GFOI

Global Forest Observations Initiative

SDCG Element-3 Strategy: Satellite Data in Support of Research & Development (R&D) Activities

for the

Global Forest Observations Initiative

Version 1.0
for CEOS SIT-30, March 2015

CEOS

Committee on Earth Observation Satellites

GEO

Committee on Earth Observation Satellites (CEOS)

Space Data Coordination Group (SDCG)

Satellite Data in support of the Global Forest Observations Initiative (GFOI) Research & Development (R&D) Activities

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SDCG Element 3

Version 1.0

March, 2015

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EXECUTIVE SUMMARY

The **SDCG Element-3 Strategy** is focussed on the acquisition and supply of Earth Observation (EO) data in support of GFOI R&D. The strategy comprises a single coordinated observation plan for acquisition of dense time-series, multi-sensor data (optical and SAR) over a limited number of dedicated study sites to address priority R&D topics as identified by GFOI. With the support of CEOS space agencies, the GFOI research programme will advance in 2015 with targeted acquisitions over dedicated study sites and R&D activity that simultaneously addresses several priority R&D topics.

The GFOI R&D programme aims at improving and operationalising EO-based inputs to countries' national forest monitoring and carbon accounting systems (Chapter 1). Specifically this will allow countries to participate effectively in IPCC Tier 3, Approach 3 reporting under the UN REDD+ initiative. Research needs were identified and prioritised (Chapter 2), after which, a dedicated R&D programme was initiated with the aim of advancing priority R&D topics towards operational status for inclusion in the GFOI Methods and Guidance Documentation MGD) and ultimately in countries NFMS.

The study sites and satellite data requirements for R&D were defined during technical expert workshops, country consultation days and former GEO Forest Carbon Tracking FCT) contacts (Chapter 3). Sites were selected on the basis of ongoing research activity, active collaboration with country representatives, and availability of ground data. The focus of the data provision under the Element-3 strategy is on dense time-series for accurate change estimates, archive data for baseline generation, and complementary SAR and optical data for exploring the benefits of sensor synergy.

The support of CEOS space agencies is reflected in the Element-3 strategy. Their contribution is by way of providing new acquisitions and archive satellite data over GFOI study sites. Data observation requests, with minimum observation requirements for each sensor have been collated (Chapter 4). The extent of space agency support, including data availability and access procedures is outlined (Annex A). An indication of archive data availability over GFOI study sties will be provided on the GFOI R&D website. The context for R&D activity, including background on study sites, research partners and R&D topics is provided (Annex B). It is anticipated that the Element-3 Strategy will be endorsed by CEOS at SIT-30 (March 31 – April 1, 2015). Satellite data acquisitions will likely commence in the second quarter of 2015, with provision of data to research teams as soon as practicable. Progress reports will be available to CEOS agencies and presentation of research results is anticipated at an annual science summit as part of the GFOI R&D programme. Depending on the level of commitment from CEOS space agencies, a research programme of around 2 – 3 years is foreseen.

1 Introduction

1.1 Background and purpose

This document is to define how Committee on Earth Observation Satellites (CEOS) space agencies will coordinate their relevant Earth observing satellite systems to acquire data to support information requirements pertaining to Research and Development (R&D) arising from the Group on Earth Observation's (GEO) Global Forest Observations Initiative (GFOI).

The GFOI (http://www.gfoi.org) has been developed to support the goal of reducing greenhouse gas emissions from deforestation, forest degradation and associated land use change. National forest information systems are recognised to be essential for effective participation in and reporting to international agreements and forest carbon incentive mechanisms. GFOI supports governments that are establishing national forest information systems by:

- Fostering the sustained availability of space-based observations for national forest monitoring systems and assisting countries to make the best use of these observations;
- Providing assistance and guidance on utilising space-based observations, collaborating with national institutions and international bodies such as the United Nations (UN) Food and Agriculture Organization (FAO) to ensure that countries are able to utilise the available data;
- Developing methods and guidance documentation (MGD) on the acquisition and use of data for national forest monitoring systems, consistent with and complementary to the work of the Intergovernmental Panel on Climate Change (IPCC);
- Promoting on-going research and development, GFOI supports continuous improvements in the use of space-based observations and the uptake of current forest carbon science.

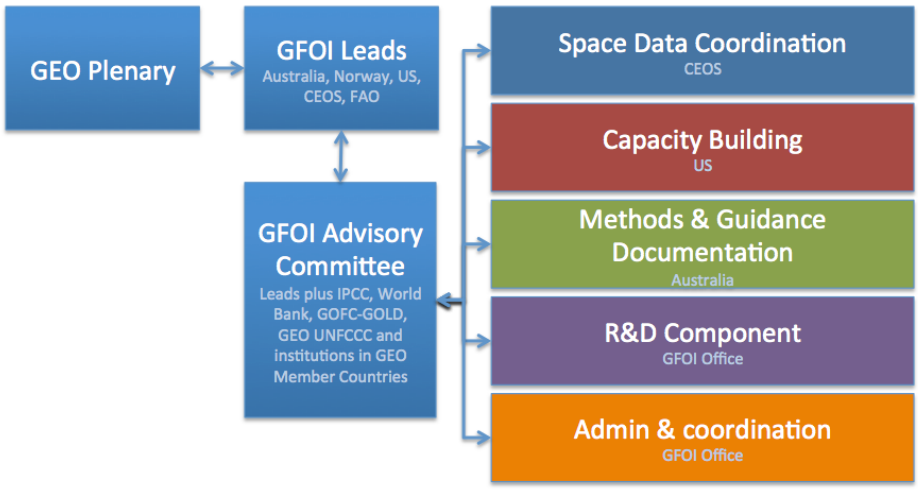

Figure 1.1 – GFOI organisational structure.

CEOS, having effectively coordinated space-based acquisitions in support of Forest Carbon Tracking (FCT) demonstration activities since 2009, has accepted responsibility for coordination of the satellite data contribution to the observations and measurement component of GFOI – the regular and routine (systematic) observations and measurements for effective reporting – ensuring continuity of supply of time series data for consistent reporting.

Recognising the magnitude of the challenge involved in meeting GFOI and FCT requirements, given the global scale and sustained coverage needed, CEOS in 2011 endorsed the three-element "CEOS Space Data Strategy for GFOI" as a framework for its coordination efforts:

Element 1: A baseline, coordinated global data acquisition strategy involving a number of space-based *core data streams* that can be utilised and shared free-of-charge for GFOI purposes. This involves systematic and sustained wall-to-wall Earth Observation (EO) acquisitions of forested areas globally and provides the default forest observations data for all countries without specific technical requirements, heritage or data preference. The Element 1 strategy is revised and endorsed by the CEOS Strategic Implementation Team (SIT) on an annual basis[1].

Element 2: A coordinated strategy for national data acquisitions. This aims to accommodate countries that have specific technical requirements, or heritage and experience on working with a particular EO data source or type, as well as the numerous intergovernmental arrangements that may exist or emerge for the supply of certain data to one or more countries. This involves a wider range of satellite data sources, including data that is ordinarily provided on a commercial basis. The Element 2 plan was endorsed by CEOS SIT in March, 2014[2].

Element 3: Data supply in support of GFOI R&D activities, including support of: the science studies assisting the development and evolution of the MGD for GFOI; interoperability studies; and validation activities – typically also involving higher resolution EO data, some of which is provided commercially and is generally beyond the scope of CEOS agency responsibility.

CEOS SIT-28 (March 2013) endorsed the Global Baseline Data Acquisition Strategy for the GFOI (Element 1) strategy, and a 2014 implementation update of this strategy was endorsed by SIT-29 (March 2014). SIT-29 also endorsed the initial release of the Space Data Services Strategy for the GFOI (Element 2).

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[1] 2014 Update of the Element 1 strategy: http://www.ceos.org/images/SIT29/CEOS-SDCG_2014_GFOI_Global_Baseline_Data_Acquisition_Strategy_v2.1.pdf

[2] Element 2 strategy: http://www.ceos.org/images/SIT29/GFOI%20Element%202%20strategy%20v1.1.pdf

1.2 Joint strategy for R&D

With the support of CEOS, GFOI will coordinate the R&D component and integrate user requests for EO data into a single coordinated observation plan (i.e., Element 3) that simultaneously aims to address several priority R&D topics identified by GFOI. It should be acknowledged however that it is not possible to anticipate all potential user requests; and that the plan therefore is based on sampled user input collected through a limited number of expert workshops, country consultations and previous GEO-FCT contacts.

1.2.1 Contribution from CEOS space agencies

The Element 3 strategy outlines different means for CEOS space agencies to support the GFOI R&D component:

- Provision of satellite data over GFOI R&D study sites
    - New data acquisitions
- Historical (archive) data Coordinated research announcements (RA) and solicitations
    - RAs targeted at selected GFOI priority R&D topics
    - Coordinated open calls targeted at GFOI support
    - Funding opportunities

Research announcements and opportunities can be posted on the GFOI R&D website (http://www.gfoi.org/rd).

1.2.2 Contribution from GFOI Research and Development teams

In return for the provision of satellite data over GFOI Study Sites, the Research and Development teams are responsible for:

- Processing and sharing data
    - Processing satellite imagery and derived map products
    - Share ground data with space agencies
- Communicating results
    - Present results at GFOI Annual Science Meeting (attendance encouraged wherever possible)
    - Contribute to GFOI annual technical report
    - Share any publications arising from R&D

1.3 Document scope

This document focuses on Element 3, satellite data acquisitions and provisions in support of the GFOI R&D component.

The prime objective of the Element 3 strategy is to provide adequate satellite data required to progress the GFOI priority R&D topics to pre-operational or operational status.

Following this introductory chapter, this report contains:

- Chapter 2: *The GFOI R&D component* – outlines the GFOI R&D strategy, supported forest map products, and review of R&D priorities
- Chapter 3: *Collection of user requirements* – summarises user requests arising from technical expert workshops, country consultations and former GEO-FCT National Demonstrator team leads, and lists the GFOI Study Sites.
- Chapter 4: *Coordinated acquisition strategy in support of GFOI R&D* – outlines coordinated acquisition requests for each data stream including archive data.
- Chapter 5: *Governance*: summarises coordinating role of CEOS, SDCG and GFOI, recommendations for advancing the Element-3 Plan, and research announcements.
- Annexes:

  A: *Contributing agencies and missions*

  B: GFOI research partners and R&D topics

1.4 Acknowledgements

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2 The GFOI R&D component

2.1 GFOI R&D Plan

The GFOI R&D Plan[3] identifies priority areas for remote sensing research and development targeted at improving and operationalising of inputs to support emissions estimation and reporting that will facilitate country engagement in IPCC Tier 3, Approach 3 accounting and future REDD+ implementation[4]. It focuses on progressing priority R&D topics to an operational status for integration in future revision and development of the GFOI Methods and Guidance Document (MGD).

The R&D component covers focused R&D actions addressing immediate needs for NFMS, rather than more long-term, basic research activities in the forest monitoring domain. Improvements to those products considered useful for a basic NFMS and non-operational products, either due to lack of regular or cost-effective data access issues or insufficient application across different regions and forest types, will be prioritised for R&D.

R&D is already underway on many topics as countries try to implement their NFMS. GFOI aims to complement these activities by promoting R&D that fills gaps in the existing work. The research needs were prioritised in the *GFOI Review of Priority R&D Topics* [5] to highlight those most urgently needed by countries to implement practical and affordable NFMS that comply with IPCC GPG. As a next step in advancing the R&D programme, a synthesis of R&D tasks and suitable research and partner organisations was completed: The *Landscaping Study* [6] . The key outcomes of these reports are outlined in the following Sections 2.3 and 2.4.

Preparations for the establishment of a dedicated R&D programme for GFOI were initiated in late 2014 with the ultimate aim to progress the priority R&D topics towards an operational status for incorporation in future revisions of the MGD. With no GFOI budget available to directly fund research groups to undertake dedicated R&D of relevance to GFOI, the approach was instead to capitalise on and catalyse already on-going R&D of relevance to GFOI and to encourage focus on operational status. This was achieved through:

- Dedicated expert workshop series that focus on specific priority topics (Section 3.1)
- Assessment of R&D needs through GFOI, SDCG and SilvaCarbon country consultations and through experiences from the GEO-FCT National Demonstrators (Sections 3.2 – 3.4)
- Invitation of research groups to participate in a dedicated research programme, and identification of a limited number of dedicated study sites (Section 3.5)

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[3] GFOI R&D Plan for 2015+. An action plan for advancing priority R&D topics related to the use of Remote Sensing in National Forest Monitoring – DRAFT, February 2015

[4] Baker et al. (2010). Achieving forest carbon information with higher certainty: A five-part plan. *Environmental Science & Policy*, 13: 249-260.

[5] http://www.gfoi.org/sites/default/files/GFOI_ReviewPrioityRDTopics_V1.pdf

[6] Landscaping the Research and Development Situation – DRAFT, July 2014

- Liaison with SDCG to establish a programme for acquisition and provision of relevant space data (i.e. the SDCG Element-3 strategy)
- Follow-up of results and progress through release of regular status reports and organisation of annual result presentation meetings (science summits).

2.2 GFOI Recommended Forest Map Products

The GFOI MGD defines seven thematic forest map products recommended to enable countries to measure *Forest Area Change* and *Carbon Stock Change Estimates*. Four supplementary forest map products defined in the *GFOI Review of Priority R&D Topics* document are also considered of high relevance to countries, but additional R&D efforts will be required to bring them to an operational or pre-operational stage, and with subsequent inclusion in the MGD. Progressing such targeted R&D is a main objective of the GFOI R&D component.

These eleven products (Table 2.1) determine the data acquisition strategies being developed by CEOS to make satellite data available. It is not the responsibility of CEOS agencies to generate these products, but to make the necessary satellite data available so that countries can generate selected products of their choice to meet their monitoring needs. It should be emphasised that the map products are not end products; rather they represent intermediate information and inputs for GHG emissions estimates that provide improved confidence intervals for country emissions estimates.

The basic requirements of a REDD+ system include estimates of the area and annual rate of land use conversion (i.e., deforestation) and the long term loss and/or gain of carbon (i.e., degradation and/or enhancement of carbon stocks). In Table 2.1, those products with a high priority rating are essential components of the system. Medium priority products can be generated routinely and at reasonable accuracy to assist the inventory, with the exception of degradation type (RD-1). Products considered a low priority may be useful in future REDD+ systems pending the success of R&D.

The perceived operational readiness of each of the forest map products is also indicated in Table 2.1. The logic behind this determination is described in the *GFOI Review of Priority R&D Topics*. All seven recommended forest map products are considered operational when suitable medium resolution optical data are available (the optimal resolution for NFMS; Table 2.1). Caveats are associated with certain products, depending on the available technology and satellite data. All four supplementary forest map products are considered to be in an R&D phase.

Code	Name	Overall Inventory priority	Operational Readiness
MGD-1	Forest / Non-Forest	Medium	Operational[(a)]
MGD-2	Forest / Non-Forest Change	Medium	Operational[(a)]
MGD-3	Forest Stratification	High	Operational[(b)]
MGD-4	All Land Use categories	Medium	Operational[(c)]
MGD-5	Land-Use Change between Forests and other Land Uses	High	Operational[(c)]
MGD-6	Change within Forest Land	High	Operational[(b)]
MGD-7	Near-Real Time Forest Change Indicators	Medium	Operational[(d)]
RD-1	Degradation Type map	Medium	R&D
RD-2	Degradation and enhancements of C stocks	High	R&D
RD-3	Above-Ground Biomass (AGB) Estimation	Low	R&D
RD-4	Change in Above-Ground Biomass	Low	R&D

Table 2.1 – GFOI recommended Forest Map Products and Supplementary Forest Map Products

[(a)] Product considered operational for key optical datasets and L-band SAR, however still in R&D phase for C-band SAR.

[(b)] Product considered operational for key optical datasets when stratification is limited between primary forest (PF) and planted forest (PlantF), but pre-operational if distinguishing between several sub-strata of natural forest. Product still considered in pre-operational and R&D phase for L-band SAR and C-band SAR respectively.

[(c)] Product considered operational for key optical datasets, however still in pre-operational and R&D phase for L-band SAR and C-band SAR respectively. Annual mapping of All Land use categories and change at sub-hectare scales is considered technically feasible, but is yet to be implemented for use in greenhouse gas inventories.

[(d)] Product considered operational for key optical datasets, however still in pre-operational and R&D phase for L-band SAR and C-band SAR respectively.

2.3 GFOI Review of Priority R&D Topics

The *GFOI Review of Priority R&D Topics* (hereafter referred to as the Review) covers those remote sensing derived forest map products needed by countries as they establish a NFMS, deciding if they are operational, pre-operational or are still in an R&D phase, and considering what additional R&D is needed to improve them. The Review identifies current gaps and opportunities for improving NFMS with newly available EO technologies or ground-based measurement methods. The research needs have been prioritised to highlight those most urgently needed by countries to implement practical NFMS that comply with IPCC GPG, and are sustainable and affordable.

The full list of R&D topics identified in the Review (Table 2.2) constitute the drivers for the GFOI R&D plan and will form the basis of a research program to improve NFMS. They also inform the observation requests in the Element-3 plan. The highest priority topics are those that address immediate data needs, including accuracy and stratification according to national requirements, sensor interoperability, data-model integration, and improvements to land use change and forest degradation products. Readers are referred to the Review document (v1.0 available at http://gfoi.org/rd) for detailed justification of the R&D topics included.

Forest stratification (MGD-3) is a minimum requirement, with forest types separated on the basis of biomass/carbon densities that can be associated with specific emissions factors. There is increasing interest in the use of SAR and LiDAR for improved discrimination and classification of forest structural types. Further R&D is needed to determine the consistency and transferability of methods across biomes. Improvements to sampling approaches and species distribution modelling would benefit from additional R&D effort.

Satellite sensor interoperability and/or complementarity ("sensor synergy") are cross-cutting topics that address the accuracy and reliability of several products. Current R&D is focused on the consistency, comparability and methods of combining time-series data/products from different satellite sensors, together with the uncertainties involved, in order to derive accurate GHG emissions estimates from forest and land use change. Optimising information extraction from optical and SAR data sources for improved accuracy of the **Land use change** (MGD-5) product is a high priority. R&D is needed on the use of very high resolution (VHR; <5 m) data for calibration and validation (cal/val) of change products.

The technical capacity to monitor forest degradation is lacking. A better understanding of the capabilities and accuracies of remote sensing approaches to fill this gap is needed. R&D on quantitative techniques (utilising SAR and LiDAR technologies) and proxy methods for producing the **degradation/enhancement of Carbon stocks** (RD-2) product is considered a high priority. Where degradation involves the removal of individual trees, the use of VHR data will likely be key. Guidance on best use of VHR and ground data for Cal/Val is needed.

An assessment of soil carbon budget dynamics in peat forests versus other tropical forests is required to better understand the emissions associated with these landscapes.

Continuous improvement of **forest/non-forest** (MGD-1) and **forest/non-forest change** (MGD-2) mapping is possible with the use of multi-sensor data. R&D in these topics is considered a medium priority, and is focussed on an assessment of the achievable accuracies of annual forest area mapping when interspersing some scenes with alternate optical (varying resolution) or SAR data (varying frequency). The research requires access to dense time-series of optical and SAR (in particular, C-band) datasets to determine the temporal imaging requirements and minimum number of observations required to adequately detect change. Improved methods of burned area mapping are also needed.

All land use categories (MGD-4) mapping would benefit from further exploitation of SAR, particularly in cloud-affected regions. Guidance is also needed on the data needs and methods for evaluation of global land use products.

