment (FP7 project REDDAF):

Figure 2.6.4 below presents the biomass map of the study area in the Adamawa region. The map is derived from ALOS PALSAR data.

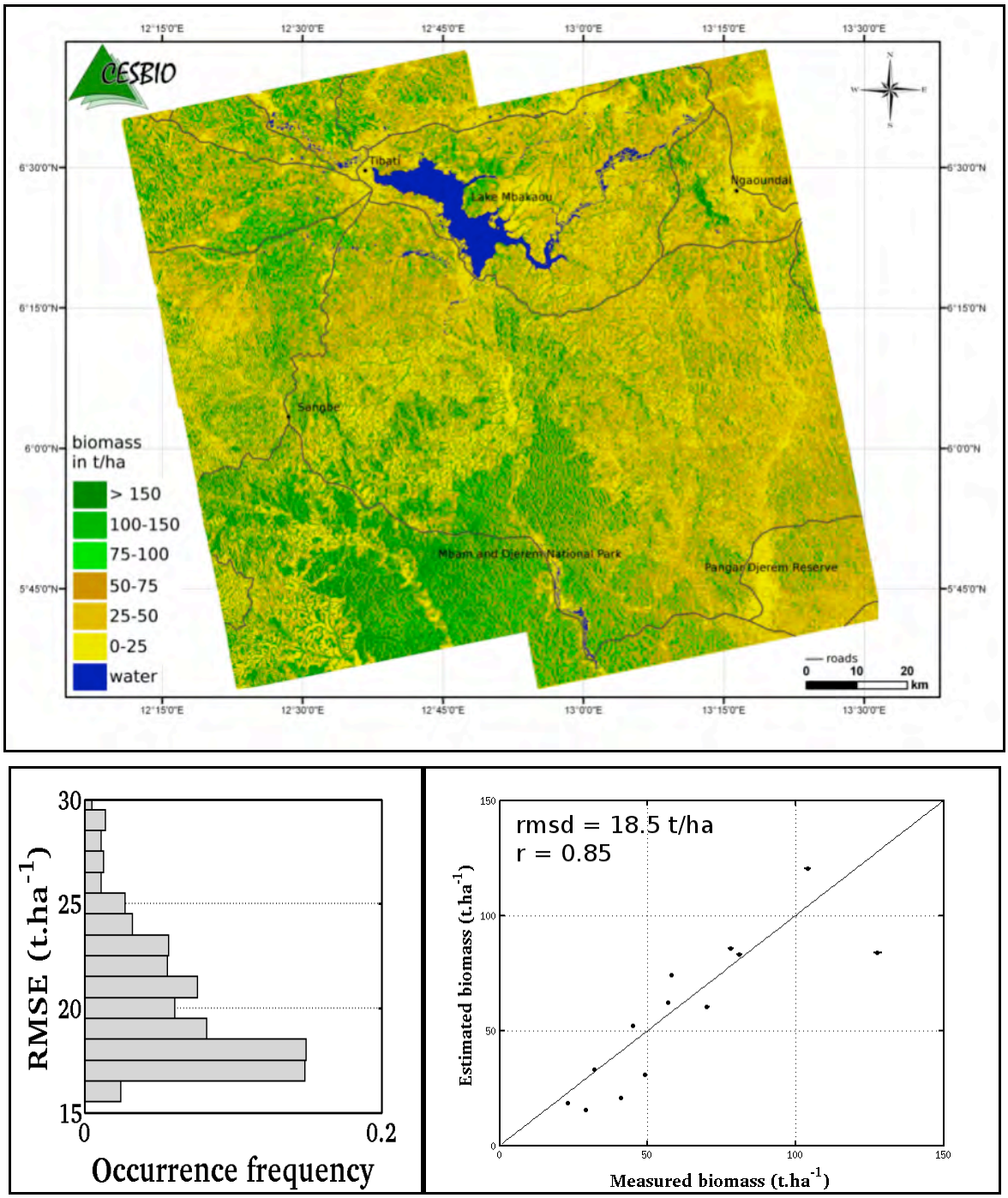


Figure 2.6.4. *Region of Adamawa, central Cameroon (about 110km x 120 km). The histogram (bottom left) shows accuracy assessment result based on a random selection of 3 in situ plot data and validation of the result with the remaining plots after 1000 realizations. The last figure (bottom right) is one of these realizations. In this example, the root mean square error is of 18.5 t/ha and the Pearson correlation coefficient 'r' is of 0.85. The probability that 'r' is significant is up to 90%.*

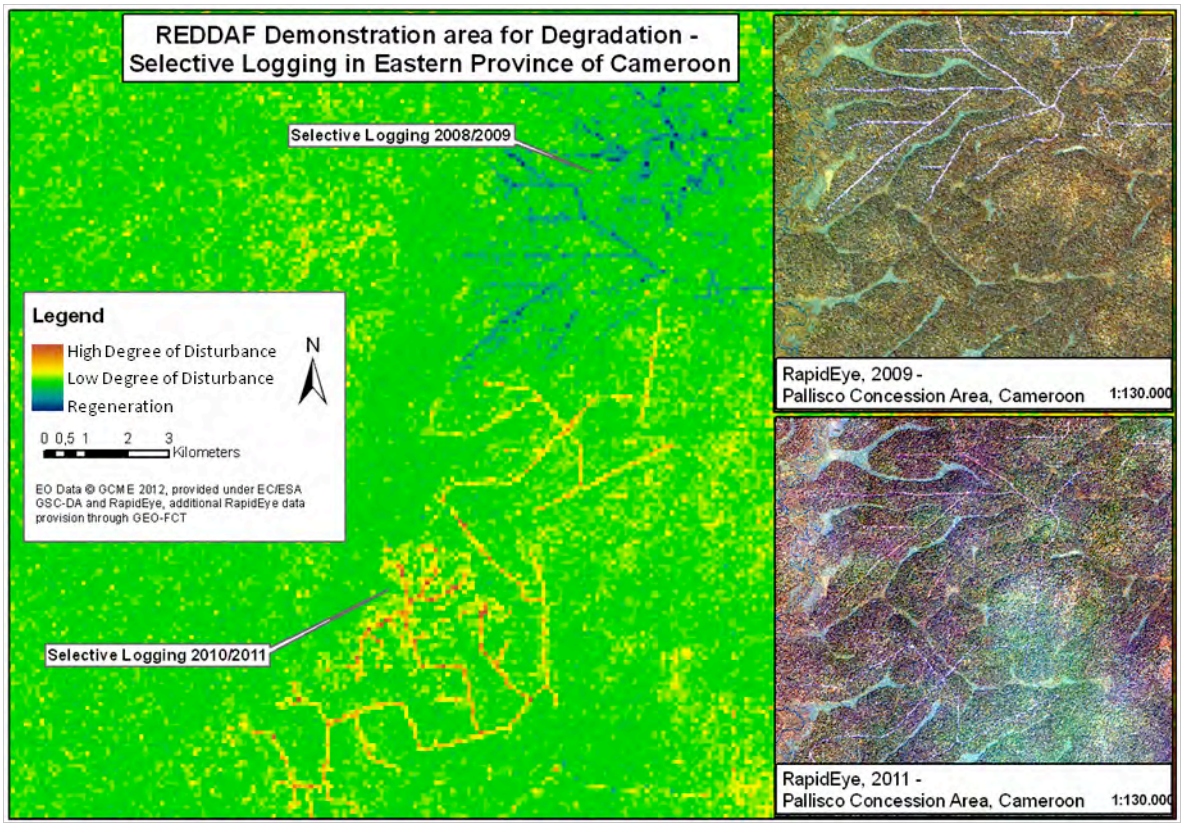


Figure 2.6.5. *Preliminary degradation product based on NDVI and multi-temporal data (RapidEye data from 2009 to 2011). The results are showing different degrees of degradation and regeneration calculated in 1 by 1 ha units with (Eastern province of Cameroon).*

Logging activities took place between 2008/2009 in the northern part of this area and new logging activities have been detected more in the south based on EO data from 2010/2011. In Phase 2 it is planned to focus to improve the new algorithm and test it in other areas, where degradation is caused by other reasons than selective timber exploitation.

2.7 DEMOCRATIC REPUBLIC OF THE CONGO

Reported by Christophe Musampa Kamungandu (DIAF), Landing Mane (OSFAC)

2012 Activity Summary

- Key Activities

  A workshop was held in Kinshasa from June, 12 to 14 on monitoring, inventory and forest carbon. Several organizations participated in this meeting, among them: DRC Minsitry of Environment (DIAF), USGS, USFS, USAID, CARPE, OSFAC, UMD, DRC National REDD Coordination, WWF, WRI, Norut (Norway), OFAC, national NGOs. This workshop was an opportunity to officially launch GEO FCT Program in DRC. The schedule of activities has been defined and presented to the various partners.

  Groups worked on three main topics:

  Group 1: Land and Sampling

  Group 2: Geospatial Data, Satellite and Aerial data, field data: Acquisition, processing, interoperability, sharing and dissemination, capacity building

  Group 3: Forest inventory, carbon maps production and Roadmap

  Workshop report is available in French version and English version is in preparation. Workshop presentations can be downloaded at the following address:

  ftp://ftp.earthobservations.org/FCT/GEO%20FCT%20DRC%20Workshop%2012-14%20June%202012/

- Product development progress
  - DRC National Forest Inventory:
    - Map of the location of selected sites for implementation of forest carbon inventories (NFI) in DRC.
    - Sites representatives of different types of forest ecosystems in the country.
    - Inventory work should started in 2012 with support from FAO-UNREDD and the Government of Japan.
  - The National forest monitoring by satellites (SSTS) or Terracongo DRC is set up with the support of FAO-UN REDD Program according to the model developed by INPE Brazil for TerrAmazon. This tool is for forest cover, deforestation and degradation evaluation to estimate carbon stock in the framework of MRV for REDD+. The results will be made available to the public for their information and interaction through the web portal.
  - Preliminary Biomass Carbon map for the DRC
    - Assessment of biodiversity and other aspects of interest to the planning for multiple benefits from REDD+;

- Collaboration between Ministry of environment of DRC (DIAF), OSFAC, UNEP-WCMC;

o Use of spatial analysis

- Several data sources used for biomass carbon map for the DRC (Above- and below-ground biomass).
- MODIS NBAR data from 2000-2003 (Baccini et al. 2008) for above-ground biomass in t/ha
- Ecosystem-specific root-to-shoot ratios (FAO 2006) + FAO ecological zones to distinguish between ecosystems (FAO 2001) applied to derive below-ground biomass
- Carbon mass estimated as half the biomass (Gibbs and Brown 2007).
- Total carbon: **24.5 Gt**.
- More than half of this biomass carbon located in areas of high and very high biomass carbon density
- These areas cover about **52**% of the area of the country

o FACET Atlas

- Monitoring the forests of Central Africa using remotely sensed data sets
- An OSFAC initiative to quantitatively assess the spatio-temporal dynamics of Central African forests using multi-temporal satellite data.
- DRC (1st Publication)

o Statistics produced show

- In 2010, the forest cover estimated to 1,558,174 km² (about 60%) of the DRC territory.
- Between 2000 and 2010, the deforestation rate of 2.34% (1.09% in 2000-05 and 1.25% in 2005-10).
- Low rate of deforestation within protected areas and the CBFP landscapes = positive impact of actions in the field of conservation and forest management.

• Field data collection campaigns

Field Validation of FACET is underway with a team of DIAF, OSFAC, University of Maryland and ERA. Area already visited are: Jolu (Equateur), Kimvula (Bas Congo) and Inongo (Bandundu).

Figure 2.7.1. *FACET validation and biomass measurement (Inongo area, DRC)*

Remote Sensing Science Questions

Through a specific Service Level Agreement (SLA), OSFAC has requested the following products: a) optical and SAR image mosaics, b) optical and SAR based forest / land cover maps, c) biomass maps, d) forest area change maps and e) forest degradation maps. A first iteration of the products a, b, and c has been delivered to OSFAC in spring 2012 by the responsible team composed by its lead, Norut (Norway), and partners, GMV (Spain) and Albert-Ludwigs-Universität Freiburg (ALU-FR, Germany) and assessed by the user.

Planned activities over the next 6 months

After the official launch of GEO in DRC, planned activities during the workshop will start on the ground:

- National forest inventories and quantification of biomass,
- monitoring of forest cover by satellites (optical and radar data),
- sharing satellite and field data,
- Capacity building, etc.

Participation at SDS#4 (tentatively Australia, Feb, 2013)

Yes, we (DIAF and OSFAC) wish to participate at the 4rd Science and Data Summit.

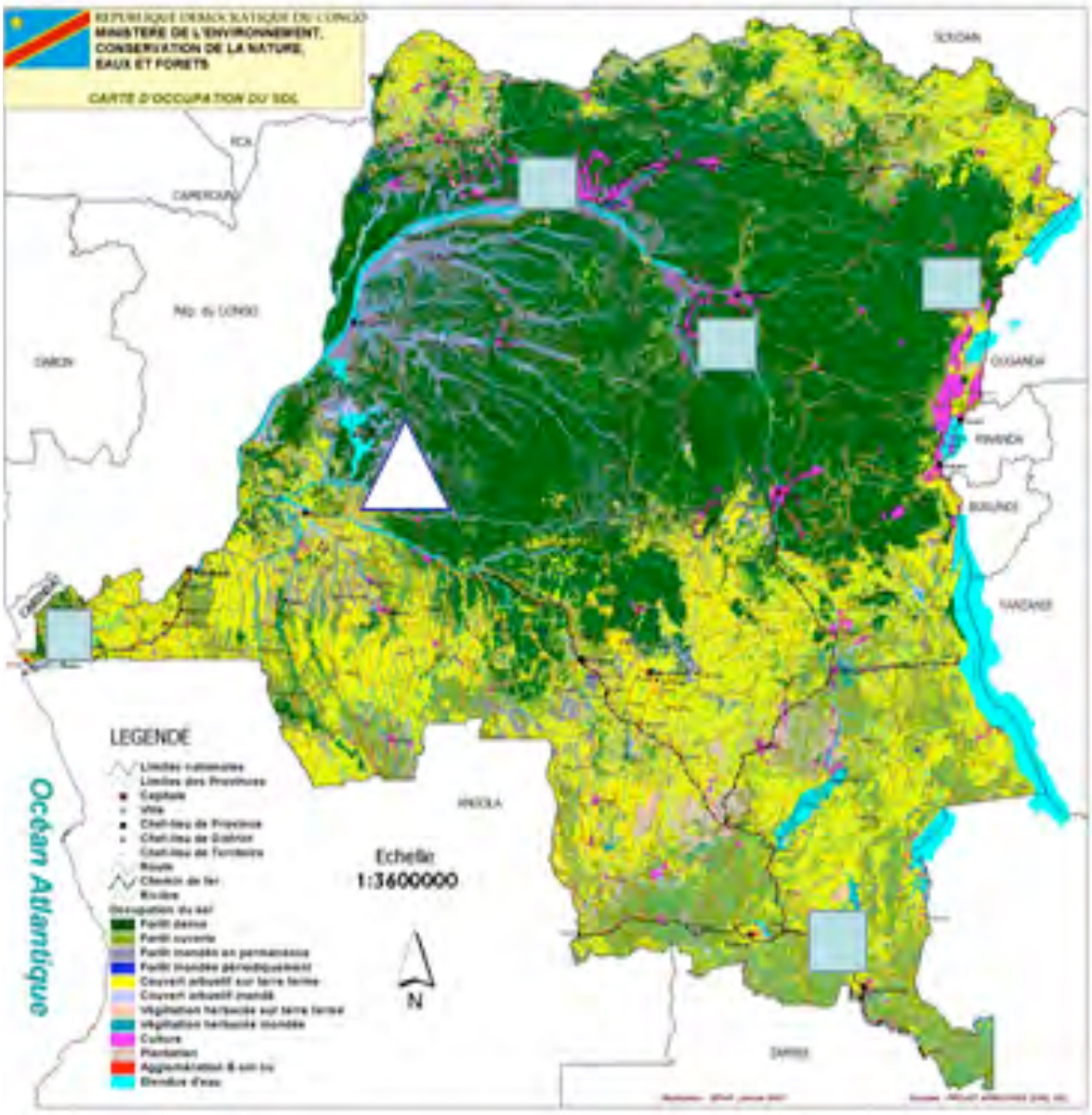


Figure 2.7.2. *DRC National Forest Inventory. Map representing different types of forest ecosystems and location of selected sites for implementation if forest carbon inventories (NFI) in DRC*

Figure 2.7.3. *The National forest monitoring by satellites (SSTS) or Terracongo DRC. This tool is for forest cover, deforestation and degradation evaluation to estimate carbon stock in the framework of MRV for REDD+. The results will be made available to the public for their information and interaction through the web portal*

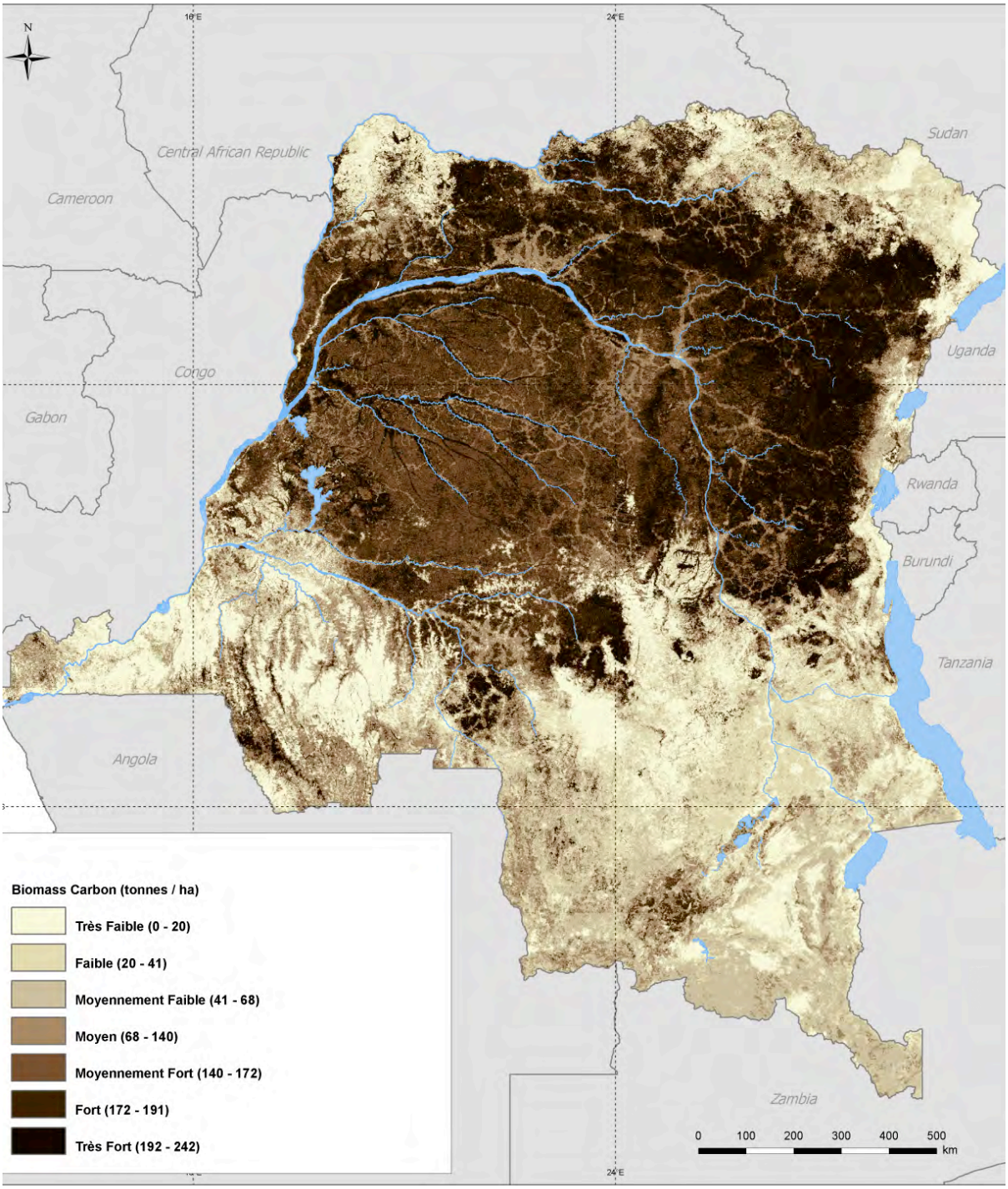


Figure 2.7.4. *Preliminary Biomass Carbon Map for the DRC.*

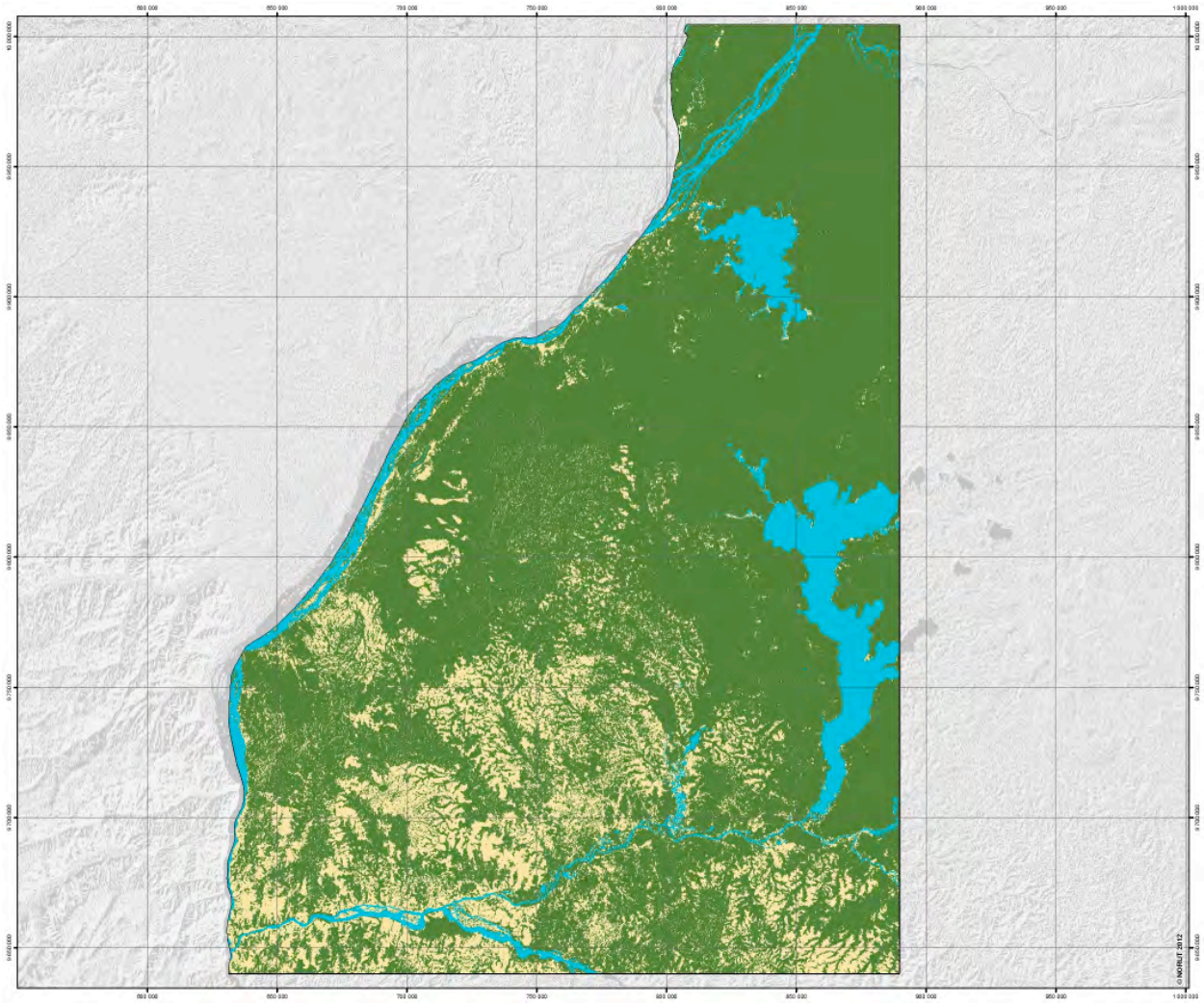


Figure 2.7.5a. 2000 ERS-2 Imagery Layers: Bandundu Area ;
Classification Forest/Non-Forest from ESA ERS-2 WSM (C-band, VV) ;
Dates range from 03/10/2000 ; Map Projection: UTM Zone 33S WGS 1984

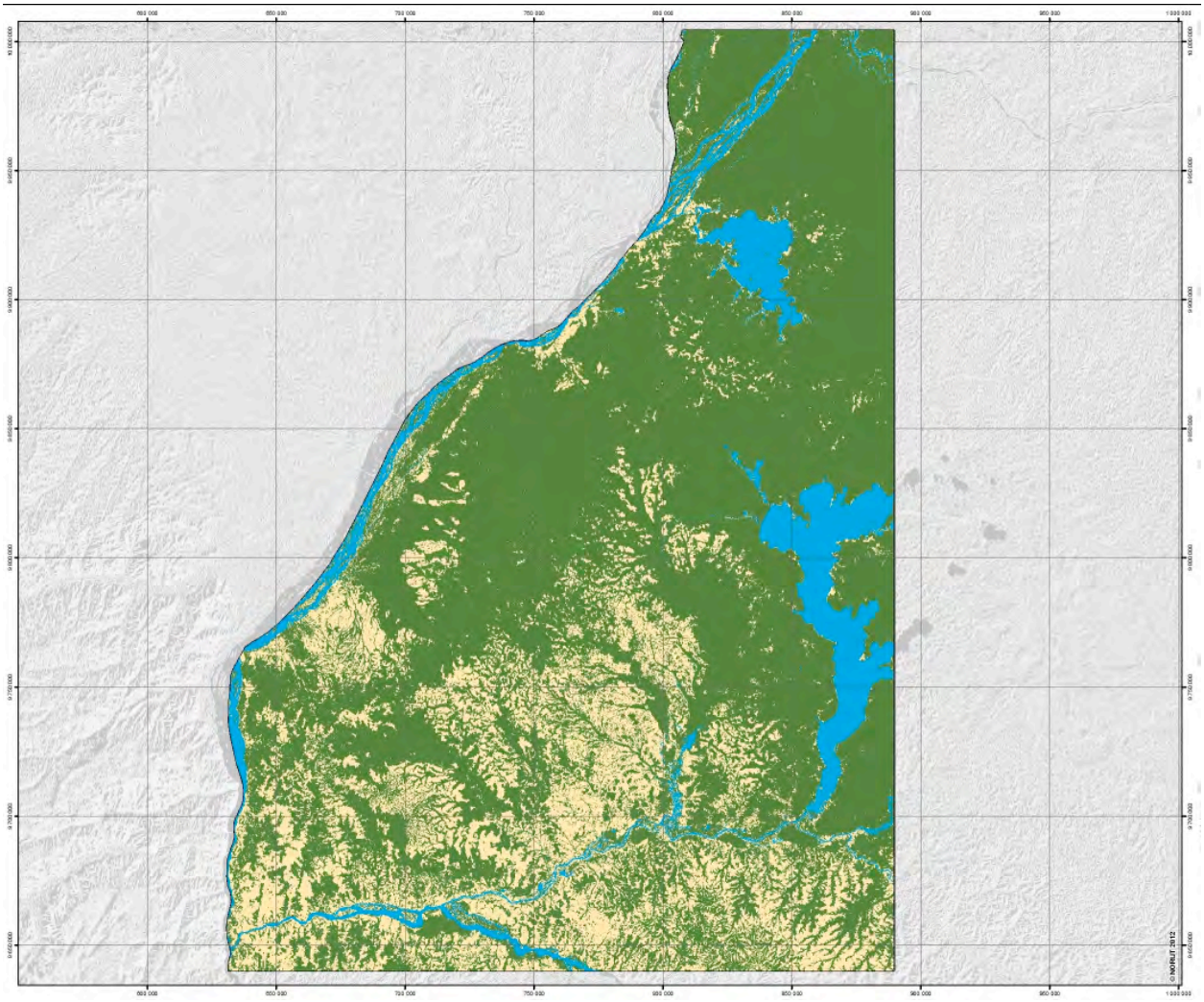


Figure 2.7.5b. *2005 Envisat ASAR Imagery Layers: Bandundu Area ;*
Classification Forest/Non-Forest from ENVISAT ASAR WSM (C-band VV) ;
Dates range from 25/01/2005 to 20/11/2005 ; Map Projection: UTM Zone 33S WGS 1984

2.8 TANZANIA

Reported by: Richard Lucas (NSC consultant/Aberystwyth Univ), based on input from the project partners in the LIDAR/FCT project, with contributions provided by Eliakimu Zahabu and Emmanuel Luoga (Sokoine University of Agriculture), Joerg Haarpaintner (Norut), Øivind Due Trier (the Norwegian Computing Centre), Stian Normann Anfinsen (University of Tromsø), Erik Næsset (University of Life Science) and Svein Solberg (The Norwegian Forest and Landscape Institute).