Although not a requirement for REDD+ reporting, there is increasing interest in establishing early warning systems of forest change. R&D is needed to determine the optimal satellite configuration (in terms of resolution and observation frequency) and methods for producing maps of **Near-Real Time forest change indicators** (MGD-7). Further exploitation of SAR wide beam modes and high frequency C- and X-band observations is needed. The development of rapid methods for NRT processing and the data needs and ways of attributing uncertainty in each identified change are required.

Mapping of forest **degradation type** (RD-1) and proxies/indicators is considered a medium priority. Advances in change detection approaches are possible, and mapping methods for regrowth and extracting land use history from time-series optical and/or SAR data are needed.

Newer techniques such as **above-ground biomass** (AGB) estimation and **change in AGB** (RD-3 and RD-4) are currently a lower priority. Once the various techniques are evaluated across a range of forest types and ecosystems, the approaches will assist countries in building their national carbon stock estimates. Further R&D is needed on multi-sensor approaches, comprising wall-to-wall optical and/or SAR data and LiDAR, and modelling approaches that integrate repeat coverage. Advances in InSAR and polarimetric InSAR (PolInSAR) techniques are needed for canopy height estimation and extending the saturation level for biomass estimation. Additional R&D is needed on robust sampling design and establishing the links between AGB and other carbon pools.

Map Code and Product (if applicable)	R&D Topics	Priority
MGD-3 **Forest stratification**	• SAR texture metrics and polarimetry • Sampling and species distribution models • Consistent methods across biomes • Airborne LiDAR or InSAR structural classification • Forest type mapping from simulated future hyperspectral data	**High**
MGD-5 **Land use change**	• Exploitation of SAR texture and polarimetry for greater class separability • Sensor interoperability and complementarity for improved detection and mapping of land use change • Use of VHR data for calibration/validation of change products	
RD-2 **Degradation/ Enhancement of Carbon stocks**	• Mapping methods for regrowth • Proxy measures • Quantitative measures of degradation • Deriving forest degradation products and field validation from VHR data • Use of SAR data for mapping degradation • Use of airborne LiDAR for deriving biomass/carbon stocks and change • Assessment of the relationship among definitions of degradation, degree of degradation that can be detected, associated accuracies, and useful kinds of remotely sensed data	
General forest mapping method improvements	• Sensor interoperability - Generating similar thematic products from different sensor systems for assembly of time-series • Sensor complementarity for improved information extraction and monitoring • Uncertainty and inference • Assess potential generation of products using simulated future datasets such as (i) Sentinel-1/RCM time-series, (ii) Sentinel-2, and (iii) Hyperspectral (EnMAP) data • Optimising information extraction using dense time-series C-band SAR	
Data-Model integration	• Improved ground data and soil carbon budget models for new forested areas (e.g., peat soils)	
MGD-1 **Forest/Non-forest**	• Investigate alternative non-GFOI data streams for F/NF mapping	**Medium**
MGD-2 **Forest/Non-forest change**	• Improved methods for burned area mapping • Optimising F/NF change mapping using dense time-series C-band SAR	
MGD-4 **All Land use categories**	• Further exploitation of SAR for mapping land use categories • Identify data needs and methods for evaluation of global product accuracy	
MGD-7 **Near-Real Time Forest Change Indicators**	• Test different spectral fractions to identify disturbance pixels in different forest types and regions • Investigate alternative non-GFOI data streams, such as TerraSAR-X and future ALOS-2 ScanSAR • Methods and data for validation of products • Exploiting dense time-series C-band SAR	

RD-1 **Degradation type**	• Methods of extracting land use history (e.g., forest type and age, land use transitions following clearing/re-clearing) from optical time-series • Automated mapping methods • Use of fractional cover and evaluate different spectral indices • Evaluate different change detection approaches	
RD-3 **Above-ground biomass**	• Biomass stock stratification approaches (design- and model-based) • Link between AGB and other carbon pools (e.g., soil carbon) • Transferability of methods from boreal to temperate to tropical forest • Airborne LiDAR or SAR tree height correction • Bi-static SAR for estimating tree height • Integration of ground,- and airborne LiDAR, SAR and optical data • Integration of LiDAR and optical data for calculating past emissions	**Low**
RD-4 **Change in above-ground biomass**	• Modelling approaches using repeat LiDAR • Integration of repeat LiDAR and SAR to estimate biomass change across different forest types • Sampling design options • Transferability of methods to tropical biome	

Table 2.2– Summary of R&D needs identified in the GFOI Review of Priority R&D Topics[4]. [GFOI R&D Review document, Table 3]

2.4 R&D Landscaping study

Brief mention is made of the GFOI Landscaping study, which provides a review of current research activity worldwide as linked to GFOI priority R&D topics. The Landscaping study identifies (i) R&D that is on-going and will progress without external funding, (ii) the shortfalls in current research that will require additional funding, and (iii) potential GFOI partner organisations who may contribute to technical advancement of products/technologies or financing thereof.

There is much NFMS related R&D activity already underway worldwide, and the GFOI R&D component aims to complement this by promoting R&D that fills gaps in the existing work. GFOI will consult with potential research partners at expert workshops and scientific forums to capitalise on and promote R&D that complements GFOI priority research. An important outcome of these consultations is a series of user requests for satellite data acquisition over key sites for coordinated R&D to advance certain forest mapping methodologies to pre-operational or operational status. The following chapter 3 outlines specific user requests for satellite data over nominated sites for R&D.

3 Collection of user requirements

3.1 GFOI R&D Expert workshops

To kick-start R&D activities with limited financial means, a series of technical Expert workshops have been undertaken during 2014/2015 to capitalise and catalyse already on-going research. The workshops are focused on selected Priority R&D Topics and involve a small number of key experts on the topics in question.

Workshop objectives:

- Assessment of existing approaches and current state of the art for the topic in question;
- Identification of obstacles to operational (widespread) use;
- Development of an action plan to progress development;
- Input/recommendations to CEOS (and commercial) data providers (Element-3 strategy)

Expert workshop 1 – Sensor interoperability/complementarity

Woods Hole, MA/USA, June 10-11 2014

Expert workshop 2 – Forest degradation

Wageningen, Holland, Oct. 1-3, 2014

Expert workshop 3 – Above-ground biomass

Brisbane, Australia, Feb. 24-26, 2015

GFOI Science Summit – Open meeting on key R&D issues

Venue TBD. Q3 2015

3.1.1 User requests from Expert Workshop 1: Sensor interoperability/complementarity

Discussions at Expert Workshop #1 centred on sensor synergy for improved forest and land cover monitoring and above-ground biomass (AGB) estimation. Much of the R&D is focussed on the integration of Optical and L- and/or C-band SAR data streams, and also its combination with LiDAR data, for improved detection of change and AGB estimates. New methods of combining dense time-series of observations and verifying change in multiple data sets are being investigated. Several experts increasingly rely on high (e.g., RapidEye) to very high resolution (VHR) optical data for training and validation of products/methods. Coupling satellite data with intensive field information was critical.

The full workshop report can be accessed at the GFOI website[7].

[7] http://gfoi.org/sites/default/files/GFOI_RDExpertWS1_Report_final.pdf

The satellite data needs to support R&D efforts for improved forest/land cover mapping and change detection and AGB estimates are summarised as follows:

i. Systematic dense time-series of Landsat-7/-8, ALOS-2 and Sentinel-1/-2 over target sites.

R&D topics addressed:

- Further exploitation of SAR and optical data combinations to progress methods to pre-operational/operational status.
- Guidance on added value of integrating a new data source for a certain thematic application (cost/benefit analysis).
- Sensor inter-calibration to ensure consistency of products.
- Further development of data fusion and trend analysis methods using time-series optical/Landsat-like and C- and L-band SAR data to improve the accuracy of detected land cover change.
- Identify the temporal resolution required to detect disturbance, and effects of seasonality, soil moisture and cloud cover on detection.
- Determine the extent to which time-series methods work on historical data.
- Test transferability of methods to newly launched (e.g., Sentinel-1, ALOS-2) or upcoming sensors (e.g., Sentinel-2) and evaluate impact on map accuracy.
- Improve our understanding of seasonal and annual phenological variations at biome level and assist interpretation of temporal signatures from both SAR and optical data sources. Requires coincident and intensive field data collection.
- Development of multi-sensor and data fusion approaches for mapping different types of forest degradation, and testing in a range of forest types/ecosystems for consistency and accuracy.
- Methods development and evaluation of the contribution of dense time-series C-band SAR observations for forest and land cover monitoring and mapping forest degradation.
- Assessment of the consistency and accuracy of different modelling approaches and integration of C- and L-band SAR and optical data for estimating AGB.

ii. Archive RADARSAT-2 (24-day repeat) and ERS-1 (3-day repeat) data over target GEO-FCT sites

R&D topics addressed:

- C-band SAR applications development, focussing on defining the optimal observation strategy (appropriate temporal sampling frequency and time windows for specific applications), and adjusting algorithms for use with limited temporal data sets.

iii. Access to X-band SAR data (stripmap and bistatic TerraSAR-X and TanDEM-X)

R&D topics addressed:

- Development of forest degradation mapping methods in cases of partial or complete removal of canopy cover.

- Improved methods of estimating AGB using bistatic TerraSAR-X and TanDEM-X observations.

iv. Access to systematic sample high (e.g., RapidEye) to VHR optical data (e.g., WorldView) is requested.

R&D topics addressed:

- Address gap in the provision of cal/val data.
- Methods and integration with SAR and LiDAR data for mapping forest degradation.

v. Access to historic ICESat GLAS and future ICESat-2 data is required. Several experts suggested that lack of a spaceborne LiDAR was the main observational gap.

R&D topics addressed:

- Further evaluation of the contribution of ICESat data and consistency of returns relative to L-band SAR and optical data for forest and land cover classification and AGB estimation.
- Algorithm development using ICESat-2 data.

vi. Access to archive SAR data (JERS-1 and ALOS-1)

R&D topics addressed:

- Generation of historic and recent baselines of forest cover.
- Further exploitation of SAR texture metrics, polarimetry, entropy and coherence, different classifiers and segmentation algorithms.
- Advanced InSAR techniques for forest cover change monitoring.

vii. Access to JAXAs 25 m ALOS PALSAR mosaics

R&D topics addressed:

- Demonstration of wide-area forest and land cover mapping capability.
- Provide feedback to JAXA on how future ALOS-2 mosaics could be improved for optimal use.

viii. Negotiate use of airborne LiDAR survey data for R&D use (project-dependent assistance from GFOI is requested).

R&D topics addressed:

- LiDAR metrics and integration with SAR and optical data for mapping forest degradation.
- Methods of calibrating wall-to-wall satellite data using sample LiDAR data.
- Scaling studies addressing field sampling, LiDAR transects and wall-to-wall mapping approaches.

Furthermore, five capacity enhancement issues were also discussed as important gaps in operationalising the technology: (i) identification of the appropriate IT/infrastructure needs of countries for data procurement and access; (ii) open source software development and training for implementation of MRV systems (possible link to CEOS working groups on software and capacity); (iii) automation of complex methods, (iv) need for increased familiarity of SAR data and processing; and (v) guidance on forest monitoring strategies, i.e., sensor/resolution requirements, and inclusion in the MGD.

3.1.2 User requests from Expert Workshop 2: Forest degradation

Discussions at Expert Workshop #2 centred on ground and remote sensing approaches to mapping different types of degradation. The IPCC methods and requirements for forest degradation monitoring in the context of REDD+ were discussed. Much of the R&D is focussed on the application of Optical, L- and X-band SAR for detection of disturbance arising from, for example, selective logging, fire and shifting cultivation. Optical methodologies included visual interpretation and manual digitizing, trend analysis and spectral unmixing, to identify different classes and intensities of degradation. SAR-based methods were reliant on backscatter intensity, multi-temporal aggregation, Polarimetric decomposition and interferometric change analysis for detecting disturbance and proxies (e.g., logging roads). Only one study considered the integration of SAR and optical data for characterising regrowth state. Limited studies utilised LiDAR structural metrics, or attempted direct estimates of biomass gain/loss in regrowth and degraded forest.

The full workshop report can be accessed at the GFOI website[7].

The satellite data needs to support R&D efforts for improved forest degradation mapping are summarised as follows:

i. Systematic dense time-series of Landsat-7/-8 and SPOT-5 over study sites.

   R&D topics addressed:

   - Methods of separating natural and anthropogenic degradation.
   - Separating disturbance (degradation) from seasonal signals using long time-series.
   - Trend analysis using dense time-series optical data.
   - Automated mapping methods, including SMA, fractional cover and spectral indices.
   - Change detection approaches, and methods of linking change in canopy cover with change in biomass.
   - Guidance on the cost/practicality of combining different sensors to determine AGB gain/loss in detected degradation.
   - Guidance on use of optical data to stratify the forest and detect change, followed by in situ sampling and/or air photo interpretation for countries with low technical capacity.
   - Transferability of methods to Sentinel-2; cloud-free compositing using Landsat and Sentinel-2.

ii. Access to VHR optical data (e.g., Pléiades, WorldView) is requested.

   R&D topics addressed:

- Development of methods that use a systematic sample of VHR optical data and wall-to-wall satellite optical or SAR data, with available ground observations and LiDAR, to estimate AGB in degraded forests.

iii. Systematic access to X-band SAR data (spotlight, stripmap and bistatic TerraSAR-X and TanDEM-X)

R&D topics addressed:

- Development of forest degradation mapping methods in cases of partial or complete removal of canopy cover.
- Determine spatial resolution requirements (spotlight vs. stripmap).
- InSAR change analysis using TanDEM-X and SRTM DEMs; correction of C- to X-band DEM.
- Methods of assessing carbon dynamics, i.e., gain/loss, and not just biomass.
- Accounting for soil/canopy moisture effects and seasonality (leaf-on/leaf-off).
- Automation and fast logging assessment methods using dense time-series.
- Speckle filtering and change detection approaches.

iv. Systematic access to ALOS-1/-2 PALSAR data is requested.

R&D topics addressed:

- Determine temporal frequency required to detect degradation.
- Polarimetry and SAR-Optical integration for discriminating degraded forests, including country-specific classes, e.g., primary and secondary peat lands.
- Transferability of monitoring methods to ALOS-2.
- Methods of transforming detected degradation and recovery into biomass gain/loss.

v. Access to RADARSAT-2 and Sentinel-1 data is requested.

R&D topics addressed:

- Methods development and evaluation of the contribution of dense time-series C-band SAR observations for mapping forest degradation.

vi. Access to historic ICESat GLAS and future ICESat-2 data is required.

R&D topics addressed:

- Integration of ICESat, Optical and L-band SAR data for characterising regrowth state.
- Transferability of methods to other forest types/regions.
- Algorithm development using ICESat-2 data (and JEDI LiDAR on ISS).

vii. Negotiate use of airborne LiDAR survey data for R&D use (project-dependent assistance from GFOI is requested).

R&D topics addressed:

- LiDAR metrics and integration with SAR and Optical data for mapping forest degradation.

- Correlating LiDAR profiles with degradation type/regrowth state.
- Quantifying uncertainty and error propagation in different AGB modelling approaches.
- Correlation of field and remote sensing data; uncertainty when upscaling point-transect-area data.

3.1.3 User requests from Expert Workshop 3: Biomass estimation

The 3rd GFOI R&D Expert workshop will focus on approaches to remote sensing for plant biomass estimation. It will be organised in collaboration with GOFC-GOLD and the CSIRO Terrestrial Ecosystem Research Network (TERN) and take place in Brisbane, Australia on February 24-26, 2015.

3.2 Country consultations

GFOI, SDCG and SilvaCarbon are working closely with a number of countries to assess their immediate and longer-term data and R&D needs. The key R&D issues and data requests arising from these capacity building exercises are summarised below.

3.2.1 SDCG country consultation days

Country consultation days were held in Pasadena (SDCG-4, Sept 2013), Rome (SDCG-5, Feb 2014) and Oslo (SDCG-6, Oct 2014). Country representatives from Bangladesh, Colombia, D.R Congo, Ecuador, Guyana, Indonesia, Kenya, Mexico, Nepal, Peru, The Philippines, Tanzania and Uganda provided input to NFMS and REDD+ monitoring needs.

Specific data requirements include:

i. Coarse resolution data for forest cover mapping and early warning systems, including

   SAR – best L-band (ALOS-1/-2) and/or C-/X-band (Sentinel-1, TerraSAR-X) data in wide beam modes

   Optical – MODIS (& continuity of MODIS products, e.g., NDVI, EVI and active fire products), SPOT VGT or IRS LISS

ii. Medium to High resolution data for annual or periodic , wall-to-wall forest and land use and change monitoring, degradation mapping and AGB estimation, including

   Optical – Landsat-5/-7/-8 (dedicated connection to whole catalogue; co-registered) and Sentinel-2

   SAR – best L-band (ALOS PALSAR) and/or C-/X-band data (Sentinel-1, TerraSAR-X)

   Other – e.g., SPOT-3/-5/-6, IRS LISS, CBERS-4, ALOS AVNIR-2, DMC

iii. VHR data for Cal/Val and identifying settlements, tree crowns and land use types (2-5 % of country area at < 5 m resolution, e.g., QuickBird, IKONOS, GeoEye, Pléiades, FormoSat), and for e.g., WorldView-2 data (10 % of country area) for land use and forest degradation mapping and AGB estimation (biennial and free of clouds).

iv. All countries indicated the need for a national high resolution DEM, e.g., TanDEM-X 5 m DEM. Alternatively, the 30 m SRTM or ASTER DEMs.

Specific R&D needs were highlighted for the following forest map products:

i. Forest degradation – testing of methods for respective forest ecosystems, SAR-optical synergy, methods for producing a preliminary forest degradation baseline, methods of identifying selective logging.

ii. Proxy indicators for conservation, sustainable management of forests and enhancement of forest carbon stocks – an assessment of what remote sensing derived proxies can be used and the likely accuracy.

iii. All Land use categories and Activity data – advanced mapping methodologies, including cloud/shadow masking and gap filling, sensor interoperability (SAR-Optical integration) and spectral indices, for improving the results of activity data and estimating uncertainty in emission factors and emission estimates. R&D on change detection techniques, computer-aided digitizing, use of open source software, segmentation and classification algorithms, methods for validation, and improved mapping methods for mosaic forest-savannah, deciduous forest, palm, wetlands, aquatic vegetation and agriculture classes, accounting for seasonality and vegetation height. Methods for the integration of high resolution data for mapping post-fire burned area extent are also required.

iv. Forest/Non-Forest and Deforestation monitoring – improved methodologies, including sensor interoperability, optimisation and use of SAR data, methods for integrating LiDAR data, methods for validation, and viable performance chains to achieve Approach 3 and/or Tier 2 reporting.

v. Forest stratification – improved mapping methodologies for the production of forest type/ecosystem maps, including optimisation of segmentation and parameterisation of algorithms for specific forest types (taking into account forests with different types of ground cover).

vi. Fast response systems – technical guidance on the implementation of early warning or Near-Ream Time (NRT) systems for detection of forest clearing. R&D needed on hyper-temporal processing algorithms and methods for validating results. Access to high frequency, coarse resolution data would be required for this purpose.

vii. AGB and change estimates - improved tools for biomass/carbon stock, emissions estimates and uncertainty tracking, including integration of ground data, Optical, SAR and LiDAR data, and image calibration.

Specific capacity building needs were identified:

i. Training on Sentinel-2 data formats, access and other specifics to assure smooth and rapid ingestion of the sensor when it becomes available.

ii. Training on generation of cloud-free mosaics.

iii. Training on integrating DEMs and remote sensing data.

iv. Training on LiDAR data processing to improve carbon stock and degradation information.

v. Support with radar data, and integration with Optical data, for land cover mapping and biomass modelling.

vi. MRV and GHG inventory design and implementation.

vii. Processing tools and/or software.