2012 Activity Summary

- Acquisitions of LiDAR data over Liwale and Amani commenced in January 2012 and were completed in February 2012 by a South African Aviation Company and Norwegian instrument operator.
- LiDAR data have been processed and checked for quality and completeness.
- Field data from sample plots were acquired for both Amani and Liwale in 2011-2012 by UMB supported by SUA and completed in November, 2012. Plots were re-measured in March–June 2012 as there was concern that the NAFORMA data were not representative of conditions at the time of the LiDAR acquisition because of deforestation and degradation in the intervening period.
- Worldview-2 data have been acquired for subsets of the areas covered by LiDAR.
- Coverage maps for the main sensors (e.g., Rapideye, Worldview, Landsat, ALOS PALSAR and ENVISAT ASAR) have been generated for the test sites and Tanzania as a whole. Landsat image footprints covering the main vegetation types in Tanzania have also been identified (Figure 1).
- Allometric equations have been generated for Miombo woodlands and harvesting within other forest types (e.g., mangroves, pine plantations) has been undertaken to generate a wider range of equations.
- Land cover classes representing the main forest types/biomass have been identified and representative areas identified to support the classification of the remote sensing data. The land cover scheme based on NAFORMA classes has been identified as appropriate for classification of the imagery.
- Preliminary classifications of dense forest, sparse forest and non-forest have been generated for selected sites based on combinations of ENVISAT ASAR and ALOS PALSAR data and compared with Landsat sensor and Very High Resolution (VHR) spectral data (Figure 2). For the classification, a 3 x 3 pixel texture analysis and a supervised maximum likelihood algorithm were used. Classifications have also been generated using ENVISAT ASAR and ALOS PALSAR data in combination (Figure 3).
- A processing chain for downloading and pre-processing Landsat sensor data has been developed, with this including orthorectification, atmospheric correction (through LEDAPS) and topographic correction.
- Methods for cloud and cloud shadow removal from Landsat sensor data have been installed at KSAT and will be tested in the next period. A change detection algorithm developed by Curtis Woodcock (Boston University) for continuous monitoring of forest disturbance using all available Landsat data is also being installed at KSAT.
- For processing SAR data (namely RADARSAT-2, TerraSAR-X, ENVISAT ASAR and ALOS PALSAR), Norut's in-house software GSAR has been improved and outputs

compared with those generated using other SAR processing software (e.g., NEST). An initial evaluation of the SAR processing chain has also been undertaken with a more detailed evaluation planned later in 2012.

- Based on GSAR, a fully automatic and operational SAR pre-processing chain for Tanzania has been developed to be included in the HUB running at Kongsberg Satellite Station
- Requests have been submitted for ongoing collection of ENVISAT ASAR, Tandem-X and Radarsat-2 data.
- For Tanzania, a mosaic of ENVISAT ASAR data has been generated by Norut at 90 m spatial resolution (for simple handling), which is fully slope corrected (Figure 4). A mosaicking algorithm has been developed for different kinds of data, prioritizing date, incidence angle or averaging over available data. The data can be pre-selected to generate monthly, seasonal, intra-annual and inter-annual mosaics for any sensor.
- Maps of forest and non-forest have been generated for the two primary test sites of Liwale and Amani by thresholding biomass maps generated using the equation developed by Mitchard et al. (2009; Figure 5).
- Interferometric techniques for processing Tandem-X data from the bi-static acquisitions are being evaluated and layers representing the height of the centre of SAR backscatter above the ground and coherence have been generated for Amani (Figure 6). By subtracting the derived heights from the LiDAR DTM, the InSAR height values have been derived and are available to support the estimation of biomass once the forest inventory data become available.
- Methods for detecting change using, for example, ALOS PALSAR data have been advanced, although further work is needed to establish optimal approaches (Figure 7).
- For the detection of change from InSAR data, three approaches have been investigated including a) the use of differential interferograms, where phase differences represent DEM and hence canopy height changes over time, b) difference in DEMs over time and c) changes in coherence.

Remote Sensing Science Questions

- The potential of Tandem-X band data for forest height retrieval and change detection has been investigated.
- Reflectance and backscatter signatures from a range of forest types have been extracted with a view to obtaining how forest extent can be mapped and forest types differentiated using a combination of SAR and optical data.
- RapidEye data are being investigated for their potential in detecting forest degradation.

Planned activities over the next 6 months

- Further investigation into the use of Rapideye data for forest monitoring. For this purpose, six images are being acquired over Liwale over a 1.5 year period allowing methods for differentiating change due to human activities (including degradation) from that associated with, for example, seasonal phenology to be established.
- Investigation into the combined use of very high resolution Worldview and airborne LiDAR for providing information on the biomass, structure and community composition of forests and ultimately the extent of change at the tree to stand level.

Such information will be used to support the interpretation of data acquired by SAR and optical sensors.

- Finalisation of ground truth datasets, including those generated from airborne data (e.g., LiDAR, Worldview) as well as field measurement (i.e., NAFORMA plots).
- Characterisation of the reflectance and backscatter characteristics of key vegetation (including forest) types across Tanzania and assessment of separability at different times of year.
- Assessment of error propagation when translating classifications or estimates of biophysical characteristics (e.g., biomass) between scales.
- Development of methods for establishing confidence in the maps of forest and non-forest generated from optical and SAR data, with consideration given to areas that are degraded rather than deforested.
- Generation of Landsat mosaics for the Tanzania.
- Generation of additional SAR mosaics for Tanzania.
- Further investigation into the use of a Hidden Markov Model (HMM) for detecting change.
- Generation of maps of biophysical properties (e.g., biomass)
- Further investigations into the use of InSAR for retrieving biophysical attributes (e.g., height, density) of vegetation and generation of maps from a range of sensors (e.g., ALOS PALSAR, Landsat sensors).
- Investigation into the use of radargrammetry for retrieving forest height, using TerraSAR-X or Cosmo Skymed data acquired over the Amani and Liwale test areas.
- Use of temporal SAR data for detecting change in, for example, height based on differences observed between 2000 SRTM C-band and Tandem-X DEMs.

Satellite data obtained during 2012

Sensor [year]	Coverage	Spatial resolution	Data provider	Obtained through GEO FCT
Landsat TM/ETM+ [1972-2009]	Selected sites	25m (full)	USGS	YES
ALOS PALSAR [2007/2008/2009/2010]	Amani/Liwale (TBC images)	SLC (full)	JAXA	Yes
Quickbird/Worldview	Amani/Liwale (12 images)	2,4m/1,8m	Digital Globe	Yes
Tandem-X	2	3m	DLR	No
IKONOS	Liwale (2 images)		GeoEye	Yes
GeoEye	Liwale (1 image)		GeoEye	Yes
RapidEye	Liwale (Liwale 18 images)	6,5m	RapidEye	Yes

Envisat ASAR	Tanzania (2009)		ESA	Yes
Radarsat	Amani,Liwale, SW Tanzania, NW Tanzania (41 images)	9m	CSA	Yes
ALOS PALSAR [2010/2011]	VS sites	SLC (full)	Jaxa	Yes
Quickbird	VS sites (6 coverages)	2,4m	Digital Globe	Provided by Digital Globe
Tandem-X	2	3m	DLR	No

Airborne data obtained during 2012

Sensor [year]	Coverage	Spatial resolution	Data provider	Obtained through GEO FCT
ALS [2012]	Amani Nature Reserve	10 p/m2	Terratec AS	No
ALS [2012]	Part of Liwale District (ca 15,000 km2) (individual strips only)	1.8 p/m2	Terratec AS	No

Verification data

Sensor [year]	Coverage	Spatial resolution	Data provider	Obtained through GEO FCT
Forest inventory (actual measurements)	Amani Nature Reserve: ca. 130 plots	Plot size: 0.1 ha	SUA, UMB	No
	Liwale District: ca. 500 plots	Plot size: 707 m2	NAFORMA, SUA, UMB	No
Land cover/vegetation data	Amani and Liwale (NAFORMA)			No
Destructive harvesting	Selected forest types			No

Demonstration products generated to date (Oct. 2012)

Thematic Product	Coverage	Spatial resolution	Data source [year]	Validation
First preliminary prototype forest/savannah/non-forest classification (Horizon 1a)	Verification Site (TNZ-3)	25 m	ALOS PALSAR FBD and Envisat ASAR APS [2009]	No
Preliminary Forest/Non-Forest (Horizon 1a)	Verification Site (TNZ-4)	25 m	ALOS PALSAR [2007-2009]	No
Preliminary Forest/Non-Forest (Horizon 1a)	Amani & Liwale test sites	30 m	ALOS PALSAR HV [2007-2009]	No
Forest Change (Horizon 1b, 1d)	Verification Sites (TNZ-3 & TNZ-4)	25 m	ALOS PALSAR [2007-2009]	No
Preliminary biomass maps	Amani & Liwale test sites	30 m	ALOS PALSAR HV [2007-2009]	No
Thematic Product	**Coverage**	**Spatial resolution**	**Data source [year]**	**Validation**
SAR mosaic	Whole Tanzania	90m (30 m possible)	Envisat ASAR APS (2009)	No
SAR mosaic	Amani & Liwale test sites	30 m	ALOS PALSAR FBD (HH&HV) [2007-2009]	No

On-going product generation for CEOS Plenary, GEO Ministerial, COP-18 and/or SDS#4

Product/topic	Coverage	Data source [year]	Target
Improved forest/non-forest maps	VS	Radarsat-2 Envisat ASAR ALOS Palsar [2009-2011]	SDS #4
Improved biomass maps	VS	ALOS PALSAR FBD [2007-2011]	SDS #4
Satellite image	VS	Radarsat-2	SDS #4

mosaic		Envisat ASAR ALOS Palsar	
Satellite image mosaic	ND wall-to-wall	Envisat ASAR APS (2009-2011)	SDS #4

Participation at SDS#4 (tentatively Australia, Feb, 2013)

Yes

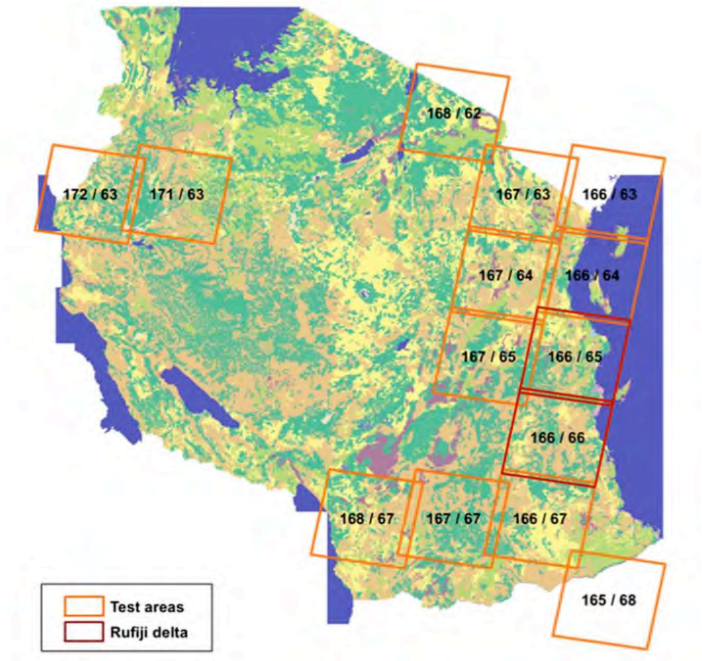


Figure 2.8.1. *Locations of Landsat* ***path/rows selected for Tanzania.***

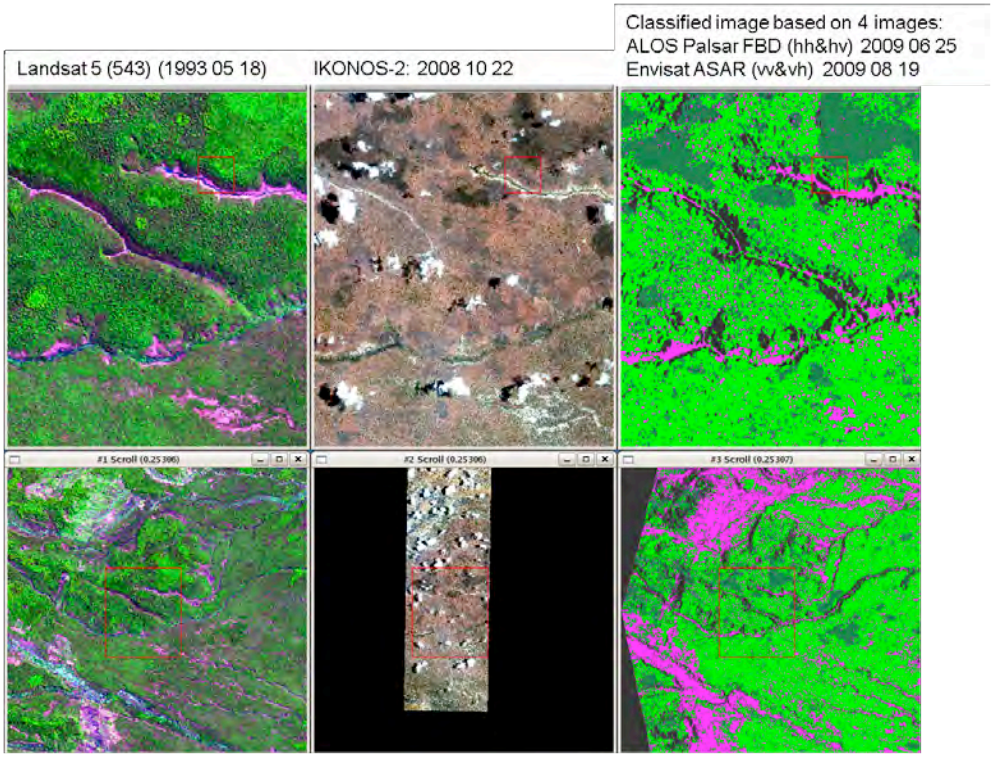


Figure 2.8.2. *Landsat (left) and Ikonos (middle) images of TNZ-3 and a classification of dense forest (dark green), sparse forest (light green) and non-forest (magenta) (right) generated from ENVISAT ASAR/ALOS PALSAR data (TNZ-3),acquired 2009 (produced by Norut,SDS#1, 2010).*

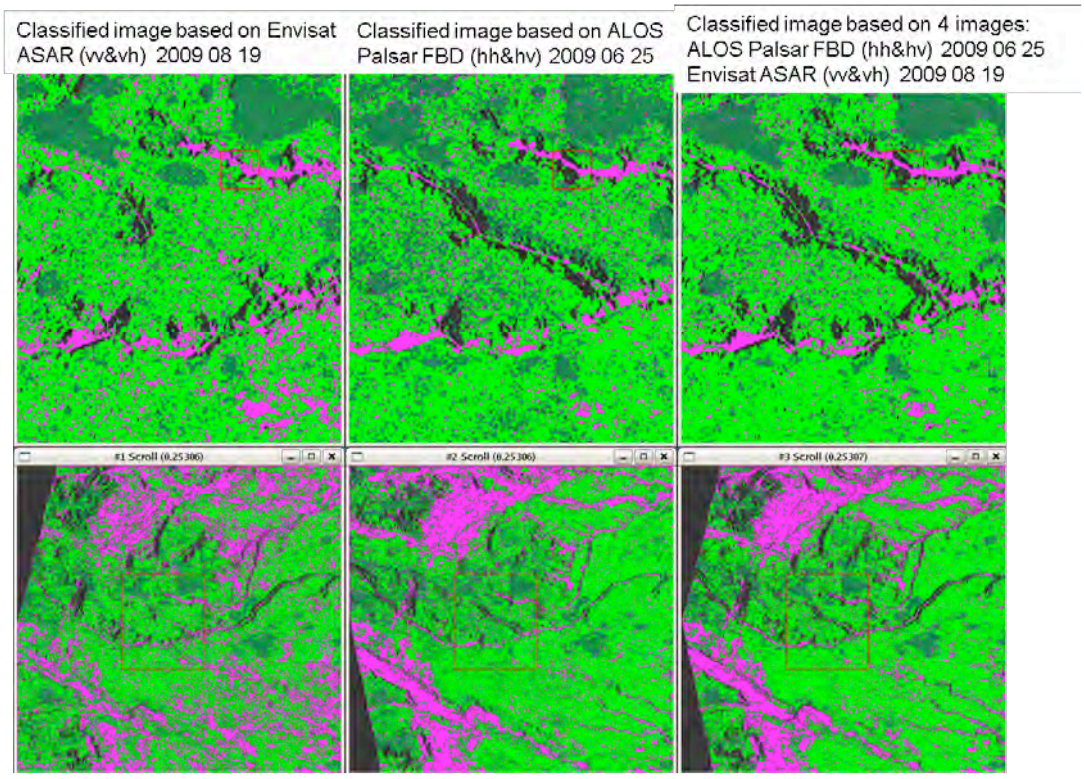


Figure 2.8.3. *Classification of dense forest (dark green), sparse forest (light green) and non-forest (magenta) generated from ENVISAT ASAR (left), ALOS PALSAR (middle) and both sensors combined (right; TNZ-3) for 2009 (produced by Norut, GEO FCT SDS#1, 2010).*

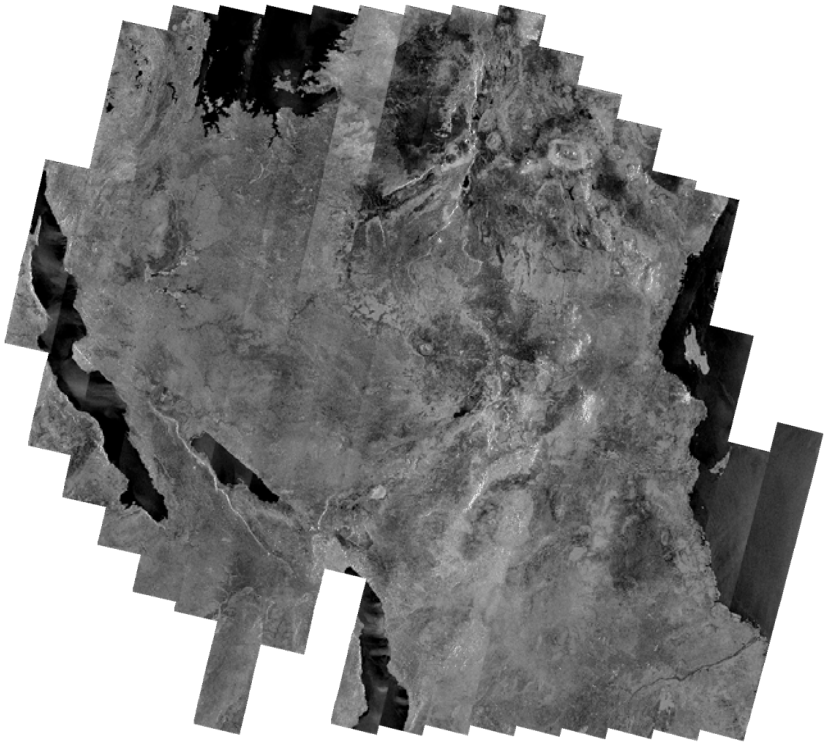


Figure 2.8.4. *Mosaic ENVISAT ASAR data for Tanzania generated at 90 m spatial resolution, VV polarization. Slope corrections applied to the entire mosaic (Norut, GEO FCT SDS#3 2012).*

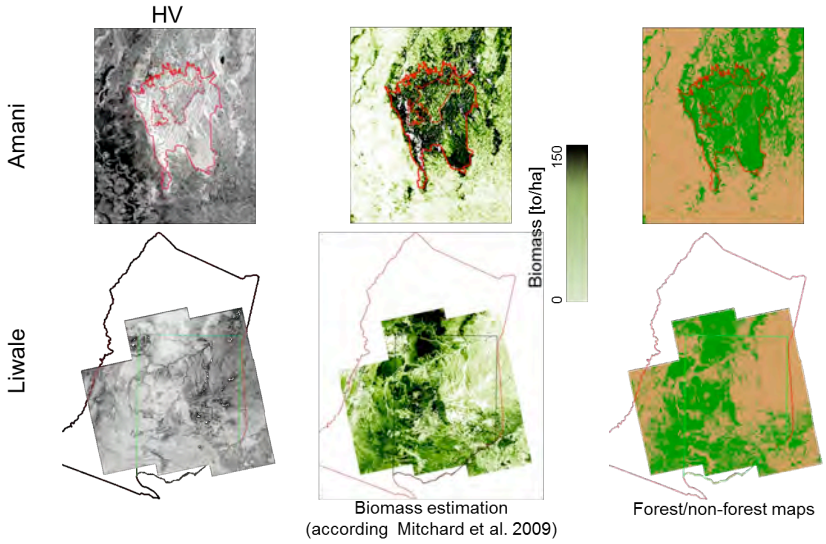


Figure 2.8.5. *Generation of biomass and forest/non-forest maps using ALOS PALSAR HV data for Liwale and Amani (preliminary results from Norut, 2012)*

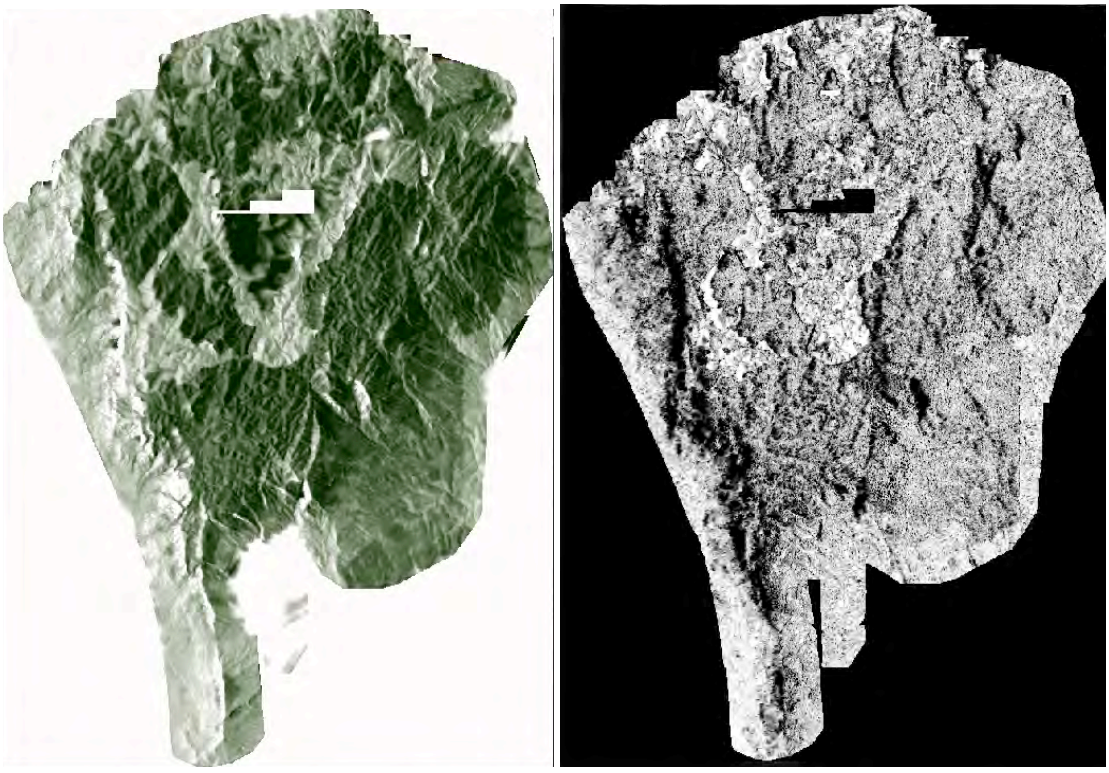


***Figure* 2.8.6.** *Tandem-X InSAR height (i.e., the height of the centre of the RADAR backscatter above ground; left) and coherence (right) obtained for Amani National Park. Logged areas can be distinguished from intact forest as the InSAR heights of the former are close to zero and the coherence is high (bright areas; right).*

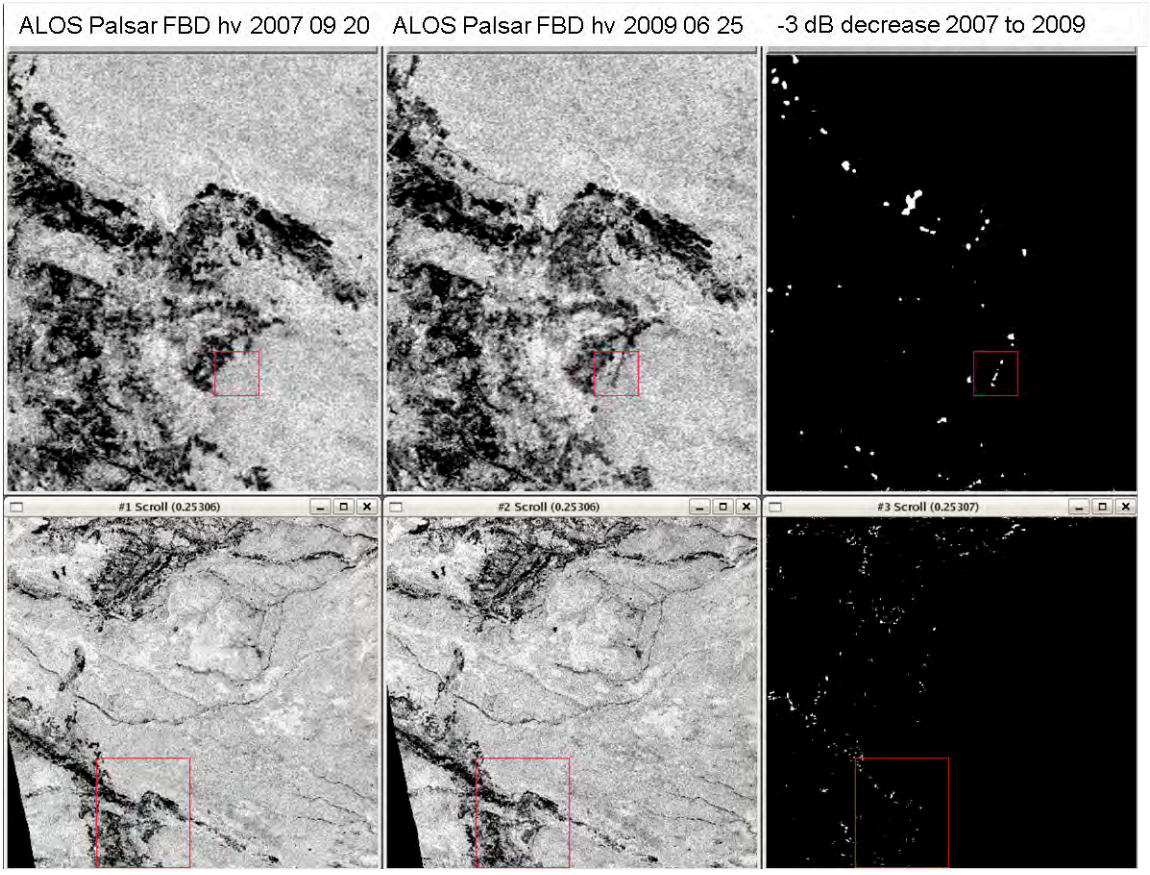


Figure 2.8.7. *Areas where a 3 dB reduction in backscatter was observed (white areas; right) between 2007 and 2009 ALOS PALSAR data acquired over TNZ-3, with these associated with deforestation (produced by Norut, GEO FCT SDS#1, 2010).*

2.9 NEPAL

Government of Nepal/Ministry of Forests and Soil Conservation

(MoFSC)

Reported by Shree Krishna Gautam, DFRS; and Anish Joshi, GEO-FCT Product Development Team Co-lead

2012 Activity Summary

- Participation and presentation of national status of Geo-FCT activities in SDS#3, in Arusha, Tanzania.
- Received wall-to-wall LANDSAT 5 and ETM+ imageries from (GLS 1975-2010) from USGS.
- Received 50 scenes of ALOS PALSAR 1b FBS imageries covering southern Terai and Siwalik physiographic regions of Nepal.
- Horizon 1a products covering Terai and Siwaliks physiographic regions completed using RapidEye images for the period of 2010-2011.
- In-situ data collection campaigns through the National Forest Inventory is on-going (40% completed). The NFI uses two phase sampling methods with more than 450 clusters and 2500 permanent sample plots (concentric circular sample plots). The NFI will be completed by the end of 2013.
- The on-going Forest resources Assessment Project has conducted introductory Remote Sensing training courses to the National Demonstrator Authority, Dept. of Forest Research and Survey attended and/or given.
- Horizon 1a (Forest/non-forest cover) product is generated for Terai and Siwaliks physiographic regions.
- Department of Forest Research and Surveys (DFRS) with technical support of FRA-Nepal Project is undertaking the development of Horizon 1a and 1c products in 2012. FRA-Nepal is also supporting the capacity buildings of the DFRS personnel for undertaking the product development activities.
- Validation of two verification sites 5 and 6 will be done during October-November 2012. Forest inventory data of NFI within these sites already available.
- Collaborations between the DFRS and Remote Sensing Technology Center (RESTEC) Japan for "Scientific Analysis and Development of Forest Monitoring Products by Satellite over Nepal for GEO/FCT Activities" is being discussed. MOU will be signed after the administrative processes in the Ministry of Forests and Soil Conservation in Nepal.
- A national workshop on Geo-FCT is being held in 3rd October 2012.