3.2.2 GFOI/SilvaCarbon Capacity building workshops and GEOSS-AP

GFOI/SilvaCarbon Capacity building workshops were held in Chiang Mai (Jan 2014), Tokyo (May 2014), Kathmandu (June 2014) and Douala (June 2014). Country representatives from Bangladesh, Thailand, Vietnam, Cambodia, Laos, Philippines, Nepal and Indonesia discussed their on-going status with regards to design and implementation of MRV systems for REDD+.

Specific data requirements include:

i. Coarse resolution data for forest cover and change mapping and NRT monitoring, including

   Optical – MODIS Terra/Aqua, NPP, NOAA-18/-19, METOP, MTSAT-1R, SPOT VGT

ii. Medium to High resolution data for annual or periodic, wall-to-wall forest cover and land use monitoring, forest stratification and quantification of AGB/carbon flux, including

   Optical – Landsat-5/-7/-8 (and future Landsat-9), SPOT-4/-5, ALOS AVNIR-2, DIEMOS-1, THEOS, IRS, VNREDSat-1A/-2, ASTER, RapidEye

   SAR – ALOS PALSAR FBS and FBD, RADARSAT-2, TerraSAR-X

iii. VHR data for forest monitoring and Cal/Val, including

   Optical – QuickBird, SPOT-5/-6/-7, ALOS PRISM, GeoEye-1, IKONOS, WorldView-2, , air photos

iv. Airborne and spaceborne (ICESat GLAS) LiDAR– for biomass/carbon and degradation assessment.

v. SRTM DEM, IfSAR DEM for pre-processing satellite data.

Specific R&D needs were highlighted for the following forest map products:

i. Forest degradation – forest degradation definition; use of LiDAR; methods for distinguishing between sustainable logging management and other logging practices, e.g., illegal logging and fuel wood extraction; methods of identifying vulnerable forests, insect and climate impact, agricultural and population pressures.

ii. All Land use categories and Activity data – multi-sensor and multi-scale mapping methods; use of SAR data; change detection methods; use of IfSAR data to identify forest plantation and other land classes; methods for integrating different data sources (resolution, timing, optical and SAR) to gap-fill nation-wide maps; future use of hyperspectral data; analysis of error propagation.

iii. Forest/Non-Forest and Deforestation monitoring –alignment of forest definitions and criteria; baseline forest cover mapping; SAR-optical interoperability; transferability of methods to Landsat-8 ; use of SAR data; change detection approaches; mapping methods using high resolution imagery.

iv. Forest stratification – stratification system for NFI.

v. Above-ground biomass and change – use of radar and LiDAR to improve biomass/carbon stock estimates for different forest types; integration of ground and multi-sensordata; sampling design; accuracy assessment methodology.

vi. Fast response systems – technical guidance and access to satellite data for Near-Real Time (NRT) monitoring of forest cover change.

Specific capacity building needs were identified:

i. Guidance on MRV system design and implementation, including IT/database management and NFI.

ii. Methods for producing cloud-free mosaics.

iii. Training in new software and mapping methods.

iv. Training in accuracy assessment and quality control.

v. Methods for integrating new data, e.g., DEMs.

3.3 Experiences from GEO-FCT R&D activities and National Demonstrators

R&D-related activities under GEO-FCT addressed a number of key science questions relating to optimising information extraction from multi-sensor and multi-temporal EO data and AGB estimation. At the completion of the program, a number of research gaps were identified. GEO-FCT National Demonstrator (ND) countries also provided advice to CEOS to optimise the FCT acquisition strategy for current and near-future satellite missions. The following recommendations were made:

i. Continue with annual, dual season, wall-to-wall coverage over the NDs with optical, L- and C-band SAR.

R&D topics addressed:

- Further testing of sensor interoperability (optical-optical, SAR-SAR, optical-SAR) for generating time-series forest and land use cover and change estimates across a range of landscapes and forest types.
- Evaluate capacity for continuous forest and land cover monitoring using data from existing (Landsat-8) and future satellites sensors (Sentinel-2A/B and CBERS-4).
- Further testing of SAR-SAR interoperability, in particular the interchangeable use of C-band SAR data acquired in specific modes for ND countries, and future interoperability using Sentinel-1A/B and RCM.
- Further testing of sensor complementarity for improved discrimination of specific forest/land cover types, in particular C- and L-band SAR.
- Further R&D to assess the potential for quantitative estimation and stratification of biomass using time-series L- and C-band SAR and other data sources (e.g., ICESat GLAS).

ii. Dense RADARSAT-2 time-series over nominated verification sites to simulate new generation C-band satellite datasets.

R&D topics addressed:

- Analysis of simulated Sentinel-1A/B and RCM time-series datasets over some ND verification sites (using ASAR and RADARSAT-2 data) for forest characterisation and change detection.

iii. FCT community to provide guidance to ESA and CSA to ensure useful acquisition of future C-band SAR, i.e., from Sentinel-1A/B and RCM (similar to that for ALOS).

iv. VHR (optical and X-band SAR) data are highly desired for verification of maps/products.

R&D topics addressed:

- Further use of VHR TerraSAR-X data for identifying forest degradation and selective logging.
- Methods for verification of derived products.

v. Provide access to a high resolution DEM (e.g., TanDEM-X DEM or best available SRTM) for ortho-rectification and terrain illumination correction of data and use in classification.

3.4 Data requirement summary

The satellite data requirements for R&D as defined during workshops, country consultation days, and from the former GEO-FCT program are summarised below.

Medium-resolution optical data (Landsat-like class of sensors; ~30 m resolution)

- 1 cloud-free coverage per year is required for priority R&D in baseline forest cover mapping, forest stratification, deforestation and degradation monitoring, generation of land use and activity data and AGB estimates.
- More dense time-series (monthly or better) is required for temporal trend analysis associated with land cover change and disturbance, and understanding seasonal and phenological effects on temporal signatures.
- Pre-processed (atmospherically and radiometrically corrected and orthorectified) consistent data that can be used to develop change detection algorithms is a critical need for forest monitoring systems.
- Data from a range of sensors is requested for each site to test optical-optical interoperability and complementarity for generating time-series forest and land cover change estimates.
- Archive Landsat data is requested for baseline generation and time-series studies.

Optical High Resolution data (5-10 m resolution)

- Systematic time-series high resolution data is requested for calibration/validation of derived forest map products and development of mapping methods for forest degradation.
- Archive Optical data, including, for example, RapidEye and ALOS AVNIR-2, is requested for temporal forest disturbance studies.

L-band SAR data (dual-polarisation stripmap, ScanSAR)

- Twice per year coverage is required for priority R&D in land cover and forest/non-forest mapping and AGB estimates.
- More frequent time series (~bi-monthly) is required for forest cover and land use change monitoring, and understanding the effects of seasonality and soil moisture on backscatter response.

- ScanSAR at ~monthly frequency for development of early warning systems of deforestation and degradation.
- While L-band SAR is not considered particularly useful for mapping degradation, it is possible to discriminate degradation due to fire and logging activity, and map regrowth stage when used in combination with other sensors (optical, LiDAR).
- Archive L-band SAR data, including JERS-1, is requested for generation of baseline forest cover. Access to JAXAs 25 m resolution annual ALOS PALSAR mosaics (2007-2010) is requested for demonstration of wide-area mapping capability.

C-band SAR data (dual-polarisation stripmap, ScanSAR)

- Twice per year coverage is considered useful for land cover and forest/non-forest mapping when used in combination with other SAR sensors (L- or X-band).
- Dense time series (monthly or better) is required for forest cover change and degradation monitoring.
- Dense time-series (monthly or better) in ScanSAR/wide beam modes is considered useful for development of early warning systems of forest cover change.
- Data from a range of sensors is requested for each site to test SAR-SAR interoperability and complementarity for generating time-series forest and land cover change estimates.
- Archive C-band SAR data, including RADARSAT-2, ENVISAT ASAR and ERS-1, for C-band SAR applications development.

X-band SAR data (dual-polarisation stripmap, ScanSAR)

- Twice per year coverage is considered useful for land cover and forest/non-forest mapping when used in combination with other sensors (L- or C-band SAR).
- Dense time series (monthly or better) is required for forest cover change monitoring and degradation assessment in hot spot areas.
- VHR mode (single-polarisation 3m stripmap) is considered useful for identifying degradation hot spots.
- Dense time series (monthly or better) in ScanSAR mode is potentially useful for development of early warning systems of forest cover change.
- Archive X-band SAR data is requested to extend the time-series of observations for development of forest degradation and change mapping methods.

Bistatic X-band SAR (TanDEM-X)

- A DEM generated using bistatic TerraSAR-X and TanDEM-X observations is useful for estimating forest canopy height, and hence, AGB.
- DEMs generated at two different epochs are potentially useful for detecting forest canopy (volumetric) change as related to forest degradation or regrowth.
- Access to a high resolution DEM is needed for all sites (TanDEM-X or 30m SRTM) for pre-processing and use in classification.

- Further research is needed to exploit the potential of TanDEM-X PolInSAR for vertical forest structure and tree height estimation.

Optical Very High Resolution (VHR) data (< 5 m resolution)

- Systematic time-series sample VHR data (e.g., Pléiades, WorldView-2) is requested for calibration/validation, forest cover mapping and stratification, and detailed biomass/carbon and forest degradation assessment when used in combination with other sensors (e.g., optical, SAR).

Sensor(s)	Observation mode	Associated map product code								
		F/NF MGD-1	F/NFC MGD-2	F strat MGD-3	LU MGD-4	LUC MGD-5	FC MGD-6	NRTFC MGD-7	Degrad RD-1/2	AGB RD-3/4
Landsat-7/-8		X	X	X	X	X	X	X	X	X
CBERS-2B	CCD WFI	X	X		X	X		 X		
SPOT		X	X		X	X	X		X	
RapidEye		X	X		X	X	X		X	
VHR Optical		X	X	X	X	X	X	X	X	
TerraSAR-X	Stripmap Spotlight Bistatic	X	X					X	X X X	 X
TanDEM-X	DEM								X	X
COSMO-SkyMed	Stripmap	X	X						X	
Sentinel-1A	IWS Dual-polarisation	X	X	X	X	X	X	X	X	X
RADARSAT-2	Dual or Quad-polarisation	X	X	X	X	X			X	X
ENVISAT ASAR		X	X	X	X	X				
ERS-1/2		X	X	X	X	X				
ALOS-2 PALSAR-2	FBD ScanSAR	X	X	X	X	X	X	 X	X	X
ALOS-1 PALSAR-1	FBD QP ScanSAR	X	X	X X	X X	X X	X	 X	X	X

Table 3.1 – Data requirement summary for R&D.

3.5 GFOI R&D Study Sites

Through the workshops, meetings and user consultations described above a limited number of research Study Sites have been identified where ground data have been collected and research activities relevant to the GFOI R&D plan are on-going (Table 3.2). Centre lat/long coordinates are provided for each study site.

Site Code	Site name	Country	Coordinates	
			lat	long
Priority 1				
BRA-1	Mato Grosso	Brazil	S11.75	W54.25
CAR-1	Mbaïki	Central African Republic	N3.872	E17.987
GAB-1	Gabon	Gabon	N0.0181	E10.1906
FCT-COL-3	Pacifico-Bajo_Mira	Colombia	N1.65	W78.76
FCT-COL-5	Andes-Antioquia		N7.83	W76.45
COL-6	Caqueta		N1.4079	W73.5747
COL-7	La Victoria		N6.26	W74.64
ETH-1	Kafa BR	Ethiopia	N7°30'29"	E35°54'29"
FIJ-1	Lololo & Nakavu	Fiji	S17.833	E177.833
PER-1	Peru	Peru	S11.1	W74.3
GFC-1	GFC Site 1	Guyana	N3.3069	W-59.6672
GFC-2	GFC Site 2		N6.4856	W-58.9471
FCT-BOR-3	Mawas	Indonesia	S2.24	E114.48
FCT-SUM-2	Harapan		S2.20	E103.38
FCT-TNZ-5	Amani	Tanzania	S5.13	E38.63
FCT-TNZ-6	Liwale		S9.50	E38.17
PNG-1	Kokoda	PNG	S9.184	E147.374
PNG-2	Milne bay		S10.598	E150.185
FCT-MEX-2	Chiapas-1	Mexico	N16.45	W91.40
MEX-8	Durango		N23.74	W105.49
AU-4	Robson Creek (QLD)	Australia	S17.119	E145.631
FCT-AU-1	Mathinna (Tasmania)		S41.37	E147.76
AU-5	Injune (QLD)		S25.5	E147.7
CAN-1	Site 1 NW Territories	Canada	N61.4	W121.3
CAN-2	Site 2 NW Territories		N62.53	W116.53
KAL-1	Central Kalimantan	Indonesia	S2°24′	E114°6′30″
SUM-1	South Sumatra		S2°29′30″	E103°28′30″
BRA-2	Novo Progresso	Brazil	S7°02′4.07″	W55°24′1.82″
SUR-1	Kabo	Suriname	N5.255928°	W55.76682°
MAL-1	Malinau	Indonesia	N3.0217°	E116.3601°
MAD-1	Mahafaly	Madagascar	S24.0304°	E43.7651°
SA-1	Lowveld / Kruger N.P.	South Africa	S24°59′45″	E31°35′30″
SA-2	Eastern Cape		S33°36′	E25°40′

Priority 2				
FCT-COL-4	Amazonia-Tinigua	Colombia	N2.17	W74.15
GFC-3	GFC Site 3	Guyana	N7.4660	W-60.0742
PNG-3	Yus	PNG	S6.028	E146.745
FIN-1 FIN-2	Hyytiälä Sodankylä	Finland	N61.85 N67.48	E24.32 E26.34
ICE-1	Hallormsstadur	Iceland	N65.12	W14.68
RUS-1	Pechora-Ilych	Russia	N62.18	E59.18
FCT-AU-2 FCT-AU-3	Takone (Tasmania) Warra (Tasmania)	Australia	S41.19 S43.1046	E145.60 E146.6560

Table 3.2 – GFOI R&D Study Sites (as of Mar, 2015)

The site list includes both new sites that previously have not been used within GFOI, and well as several of the Validation Sites in the GEO-FCT National Demonstrator countries that still are active, where time-series data have already been collected by CEOS agencies and where good opportunities for change studies exist. The study sites are mostly located in sub/tropical regions, with a few in temperate-boreal biomes to test the transferability of methods across different regions/forest types.

- The GFOI R&D Study Sites are the sites over which CEOS space agencies will be asked to focus their efforts within the Element 3 framework.
- The sites are multi-disciplinary and aim to address several of the GFOI priority R&D topics. Details of the R&D to be undertaken at each site are provided in Annex B.
- The sites are conceived to be used on a long-term basis, in combination with permanent sample plots or national forest inventories.

4 Coordinated Strategy for satellite observations in support of GFOI R&D

4.1 A consolidated acquisition strategy

As can be seen from preceding chapters, there are many active R&D topics being addressed, each with specific data requests. In order to avoid a too complex acquisition plan, a more simple strategy has been attempted where several of the priority R&D topics are addressed simultaneously and where the same data sets may be used to assess multiple R&D topics. The proposed Element-3 acquisition strategy comprises systematic dense time-series of multi-sensor data (optical, L-, C- and X-band SAR) over a limited number of study sites in order to provide information-rich datasets which fulfil the requirements for experimental analysis. Redundancy is built into the strategy to test the transferability of methods using similar sensors.

Common for all sensors is that dense time-series are required for testing the robustness and consistency of methods of deriving change estimates. Historic (archive) data are needed to extend time series backwards and for baseline generation. Complementary SAR and optical data are needed to assess the benefits of sensor synergy for forest monitoring and degradation assessment. Additional R&D tasks can be added for sites at a later stage.

The sections below comprise the data observation requests for each sensor, both new acquisitions and archive, for the GFOI R&D Study Sites. Minimum requirements for are given in case of capacity constraints.

SAR mission agencies are asked to keep the following general considerations in mind:

- Collection of consistent time-series is a key requirement and missed acquisitions and data gaps that inevitably will occur should be re-programmed for fill-in acquisitions the next satellite cycle.
- In order to accommodate SAR-optical interoperability studies, observations in descending pass direction are recommended.
- A key point for each of the SAR sensors is to remain consistent with one single observation mode selected to maximise band sensitivity to forest parameters, and successively build up a uniform and homogeneous multi-temporal coverage over each of the Study Sites. In particular it should be noted that a change in the SAR off-nadir look angle introduces additional uncertainty in time-series analyses and should be avoided.

4.2 ASI

4.2.1 New acquisitions: COSMO-SkyMed

New acquisitions of COSMO-SkyMed are requested over selected GFOI R&D Study Sites (Table 4.1).

Observation mode: Stripmap Dual polarisation (VV+VH)

Processing level to be defined;

Incidence angle: >30° @ near range

Observation frequency: Optimal: ~Monthly

Minimum requirement: As of table below.

Time window: Optimal: All year.

Minimum requirement: As of table below.

Site Code	Site name	Research group	Location		Minimum requirement:	
			Lat	Long	Time window	Obs. frequency
Priority 1 (Group eligibility to be confirmed by ASI)						
FCT-MEX-2	Chiapas-1	Group 9	N16.45	W91.40	All year	Monthly +1day InSAR pairs
MEX-8	Durango		N23.74	W105.49	All year	
Priority 2 (resources allowing) **(Group eligibility to be confirmed by ASI)**						
FIN-1	Hyytiälä	Group 9	N61.85	E24.32	All year	Monthly +1day InSAR pairs
FIN-2	Sodankylä		N67.48	E26.34	All year	
ICE-1	Hallormsstadur		N65.12	W14.68	All year	Monthly +1day InSAR pairs
RUS-1	Pechora-Ilych		N62.18	E59.18	All year	Monthly +1day InSAR pairs

Table 4.1 – GFOI R&D Study Sites requested for coverage by X-band SAR. **Requested by groups whose eligibility to obtain COSMO-SkyMed data need to be confirmed by ASI**

4.2.2 Archive data: COSMO-SkyMed

Refer to http://gfoi.org/RD for the COSMO-SkyMed Background Mission on Guyana, Cameroon, Borneo, Tasmania, Peru, Colombia, DRC and Sumatera sites and for the COSMO-SkyMed archive data on GFOI R&D Study Sites.

4.3 CNES

4.3.1 New acquisitions: Pléiades

Pléiades VHR (<5 m resolution) data are requested for validation (Table 4.2a and Table 4.2b). A total of 12 scenes (100 km²) are requested for each GFOI R&D Study Site.

Site Code	Site name	Resarch group	Location		Minimum requirement:	
			Lat	Long	Time window	Obs. Freq.
Priority 1						
BRA-1	Mato Grosso	Group 1	S11.75	W54.25	Jun-Nov	Monthly
FIJ-1	Lololo & Nakavu	Group 4	S17.833	E177.833	All year	1 scene
GFC-1	GFC Site 1	Group 5	N3.3069	W-59.6672	All year	Monthly
GFC-2	GFC Site 2		N6.4856	W-58.9471	All year	Monthly
FCT-BOR-3	Mawas	Group 6	S2.24	E114.48	All year	Monthly
FCT-SUM-2	Harapan		S2.20	E103.38	All year	Monthly
FCT-TNZ-5	Amani	Group 7	S5.13	E38.63	June-Sept, Jan-Feb	2 scenes
FCT-TNZ-6	Liwale		S9.50	E38.17		2 scenes
PNG-1	Kokoda	Group 8	S9.184	E147.374	All year	Monthly
PNG-2	Milne bay		S10.598	E150.185	All year	Monthly
FCT-AU-1	Mathinna	Group 10	S41.37	E147.76	All year	Monthly
AU-4	Robson Creek		S17.119	E145.631	Apr-Dec	Monthly
AU-5	Injune		S25.5	E147.7	All year	Monthly
Priority 2 (resources allowing)						
GFC-3	GFC Site 3	Group 5	N7.4660	W-60.0742	All year	Monthly
PNG-3	Yus	Group 8	S6.028	E146.745	All year	Monthly
FCT-AU-2	Takone	Group 10	S41.19	E145.60	All year	Monthly
FCT-AU-3	Warra		S43.1046	E146.6560	Apr-Dec	Monthly

Table 4.2a – GFOI R&D Study Sites requested for coverage by optical VHR sensors.

Site Code	Site name	Resarch group	Location		Minimum requirement:	
			Lat	Long	Time window	Obs. Freq.
Group eligibility to be confirmed by CNES						
CAR-1	Mbaïki	Group 2	N3.872	E17.987	May-Oct	Monthly
GAB-1	Gabon		N0.0181	E10.1906	All year	1 scene
FCT-MEX-2	Chiapas-1	Group 9	N16.45	W91.40	All year	Monthly
MEX-8	Durango		N23.74	W105.49	Jun-Aug	Monthly
FIN-1	Hyytiälä	Group 9	N61.85	E24.32	All year	Monthly
FIN-2	Sodankylä		N67.48	E26.34	All year	Monthly
ICE-1	Hallormsstadur		N65.12	W14.68	All year	Monthly
RUS-1	Pechora-Ilych		N62.18	E59.18	All year	Monthly
BRA-2	Novo Progresso	Group 12	S7°02'4.07"	W55°24'1.82"	May-Nov	2 scenes
SUR-1	Kabo		5.255928°N	-55.76682°E	Mar-Oct	2 scenes
MAL-1	Malinau		3.0217°N	116.3601°E	Mar-Oct	2 scenes
MAD-1	Mahafaly		24.0304°S	43.7651°E	Mar-Oct	2 scenes

Table 4.2b – GFOI R&D Study Sites coverage by optical VHR sensor
requests by groups whose eligibility to obtain Pléiasdes data need to be confirmed by CNES

4.3.1 New acquisitions: SPOT-5

SPOT-5 data requested as part of the SPOT5(Take5) experiment over GFOI R&D Study Sites are being been collected by ESA, and to avoid duplication of requests, they are not repeated here.

4.3.2 Archive data: SPOT-4, SPOT-5 and Pléiades

Refer to http://www.geostore.com

4.4 CSA

The Canadian Space Agency (CSA) overarching objectives in support of the GFOI Element-3 are to support our National Forest community (government, academic and private sectors) and to enable end-users to exploit the large amount of SAR data that is now or will soon be available in support of their programs for forest management, ecosystem protection, carbon accounting, etc.

Due to the commercial nature of the RADARSAT-2 mission, the CSA is restricted to supporting science related activities as identified and endorsed by the GFOI science framework under the Element-3. The CSA is mostly interested in the following topics:

- Use of Synthetic Aperture RADAR (SAR) for the monitoring of forest related attributes;
- Interoperability and complementarity between SAR and optical datasets;
- SAR/SAR mission interoperability;
- Development of SAR-based approaches, algorithms, and methods that are viably sustainable to support local, regional, national, continental and global forest monitoring and carbon accounting.

In this context the CSA is willing to contribute archive data and develop dense time series over punctual sites to support key science and demonstration activities.

4.4.1 New acquisitions: RADARSAT-2

New acquisitions of RADARSAT-2 are requested over selected GFOI R&D Study Sites (Table 4.3).

Beam mode:	Fine Beam Full polarisation (HH+HV+VV+VH)
Incidence angle:	>30° @ near range, if possible
Observation direction:	Descending (to accommodate optical-SAR analysis)
Observation frequency:	Optimal: ~Monthly (every 24 days)
	Minimum requirement: As of table below.
Time window:	Optimal: All year.
	Minimum requirement: As of table below.

The Canadian Space Agency will contribute data, under the SDMS framework, to projects which will directly contribute to the defined and agreed upon key science questions articulated under the GFOI Element-3 component. The number of scenes, the preferred sites, and the observation frequency are to be defined and agreed with the project PIs.

The Canadian Space Agency will need to go through a user/data set certification process as planned under the Master Agreement with the owner of the satellite (MDA) and the Canadian remote sensing space system act (RSSSA). Once users and data will be certified, it is expected that a secured access/open sharing system cloud computing framework (SDMS) will be put in place by the SEO. All of the RADARSAT 2 data contributed to the Element-3 component will be open for internal sharing among the list of certified PIs of GFOI. This will include the pertinent dataset acquired under the framework of the FCT project and new dataset acquired in a background mission framework to be defined and agreed under the GFOI.

The Canadian Space agency will comply to the open sharing principle of the Element-3 and expects, in return, an open sharing of ground data, methods, and derived results. The RADARSAT-2 data will be contributed at no costs to the users. All of the data and processing costs will be covered by the CSA.

In summary, the CSA expects its contribution to GFOI science plan (Element-3 component) to generate better understanding on issues related to SAR only, SAR/SAR and SAR/Optical data interoperability for forest attributes derived information.

It is expected that the key science requirements, articulated in the context of Element-3, represent the position of the Global federated community under GFOI.

In addition to our data contribution, the CSA Earth Observation programs (for data, science and demonstration) will remain available to support innovative development of solutions. In this context the CSA will support a Canadian Research Team proposing to a boreal forest site.

Site Code	Site name	Research group	Location		Minimum requirement:	
			Lat	Long	Time window	Obs. frequency
Priority 1						
GAB-1	Gabon	Group 2	N0.0181	E10.1906	All year	4/yr
ETH-1	Kafa BR	Group 4	N7°30'29"	E35°54'29"	All year	Monthly
FIJ-1	Lololo & Nakavu		S17.833	E177.833	All year	Monthly
PER-1	Peru		S11.1	W74.3	All year	Monthly
FCT-TNZ-5	Amani	Group 7	S5.13	E38.63	June-Sept, Jan	Monthly
FCT-TNZ-6	Liwale		S9.50	E38.17		Monthly
PNG-1	Kokoda	Group 8	S9.184	E147.374	All year	Monthly
PNG-2	Milne bay		S10.598	E150.185	All year	Monthly
AU-4	Robson Creek	Group 10	S17.119	E145.631	Apr-Dec	Monthly
Priority 2 (resources allowing)						
PNG-3	Yus	Group 8	S6.028	E146.745	All year	Monthly
FCT-AU-3	Warra	Group 10	S43.1046	E146.6560	Apr-Dec	Monthly

Table 4.3 – GFOI R&D Study Sites requested for coverage by C-band SAR.

4.4.2 Archive data: RADARSAT-2

Refer to http://gfoi.org/RD. Full or partial wet and dry coverage was acquired over Mexico, Colombia, Guyana, Cameroon, Tanzania, Indonesia and Tasmania by RADARSAT-2. A total of 727 images were acquired, with 2 national coverages planned. The RADARSAT-1 archive is of limited coherent use for forest monitoring.

4.5 DLR

4.5.1 New acquisitions: TerraSAR-X

New acquisitions of TerraSAR-X and TanDEM-X are requested over selected GFOI R&D Study Sites (Table 4.4).

Observation mode: Stripmap Dual polarisation (VV+VH)

Incidence angle: >30° @ near range

Observation direction: Descending

Observation frequency: Optimal: ~Monthly or better (every 24 days)

Minimum requirement: As of table below.

Time window: Optimal: All year.

Minimum requirement: As of table below.

Site Code	Site name	Resarch group	Location		Minimum requirement:	
			Lat	Time window	Time window	Obs. frequency
Priority 1						
GFC-1	GFC Site 1	Group 5	N3.3069	W-59.6672	All year	Monthly
GFC-2	GFC Site 2		N6.4856	W-58.9471	All year	Monthly
FCT-BOR-3	Mawas	Group 6	S2.24	E114.48	All year	Monthly
FCT-SUM-2*	Harapan		S2.20	E103.38	All year	Monthly
PNG-1	Kokoda	Group 8	S9.184	E147.374	All year	Monthly
PNG-2	Milne Bay		S10.598	E150.185	All year	Monthly
FCT-MEX-2	Chiapas-1	Group 9	N16.45	W91.40	All year	Monthly
MEX-8	Durango		N23.74	W105.49	All year	Monthly
AU-4	Robson Creek	Group 10	S17.119	E145.631	Apr-Dec	Monthly
FCT-AU-1	Mathinna		S41.37	E147.76	All year	Monthly
AU-5	Injune		S25.5	E147.7	All year	Monthly
KAL-1	Central Kalimantan	Group 12	S2°24′	E114°6′30″	Jun-Nov	Monthly
SUM-1	South Sumatra		S2°29′30″	E103°28′30″	Apr-Nov	Monthly
SA-1	Lowveld/Kruger N.P.	Group 13	S24°59′45″	E31°35′30″	All year	Monthly
SA-2	Eastern Cape		S33°36′	E25°40′	All year	Monthly
Priority 2 (resources allowing)						
GFC-3	GFC Site 3	Group 5	N7.4660	W-60.0742	All year	Monthly
PNG-3	Yus	Group 8	S6.028	E146.745	All year	Monthly
FIN-1	Hyytiälä	Group 9	N61.85	E24.32	All year	Monthly
FIN-2	Sodankylä		N67.48	E26.34	All year	Monthly
ICE-1	Hallormsstadur		N65.12	W14.68	All year	Monthly
RUS-1	Pechora-Ilych		N62.18	E59.18	All year	Monthly
FCT-AU-3	Warra	Group 10	S43.1046	E146.656	Apr-Dec	Monthly
FCT-AU-2	Takone		S41.19	E145.60	All year	Monthly

**Note for Harapan site (FCT-SUM-2), TSX observation: Stripmap, strip_008, VV pol, Right, Ascending*

Table 4.4 – GFOI R&D Study Sites requested for coverage by TanDEM-X.

4.5.2 New acquistions TanDEM-X

The TanDEM-X bistatic phase will be continued in March 2015, with large baselines (3-4 km). This will drift back to shorter baselines in September 2015 (0-300 m). Under this scenario, new TanDEM-X acquisitions are requested from September 2015 onward. Continuation of TanDEM-X acquisition modes beyond 2015 is currently under review.

Observation direction: Ascending

Site Code	Site name	Resarch group	Location		Obs. direction
			Lat	Time window	
GFC-1 GFC-2	GFC Site 1 GFC Site 2	Group 5	N3.3069 N6.4856	W-59.6672 W-58.9471	Ascending
FCT-BOR-3 FCT-SUM-2*	Mawas Harapan	Group 6	S2.24 S2.20	E114.48 E103.38	
FCT-TNZ-5 FCT-TNZ-6	Amani Liwale	Group 7	S5.13 S9.50	E38.63 E38.17	
PNG-1 PNG-2	Kokoda Milne Bay	Group 8	S9.184 S10.598	E147.374 E150.185	
FCT-MEX-2 MEX-8	Chiapas-1 Durango	Group 9	N16.45 N23.74	W91.40 W105.49	
AU-4 FCT-AU-1	Robson Creek Mathinna	Group 10	S17.119 S41.37	E145.631 E147.76	
AU-5	Injune		S25.5	E147.7	
CAN-1 CAN-2	Site 1 NW Territories Site 2 NW Territories	Group 11	N61.4 N62.53	W121.3 W116.53	
KAL-1	Central Kalimantan	Group 12	S2°24’	E114°6’30”	
SUM-1	South Sumatra		S2°29’30”	E103°28’30”	
BRA-2	Novo Progresso		S7°02’4.07”	W55°24’1.82 ”	
Priority 2 (resources allowing)					
GFC-3	GFC Site 3	Group 5	N7.4660	W-60.0742	Ascending
PNG-3	Yus	Group 8	S6.028	E146.745	
FIN-1 FIN-2	Hyytiälä Sodankylä	Group 9	N61.85 N67.48	E24.32 E26.34	
ICE-1	Hallormsstadur		N65.12	W14.68	
RUS-1	Pechora-Ilych		N62.18	E59.18	
FCT-AU-3 FCT-AU-2	Warra Takone	Group 10	S43.1046 S41.19	E146.656 E145.60	

Table 4.5 – GFOI R&D Study Sites requested for coverage by TanDEM-X.

4.5.3 Archive data: TerraSAR-X and TanDEM-X

Detailed search results available over selected GEO-FCT and GFOI R&D Study Sites at http://gfoi.org/RD and via the EOWEB NG tool:

https://centaurus.caf.dlr.de:8443/eoweb-ng/template/default/welcome/entryPage.vm

4.6 ESA

4.6.1 New acquisitions: Sentinel-1A

New acquisitions of Sentinel-1A are requested over selected GFOI R&D Study Sites (Table 4.6).

Observation mode: Interferometric Wide-Swath (IWS) Dual polarisation (VV+VH)
(Note: cross-polarisation channel (VH) critical).

Observation direction: Descending (to accommodate optical-SAR analysis)

Observation frequency: Optimal: ~ 2 times/month
Minimum requirement: As of table below.

Time window: Optimal: All year.
Minimum requirement: As of table below

Site Code	Site name	Research group	Location		Minimum requirement:	
			Lat	Long	Time window	Obs. frequency
Priority 1						
BRA-1	Mato Grosso	Group 1	S11.75	W54.25	Jun-Nov	Bi-monthly
CAR-1	Mbaïki	Group 2	N3.872	E17.987	All year	Bi-monthly
GAB-1	Gabon		N0.0181	E10.1906	All year	Bi-monthly
ETH-1	Kafa BR	Group 4	N7°30'29"	E35°54'29"	All year	Monthly
FIJ-1	Lololo & Nakavu		S17.833	E177.833	All year	Monthly
PER-1	Peru		S11.1	W74.3	All year	Monthly
GFC-1	GFC Site 1	Group 5	N3.3069	W-59.6672	All year	Bi-monthly
GFC-2	GFC Site 2		N6.4856	W-58.9471	All year	Bi-monthly
FCT-BOR-3	Mawas	Group 6	S2.24	E114.48	All year	Monthly
FCT-SUM-2	Harapan		S2.20	E103.38	All year	Monthly
FCT-TNZ-5	Amani	Group 7	S5.13	E38.63	All year	Monthly
FCT-TNZ-6	Liwale		S9.50	E38.17	All year	Monthly
PNG-1	Kokoda	Group 8	S9.184	E147.374	All year	Bi-monthly
PNG-2	Milne Bay		S10.598	E150.185	All year	Bi-monthly
FCT-MEX-2	Chiapas-1	Group 9	N16.45	W91.40	All year	Bi-monthly
MEX-8	Durango		N23.74	W105.49	All year	Bi-monthly
AU-4	Robson Creek	Group 10	S17.119	E145.631	Apr-Dec	Bi-monthly
FCT-AU-1	Mathinna		S41.37	E147.76	All year	Bi-monthly
AU-5	Injune		S25.5	E147.7	All year	Bi-monthly
CAN-1	Site 1 NW Territories	Group 11	N61.4	W121.3	May-Sept	Bi-monthly
CAN-2	Site 2 NW Territories		N61.52	W116.39	May-Sept	Bi-monthly
KAL-1	Central Kalimantan	Group 12	S2°24′	E114°6′30″	All year	Bi-monthly
SUM-1	South Sumatra		S2°29′30″	E103°28′30″	Apr-Nov	Bi-monthly

BRA-2	Novo Progresso		S7°02'4.07"	W55°24'1.82"	All year	Bi-monthly
SUR-1	Kabo		5.255928°N	-55.76682°E	Mar-Oct	Monthly
MAL-1	Malinau		3.0217°N	116.3601°E	Mar-Oct	Monthly
MAD-1	Mahafaly		24.0304° S	43.7651°E	Mar-Oct	Monthly
Priority 2 (resources allowing)						
GFC-3	GFC Site 3	Group 5	N7.4660	W-60.0742	All year	Bi-monthly
PNG-3	Yus	Group 8	S6.028	E146.745	All year	Bi-monthly
FIN-1	Hyytiälä	Group 9	N61.85	E24.32	All year	Bi-monthly
FIN-2	Sodankylä		N67.48	E26.34	All year	Bi-monthly
ICE-1	Hallormsstadur		N65.12	W14.68	All year	Bi-monthly
RUS-1	Pechora-Ilych		N62.18	E59.18	All year	Bi-monthly
FCT-AU-3	Warra	Group 10	S43.1046	E146.6560	Apr-Dec	Bi-monthly
FCT-AU-2	Takone		S41.19	E145.60	All year	Bi-monthly

Table 4.6 – GFOI R&D Study Sites requested for coverage by C-band SAR.

4.6.2 Archive data: SENTINEL-1A and ENVISAT ASAR

A two-months rolling archive of Sentinel-1A data is available on http://scihub.esa.int

ENVISAT ASAR wall-to-wall coverage has been acquired over Guyana, Brazil, Cameroon, Tanzania, Tasmania and additionally Sumatra, DC Congo, Peru and Colombia (from 2010 onwards) in 2009 to 2012. Data acquisitions can be viewed with the EOLi catalogue and ordering tool at http://earth.esa.int/EOLi/EOLi.html

4.7 INPE / CRESDA

4.7.1 New acquisitions: CBERS-4

INPE and CRESDA are requested – to the extent feasible – to cover all GFOI R&D Study Sites with data from all four instruments onboard CBERS-4 (Table 4.7).

Site Code	Site name	Research group	Country	Coordinates	
				lat	long
Priority 1					
BRA-1	Mato Grosso	Group 1	Brazil	S11.75	W54.25
GAB-1	Gabon	Group 2	Gabon	N0.0181	E10.1906
FCT-COL-3	Pacifico-Bajo_Mira	Group 3	Colombia	N1.65	W78.76
FCT-COL-5	Andes-Antioquia			N7.83	W76.45
COL-6	Caqueta			N1.4079	W73.5747
FIJ-1	Lololo & Nakavu	Group 4	Fiji	S17.833	E177.833
GFC-1	GFC Site 1	Group 5	Guyana	N3.3069	W-59.6672
GFC-2	GFC Site 2			N6.4856	W-58.9471
FCT-BOR-3	Mawas	Group 6	Indonesia	S2.24	E114.48
FCT-SUM-2	Harapan			S2.20	E103.38
FCT-TNZ-5	Amani	Group 7	Tanzania	S5.13	E38.63
FCT-TNZ-6	Liwale			S9.50	E38.17
PNG-1	Kokoda	Group 8	PNG	S9.184	E147.374
PNG-2	Milne bay			S10.598	E150.185
FCT-MEX-2	Chiapas-1	Group 9	Mexico	N16.45	W91.40
MEX-8	Durango			N23.74	W105.49
AU-4	Robson Creek	Group 10	Australia	S17.119	E145.631
Priority 2 (resources allowing)					
FCT-COL-4	Amazonia-Tinigua	Group 3	Colombia	N2.17	W74.15
GFC-3	GFC Site 3	Group 5	Guyana	N7.4660	W-60.0742
FIN-1	Hyytiälä	Group 9	Finland	N61.85	E24.32
FIN-2	Sodankylä			N67.48	E26.34
ICE-1	Hallormsstadur		Iceland	N65.12	W14.68
RUS-1	Pechora-Ilych		Russia	N62.18	E59.18
FCT-AU-3	Warra	Group 10	Australia	S43.1046	E146.6560

Table 4.7 – GFOI R&D Study Sites requested for coverage by optical sensors.

4.8 JAXA

4.8.1 New acquisitions: ALOS-2 PALSAR-2

The Element-3 strategy comprises no new observation requests for ALOS-2 PALSAR-2 data, as all GFOI R&D Study Sites are expected to be covered within the global systematic acquisition plan - the ALOS-2 Basic Observation Scenario – implemented by JAXA (Table 4.8).