Remote Sensing Science Questions

Due to the unavailability of C-Band SAR data, Geo-FCT Nepal PDT has not been able to undertake any works using this imagery. We have been using RapidEye (commercially acquired) imagery along with LANDSAT 5 (available through USGS) to develop Horizon 1c products. Complementary usage of ALOS PALSAR (FBS) data with Rapid Eye is being investigated.

We do not have X-Band SAR and dense time series data. Usage of C-band and X-band is planned for the year 2013.

Forest degradation has been significant issue in the forest of Nepal. Multi-source inventory and analysis of forest degradation has not been started as yet. Joint research with international partners such as RESTEC is necessary for combined usages of optical and SAR data for assessment of degradation, especially for assessment and monitoring of forest crown densities and stockings.

Planned activities over the next 6 months

- Wall-to-wall satellite image mosaic of orthorectified RapidEye 1b product.
- Development of Horizon 1a products for three sub-national level physiographic regions of Nepal (viz. Terai, Siwaliks and Mid hills) using RapidEye images
- Development of Horizon 1c products for Terai region using RapidEye; supported by LANDSAT 5 images
- Development of Horizon 1a and 1c products of VS 5 and 6. Along with field verifications.
- In-situ forest inventory data collection in Mid Hills.
- Demonstration products

    - Horizon 1c for Riau Province demonstration at the GEO-IX Ministerial meeting (Foz do Iguazu, Brazil, Nov 22-23, 2012:
    - Horizon 1a product for Terai physiographic region using RapidEye

    - for the 4rd Science and Data Summit (tentatively to be held in Australia in Feb, 2013)
    - Horizon 1a product for Terai and Siwalik physiographic regions using RapidEye
    - Horizon 1a and 1c for VS 5 and 6 with field verifications

Satellite data obtained during 2012

Sensor [year]	Coverage	Spatial resolution	Data provider	Obtained through GEO FCT
Landsat TM/ETM+ [1975-2010]	ND wall-to-wall	25m (full)	USGS	Yes (no cost)
ALOS PALSAR 1b FBS [2010]	ND wall-to-wall	SLC (full)	JAXA	Yes (no cost)

Verification data

- Ground data collected in situ (2011-2012)
- Other data sets (various secondary images from various internal sources but no wall-to-wall coverages)

Demonstration products generated to date (Oct. 2012)

Thematic Product	Coverage	Spatial resolution	Data source [year]	Validation
Forest/Non Forest	ND Sub-national level	5 m	RapidEye [2010]	On-going (FRA-Nepal)
Forest/Non Forest	ND Sub-national level	25 m	LANDSAT [2010]	On-going (FRA-Nepal)
Image Product	**Coverage**	**Spatial resolution**	**Data source [year]**	**Validation**
Satellite image mosaic	ND wall-to-wall	25 m	Landsat TM/ETM+ [2010]	N/A
Satellite image mosaic	ND wall-to-wall	5 m	RapidEye [2010/2011]	N/A

On-going product generation for CEOS Plenary, GEO Ministerial, COP-18 and/or SDS#4

Product/topic	Coverage	Data source [year]	Target
Horizon 1a	Wall-to-wall Sub-national – Terai Region	RapidEye [2010]	GEO-9
Horizon 1a	Wall-to-wall Sub-national – Terai and Siwalik Region	RapidEye [2010]	SDS#4
Horizon 1a & 1c	VS 5 and 6	RapidEye [2010]	SDS#4
Satellite image mosaic	ND wall-to-wall	RapidEye [2010]	SDS#4

Participation at SDS#4 (Australia, Feb, 2013)

Yes

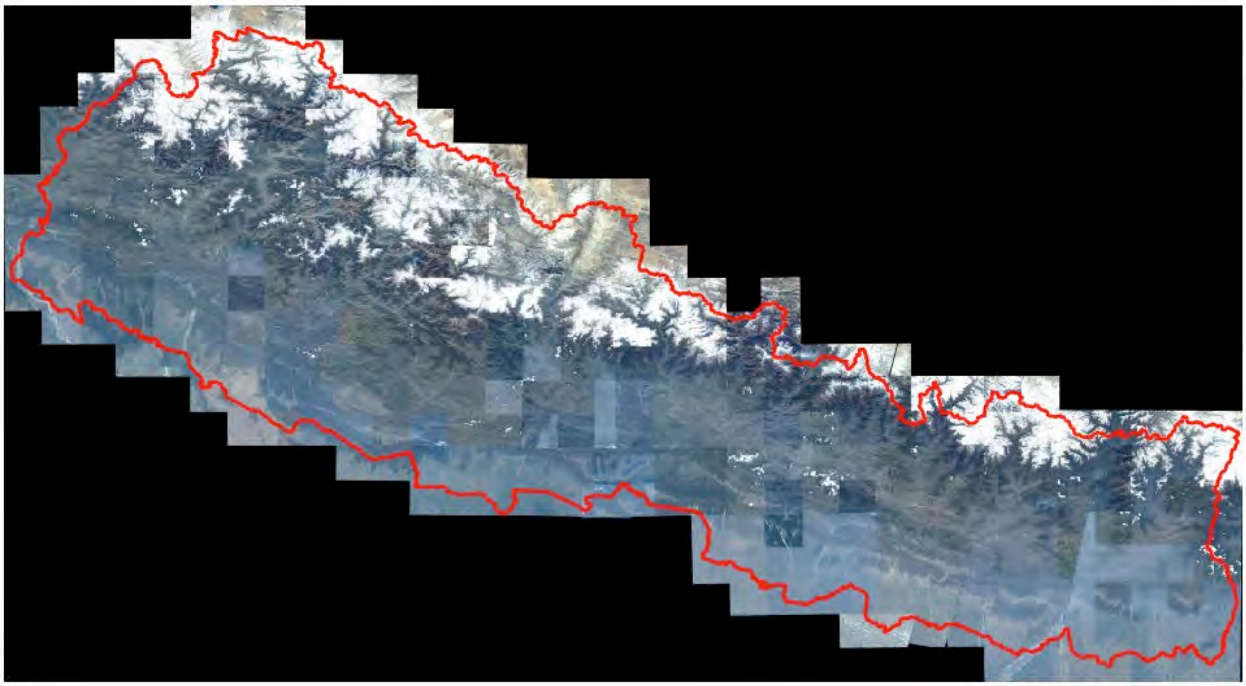


Figure 2.9.1. RapidEye wall-to-wall mosaic (2010)

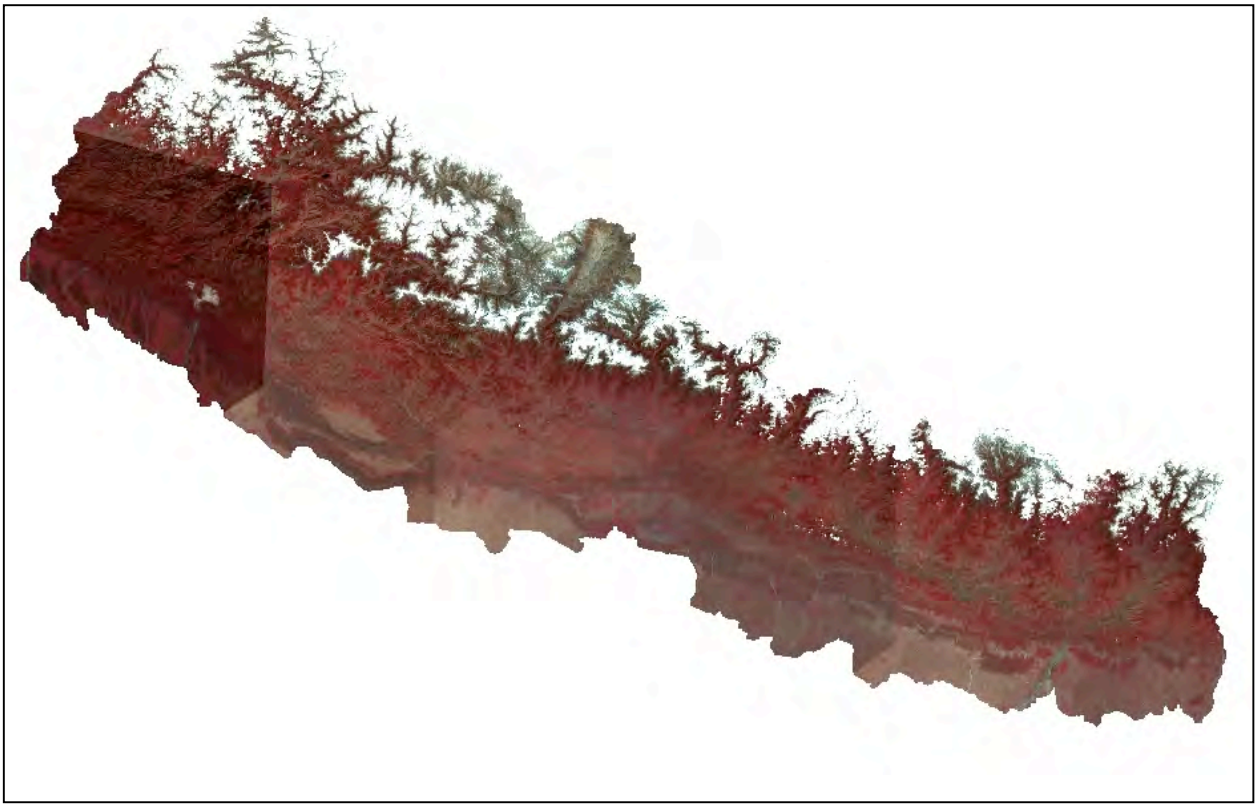


Figure 2.9.2. *Landsat 5 wall-to-wall mosaic (2010, USGS)*

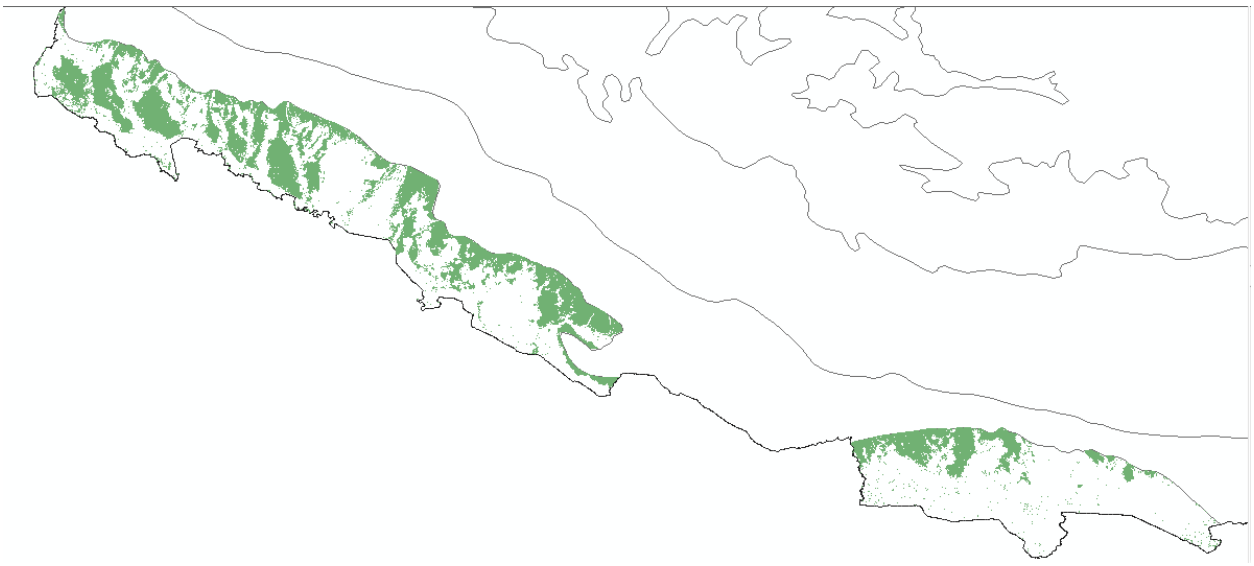


Figure 2.9.3. *Horizon 1a Forest/Non Forest of Western Terai (RapidEye 2010) – using OBIA method*