Site Code	Site name	Research group	Location		Minimum requirement:	
			Lat	Long	Time window	Obs. frequency
Priority 1						
BRA-1	Mato Grosso	Group 1	S11.75	W54.25	Apr-Nov	2-6/yr
CAR-1	Mbaïki	Group 2	N3.872	E17.987	All year	Bi-monthly
GAB-1	Gabon		N0.0181	E10.1906	All year	Bi-monthly
ETH-1	Kafa BR	Group 4	N7°30'29"	E35°54'29"	All year	Monthly
FIJ-1	Lololo & Nakavu		S17.833	E177.833	All year	Monthly
PER-1	Peru		S11.1	W74.3	All year	Monthly
GFC-1	GFC Site 1	Group 5	N3.3069	W-59.6672	All year	Monthly
GFC-2	GFC Site 2		N6.4856	W-58.9471	All year	Monthly
FCT-TNZ-5	Amani	Group 7	S5.13	E38.63	June-Sept, Jan	Monthly
FCT-TNZ-6	Liwale		S9.50	E38.17		Monthly
PNG-1	Kokoda	Group 8	S9.184	E147.374	All year	Monthly
PNG-2	Milne Bay		S10.598	E150.185	All year	Monthly
FCT-MEX-2	Chiapas-1	Group 9	N16.45	W91.40	All year	Bi-monthly
MEX-8	Durango		N23.74	W105.49	All year	Bi-monthly
AU-4	Robson Creek	Group 10	S17.119	E145.631	Apr-Dec	Monthly
FCT-AU-1	Mathinna		S41.37	E147.76	All year	Bi-monthly
AU-5	Injune		S25.5	E147.7	All year	Bi-monthly
CAN-1	Site 1 NW Territories	Group 11	N61.4	W121.3	May-Sept	Bi-monthly
CAN-2	Site 2 NW Territories		N60.71 N61.28 N61.84 N62.47	W115.84 W116.14 W116.42 W116.71	May-Sept	Bi-monthly
KAL-1	Central Kalimantan	Group 12	S2°24′	E114°6′30″	Jun-Nov	Monthly
SUM-1	South Sumatra		S2°29′30″	E103°28′30″	Apr-Nov	Monthly
BRA-2	Novo Progresso		S7°02′4.07″	W55°24′1.82″	May-May	Bi-monthly
SUR-1	Kabo		5.255928°N	-55.76682°E	Mar-Oct	Monthly
MAL-1	Malinau		3.0217°N	116.3601°E	Mar-Oct	Monthly
MAD-1	Mahafaly		24.0304°S	43.7651°E	Mar-Oct	Monthly

SA-1 SA-2	Lowveld/Kruger N.P. Eastern Cape	Group 13	S24°59'45" S33°36'	E31°35'30" E25°40'	All year All year	Bi-monthly Bi-monthly
Priority 2 (resources allowing)						
GFC-3	GFC Site 3	Group 5	N7.4660	W-60.0742	All year	Monthly
PNG-3	Yus	Group 8	S6.028	E146.745	All year	Monthly
FIN-1	Hyytiälä	Group 9	N61.85	E24.32	All year	Bi-monthly
FIN-2	Sodankylä		N67.48	E26.34	All year	Bi-monthly
ICE-1	Hallormsstadur		N65.12	W14.68	All year	Bi-monthly
RUS-1	Pechora-Ilych		N62.18	E59.18	All year	Bi-monthly
FCT-AU-3	Warra	Group 10	S43.1046	E146.6560	Apr-Dec	Monthly
FCT-AU-2	Takone		S41.19	E145.60	All year	Bi-monthly

Table 4.8 – GFOI R&D Study Sites requested for coverage by L-band SAR.

4.8.2 Archive data: ALOS PALSAR and ALOS-2 PALSAR-2

ALOS PALSAR featured a global systematic acquisition strategy through which all land areas on Earth were acquired in stripmap 20m (HH+HV) and 10m (HH) mode 3-5 times per year between 2007 and 2011. Consistent time-series over all GFOI R&D sites are available. Detailed archive information is available at https://auig2.jaxa.jp/

Ortho-corrected PALSAR mosaics (2007, 2008, 2009 and 2010) at 25m pixel spacing are available for free download at

http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm

The ALOS-2 BOS plans for past and future acquisitions can be viewed at http://www.eorc.jaxa.jp/ALOS-2/en/obs/pal2_obs_guide.htm

4.9 USGS

4.9.1 New acquisitions: Landsat-7 and -8 (ETM+/OLI)

While all global land areas are expected to be covered by ETM+ and OLI data within the Landsat Long-Term Acquisition Plan (LTAP), USGS is encouraged to ensure that acquisition requests for all GFOI R&D Study Sites are included, if possible, every cycle (Table 4.9).

Site Code	Site name	Research group	Country	Location	
				Lat	Long
Priority 1					
BRA-1	Mato Grosso	Group 1	Brazil	S11.75	W54.25
CAR-1	Mbaïki	Group 2	Central African Republic	N3.872	E17.987
GAB-1	Gabon		Gabon	N0.0181	E10.1906
FCT-COL-3	Pacifico-Bajo_Mira	Group 3	Colombia	N1.65	W78.76
FCT-COL-5	Andes-Antioquia			N7.83	W76.45
COL-6	Caqueta			N1.4079	W73.5747
COL-7	La Victoria			N6.26	W74.64
ETH-1	Kafa BR	Group 4	Ethiopia	N7°30'29"	E35°54'29"
FIJ-1	Lololo & Nakavu		Fiji	S17.833	E177.833
PER-1	Peru		Peru	S11.1	W74.3
GFC-1	GFC Site 1	Group 5	Guyana	N3.3069	W-59.6672
GFC-2	GFC Site 2			N6.4856	W-58.9471
FCT-BOR-3	Mawas	Group 6	Indonesia	S2.24	E114.48
FCT-SUM-2	Harapan			S2.20	E103.38
FCT-TNZ-5	Amani	Group 7	Tanzania	S5.13	E38.63
FCT-TNZ-6	Liwale			S9.50	E38.17
PNG-1	Kokoda	Group 8	PNG	S9.184	E147.374
PNG-2	Milne bay			S10.598	E150.185
FCT-MEX-2	Chiapas-1	Group 9	Mexico	N16.45	W91.40
MEX-8	Durango			N23.74	W105.49
AU-4	Robson Creek	Group 10	Australia	S17.119	E145.631
FCT-AU-1	Mathinna			S41.37	E147.76
AU-5	Injune			S25.5	E147.7
CAN-1	Site 1 NW Territories	Group 11	Canada	N61.4	W121.3
CAN-2	Site 2 NW Territories			N62.53	W116.53
KAL-1	Central Kalimantan	Group 12	Indonesia	S2°24′	E114°6′30″
SUM-1	South Sumatra			S2°29′30″	E103°28′30″
BRA-2	Novo Progresso		Brazil	S7°02′4.07″	W55°24′1.82″
SUR-1	Kabo		Suriname	5.255928°N	-55.76682°E
MAL-1	Malinau		Indonesia	3.0217°N	116.3601°E

MAD-1	Mahafaly		Madagascar	24.0304°S	43.7651°E
SA-1 SA-2	Lowveld/Kruger N.P. Eastern Cape	Group 13	South Africa	S24°59′45″ S33°36′	E31°35′30″ E25°40′
Priority 2 (resources allowing)					
FCT-COL-4	Amazonia-Tinigua	Group 3	Colombia	N2.17	W74.15
GFC-3	GFC Site 3	Group 5	Guyana	N7.4660	W-60.0742
FIN-1 FIN-2	Hyytiälä Sodankylä	Group 9	Finland	N61.85 N67.48	E24.32 E26.34
ICE-1	Hallormsstadur		Iceland	N65.12	W14.68
RUS-1	Pechora-Ilych		Russia	N62.18	E59.18
FCT-AU-3	Warra	Group 10	Australia	S43.1046	E146.6560
FCT-AU-2	Takone			S41.19	E145.60

Table 4.9 – GFOI R&D Study Sites requested for coverage by Landsat.

4.9.2 Archive data: Landsat-5, -7 and -8 (TM/ETM+/OLI)

The Landsat archive can be accessed through the USGS Global Visualization Viewer (GloVis) at http://glovis.usgs.gov/

4.10 Optical High Resolution

4.10.1 New acquisitions: Optical High Resolution

A systematic sample of optical high resolution data (5-10 m) are requested over GFOI R&D Study Sites as shown in Table 4.10. Numerous users have requested high resolution optical data for methods development and Cal/Val. Dense time-series systematic coverage in the dry season is optimal for all priority 1 sites. If capacity allows, sample data should be provided for priority 2 sites.

Site Code	Site name	Research groups	Location		Minimum requirement:	
			Lat	Long	Time window	Obs. Freq.
Priority 1						
BRA-1	Mato Grosso	Group 1	S11.75	W54.25	Jun-Nov	Monthly
FCT-COL-3	Pacifico-Bajo_Mira	Group 3	N1.65	W78.76	All year	Monthly
FCT-COL-4	Amazonia-Tinigua		N2.17	W74.15	All year	Monthly
FCT-COL-5	Andes-Antioquia		N7.83	W76.45	All year	Monthly
COL-6	Caqueta		N1.4079	W73.5747	All year	Monthly
COL-7	La Victoria		N6.26	W74.64	All year	Monthly
FIJ-1	Lololo & Nakavu	Group 4	S17.833	E177.833	All year	Monthly
GFC-1	GFC Site 1	Group 5	N3.3069	W-59.6672	All year	Monthly
GFC-2	GFC Site 2		N6.4856	W-58.9471	All year	Monthly
FCT-BOR-3	Mawas	Group 6	S2.24	E114.48	All year	Monthly
FCT-SUM-2	Harapan		S2.20	E103.38	All year	Monthly
FCT-TNZ-5	Amani	Group 7	S5.13	E38.63	June-Sept, Jan-Feb	Monthly
FCT-TNZ-6	Liwale		S9.50	E38.17		Monthly
PNG-1	Kokoda	Group 8	S9.184	E147.374	All year	Monthly
PNG-2	Milne bay		S10.598	E150.185	All year	Monthly
FCT-MEX-2	Chiapas-1	Group 9	N16.45	W91.40	All year	Monthly
MEX-8	Durango		N23.74	W105.49	Jun-Aug	Monthly
FCT-AU-1	Mathinna	Group 10	S41.37	E147.76	All year	Monthly
AU-4	Robson Creek		S17.119	E145.631	Apr-Dec	Monthly
AU-5	Injune		S25.5	E147.7	All year	Monthly
BRA-2	Novo Progresso	Group 12	S7°02'4.07"	W55°24'1.82"	May-Nov	1-2 images
SUR-1	Kabo		5.255928° N	-55.76682° E	Mar-Oct	2 images
MAL-1	Malinau		3.0217°N	116.3601° E	Mar-Oct	2 images
MAD-1	Mahafaly		24.0304°S	43.7651°E	Mar-Oct	2 images
Priority 2 (resources allowing)						
GFC-3	GFC Site 3	Group 5	N7.4660	W-60.0742	All year	Monthly
PNG-3	Yus	Group 8	S6.028	E146.745	All year	Monthly

FIN-1 FIN-2	Hyytiälä Sodankylä	Group 9	N61.85 N67.48	E24.32 E26.34	All year All year	Monthly Monthly
ICE-1	Hallormsstadur		N65.12	W14.68	All year	Monthly
RUS-1	Pechora-Ilych		N62.18	E59.18	All year	Monthly
FCT-AU-2	Takone	Group 10	S41.19	E145.60	All year	Monthly
FCT-AU-3	Warra	Group 10	S43.1046	E146.6560	Apr-Dec	Monthly

Table 4.10 – GFOI R&D Study Sites requested for coverage by high resolution Optical data.

5 Coordinated Research Announcements

Forthcoming research announcements and funding opportunities are provided below. Proposals that address priority R&D topics and multi-sensor studies are encouraged.

5.1 ASI

- The "Open Call for Science" is started and is available on the ASI website at the following link:
  http://www.asi.it/en/agency/bandi_en/calls/cosmoskymed_open_call_for_science

- The Open Call is open to national and international scientific investigators and submission of proposals will be accepted anytime. The selected projects will be supported for two years with a quota of data free-of-charge.
- Land cover and vegetation will be among the primary application domains.
- ASI is open to exploring the possibility of a coordinated announcement of opportunity (AO) for R&D on GFOI key science questions with CEOS partners.

5.2 CNES

- Offer annual calls for science proposals ("TOSCA"), open to French laboratories in February of each year for funding commencing the following year. Project support is provided for the purchase of data, experimental equipment, travel and temporary (post-doc) positions.
- Coordination with other national/international initiatives is possible, e.g., future research announcements that partly/fully support GFOI.
- CNES is open to exploring the possibility of a coordinated announcement of opportunity (AO) for R&D on GFOI key science questions with CEOS partners.
- CNES is looking for co-funding opportunities to process all SPOT1-5 archive data over GFOI countries through the SPOT World Heritage Programme. The SPOT archive presents a substantial resource for establishing forest baseline information.

5.3 CSA

- CSA is open to exploring the possibility of a coordinated announcement of opportunity (AO) for R&D on GFOI key science questions with CEOS partners.

5.4 DLR

- TerrSAR-X data: Proposals for acquisition and use of TerraSAR-X data are accepted at any time. For GFOI purposes, COFUR costs will be waived. An unlimited AO on TerraSAR-X archive data (free of charge) has been launched in December 2014.

- TanDEM-X DEM products: Previously, there was an AO for TanDEM-X "Intermediate DEM" data (closed 12 March, 2014). The available DEM tiles, produced for selected regions of the globe and solely based on the first global coverage of the mission, give a first impression and preview for the DEM products to come. There is a quoted access for the data in the two highest posting classes (12m & 30m), while for the 90m posting class there is no quota limit planned. The data provision is free of charge for all approved proposals submitted before the due date. For proposals arriving after the due date, the COFUR price list will be applied. Final DEM data will be made available in the first half of 2015 (current planning), for which a special AO will be launched.
- DLR plans an AO in 2015 for funding German researchers on global initiatives, including GFOI (project to start in 2016). Collaboration with international partners would be integrated.
- DLR is open to exploring the possibility of a coordinated announcement of opportunity (AO) for R&D on GFOI key science questions with CEOS partners.

5.5 ESA

- ESA issued a Call on DUE Innovators with reference to the GFOI R&D review and gap analysis. Three activities have been selected for funding addressing sensor interoperability and forest degradation.
- A joint call for Spot-5/Take-5 study sites was open in 2014. During Spot-5 deorbiting from April to August 2015, every 5 days an image will be taken under the same geometry for these sites. More than 20 forestry sites in the tropics will be included.
- After consultations with users during the SDCG Country Days, several sites and areas have been included for frequent Sentinel-1 acquisition during its ramp-up phase (Columbia, Ecuador, Peru, Tanzania, Sumatra), unfortunately not all in dual polarisation. A similar approach will be done for the Sentinel-2 ramp-up phase.

5.6 INPE/CRESDA

5.7 JAXA

- The next RA for ALOS-2 (RA6) will be issued in July 2015 for application research for PALSAR-2.
- There is a possibility for open calls targeted at GFOI support, coordinated partly/fully through SDCG Element-3 (coordination with ALOS-2 RA6 may be foreseen).
- Support is provided for satellite data only; JAXA does not provide funding for research.

5.8 USGS

- USGS funds the Landsat Science Term co-chaired by USGS and NASA (landsat.usgs.gov/science_Landsat_Science_Team.php). The current team is funded through 2017. In 2017, a request for proposals for the next Landsat Science Team will be announced.
- NASA publishes open solicitations for Earth Science Data Systems (http://science.nasa.gov/earth-science/earth-science-data/open-solicitations-earth-science-data-systems/)

6 Governance and Recommendations

6.1 Roles and responsibilities

The Element 3 strategy for provision of satellite data for GFOI R&D will continue to be maintained by the **SDCG** in response to the evolving needs of countries – as the understanding of requirements grows in response to country experiences, expert workshops and changing policies and reporting obligations.

The **GFOI Office** will continue in its coordinating role and endeavour to direct the R&D activity in keeping with identified research priorities. GFOI will liaise with potential research partners and discuss the implementation of proposals and relevant funding opportunities. GFOI will continue to host expert workshops and an annual science meeting and facilitate contributions to the MGD where appropriate.

GFOI research partners are responsible for coordinating research teams and drafting proposals in response to open calls and research announcements, downloading EO data and undertaking the R&D.

6.2 Recommendations

To advance the Element-3 Plan, the following recommendations are made:

- The Element-3 plan will be updated on a regular basis, until such a time as it is endorsed by CEOS at SIT-30 (Mar 31 - April 1, 2015).
- Space agencies are requested to provide a list of archive data available over GEO-FCT ND verification sites and new study sites (when available).
- In the interests of securing dense time-series and extending previous R&D, space agencies are encouraged to start acquiring data over ND and new study sites as soon as can be accommodated in their acquisition plan.
- GFOI research partners are encouraged to consult the data archives and advise GFOI on specific data requests for R&D.

6.3 General schedule

Satellite data acquisitions are foreseen to commence in the second quarter of 2015. Data will be made available to research teams as soon as practicable.

To ensure regular reporting of progress and outcomes, an annual science and result reporting meeting is proposed as part of the GFOI R&D programme. The objective of such meetings would be to share results and outcomes with GFOI stakeholders, including country representatives, CEOS agencies, leads), assess methods for possible inclusion in the MGD, and foster collaboration amongst GFOI components and participating countries. The first GFOI R&D science meeting is proposed for late 2015/early 2016, depending on the progress of data distribution and R&D.

An annual technical report on R&D outcomes will be published and shared with space agencies and GFOI participants. This will provide assurance to space agencies that the satellite data is being used for its intended purpose. This will be produced for each year that the R&D programme is underway.

Depending on the level of commitment from CEOS space agencies for provision of data under Element-3, a research period of 2 - 3 years is foreseen. This will enable users to extend their time-series and engage in longer-term studies in, for example, forest degradation or land cover change in response to natural and anthropogenic activity.

Annex A. Contributing agencies and missions

Annex A outlines the CEOS agencies and satellite missions willing to contribute data to support Element-3 GFOI R&D activities. Data availability and access procedures are included.

A.1 ASI

Sensor	Agency	Contact point(s)	Email	Access conditions	Archive and Data search tool
COSMO-SkyMed	ASI	Anna Rita Pisani	annarita.pisani@est.asi.it	Research institutional users	http://87.241.31.78/index.php

A.1.1 COSMO-SkyMed

New acquisitions: ASI is currently making significant contributions to the GEO Geohazard Supersites and Natural Laboratories (GSNL) initiative. ASI is interested in supporting R&D activities involving X-Band – in particular integration with C-band and L-band.

Archive data availability: Refer to http://gfoi.org/RD for the COSMO-SkyMed Background Mission on Guyana, Cameroon, Borneo, Tasmania, Peru, Colombia, DRC and Sumatera sites and for the COSMO-SkyMed archive data on GFOI R&D Study Sites.

Data access procedure:

- Submission of an R&D project to ASI for the exploitation of COSMO-SkyMed data;
- Accepted proposals must sign an agreement with ASI and obtain a data license.
- The access to the official COSMO-SkyMed archive is possible through the website http://87.241.31.78/index.php by subscription.

A.2 CNES

Sensor	Agency	Contact point(s)	Email	Access conditions	Archive and Data search tool
SPOT 1 to 5	CNES	Steven Hosford	Steven.hosford@cnes.fr	Non commercial use	www.geostore.com Data access via SWH website (not yet open)
Pléiades	CNES	Steven Hosford	Steven.hosford@cnes.fr	Research use	www.geostore.com Data access via CNES website (not yet open)

A.2.1 SPOT-4 and -5

New acquisitions: Following approval of the SPOT5(Take) experiment, CNES will check for conflicts and then set up an acquisition plan for GFOI R&D Study Sites. Data quantity from the SPOT5(Take) experiment is limited by the production cost for each product.