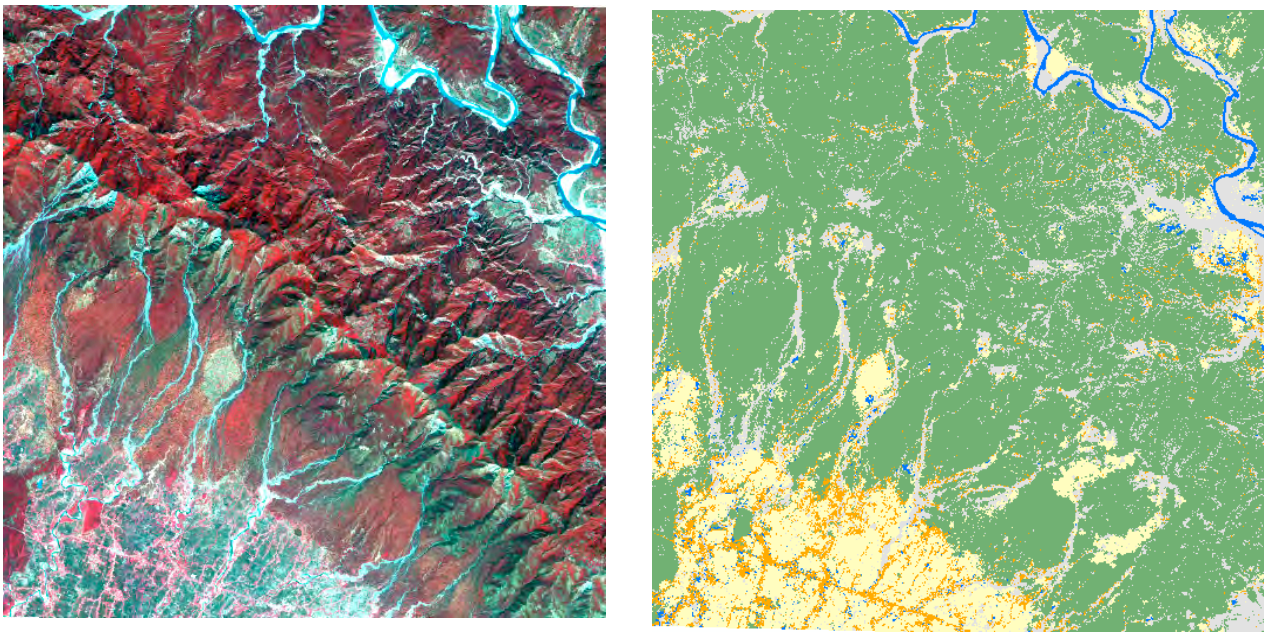


Figure 2.9.3. Horizon 1c Landcover of VS 5 (RapidEye 2010) – using OBIA method

2.10 INDONESIA

2.10.1 Borneo and Sumatra (U. Wageningen)

Reported by Dirk Hoekman (Univ. Wageningen)

2012 Activity Summary

- Refinement of techniques for production of consistent time series and further improvement of the (2007-2010) LC/LCC maps of Borneo. On the basis of additional ICESat GLAS data and some field observations a first version of a biomass stratification map [Fig.1] was made.
- Wall-to-wall mosaic generation for Borneo with RS-2 data (2009/2010) and study of complementarity/interoperability of C- and L-band data. Relevant results for Borneo include improved classification for low biomass forests (heath forest) and Acacia plantations.
- Further development of dense time series monitoring products at the validation sites BOR-3 and SUM-2 with ASAR APV IS4, TSX 3m and Cosmo-SkyMed data, using RapidEye data and field checks for validation purposes.
- Execution of a reconnaissance aerial survey over Borneo in December 2011 yielding over 6000 geo-tagged photographs along a 1300 km path covering most land cover classes. This dataset serves as a good basis for validation of all kinds of mapping products and will be used to harmonise radar and optical based products [Fig.2].
- Validation efforts have been undertaken in the framework of INCAS with strong involvement of staff from LAPAN and the Ministry of Forestry. For this purpose 53 VHR optical images (res < 1m) spread over Kalimantan (Indonesian part of Borneo) are available for our Indonesian partners.
- Bilateral Indonesian – Netherlands cooperation on capacity building for the radar component of INCAS (the national MRV) entered the second year. Four workshops are carried out in 2012 (3 at LAPAN and 1 in Bogor). LAPAN now has the technical capability to pre-process all kinds of radar data and to produce PALSAR Fine-Beam based wide-area consistent annual LC maps, with the flexibility to adapt the legend. Harmonisation activities started between the radar group (LAPAN-Wageningen) and the optical group (LAPAN-CSIRO-Matt Hansen).
- The above cooperation can be considered as a Netherlands contribution to GEO-FCT and is coordinated in Indonesia by LAPAN and the Ministry of Forestry within the presidential office (UKP4) for REDD.

Remote Sensing Science Questions

- Enhancing information extraction by C-band SAR:
    - For SUM-2 a series of 2011-2012 ASAR APV IS4 data were processed as a dense time series. This results in a series of deforestation maps that could be validated with other RS data (mainly Landsat and RapidEye), and feedback from the field teams. Good results are obtained at 25 m resolution when

using improved multi-temporal speckle filtering and improved multi-temporal change detection techniques [Fig.3]. Such results were already achieved for peat swamp areas in Central Kalimantan (flat terrain, relatively low and even forest canopy). The main advancement is that the technique is now demonstrated to work well in the more complex situations of dryland Dipterocarp forest (hilly terrain, presence of large emergent trees, uneven canopy).

- Sensor interoperability (SAR/SAR) and applications and optimal use of X-band SAR
    - Complementarity and interoperability of C- and L-band data for wide-area mapping of Borneo was studied. Relevant results for Borneo include improved classification for low biomass forests (heath forest) and Acacia plantations.
    - In the framework of the EU project REDD-FLAME short dense time series of 3m strip data with VV-polarization for (a) Ultra Fine Mode RS-2, (b) TSX and (c) Cosmo-SkyMed are studied with the purpose of developing Fast Logging Assessment monitoring systems (in BOR-3 and a non-VS area in Brazil). In SUM-2 similar work started last April. First results show that by visual analysis good results can be obtained. Fully automating this process is still a challenge but important progress is now made. Maps of illegal logging trails can be generated automatically. More demonstration products are expected to be available soon.

Planned activities over the next 6 months

- Fieldwork campaign to BOR-3 with focus on application of TSX and TDX data in the areas of inventory, biomass stratification and canopy structure assessment
- Continued training in Indonesia (October 2012: Visit to UKP4 REDD office for continuation of current capacity building program and implementation of national forest monitoring systems; November: Harmonisation workshop optical-radar; February 2013: REDD-FLAME Workshop on Fast Logging Assessment)
- Product development for dense time series deforestation and degradation monitoring in BOR-2 and SUM-3.

- Demonstration products
    - For GEO- IX Ministerial Meeting (Foz do Iguazu, Brazil, Nov 22-23, 2012):
        - First biomass stratification map Borneo based on PALSAR FBS-FBD
        - Map of illegal logging trails based on RS-2 FB-QP data for BOR-3
        - Improved deforestation monitoring series product SUM-2 (based on ASAR)
    - For the 4th Science and Data Summit (tentatively to be held in Australia in Feb, 2013):
        - Improved LC/LCC consistent time-series of Borneo based on PALSAR 2007-2010
        - First classification and biomass stratification map based of BOR-3 TSX/TDX intensity and interferometric coherence data

Satellite data obtained during 2012

Sensor [year]	Coverage	Spatial resolution	Data provider	Obtained through GEO FCT
Landsat TM/ETM+ [2011-2012]	partly	25 m		No
ALOS PALSAR [FBD single year]	Borneo wall-to-wall	Strip (w2w) 25 m	JAXA	No (K&C)
ENVISAT ASAR [2012]	SUM-2 VS	SLC 25 m	ESA	No (commercial purchase)
Cosmo-SkyMed [2012]	SUM-2, BOR-3 VS's	3 m		No (EU-project)
TerraSAR-X [2012]	BOR-3 Dense time series	3m strip map VV		No (EU-project)
TerraSAR-X [2012]	SUM-2 Dense time series	3m strip map VV	DLR	Yes (GEO-FCT proposal)
RapidEye [2012]	BOR-3, SUM-2	6 m		Yes

Verification data

- Ground data collected in situ (date of field work)
- Other data sets (specify)

Through INCAS there is access to an extensive validation data set available at LAPAN. An aerial reconnaissance flight was made over Borneo covering (the variability in) most land cover types. Several biomass data sets were obtained over Borneo. Field observations at SUM-2 are continued and reported every quarter year.

Demonstration products generated to date (Oct. 2012)

Thematic Product	Coverage	Spatial resolution	Data source [year]	Validation
Forest and Land Cover Change	ND Borneo wall-to-wall	50 m	ALOS PALSAR [2007-2010]	Yes
Biomass stratification	ND Borneo wall-to-wall	50 m	ALOS PALSAR [2008] ICESat GLAS	Yes
Deforestation series	SUM-2	25 m	ASAR [2011-2012]	Yes
Illegal logging trails	BOR-3	10 m	RS-2 [2010-2011]	Yes
Image Product	**Coverage**	**Spatial resolution**	**Data source [year]**	**Validation**
Satellite image mosaic	Borneo ND wall-to-wall	50 m	PALSAR FBS-FBD [2010]	N/A
Satellite image mosaic	Borneo ND wall-to-wall [incomplete]	25 m	RS-2 [2010]	N/A
Satellite image mosaic	Sumatra ND wall-to-wall [incomplete]	25 m	ENVISAT ASAR [2010]	N/A

On-going product generation for CEOS Plenary, GEO Ministerial, COP-18 and/or SDS#4

Product/topic	Coverage	Data source [year]	Target
Deforestation series	SUM-2	ASAR [2011-2012] TSX [2012] RapidEye [2012]	Products will be updated every time new acquisitions of the (dense) time series come available
Illegal logging detection	BOR-3	ASAR [2011-2012] TSX [2012] RS-2 Ultra-fine [2012] Cosmo-SkyMed [2012] RapidEye [2012]	Idem

Participation at SDS#4 (Australia, Feb, 2013)

Yes (supposing funding will be available)

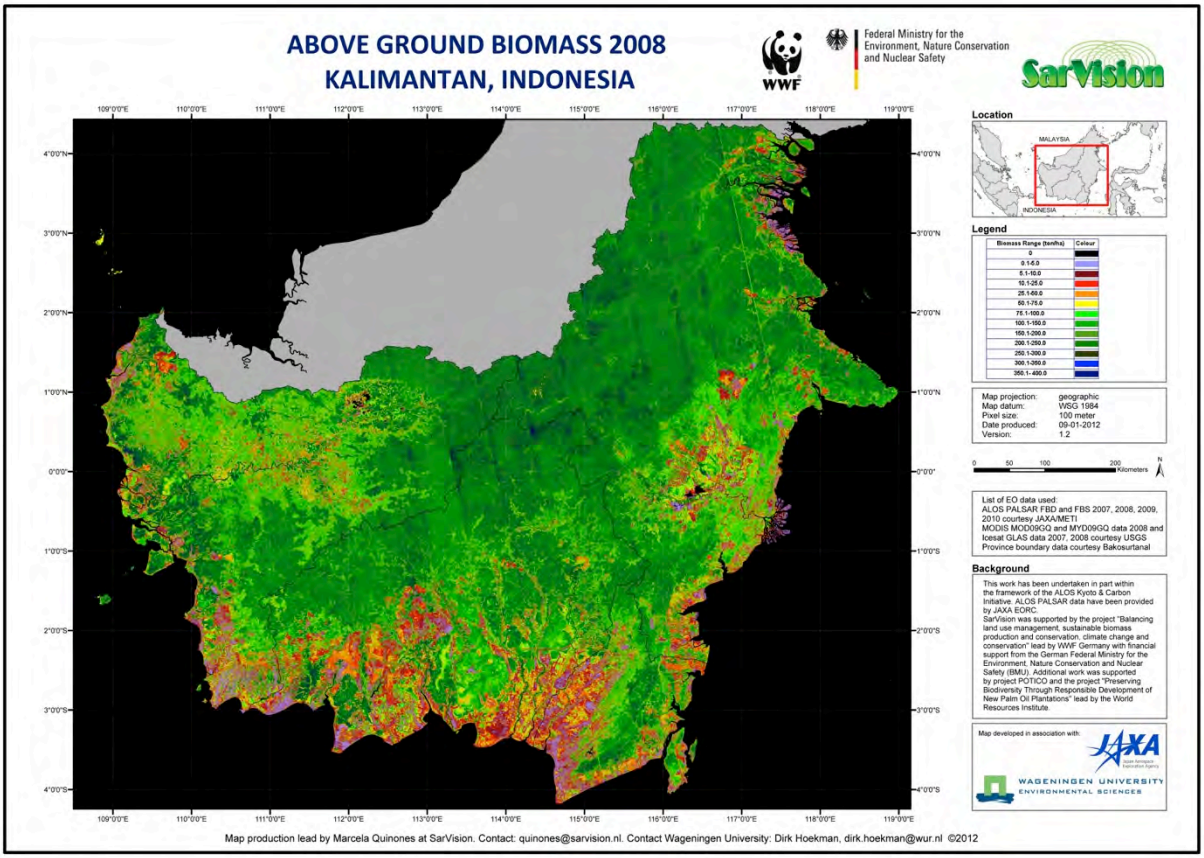


Figure 2.10.1. *Borneo biomass stratification map. [Source: Quiñones, Hoekmanand Vissers, 2011, A two step biomass mapping approach integrating L Band ALOSPALSAR and Lidar GLAS height data for high resolution wall to wall above ground biomass mapping. PEP-BIOMASS report.]*

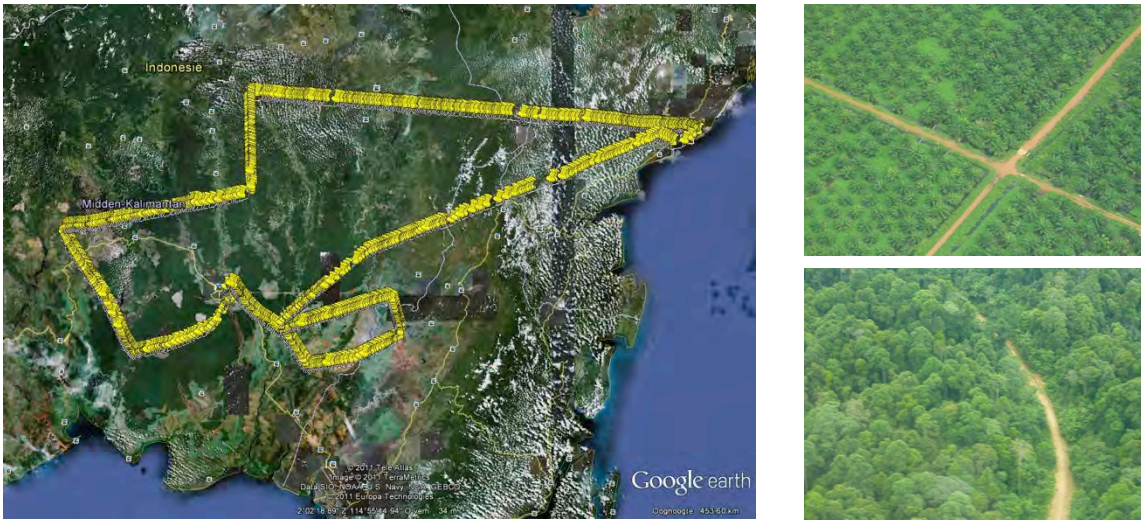


Figure 2.10.2. *Over 6000 geo-tagged photographs were collected along a 1300 km route in East and Central Kalimantan at 4 December 2012. Using a Cessna-Caravan from Balikpapan airport, the route carries along the main land cover types: the rubber and oil palm plantations in Penajam, crossing the Meratus mountain range, into forest conversion areas, wide river floodplains and peat swamp complexes in Central Kalimantan, extensive areas of wasteland, oil palm plantation and rice*

cultivation, into the kerangas (or heath forests), mining areas (for white sand, gold and coal), and, on the way back, major logging areas, coal mines, the Meratus range, tree plantations and gold mining. Since the route was too long a stop was made in Palangkaraya. During the flight oblique aerial photography was made in sideward direction with 6 cameras. The locations are indicated on the left. On the right two examples are shown.

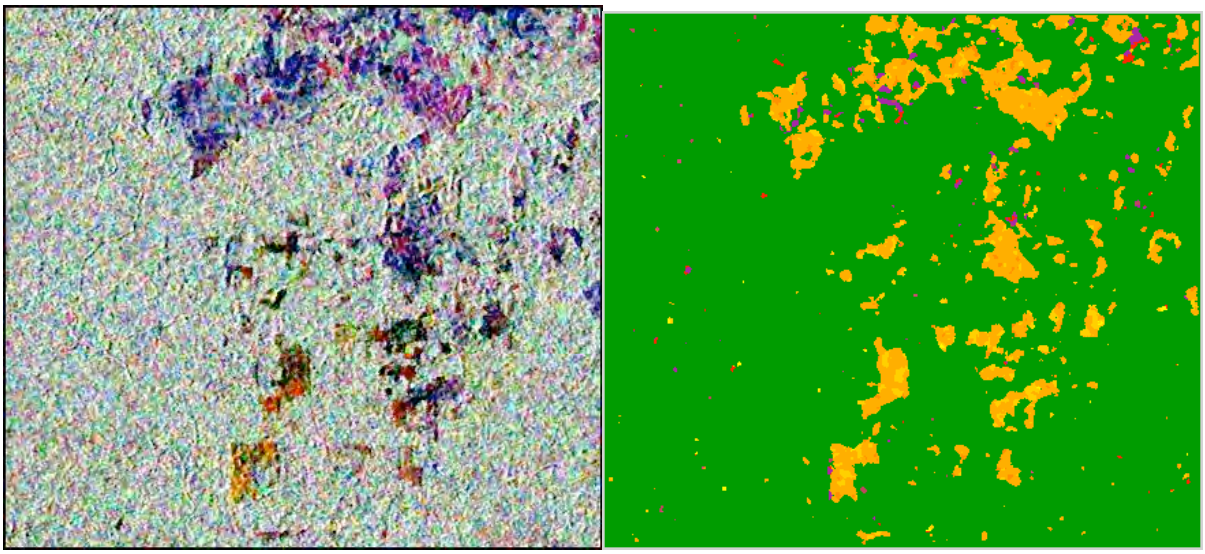


Figure 2.10.3. *The SUM-2 VS is covered by dryland Dipterocarp forest on hilly terrain. Several types of logging and forest degradation occur. Results for an ASAR APV IS4 short dense time series (4 acquisitions at 1 month interval) are shown. (left) Composite (of 3 HV bands) after multi-temporal speckle filtering (over all 8 bands): the decrease in speckle variance is a factor of 3 (this is large) while (spatio-temporal radiometric) deformations are negligible. As a result we can now see logging roads well. (right) Fully automated 'fast logging assessment' product showing all new clearings while the number of false detections is very low. Note that in the near future similar products can be made with SENTINEL-1 data.*

2.10.2 Sumatra (JAXA)

Reported by Masanobu Shimada, JAXA

2012 Activity Summary

- **Product development progress**
  - Developing and improving the classification algorithm and selecting the most accurate one
  - generating the LULUCF and FNF for Riau province of Sumatra.

- **Field data collection campaigns**
  We have been conducting the ground truth measurement at several sites in Riau. LULUCF, Biomass, and lidar data were collected.

- **Training courses attended and/or given**
  We have conducted the training course three times (March 2012, Japan, Nov. Japan and, Nov. Indonesia)

- **Level of involvement with ND country members**
  All are technical levels.

- **Organisation within the ND that is involved in the product generation**
  LAPAN

- **Validation efforts and results**
  Biomass will be validated within the latter half of 2012 activity.

Remote Sensing Science Questions

- Utilization of dense time series data: JAXA is using the dense time series of the PALSAR data for LULUCF estimation and the deforestation monitoring. Deforestation can be estimated by differencing two consecutive SAR images and thresholding them. The threshold level needs to be tuned depending on the forest (and country), but, it can be suitable for estimating the deforestation. Estimation accuracy is validated at the Riau compared with the data acquired from the optical data and ground truth data.

Planned activities over the next 6 months

- **Demonstration products**
  - for the 4rd Science and Data Summit (tentatively to be held in Australia in Feb, 2013): We will show the comparative study of the LULUCF algorithm, LULUCF accuracy, Biomass estimation (validation) using two methods, i.e., gamma-naught-biomass and LULUCF-biomass methods. We will finalize the global FNF map from the time series PALSAR data.

Demonstration products generated to date (Oct. 2012)

Thematic Product	Coverage	Spatial resolution	Data source [year]	Validation
Forest/Non-Forest	ND wall-to-wall	10, 25, 50, 100 m	ALOS PALSAR [2007, 2008, 2009, 2010]	On-going
Forest and Land Cover Change	Riau, verification Site	25m, 50m	ALOS PALSAR	On-going
Image Product	**Coverage**	**Spatial resolution**	**Data source [year]**	**Validation**
Satellite image mosaic	ND wall-to-wall	50, 100 m	JERS-1 SAR, PALSAR	Yes

Participation at SDS#4 (Australia, Feb, 2013)

Yes

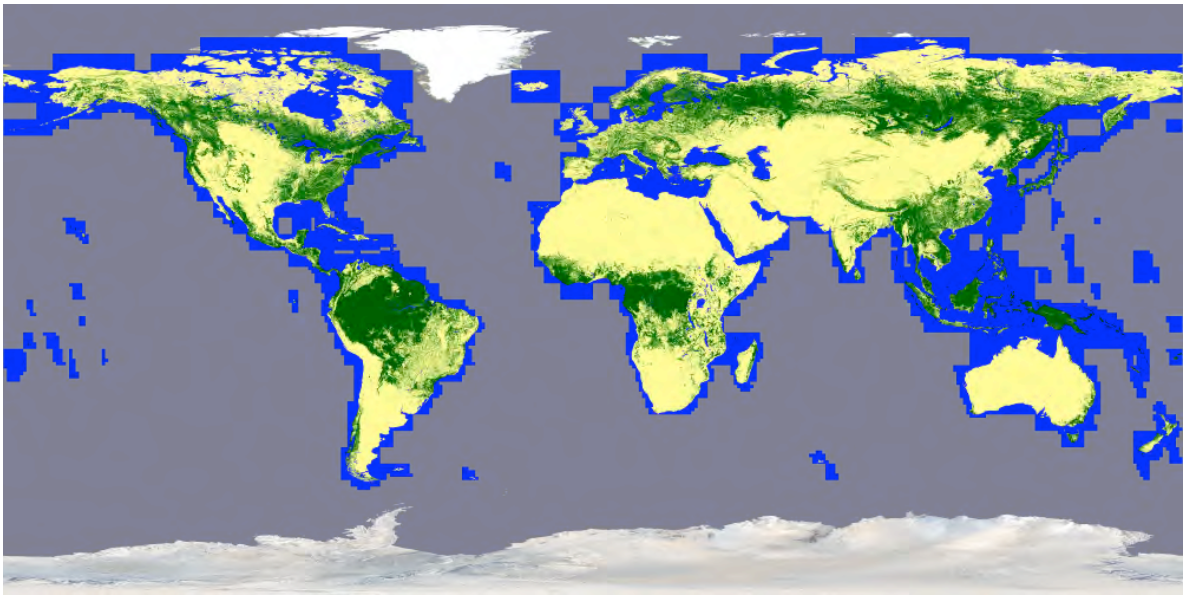


Fig 2.10.4. *Forest/Non-Forest map generated from PALSAR 2009 global data. Green is the forest and yellow is Non-Forest.*

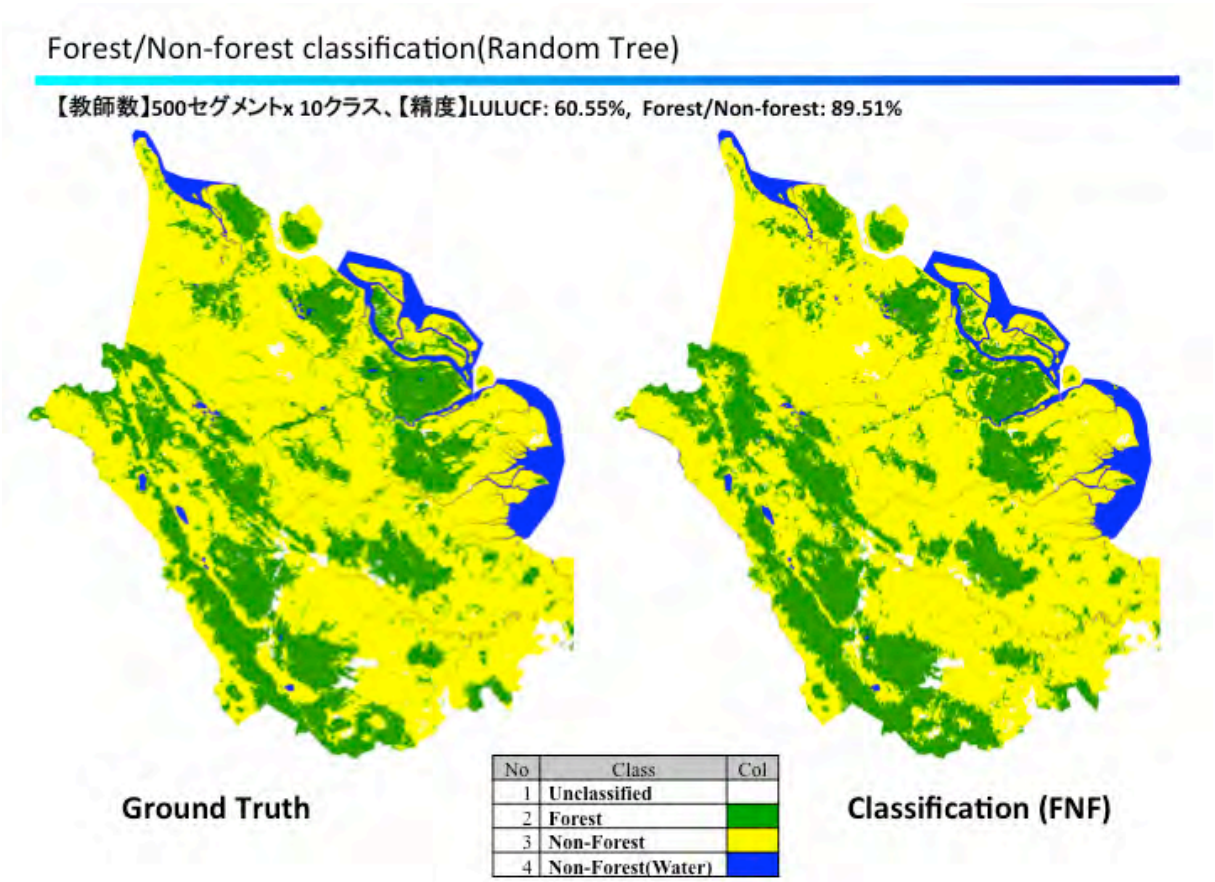


Figure 2.10.5. *Horizon 1c for Riau Province Forest(green)/Non-Forest(yellow) and evaluation points (blue for success and red for failure) at Riau Province of Sumatra, Indonesia*

2.11 AUSTRALIA - TASMANIA

Reported by Anthony Milne and Anthea Mitchell

As part of the Australian International Forest Carbon Initiative (IFCI), the Department of Climate Change and Energy Efficiency funded the establishment of a Research Alliance between CSIRO and the Cooperative Research Centre for Spatial Information (CRCSI). The Research Alliance established Tasmania as Australia's National Demonstrator site under the Group of Earth Observations-Forest Carbon Tracking (GEO-FCT) task initiative. The Research Alliance was aided greatly in this endeavour by collaboration with Forestry Tasmania. This Project was officially completed 30th June, 2012.

2012 Activity Summary

The following is a summary of major achievements of the Tasmanian ND project within the context of the IFCI Research Alliance:

- A robust strategy for the processing of SAR data and generation of wall-to-wall, time-series, calibrated SAR mosaics was established.
- Operational procedures for processing SAR data to map forest extent and land cover were established and documented.
- Operational procedures for processing time-series SAR data to map and monitor deforestation and changes in land cover were established and documented.
- The reality of using SAR data acquired by C-band sources as an alternative to L-band data for mapping forest extent in the absence of ALOS PALSAR data (following system failure in May, 2011) was demonstrated.
- The magnitude of differences that can be expected in estimating forest extent from optical data or from SAR data were quantified and documented.
- The conceptual thinking required to undertake operational accuracy assessment for Horizon 1 and 2 maps in the context of probable real-world data availability was developed and documented.
- Specific metrics for providing information to satisfy the needs of verification and continuous improvement of mapping procedures were identified and evaluated.
- A framework for merging optical and SAR data including quantifying improvement resulting from merging was established and documented.
- Key deliverables include this research report, two technical documents outlining radar processing methodologies, two technical documents outlining verification procedures, a series of publications and conference proceedings, and sample data (SAR mosaics, forest products and field data).