Archive data availability: Refer to http://www.geostore.com. Archive data available to be processed through SPOT World Heritage programme includes all SPOT 1-5 data at least 5 years old and data acquired in the Congo Basin Initiative. All archive data over GFOI R&D Study Sites will be processed and made available at no cost.

Data access procedure:

- Free and open access via SPOT World Heritage website to all data already processed. User must be identified and non-commercial use licence must be signed.
- One proposal is recommended to cover all GFOI R&D Study Site requests for the SPOT5(Take5) experiment.

A.2.2 PLÉIADES

New acquisitions: Requests for new acquisitions with Very High Resolution Pléiades-1A and -1B is possible. With the current budget available for processing, CNES would be able to provide in the order of a total 25 scenes per year for GFOI.

GFOI R&D priority sites are currently being acquired/produced and should be available by June 2015.

Archive data availability: Refer to http://www.geostore.com

Data access procedure:

- Registered science users (ISIS programme) can download data from the CNES image database. Registration involves the laboratory signing an agreement with CNES.

A.3 CSA

CSA is able to provide access to the archive collected under the GEO-FCT framework and develop dense time-series over a limited number of study sites to support key science and demonstration activities. Given the commercial nature of the RADARSAT-2 mission, CSA is restricted to support only science related activities as identified and endorsed by the GFOI science framework under the Element-3 Strategy.

R&D in C-band SAR applications is increasingly valued as CSA prepares for the Radarsat Constellation Mission (RCM). There is an urgent need to address key science issues related to C-band SAR and forests so that data can be used in an operational fashion.

The overarching objectives of the CSA will coincidentally support the GFOI Element-3 strategy, by:

- Supporting the national forest community;
- Enabling end-users to exploit the large amount of SAR data that is now, or will soon be available;
- Focusing investments in missions that meet user requirements, operationally focused science, and societal benefits.

Sensor	Agency	Contact point(s)	Email	Access conditions	Archive and Data search tool
Radarsat-2	CSA	Yves Crevier	Yves.Crevier@asc-csa.gc.ca	Restricted to science support (NEODF)	NEODF-Cat. www.neodf.nrcan.gc.ca
	MDA	MDA Client Service Rep	clientservices@mdacorporation.com	Commercial	Same as above

A.3.1 RADARSAT-2

New acquisitions: New acquisitions will operate under a background mission framework. There is not set quota for data as such; CSA will weigh their contribution in terms of what is necessary to answer the relevant science questions.

Archive data availability: Refer to http://gfoi.org/RD. Full or partial wet and dry coverage was acquired over Mexico, Colombia, Guyana, Cameroon, Tanzania, Indonesia and Tasmania by RADARSAT-2. A total of 727 images were acquired, with 2 national coverages planned. The RADARSAT-1 archive is of limited coherent use for forest monitoring.

Data access procedure:

- The data are provided free of charge by CSA and MacDonald Dettwiler (MDA). User certification is required and the data are restricted to research use within the GFOI only.
- Data requests will need to comply with the Canadian Remote Sensing Space System Act (RSSSA) and underlying Master Agreement principles between the Crown and MDA.

- The CSA are moving from a SOAR-based data dissemination approach to an open sharing process as defined within a potential data service element, similar to GEOGLAM, assuming a secure cloud computing and data repository environment.
- Access will require a thorough a priori identification of image products and certification of data users and intended use of the data.
- Scene limitations and access is project dependent and yet to be determined.

A.4 DLR

Sensor	Agency	Contact point(s)	Email	Access conditions	Archive and Data search tool
TerraSAR-X	DLR	TerraSAR-X Science Service System	tsx.science @dlr.de	Standard DLR research type. COFUR costs waived for GFOI related proposals	http://terrasar-x-archive.infoterra.de/
TanDEM-X	DLR	TanDEM-X Science Service System	tandemx-science @dlr.de	Standard DLR research type	http://tandemx-science.dlr.de/

A.4.1 TerraSAR-X

New acquisitions: GFOI R&D Study Sites can be covered systematically in a background mission. All acquisition modes are possible, according to user requests. Specific data volumes and license and access conditions are currently in preparation and will be provided in the first quarter of 2015.

Archive data availability: TerraSAR-X acquisitions (mostly StripMap) have been acquired and archived since 2009 over selected GEO-FCT and GFOI R&D Study Sites. Detailed search results available at http://gfoi.org/RD.

The archives can be also searched with the EOWEB NG tool:

https://centaurus.caf.dlr.de:8443/eoweb-ng/template/default/welcome/entryPage.vm

Data access procedure:

- For new acquisitions over GFOI R&D Study Sites a research proposal is required. The primary entry point is the TerraSAR-X Science Service System: http://sss.terrasar-x.dlr.de. GFOI R&D purposes have to be described in the proposal for obtaining the specific conditions.
- All science proposal submission details are included in http://sss.terrasar-x.dlr.de/pdfs/how_to_submit_a_tsx_proposal.pdf. Please note, that for GFOI related proposals, the usual COFUR costs are waived.
- Archived data is provided free of charge on request through a specific AO on the utilization of the TerraSAR-X archive. Entry point is also the TerraSAR-X Science Service System: http://sss.terrasar-x.dlr.de. For specific conditions, see http://sss.terrasar-x.dlr.de/pdfs/TSX-Archived-Data-2014-AO-1.0.pdf for archived data requests.
- The content of the TerraSAR-X data archive can be easily analysed with the DLR EOWEB-NG tool: https://centaurus.caf.dlr.de:8443/eoweb-ng/index2.html.

A.4.2 TanDEM-X

New acquisitions: TanDEM-X bistatic and/or polarimetric acquisitions within the ongoing science phase are possible on request. License and access conditions will be provided in 2015.

DEM products: Final DEM data will be made available by mid spring 2015 (current planning), for which a special AO will be launched. There will be a quoted access for the data in the two highest posting classes (12m & 30m), while for the 90m posting class there is no quota limit planned. Note that the processing of the DEM data is ongoing. Currently, some 35% percent of the globe's surface is available, 100 % will be reached by mid 2016.

Data access procedure:

- A research proposal is required. The primary entry point is the TanDEM-X Science Service System: https://tandemx-science.dlr.de/. All science proposal submission details are included in https://tandemx-science.dlr.de/pdfs/TD-GS-UM-0115-TanDEM-X-Science-Service-System-Manual_V1.0.pdf.
- Please note, that note that Co-registered Single Look Complex (CoSSC) data will be delivered according to the COFUR price list.

Archive data availability: TanDEM-X acquisitions have been acquired and archived since 2011 over selected GEO-FCT and GFOI R&D Study sites. Detailed search results available at http://gfoi.org/RD.

The archives can be also searched with the EOWEB NG tool:

https://centaurus.caf.dlr.de:8443/eoweb-ng/template/default/welcome/entryPage.vm

A.5 ESA

Sensor	Agency	Contact point(s)	Email	Access conditions	Archive and Data search tool
Sentinel-1A	ESA	Frank Martin Seifert	frank.martin.seifert@esa.int	Free and open	https://scihub.esa.int/
ENVISAT ASAR (archive)				One Category-1 proposals	http://earth.esa.int/EOLi/EOLi. Html

A.5.1 Sentinel-1A

New acquisitions: Sentinel-1A data in Interferometric Wide-Swath (IWS) mode will be acquired over GFOI R&D Study Sites.

Archive data availability: A two-months rolling archive is available on http://scihub.esa.int

Data access procedure:

- The Sentinel-1 Scientific Data Hub (https://scihub.esa.int/) provides free and open access to a rolling archive of Sentinel-1 L0 and L1 products. The latest 2 months of data acquired over specific regions of interest are stored in the archive.
- Data can be downloaded via HTTP.

A.5.2 ENVISAT ASAR

Satellite operations: ENVISAT operations were terminated on April 8, 2012. ENVISAT ASAR are provided free of charge by ESA.

Archive data availability: ENVISAT ASAR wall-to-wall coverage has been acquired over Guyana, Brazil, Cameroon, Tanzania, Tasmania and additionally Sumatra, DC Congo, Peru and Colombia (from 2010 onwards) in 2009 to 2012. Data acquisitions can be viewed with the EOLi catalogue and ordering tool (see below)

Data access procedure:

- Order preparation within EOLI-SA – download latest version at http://earth.esa.int/EOLi/EOLi.html and save as user set.
- Send processing order to Frank Martin Seifert (frank.martin.seifert@esa.int)
- L1 Processing by ESA (either Single look Complex or multi-look Precision Image)

A.6 INPE

Sensor	Agency	Contact point(s)	Email	Access conditions	Archive and Data search tool
CBERS-2B (archive)	INPE	Hilcéa Ferreira	hilcea@dpi.inpe.br	Unrestricted use	http://www.dgi.inpe.br/CDSR/

A.6.1 CBERS-4

New acquisitions:

Data access procedure:

A.6.2 CBERS 2B and Landsat TM

Data access procedure:

- INPE will process and distribute, free of charge, via its Image Data Catalogue (www.dgi.inpe.br/CDSR), all CBERS-2 CCD data available over GEO-FCT verification sites in Brazil and Guyana.
- Similarly, any requested Landsat TM data can be directly downloaded at no cost using the Catalogue.

A.7 JAXA

Sensor	Agency	Contact point(s)	Email	Access conditions	Archive and Data search tool
ALOS PALSAR (archive)	JAXA	Masanobu Shimada / Ake Rosenqvist	shimada.masanobu@jaxa.jp / ake.rosenqvist@soloEO.com	Standard data: 50 scenes/yr for GFOI use	http://auig.eoc.jaxa.jp
				50m mosaic data: Free of charge	www.eorc.jaxa.jp/ALOS/en/palsar_fnf/data/index.htm

A.7.1 ALOS-2 PALSAR-2

New acquisitions: New acquisition requests for GFOI cannot be accommodated, however it is anticipated that the ALOS-2 Basic Observation Strategy (BOS), which is fully compliant with SDCG recommendations for L-band SAR (at least dual season, resolution <30 m, dual polarisation) will satisfy the requirements for GFOI R&D.

The ALOS-2 BOS plans for past and future acquisitions can be viewed at http://www.eorc.jaxa.jp/ALOS-2/en/obs/pal2_obs_guide.htm

Data access procedure:

- **To be determined**

A.7.2 ALOS PALSAR

Archive data availability: ALOS PALSAR featured a global systematic acquisition strategy through which all land areas on Earth were acquired in stripmap 20 m (HH+HV) and 10 m (HH) mode 3-5 times per year between 2007 and 2011. Consistent time-series over all GFOI R&D sites are available. Detailed archive information is available at https://auig2.jaxa.jp/

In addition, ortho-corrected PALSAR mosaics (2007-2010) at 25 m pixel spacing are available for free download at http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm

Data access procedure:

- **To be determined**

A.8 USGS

All Landsat data archived by the US Geological Survey (USGS) is accessible, free of charge to users. The Landsat-8 Long Term Acquisition Plan (LTAP), as of December 2014, was modified to acquire all descending day-lit land images between 58° N and S latitude. At higher latitudes with more than 50% side lap, the priority is decreased in proportion to the amount of overlap between paths to maintain a 16-day or better revisit period.

Landsat-7 continues to operate within the continental landmass model. Ninety percent of the opportunities are acquired with Landsat-7. No daily limits are set for Landsat-7. All images rejections are due to instrument duty cycle and onboard memory constraints. Investigations are ongoing to reduce these constraints.

Sensor	Agency	Contact point(s)	Email	Access conditions	Archive and Data search tool
Landsat 7 & 8	USGS	Eugene Fosnight	fosnight @usgs.gov	Unrestricted use	http://earthexplorer.usgs.gov

A.8.1 Landsat TM/ETM+/OLI

New acquisitions: Both missions support special requests that can be used to improve the probability of acquisitions in support of coordinated field measurements. Special requests are more critical to Landsat-7 acquisitions than for Landsat-8 acquisitions.

Archive data availability: The Landsat archive can be accessed through the USGS Global Visualization Viewer (GloVis) at http://glovis.usgs.gov/

Data access procedure:

- Research teams can be directly download Landsat data using Earth Explorer or GloVis. Data are available without restriction, at no cost to users.

Annex B. GFOI R&D Study Sites, research partners and R&D topics

This section outlines the R&D to be undertaken at the nominated GFOI R&D Study Sites. A brief description of each site, the primary (related to GFOI priority R&D topics) and secondary (additional R&D topics) research topics, sensors used and requested is provided.

Site Code	Site name	Country	Research group	Coordinates	
				lat	long
BRA-1	Mato Grosso	Brazil	Group 1	S11.75	W54.25
CAR-1	Mbaïki	Central African Republic	Group 2	N3.872	E17.987
GAB-1	Gabon	Gabon		N0.0181	E10.1906
FCT-COL-3	Pacifico-Bajo_Mira	Colombia	Group 3	N1.65	W78.76
FCT-COL-4	Amazonia-Tinigua			N2.17	W74.15
FCT-COL-5	Andes-Antioquia			N7.83	W76.45
COL-6	Caqueta			N1.4079	W73.5747
COL-7	La Victoria			N6.26	W74.64
ETH-1	Kafa BR	Ethiopia	Group 4	N7°30'29"	E35°54'29"
FIJ-1	Lololo & Nakavu	Fiji		S17.833	E177.833
PER-1	Peru	Peru		S11.1	W74.3
GFC-1	GFC Site 1	Guyana	Group 5	N3.3069	W-59.6672
GFC-2	GFC Site 2			N6.4856	W-58.9471
GFC-3	GFC Site 3			N7.4660	W-60.0742
FCT-BOR-3	Mawas	Indonesia	Group 6	S2.24	E114.48
FCT-SUM-2	Harapan			S2.20	E103.38
FCT-TNZ-5	Amani	Tanzania	Group 7	S5.13	E38.63
FCT-TNZ-6	Liwale			S9.50	E38.17
PNG-1	Kokoda	Papua New Guinea	Group 8	S9.184	E147.374
PNG-2	Milne bay			S10.598	E150.185
PNG-3	Yus			S6.028	E146.745
FCT-MEX-2	Chiapas-1	Mexico	Group 9	N16.45	W91.40
MEX-8	Durango			N23.74	W105.49
FIN-1	Hyytiälä	Finland		N61.85	E24.32
FIN-2	Sodankylä			N67.48	E26.34
ICE-1	Hallormsstadur	Iceland		N65.12	W14.68
RUS-1	Pechora-Ilych	Russia		N62.18	E59.18
AU-4	Robson Creek (QLD)	Australia	Group 10	S17.119	E145.631
FCT-AU-3	Warra (Tasmania)			S43.1046	E146.6560
FCT-AU-1	Mathinna (Tasmania)			S41.37	E147.76
FCT-AU-2	Takone (Tasmania)			S41.19	E145.60
AU-5	Injune (QLD)			S25.5	147.7

CAN-1	Site 1 NW Territories	Canada	Group 11	N61.4	W121.3
CAN-2	Site 2 NW Territories			N62.53	W116.53
KAL-1 SUM-1	Central Kalimantan South Sumatra	Indonesia	Group 12	S2°24′ S2°29′30″	E114°6′30″ E103°28′30″
BRA-2	Novo Progresso	Brazil		S7°02′4.07″	W55°24′1.82″
SUR-1	Kabo	Suriname		5.255928°N	-55.76682°E
MAL-1	Malinau	Indonesia		3.0217°N	116.3601°E
MAD-1	Mahafaly	Madagascar		24.0304°S	43.7651°E
SA-1 SA-2	Lowveld / Kruger N.P. Eastern Cape	South Africa	Group 13	S24°59′45″ S33°36′	E31°35′30″ E25°40′

Table B.1 – GFOI R&D Study Sites (as of Mar, 2015)

R&D Group 1:

Organisation: INPE (Brazil)

Principal Investigator: Y.Shimabukuro

Study Sites: Mato Grasso (BRA-1), Brazil

Mato Grasso (BRA-1), Brazil

Site description: The study area is a subset of a Landsat scene (path/row 226/068) located in the State of Mato Grosso, within the 'Deforestation Arc' of the Brazilian Amazon. This region is showing high deforestation rates since the late 1980s, combined with intense forest degradation activities due to fire and selective logging.

R&D objective: Estimating forest degradation in Brazilian Amazon due to selective logging and fires through satellite imagery.

The main purpose of our study is to develop and apply a semi-automated procedure based on fraction images from multi-temporal dataset for mapping and differentiating forest degradation by selective logging and fires in the Brazilian Amazon. The future availability of 5-day temporal resolution of 10-m spatial resolution data from Sentinel-2 satellites is expected to improve the assessment and monitoring of forest degradation processes and consequently to facilitate implementing actions in the framework of REDD+.

Primary GFOI Priority R&D Topic(s):

- Forest degradation assessment due to selective logging and forest fires.
- SAR/Optical interoperability and complementarity studies

Secondary GFOI Priority R&D Topic(s): N/A

Sensors currently used:

- Optical - Landsat, SPOT
- SAR – Sentinel-1, ALOS PALSAR

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe			
VHR Optical					
VHR	Y	June-Nov	1		
SAR					
Sentinel-1A	Y	June-Nov		1. Dual pol 2. IWS (default	

				mode).	
ALOS-2 PALSAR-2	Y	April-Nov 2014-2016	2-6 cov/year	1. Dual-pol (HH+HV) GSD: 10m 2. Stripmap. 3. Desc-14dayInSAR and Asc-World 1/2	Yes
ALOS PALSAR (archive)	Y	June-2006, Apr-2011	46 day	1. Dual-pol (HH+HV) 14m 2. Stripmap. 3. Asc/Desc	Yes

Table B.2 – Satellite data requests for Mato Grasso (Brazil) study sites.

Previous R&D: The proposed method consists in the further development of the approach used in the TREES-3 pan-tropical deforestation survey conducted at the Joint Research Centre (JRC) using satellite imagery dataset. The approach is based on a systematic sample of Landsat imagery and consists in a few steps: (i) satellite data pre-processing (Bodart et al., 2011), (ii) production of vegetation, soil and shade fraction images and (iii) creation of spatially and spectrally homogeneous mapping units. Soil fraction images are used for mapping deforestation and selective logging while shade fraction images are used for mapping burned areas (Shimabukuro et al., 2014). The resulting map is then combined with the forest/non-forest mask to generate statistical estimates of deforestation and forest degradation by selective logging and fires. This method will be developed and tested using an area corresponding to a subset of a Landsat scene (path/row 226/068) located in the State of Mato Grosso, within the 'Deforestation Arc' of the Brazilian Amazon. This region is showing high deforestation rates since the late 1980s, combined with intense forest degradation activities due to fire and selective logging. The preliminary results show a great potential for assessing forest degradation from sensors with fine spatial resolution and high-temporal frequency.

In situ data: Not available

Key references:

Achard, A., R. Beuchle, P. Mayaux, H.-J. Stibig, C. Bodart, A. Brink, S. Carboni, B. Desclée, F. Donnay, H. D. Eva, A. Lupi, R. Raši, R. Seliger, and D. Simonetti, 2014. Determination of tropical deforestation rates and related carbon losses from 1990 to 2010. Global Change Biology 20: 2540–2554.

Asner, G. P., D. E. Knapp, A. Balaji, and G. Páez-Acosta. 2009. "Automated Mapping of Tropical Deforestation and Forest Degradation: CLASlite." Journal of Applied Remote Sensing 3:033543. doi:10.1117/1.3223675.

Berenguer, E., Ferreira, J., Gardner, T. A., Aragão, L. E. O. C., Camargo, P. B., Cerri, C. E., Durigan, M., Oliveira, R. C., Vieira, I. C. G., Barlow, J. A large-scale field assessment of carbon stocks in human-modified tropical forests. Global Change Biology, doi: 10.1111/gcb.12627, 2014.

Bodart, C., H. Eva, R. Beuchle, R. Raši, D. Simonetti, H.-J. Stibig, A. Brink, E. Lindquist and F. Achard: Pre-processing of a sample of multi-scene and multi-date Landsat imagery used to monitor forest cover changes over the tropics, ISPRS J. Photogramm., 66, 555–563, 2011.

Eva, H. D., F. Achard, R. Beuchle, E. De Miranda, S. Carboni, R. Seliger, M. Vollmar, W. A. Holler, O. T. Oshiro, V. Barrena Arroyo, and J. Gallego. 2012. "Forest Cover Changes in Tropical South and Central America from 1990 to 2005 and Related Carbon Emissions and Removals." Remote Sensing 4: 1369–1391. doi:10.3390/rs4051369.

INPE (National Institute for Space Research). 2014. "Monitoramento da Floresta Amazônica Brasileira por Satélite. Instituto Nacional de Pesquisas Espaciais." Accessed April 2014. http://www.obt.inpe.br/prodes/index.html

Shimabukuro, Y. E., R. Beuchle, R. Grecchi, F. Achard. 2014. "Assessment of forest degradation in Brazilian Amazon due to selective logging and fires using time series of fraction images derived from Landsat ETM+ images." Remote Sensing Letters, 5:9, 773-782.

Souza, C. M., D. A. Roberts, and M. A. Cochrane. 2005. "Combining Spectral and Spatial Information to Map Canopy Damage from Selective Logging and Forest Fires." Remote Sensing of Environment 98: 329–343. doi:10.1016/j.rse.2005.07.013.

Souza, C. M., J. Siqueira, M. H. Sales, A. Fonseca, J. G. Ribeiro, I. Numata, M. A. Cochrane, C. P. Barber, D. A. Roberts, and J. Barlow. 2009. "Ten-Year Landsat Classification of Deforestation and Forest Degradation in the Brazilian Amazon." Remote Sensing 5: 5493–5513. doi:10.3390/rs5115493.

R&D Group 2:

Organisation: SIRS (France)

Principal Investigator: C. Sannier

Study Sites: Mbaïki (CAR-1), Central African Republic, Gabon (GAB-1)

Mbaïki (CAR-1), Central African Republic

Site description: Transition between dense humid and dry forest with intense human activity

R&D objective: To develop methods for mapping and characterising forest disturbance in a complex landscape

Primary GFOI Priority R&D Topic(s):

- Forest degradation from selective logging, subsistence agriculture and fire
- Forest type mapping including humid and dry forest
- SAR/Optical integration studies

Secondary GFOI Priority R&D Topic(s):

- Methods for monitoring deforestation

Sensors currently used:

- Optical – Landsat, RapidEye, SPOT; SAR – ALOS PALSAR

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc / Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe			
VHR Optical					
VHR	Y	Most recent possible from May to October	once		
SAR					
Sentinel-1A	Y		As frequent as possible	1. Dual pol 2. IWS (default mode).	
ALOS-2 PALSAR-2	Y	To coincide with S1	As frequent as possible	FBD (default)	

Table B.3 – Satellite data requests for Mbaïki (Central Afriacn Republic) study sites.

Previous R&D: FP7 REDDAF project

In situ data: VHR data, field visits with ground photos located around the Mbaiki research station with long-term forest monitoring data.

Key references:

Fichet, L. V., C. Sannier, S. Mermoz, A. Pennec, and T. Le Toan. Mapping dry forest in Central African Republic using optical and radar data. InGeoscience and Remote Sensing Symposium (IGARSS), 2014 IEEE International, pp. 2336-2339. IEEE, 2014.

Gabon (GAB-1)

Site description: The site has undergone intense degradation and deforestation since the establishment of an oil palm plantation.

R&D objective: To investigate near real time forest disturbance monitoring based on the integration of optical and SAR data streams

Primary GFOI Priority R&D Topic(s):

- Methods for monitoring deforestation
- Methods for detecting and monitoring degradation
- SAR/Optical integration studies

Secondary GFOI Priority R&D Topic(s):

- Forest type mapping

Sensors currently used:

- Optical – Landsat, RapidEye, SPOT

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe			
SPOT1-5 (archive)	Y	As available from 2010 onward	As Frequent as possible		
VHR Optical					
VHR	Y	As available from 2010 onward	At least once per year		
SAR					

Sentinel-1A	Y	To coincide with ALOS PALSAR-2 and S5T5		1. Dual pol 2. IWS (default mode) 3.	
RADARSAT-2	Y	Prior to S1 from 2010	Throughout the year (at least one image every 3 months if available)	1.	
ALOS-2 PALSAR-2	Y			1.HH+HV 2. FBD (default)	
ALOS PALSAR (archive)	Y	2010 onward	Throughout the year (at least one image every 3 months if available)	FBD	

Table B.4 – Satellite data requests for Gabon study sites.

Previous R&D: ESA GSE FM REDD Extension project

In situ data: VHR data

Key references:

Fichet, L.-V.; Sannier, C.; Makaga, E.M.K.; Seyler, F., (2014) Assessing the Accuracy of Forest Cover Map for 1990, 2000 and 2010 at National Scale in Gabon, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol.7, no.4, 1346-1356

Sannier, C., McRoberts, R. E., Fichet, L. V., & Makaga, E. M. K. (2014). Using the regression estimator with Landsat data to estimate proportion forest cover and net proportion deforestation in Gabon. Remote Sensing of Environment, 151, 138-148.

R&D Group 3:

Organisation: Boston University, Woods Hole Research Center (USA)

Principal Investigators: P. Olofsson, J. Kellndorfer

Study Sites: Pacifico-Bajo Mira (FCT-CO-3), Amazonia-Tinigua (FCT-COL-4), Andes-Antioquia (FCT-COL5), Caqueta (COL-6), La Victoria (COL-7), Colombia

Pacifico-Bajo-Mira (FCT-COL-3), Amazonia-Tinigua (FCT-COL-4), Andes-Antioquia (FCT-COL-5), La Victoria (COL-7), Colombia

Site description: Tropical rainforest

R&D objective: Time series-based monitoring of IPCC land category conversions using data from multiple sensors. More specifically, we want investigate the possibility of ingesting data from for example SPOT into a time series of Landsat for land change monitoring. We are also studying ALOS/ALOS-2 and Sentinel-1 time series to fuse with the optical time series.

Primary GFOI Priority R&D Topic(s):

- Time-series SAR/Optical data for monitoring forest and land cover change
- Time-series SAR/Optical methods development for monitoring degradation
- Use of SPOT to fill gaps in Landsat monitoring
- Use Sentinel-1 to complement ALOS-1/2 L-Band time series

Secondary GFOI Priority R&D Topic(s): N/A

Sensors currently used

- Optical – Landsat
- SAR – ALOS-1/2 PALSAR-1/2, Sentinel-1

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe	Maximum		

Table B.5 – Satellite data requests for Pacifico-Bajo-Mira, Amazonia-Tinigua, Andes-Antioquia and La Victoria (Colombia) study sites.

Previous R&D: Forest cover and land use monitoring has been previously undertaken using Landsat and ALOS-1 PALSAR data.

In situ data: Not available

Caqueta (COL-6), Colombia

Site description: Tropical rainforest, deforestation hotspot

R&D objective: Time series-based monitoring of IPCC land category conversions using data from multiple sensors. More specifically, we want investigate the possibility of ingesting data from for example SPOT into a time series of Landsat for land change monitoring.

Primary GFOI Priority R&D Topic(s):

- Time-series SAR/Optical data for monitoring forest change and degradation
- Use of SPOT data to fill gaps in Landsat monitoring

Secondary GFOI Priority R&D Topic(s): N/A

Sensors currently used:

- Optical – Landsat
- SAR – ALOS PALSAR

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe	Maximum		
SPOT1-5 (archive)	Y	All year	Maximum		

Table B.6 – Satellite data requests for Caqueta (Colombia) study sites.

Previous R&D: Nothing that I'm aware of except the national maps of Colombia of IDEAM and the global map UMD map – both focused on forest cover change.

In situ data: None

Key references: None

R&D Group 4:

Organisation: Wageningen University (The Netherlands)

Principal Investigators: M. Herold, J.Reiche

Study Sites: Kafa BR (ETH-1), Ethiopia, Lololo and Nakavu (FIJ-1), Fiji, Peru (PER-1)

Kafa BR (ETH-1), Ethiopia

Principal Investigator: M. Herold (WUR, The Netherlands)

Co-investigators: Johannes Reiche; Arun Kumar Pratihast; Ben DeVries; Mathieu Decuyper (WUR, The Netherlands), Mesfin Tekle (Local Project Coordinator, Project Office Bonga, Kafa Zone, Ethiopia)

Site description: Inaugurated in 2011, the UNESCO Kafa Biosphere Reserve (BR) in southwestern Ethiopia is home to some of Ethiopia's last remaining Afromontane forests. As a result of decades of deforestation and degradation driven by smallholder agriculture and fuelwood harvesting, these forests are highly fragmented. In recent years, higher priority has been given to forest conservation and participatory forest management (PFM) in Ethiopoia, under such programmes as REDD+. Since its inauguration, the Kafa BR has been the target of a large project funded by the German International Climate Initiative (IKI) and implemented by the Nature and Biodiversity Conservation Union (NABU). As part of this project, research has been undertaken in the Kafa BR related to satellite time series based forest change monitoring, community-based monitoring, biodiversity monitoring, among other topics.

R&D objective:

The link and interaction between remote sensing and ground observation to monitor forest disturbances in near real-time at spatial scales remains largely unstudied. This research will exploit synergies between optical and SAR remote sensing and community-based observations through mobile phone technologies, and will focuses on the implementation of an interactive near real-time forest monitoring system in Kafa, Ethiopia. Furthermore, this research will also include the integration of Biodiversity monitoring with remote sensing.

We are planning to integrate the following data streams in near real-time:

- Community-based observations through mobile phone technologies (deforestation, degradation), using the approach by Pratihast et.al. 2012.
- Landsat based deforestation and forest degradation information, using an extended version of the novel approach of DeVries et al, Under Review: A robust and iterative method by which small-scale deforestation and degradation can be monitored at high temporal resolution using Landsat time series.
- Combined Landsat – PALSAR-2 – Sentinel-1 based deforestation and forest degradation information, using and extended version of the novel approach of Reiche et al., Under Review: A novel Bayesian-based approach to integrate multi-sensor SAR and optical time series for near real-time deforestation detection at times when new observations become available.

The integration will be done to:

- Improve the better forest monitoring forecasting
- Change detection improvement

- Law enforcement and reduce the risk of forest monitoring

The integration will allows for the systematic capture of forest disturbance events from the ground on a near real-time basis. By combining these observations with continually updated remote sensing change results helps to understand the complete change process. **Error! Reference source not found.**C.1 shows the deforestation detected by remote sensing and local rangers, where complete details of change processes including photographs from all direction on ground are documented. This documentation format helps to better understand the complete forest change processes on the ground.

Date	14-3-2013
Woreda	Gesha
Kebele	Ata wedi
DistanceToRoad	More than 3 Km
DistanceToNearestVillage	1-2 Km
DistanceToCoreForest	2-3 Km
Topography	Medium slope
Is forest?	yes
Forest Type	Degraded forest
CanopyCover	Very open (1 - 15% canopy cover)
CanopyHeight	Medium (10 - 25m tall)
CanopyStructure	Monoplane (trees mostly same height)
UnderstoryType	GRASS
DominantTreespecies	Chago
Is Disturbance?	yes
Date Of Disturbance	14-2-2013
Calendar	EUROPEAN
EvidenceOfDisturbance	Selective Logging, Grazing, DeBarking
ApproximateAreaAffected	2 Ha
DriverOfDisturbance	Charcoal,FirewoodCollection
counttree	7
reforestation	No

Figure B.1 – Integration of near real-time forest monitoring using remote sensing and local expert data

Primary GFOI Priority R&D Topic(s):

- Forest/non-forest change (Near real-time)
- Change within forest land (Near real-time)

Secondary GFOI Priority R&D Topic(s):

- Community based forest monitoring (Near real-time)

Sensors currently used:

- Optical - Landsat 5, 7 and 8, SPOT4 and 5, RapidEye
- SAR – none

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					

SPOT5(Take5)	Y	Fixed timeframe	Maximum		
SAR					
Sentinel-1A	Y		As frequent as possible, but at least 8-10 observations/year	1. Dual pol 2. IWS (default mode) 3.	
RADARSAT-2	Y		As frequent as possible, but at least 8-10 observations/year	1. Dual pol 2. Stripmap 3.	
ALOS-2 PALSAR-2	Y		As frequent as possible, but at least 3-5 observations/year	1. HH+HV 2. FBD (default) 3.	
ALOS PALSAR (archive)	Y		All archived FBD scenes	1. HH+HV 2. FBD (default) 3.	

Table B.7 – Satellite data requests for Kafa BR (Ethiopia) study sites.

Previous R&D: As of 2011, Wageningen University has led research in the Kafa BR under a large project implemented by NABU entitled "…". This research has focussed on forest and climate monitoring following an integrated approach using a range of data streams. First, methods using Landsat time series data to track small-scale changes in the Kafa BR were developed. Second, research into the effectiveness of community-based activity data (related to forest change) using smart phones has been previously carried out. Finally, a novel forest stratification approach using these continuous activity data streams towards estimation of forest carbon stock changes with higher accuracies is currently being researched.

In situ data:

Forest disturbance data collected at regular intervals by local forest rangers:

The proposed system has the capability of automatically capturing a larger variety of data types such as Geo-location, date, text, audio, video and images through smart phones, adding more flexibility in data collection at the local level. The proposed system provides a complete end-to-end platform for local community to gather and deployed these measurements effectively. The general overview of functional architecture of the system is mentioned in Following Figure C.2. The core elements of the system are: Data collection, data transmission, database management system, information processing and analysis and visualization.

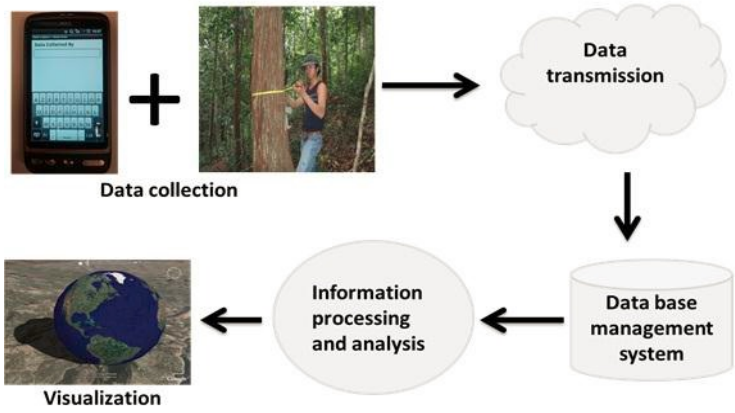

Figure B.2 Service Platform Architecture for community based monitoring

Data collection component enables local community to acquire the data. Data is acquired through systematically designed form based on the monitoring activities and requirements of national REDD+ programmes. These forms contains optional input constraints, flow depending on previous answers, icon based user-friendly graphics and local language support. The form is deployed on handheld devices such as smart phone, tablet PC, personal digital assistants (PDA) devices with integration of GPS and camera. Handheld devices store the data asynchronously and transfer to the data servers over GPRS, Wi-Fi, or USB when connectivity permits. A suitable database management system is designed for the proper storage of acquired data. The local data, upon meeting all the national requirements, can be integrated into the national database. The aggregated data will be processed, analysed and feed into estimations on emissions and removals at the national level. The results can be reported (using the IPCC GPG) to an international body for carbon crediting and will be visualized though the Google Earth Engine and map forms.

Year	**Number of ground observations**
2012	355
2013	400
2014	300

Table B.8 Frequency of ground observations collected by local experts

Very high resolution satellite data: Through a SPOT Planet Action proposal, annual time series of SPOT4 and SPOT5 data from 2005 to 2011 have been used in the research described above. Full coverage for 2011 is available as well as partial coverage for every year from 2005 – 2010. Annual RapidEye data from 2012 to 2013 are also available for the study area.

Key references:

Pratihast, A.K., B. DeVries, V. Avitabile, S. de Bruin, L. Kooistra, M. Tekle, M. Herold. 2014. Combining Satellite Data and Community-Based Observations for Forest Monitoring. Forests, 5: 2464-2489. DOI: 10.3390/f5102464.

Pratihast, A.K.; Herold, M.; Avitabile, V.; de Bruin, S.; Bartholomeus, H.; Jr., C.M.S.; Ribbe, L. Mobile Devices for Community-Based REDD+ Monitoring: A Case Study for Central Vietnam. Sensors 2013, 13, 21-38.

Pratihast, A.K.; Herold, M.; de Sy, V.; Murdiyarso, D.; Skutsch, M. Linking community-based and national REDD+ monitoring: A review of the potential. Carbon Manag. 2013, 4, 91–104.

Dresen, E., B. DeVries, M. Herold, L. Verchot, R. Müller. 2014. Fuelwood Savings and Carbon Emission Reductions by the Use of Improved Cooking Stoves in an Afromontane Forest, Ethiopia. Land, 10: 1137-1157. DOI: 10.3390/land3031137.

DeVries, B., A.K. Pratihast, J. Verbesselt, L. Kooistra, S. de Bruin, M. Herold. 2014. Near Real-Time Tropical Forest Disturbance Monitoring Using Landsat Time Series and Local Expert Monitoring Data. Conference: MultiTemp 2013: 7th International Workshop on the Analysis of Multi-temporal Remote Sensing Images. DOI: 10.1109/Multi-Temp.2013.6866022.

Reiche, J., Verbesselt, J., Hoekman, D. & M. Herold (2015): Fusing Landsat and SAR time series to detect deforestation in the tropics. Remote Sensing of Environment. 156, 276-293, doi: 10.1016/j.rse.2014.10.001.

Reiche, J., de Bruin, S., Hoekman, D., Verbesselt. & M. Herold (Under Review): Integrating Landsat and SAR time series in a Bayesian approach for near real-time deforestation detection in the tropics. Remote Sensing of Environment.

Lololo and Nakavu (FIJ-1), Fiji

Principal Investigator: J.Reiche (WUR, The Netherlands)

Co-investigators: Samuela Legataki (Forest Conservator, Fiji Forestry Department), Wolf Forstreuter (GIS and RS Specialist, SOPAC, Fiji)

Site description: Fiji archipelago is located in the seasonal tropics, 3000 km east of continental Australia – New Guinea. The total land area of 18,376 km^2 is largely distributed between the three main islands of Viti Levu (56%), Vanua Levu (30%) and Taveuni (6%). Fiji's forested area covers approximately 9,600 km^2, consisting mainly of indigenous forest, softwood plantations (mostly Pinus caribea) and hardwood plantations covering 89.3%, 5.6% and 5.1% of the total forested area respectively. Particular focus for the Fiji case, is on the main island Viti Levu, where the three demonstration sites are located (Figure C.3).