Remote Sensing Science Questions

Image processing objectives included the generation of time-series forest/non-forest, land cover and change maps using SAR data both independently and interoperable, linkage with field inventory data, and comparison of accuracy metrics for derived products. Detailed strategies for the generation of forest information products are documented in Mitchell *et al.* (2012b). That document is targeted at technical personnel responsible for direct implementation and operationalization of forest monitoring schemes utilising satellite and ground data. A series of case studies are presented that demonstrate robust methods for extracting spatially explicit forest information using data acquired by radar and optical sensors. Case studies include:

i. The use of ALOS PALSAR data for forest mapping and monitoring in Tasmania.
ii. Interoperability of multi-frequency SAR data for forest/non-forest extent mapping.
iii. Interoperability of multi-frequency SAR data for land cover mapping.
iv. Deforestation monitoring using time-series ALOS PALSAR data.
v. Interoperability of radar and optical data for forest information assessment.

Planned activities over the next 6 months

- No planned activity at this stage.
- Demonstration products

  For the Tasmania Demonstrator, the following SAR products were generated:

  - Time-series-calibrated ALOS PALSAR FBD (L-band HH and HV) wall-to-wall mosaics for 2007 - 2010, and 1 FBS (HH) mosaic for 2011.
  - Wall-to-wall mosaic generated using RADARSAT-2 (C-band VV and VH) data for 2009.
  - Wall-to-wall mosaic generated using ENVISAT ASAR (C-band VV and VH) data for 2009.
  - Dense calibrated time-series over three calibration sites using RADARSAT-2 data (2009 - 2010).

Forest information products including forest/non-forest extent, land cover, and land cover/land use change maps were generated at wall-to-wall scale for Tasmania. Approaches to classification including manual decision trees and Support Vector Machine (SVM) were outlined. The integration of SAR derived spectral, spatial, textural and polarimetric features for improved separation of forest/non-forest was demonstrated. The capacity to discriminate forest types and land cover using C- and L-band SAR was assessed. A strategy for semi-automated detection and monitoring of deforestation using ALOS PALSAR data was outlined. SAR-SAR interoperability and SAR-optical interoperability for forest/non-forest mapping was investigated. The interchangeable use of SAR and optical data within a spatial-temporal processing framework for improved forest accounting was demonstrated. SAR derived forest information products were validated using existing state-wide vegetation mapping (TASVEG), field survey, forestry data (supplied by Forestry Tasmania) and Landsat data. All procedures were documented in Mitchell *et al*. (2012b).

Satellite data obtained during 2012

No data has been received since October 2011.

Verification data

No further ground data in addition to that reported at the Arusha Meeting in March has been obtained.

Demonstration products generated to date (Oct. 2012)

Thematic Product	Coverage	Spatial resolution	Data source [year]	Validation
Forest/Non-Forest [NCAS]	ND wall-to-wall	25 m	ALOS PALSAR FBD (L-band HH and HV) mosaics for 2007 - 2010, and 1 FBS (HH) mosaic for 2011.	Yes (NCAS)
Forest/Non-Forest	ND wall-to-wall	25m	ALOS PALSAR [2010]	On-going
Forest and Land Cover Change	Three Verification Sites	25m	ENVISAT ASAR RADARSAT- (2009]	On-going
Image Product	**Coverage**	**Spatial resolution**	**Data source [year]**	**Validation**
Satellite image mosaic	ND wall-to-wall	25 m	Landsat TM/ETM+ [2009-2011]	N/A
Satellite image mosaic	ND wall-to-wall	25 m	ENVISAT ASAR [2011]	N/A
Satellite image mosaic	ND wall-to-wall	25 m	RADARSAT-2	N/A

On-going product generation for CEOS Plenary, GEO-IX, COP-18 and/or SDS#4

Product/topic	Coverage	Data source [year]	Target
Forest Cover Change	VS	Radarsat-2 [2009/2010/2011]	GEO-9
Land Cover Change	ND wall-to-wall	ALOS PALSAR [2007/2008; 2008/2009]	SDS#4
Satellite image mosaic	ND wall-to-wall	RADARSAT-2 [2009]	SDS#4

Participation at SDS#4 (tentatively Australia, Feb, 2013)

Possibly depending on DCCEE advice and direction

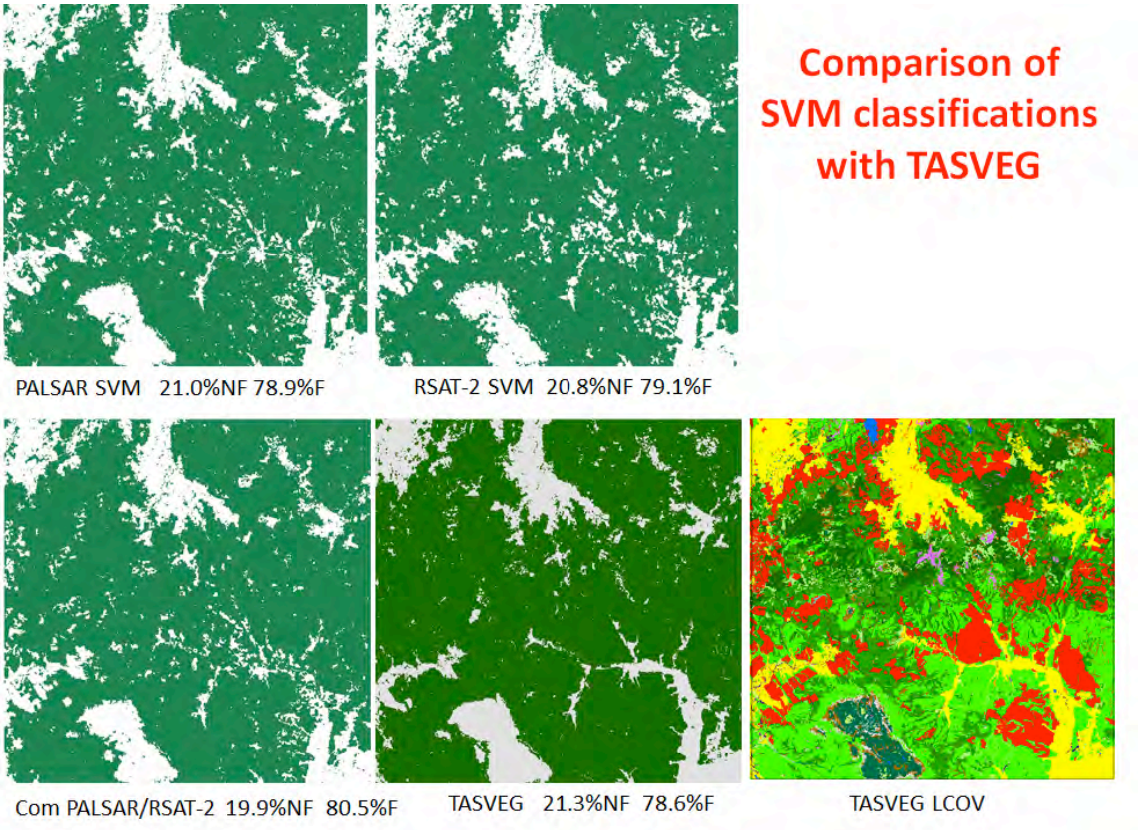


Figure 2.11.1. *Comparison of PALSAR and RSAT-2 Support Vector Machine classification results with the TASVEG. Classification implemented in image SVM (free module for ENVI/IDL)*

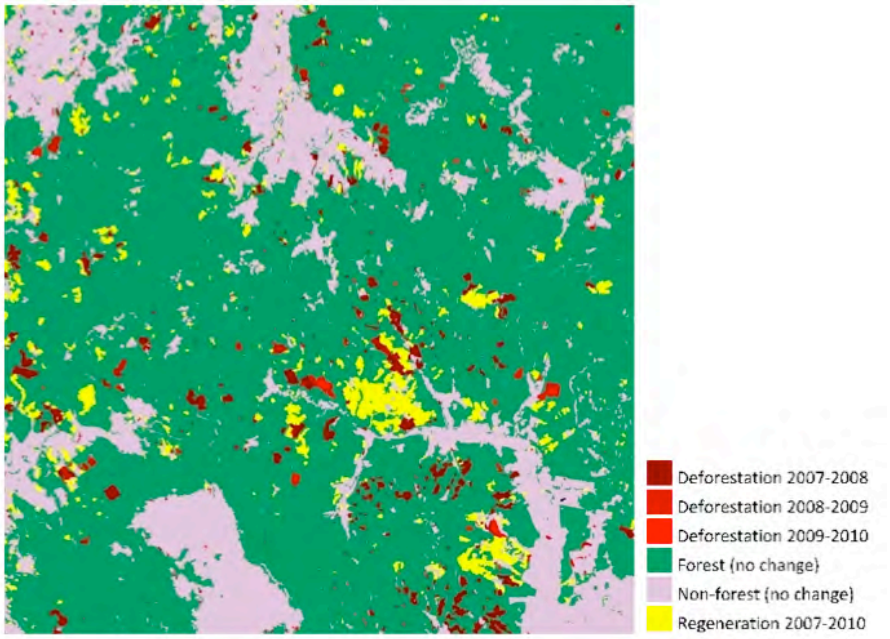
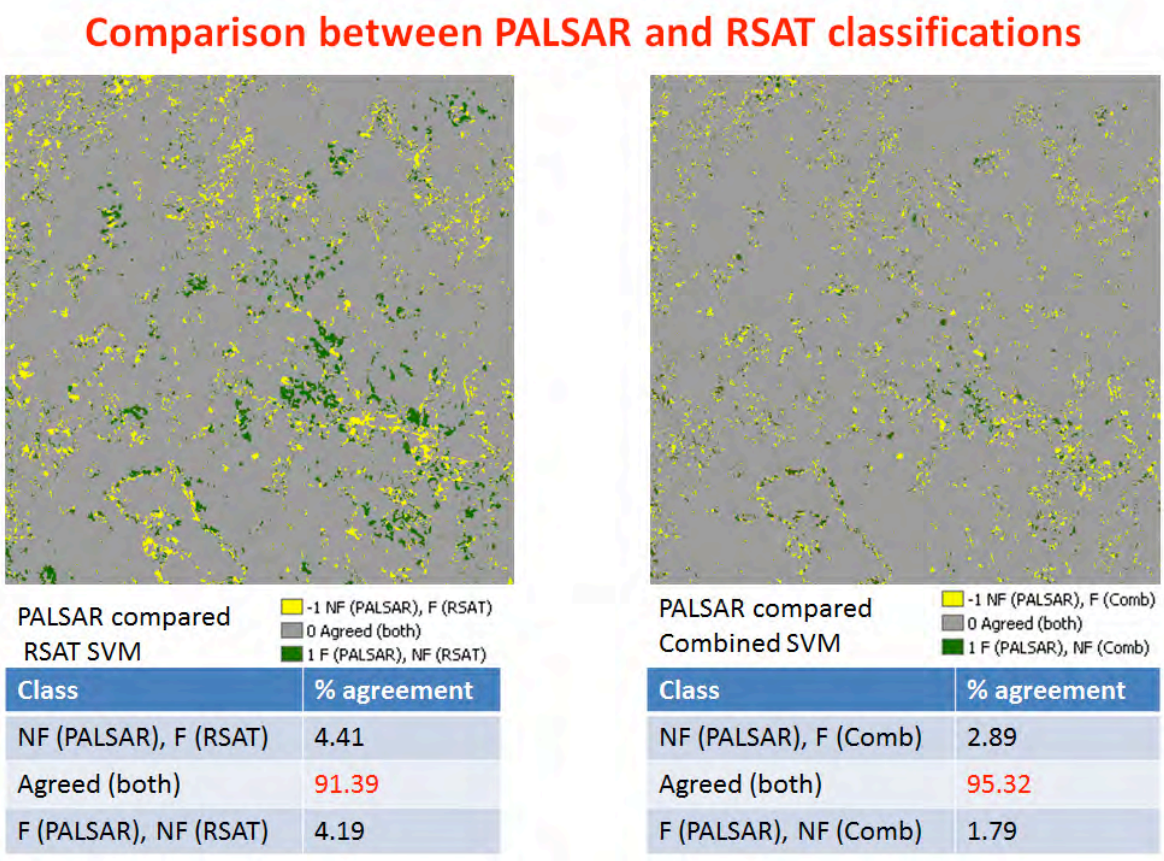


Figure 2.11.2. *Deforestation and Regeneration Map over Mathinna, Tasmania. Generated using ALOS PALSAR time-series data 2007-2010*



Class	% agreement
NF (PALSAR), F (RSAT)	4.41
Agreed (both)	91.39
F (PALSAR), NF (RSAT)	4.19

Class	% agreement
NF (PALSAR), F (Comb)	2.89
Agreed (both)	95.32
F (PALSAR), NF (Comb)	1.79

Figure 2.11.3. *Comparison of the classification Forest (F)- Non-Norest (NF) results using Support Vector Machines*

Documents Produced

Instruction Manuals

Mitchell, A.L., Tapley, I., Milne, A.K. and Williams, M. 2012a. GEO Forest Carbon Tracking Tasmania National Demonstrator: Radar processing methodologies for generation of wall-to-wall mosaics. Technical document, Vol I, 71 pp.

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3 References and Acknowledgements

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Tasmania ND

SAR Processing

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Zhou, Z-S., Lehmann, E., Wu, X., Cacetta, P., Mitchell, A., Tapley, I., Lowell, K., Milne, T., 2011. Practices of Terrain Slope Correction and Precise Registration of SAR Data for Forest Mapping and Carbon Tracking in Tasmania. Proceedings: 34th International Symposium on Remote Sensing of the Environment, April, Sydney, Australia.

Interoperability

Lehmann, E., Caccetta, P., Zhou, Z-S., Wu, X., Mitchell, A., Tapley, I., Milne, T., Held, A., Lowell, K., McNeill, S., 2011. Forest Discrimination Analysis of Combined LANDSAT and ALOS-PALSAR Data. Proceedings: 34th International Symposium on Remote Sensing of the Environment, April, Sydney, Australia.

Lehmann, E., Zhou, Z.-S., Caccetta, P., Mitchell, A., Milne, T., Lowell, K., McNeill, S., 2011. Combined analysis of SAR and optical remote sensing data for forest mapping and monitoring. Proceedings: 7th International Symposium on Digital Earth. August, Perth, Australia.

Lehmann, E., Caccetta, P., Zhou, Z-S., McNeill, S.J., Wu, X. and Mitchell, A.L. 2012. Joint processing of Landsat and ALOS PALSAR data for forest mapping and monitoring. *IEEE Transactions on Geoscience and Remote Sensing* (TGRS), Vol 50, 1: 55-67.

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