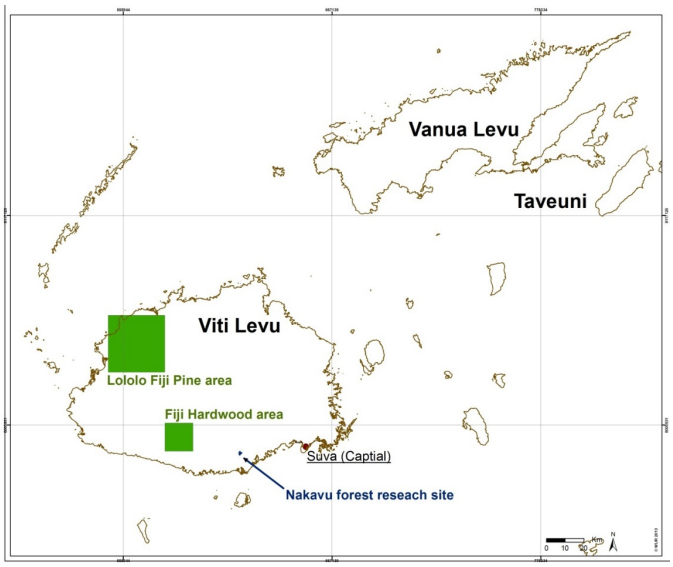

Figure C.3 Fiji islands and demonstration areas on Viti Levu.

The three main forest dynamics present in Fiji, including destructive degradation in managed tropical forest, hardwood plantation cycles and pine plantation cycles, can be found in the two demonstration sites of Lololo Fiji Pine area and Fiji Hardwood area. The Nakavu forest research area was logged with different logging intensities in 1990. Since then, the regrowth and a large number of forest parameters are monitored consistently.

The Lololo Fiji Pine Ltd. Lease (major research site) is fully managed softwood forest plantation (Pinus caribea), located in the north western part of the Viti Levu Island, Fiji (Lat. 17,32° S, Lon. 177.37° E). Viti Levu, the main island of the Fijian archipelago, lies in the seasonal tropics and experiences persistent and strongly varying cloud cover. Logging cycles have an average turn-over rate of 15-20 years. During logging activities, forest stands are fully harvested within a very short period and stems are removed immediately after logging. Subsequently, forest stands are replanted entirely. Forest stands remaining unlogged over a long period (greater than 10 years) are covered with fully grown pine.

R&D objective: To expand and improve very recently developed SAR-optical time series fusion methods for detecting deforestation that have been successfully demonstrated using Landsat and ALOS PALSAR time series.

The first method is a novel pixel-based Multi-sensor Time-series correlation and Fusion approach (MulTiFuse) that exploits the full observation density of optical and SAR time series (Reiche et al., 2015). MulTiFuse is designed to fuse historical SAR and optical time series to detect deforestation. A main objective is the expansion of MulTiFuse to use multiple time series from Landsat, C-band and L-band.

The second approach is a novel Bayesian-based approach to integrate multi-sensor SAR and optical time series for near real-time deforestation detection at times when new observations become available (Reiche et al, Under Review). We plan to expand this approach to integrate C-band, L-band and optical data streams for near real-time detection of deforestation.

Primary GFOI Priority R&D Topic(s):

- Time-series fusion of Landsat, C- and L-band SAR for detecting deforestation, also in near-real time

- Assessment of the contribution of Sentinel-1 time-series to deforestation monitoring, also in near-real time.

Secondary GFOI Priority R&D Topic(s): N/A

Sensors currently used:

- Optical – Landsat
- SAR – ALOS PALSAR

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe			
SPOT1-5 (archive)	Y				
VHR Optical					
VHR	Y				
SAR					
Sentinel-1A	Y		As frequent as possible, but at least 8-10 observations/year	1. Dual pol 2. IWS (default mode) 3.	
RADARSAT-2	Y		As frequent as possible, but at least 8-10 observations/year	1. Dual pol 2. Stripmap 3.	
ALOS-2 PALSAR-2	Y		As frequent as possible, but at least 3-5 observations/year	1. HH+HV 2. FBD (default) 3.	

Table B.9 – Satellite data requests for Lololo and Nakavu (Fiji) study sites.

Previous R&D: Previous research has developed methods for SAR-optical time-series fusion for detecting deforestation (Reiche et al., 2015) and in near real-time (Reiche et al., Under review).

In situ data: Available reference data are listed in Table B.10 and illustrated in Figure C.4 below.

Data type	Date	Owner	Description
Ground-truth GPS data	2012	WUR	Ground-truth data acquired during the 2012 field trip, including GPS locations with land cover and land cover change information from local experts.
Fiji Pine logging data	2000-2014	Fiji Pine, Fiji	Detailed 3-monthly wall-to-wall harvest data for the Fiji pine area for 2000-2014. Data includes the area and the date of harvest.
Fiji Pine reforestation data	1990-2014	Fiji Pine, Fiji	Detailed 3-monthly wall-to-wall reforestation data for the Fiji pine area for 1990-2014. Data includes the area and the date of reforestation.
Fiji Hardwood harvest and reforestation data	2005-2013	Fiji Hardwood, Fiji	Detailed harvest and reforestation data for the Fiji hardwood area for 2005-2012. Data includes the area, volume and the date of harvest/reforestation.
Harvest information for mature forest	2003-2010	Fiji Forestry, Fiji	Harvest information (mainly destructive degradation) of logging activities in managed tropical forest for 2003 - 2010. Data is acquired by Fiji Forestry and comprises the location and volume removed.
Landslide data	2008-2014	Fiji Pine, Fiji	Landslide data covering the Fiji Pine area. The affected area and the date of the landslide event are given.
PSP 2010	2010	Fiji Forestry, Fiji	Forest/ Non-forest information for 100 plots across Fiji
WorldView-2 2012 classification	2012	SOPAC, Fiji	Very high resolution land use information, manually digitized for parts of Fiji
Wood volume Nakavu	2013	Fiji Forestry, GIZ	Wood volume for different compartments of the forest research site ”Nakavu”

Table B.10 In situ data for Fiji demonstration sites.

For the Lololo Fiji Pine Ltd. leases, detailed spatial wall to wall inventory data of forest stands (9,570 ha) are available, comprising quarterly (3-monthly) harvesting information from 2000-2014 and replanting information dating back to 1975. The same information is available for other Fiji Pine Ltd. Leases in Viti Levu and Vanua Levu, Fiji islands. In addition, similar datasets are available from Fiji Hardwood and Fiji Forestry Department that report on logging activities in natural forest.

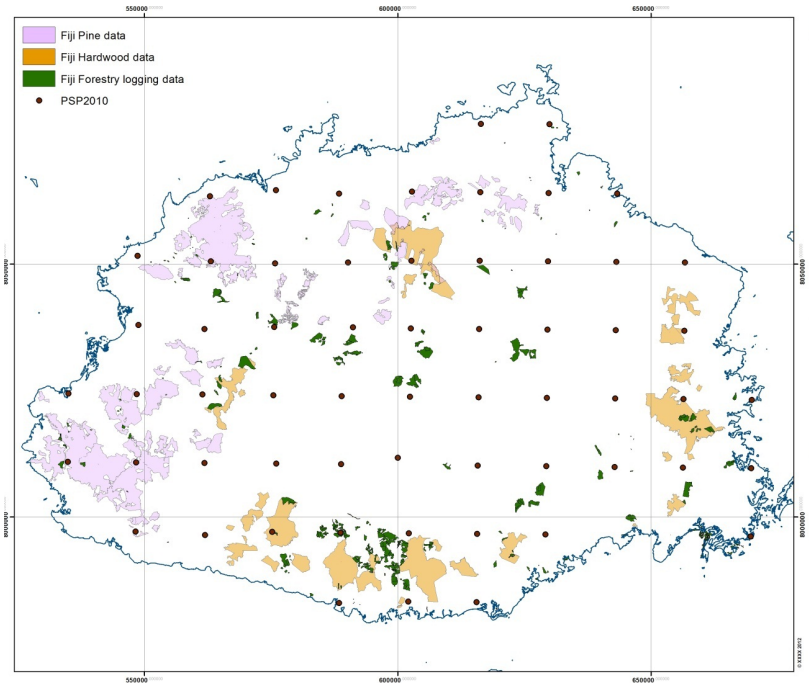

Figure B.4 Local forest reference data for Fiji, including Fiji Pine data, Fiji Hardwood data, Fiji Forestry logging information and PSP2010 plots (see Table).

Key references:

Reiche, J., Souza, C., Hoekman, D., Verbesselt, J., Haimwant, P., D. and Herold, M. 2013. Feature level fusion of multi-temporal ALOS PALSAR and Landsat data for mapping and monitoring of tropical deforestation and forest degradation. *IEEE Journal of Selected Topics in Applied Earth Observation and Remote Sensing*, 6, 5: 2159 – 2173.

Reiche, J., Verbesselt, J., Hoekman, D. & M. Herold (2015): Fusing Landsat and SAR time series to detect deforestation in the tropics. *Remote Sensing of Environment*. 156, 276-293, doi: 10.1016/j.rse.2014.10.001.

Hoekman, D., & J. Reiche (2015): Multi-model radiometric slope correction of SAR Images of complex terrain using a two-stage semi-empirical approach. *Remote Sensing of Environment*, 156, 1-10, doi: 10.1016/j.rse.2014.08.037.

Reiche, J., de Bruin, S., Hoekman, D., Verbesselt. & M. Herold (Under Review): Integrating Landsat and SAR time series in a Bayesian approach for near real-time deforestation detection in the tropics. *Remote Sensing of Environment*.

Peru (PER-1)

Principal Investigator: Johannes Reiche (WUR, The Netherlands)

Co-investigators: Arun Kumar Pratihast, Ben DeVries, Martin Herold (WUR, The Netherlands), Anne Larson (Principal Scientist, Center for International Forestry Research, Lima, Peru)

Site description: The community of Puerto Ocopa located in the Department of Junin, the province is Satipo and the district is Rio Tambo (lat: -11.1/ long: -74.3) and its surrounding districts are the research areas of this project. Peru is committed to meeting a target of zero net emissions in the land and forest sector by 2021. The Ministry of the Environment (MINAM) plays the central coordinating role on REDD+ activities, though the Ministry of Agriculture (MINAG) oversees key aspects of forests while the Ministry of Economy and Finance considers REDD+ a source of additional funding for sustainable development initiatives. In recent years, higher priority has been given to forest conservation and Community based forest monitoring in Peru, under such programmes as REDD+. To support REDD+ agenda, this project tilted as "community-based interactive monitoring for effective REDD+ implementation in Peru" is funded by USAID, United states of America and implemented by Wageningen university, Center for International Forestry Research (CIFOR), Peru and USGS – SilvaCarbon.

R&D objective: The link and interaction between remote sensing and ground observation to monitor forest disturbances in near real-time at spatial scales remains largely unstudied. This research will exploit synergies between optical and SAR remote sensing and community-based observations through mobile phone technologies, and will focuses on the implementation of an interactive near real-time forest monitoring system in Peru. Furthermore, this research will also include the integration of Biodiversity monitoring with remote sensing.

We are planning to integrate the following data streams in near real-time:

- Community-based observations through mobile phone technologies (deforestation, degradation), using the approach by Pratihast et.al. 2012.
- Landsat based deforestation and forest degradation information, using an extended version of the novel approach of DeVries et al, Under Review: A robust and iterative method by which small-scale deforestation and degradation can be monitored at high temporal resolution using Landsat time series.
- Combined Landsat – PALSAR-2 – Sentinel-1 based deforestation and forest degradation information, using and extended version of the novel approach of Reiche et al., Under Review: A novel Bayesian-based approach to integrate multi-sensor SAR and optical time series for near real-time deforestation detection at times when new observations become available.

The integration will be done to:

- Improve the better forest monitoring forecasting
- Change detection improvement
- Law enforcement and reduce the risk of forest monitoring

The integration will allows for the systematic capture of forest disturbance events from the ground on a near real-time basis. By combining these observations with continually updated remote sensing change results helps to understand the complete change process.

Primary GFOI Priority R&D Topic(s):

- Forest/non-forest change (Near real-time)
- Change within forest land (Near real-time)

Secondary GFOI Priority R&D Topic(s):

- Community based forest monitoring (Near real-time)

Sensors currently used:

- Optical - Landsat 5, 7 and 8, SPOT4 and 5, RapidEye
- SAR – none

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe	Maximum		
SAR					
Sentinel-1A	Y		As frequent as possible, but at least 8-10 observations/year	1. Dual pol 2. IWS (default mode) 3.	
RADARSAT-2	Y		As frequent as possible, but at least 8-10 observations/year	1. Dual pol 2. Stripmap 3.	
ALOS-2 PALSAR-2	Y		As frequent as possible, but at least 3-5 observations/year	1. HH+HV 2. FBD (default) 3.	
ALOS PALSAR (archive)	Y		All archived FBD scenes	1. HH+HV 2. FBD (default) 3.	

Table B.11 – Satellite data requests for Peru study sites.

Previous R&D: Wageningen University has served as the project's lead implementing organisation in this research. Wageningen University has coordinated the partnership consortium (i.e. CIFOR Peru, USGS – SilvaCarbon, USA) and oversee implementation of the project activities in target communities in Peru. This research has focussed on community-based interactive monitoring for effective REDD+ implementation. The objective of this project is: to assess the potential role of local communities in monitoring forest changes due deforestation and forest degradation; to explore and implement an application for handheld devices to measure forest change activities and their impacts; to integrate community based monitored data with other existing data such as optical and SAR remote sensing and expert field measurements for effective and interactive REDD+ participation and implementations on the local and the regional/provincial level.

In situ data:

Forest disturbance data collected at regular intervals by local forest rangers:

Data acquisition is ensured through funding from USID & USGS – SilvaCarbon, USA. The proposed system has the capability of automatically capturing a larger variety of data types such as Geo-location, date, text, audio, video and images through smart phones, adding more flexibility in data collection at the local level. The proposed system provides a complete end-to-end platform for local community to gather and deployed these measurements effectively. The general overview of functional architecture of the system is mentioned in Following C.6. The core elements of the system are: Data collection, data transmission, database management system, information processing and analysis and visualization.

Data collection component enables local community to acquire the data. Data is acquired through systematically designed form based on the monitoring activities and requirements of national REDD+ programmes. These forms contains optional input constraints, flow depending on previous answers, icon based user-friendly graphics and local language support. The form is deployed on handheld devices such as smart phone, tablet PC, personal digital assistants (PDA) devices with integration of GPS and camera. Handheld devices store

the data asynchronously and transfer to the data servers over GPRS, Wi-Fi, or USB when connectivity permits. A suitable database management system is designed for the proper storage of acquired data. The local data, upon meeting all the national requirements, can be integrated into the national database. The aggregated data will be processed, analysed and feed into estimations on emissions and removals at the national level. The results can be reported (using the IPCC GPG) to an international body for carbon crediting and will be visualized though the Google Earth Engine and map forms. Data acquisition will start from 2015 onwards.

Key references:

Pratihast, A.K., B. DeVries, V. Avitabile, S. de Bruin, L. Kooistra, M. Tekle, M. Herold. 2014. Combining Satellite Data and Community-Based Observations for Forest Monitoring. Forests, 5: 2464-2489. DOI: 10.3390/f5102464.

Pratihast, A.K.; Herold, M.; Avitabile, V.; de Bruin, S.; Bartholomeus, H.; Jr., C.M.S.; Ribbe, L. Mobile Devices for Community-Based REDD+ Monitoring: A Case Study for Central Vietnam. Sensors 2013, 13, 21-38.

Pratihast, A.K.; Herold, M.; de Sy, V.; Murdiyarso, D.; Skutsch, M. Linking community-based and national REDD+ monitoring: A review of the potential. Carbon Manag. 2013, 4, 91–104.

Dresen, E., B. DeVries, M. Herold, L. Verchot, R. Müller. 2014. Fuelwood Savings and Carbon Emission Reductions by the Use of Improved Cooking Stoves in an Afromontane Forest, Ethiopia. Land, 10: 1137-1157. DOI: 10.3390/land3031137.

DeVries, B., A.K. Pratihast, J. Verbesselt, L. Kooistra, S. de Bruin, M. Herold. 2014. Near Real-Time Tropical Forest Disturbance Monitoring Using Landsat Time Series and Local Expert Monitoring Data. Conference: MultiTemp 2013: 7th International Workshop on the Analysis of Multi-temporal Remote Sensing Images. DOI: 10.1109/Multi-Temp.2013.6866022.

Reiche, J., Verbesselt, J., Hoekman, D. & M. Herold (2015): Fusing Landsat and SAR time series to detect deforestation in the tropics. Remote Sensing of Environment. 156, 276-293, doi: 10.1016/j.rse.2014.10.001.

Reiche, J., de Bruin, S., Hoekman, D., Verbesselt. & M. Herold (Under Review): Integrating Landsat and SAR time series in a Bayesian approach for near real-time deforestation detection in the tropics. Remote Sensing of Environment.

R&D Group 5:

Organisation: Guyana Forest Commission (Guyana), Indufor (Asia Pacific)

Principal Investigators: P. Bolanath, Pete Watt

Study Sites: (GFC-1), (GFC-2), (GFC-3), Guyana

Guyana Forest Commission Site 1 (GFC-1), Site 2 (GFC-2) and Site 3 (GFC-3), Guyana

Principal Investigator: P. Bolanath (Guyana Forest Commission, Guyana), Pete Watt (Indufor, Asia Pacific)

Site description: Since 2012, Guyana has routinely mapped degradation (>0.25 ha) surrounding all deforestation sites >1 ha and also in 2014 across areas of shifting cultivation >0.25 ha. National coverage of RapidEye imagery is used for detection and monitoring. This is validated using 0.25 – 0.60 m CIR airborne photography. The detection methods and literature consulted and accuracy of the results are published on the GFC's website. http://www.forestry.gov.gy/publications.html

R&D objective: To advance Guyana's national MRV System to include crucial elements of forest degradation monitoring, specifically in the areas of mining and shifting agriculture.

Primary GFOI Priority R&D Topic(s):

- Methods of detecting and monitoring forest degradation arising from mining and shifting agriculture/rotational farming
- SAR/Optical interoperability and complementarity studies
- Use of VHR data for Cal/Val of products

Secondary GFOI Priority R&D Topic(s): N/A

Sensors currently used:

- Optical – Landsat-8, RapidEye, VHR airborne VIR photography
- SAR – ALOS PALSAR

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe	Every 5 days	N/A	N
VHR Optical					
VHR	Y	Coincide with SPOT 5 (Take 5)	monthly	N/A	Y (Prior to Aug 2015)
SAR					

Sentinel-1A	Y	2014-2016	Bi-monthly	1. Dual pol 2. IWS (default mode) 3.	Y (2014-)
ENVISAT ASAR (archive)	Y	Aug-Dec	N/A	1. HH+HV 2. Image(30 m) 3. Any	Y – historical baseline
ALOS-2 PALSAR-2	Y	Coincide with SPOT 5 (Take 5)	monthly	1. HH+HV 2. FBD (< 5m) 3. Any	N
TerraSAR-X	Y	2015-2016	Monthly	1. Single pol 2. Stripmap 3m 3.	N
TanDEM-X	Y	Fixed timeframe			N

Table B.12 – Satellite data requests for Guyana study sites.

Previous R&D: See site description – Extensive literature review, field work, plot measurements, aerial photography and high resolution imagery. Operational method in place for measuring and reporting annual deforestation and degradation.

In situ data: Ground observations for degradation and deforestation from Guyana Forestry Commission.

Key references:

GFC & Indufor National Forest Change Mapping and Accuracy Assessments 2011 to 2014

1. http://www.forestry.gov.gy/Downloads/MRVS_Interim_Measures_Report%20_Year_4_Version_1.pdf
2. http://www.forestry.gov.gy/Downloads/MRVS_Interim_Measures_Report_Year_3_Version_3.pdf
3. http://www.forestry.gov.gy/Downloads/Guyana_MRVS_Interim_Measures_Report%20_Year_2_Version_3.pdf

Other Science Papers: Reiche J; Souza C.M, Hoekman, D.H; Verbesselt, J, Persaud, H; Herold, M 2013 Feature Level Fusion of Multi-Temporal ALOS PALSAR and Landsat Data for Mapping and Monitoring of Tropical Deforestation and Forest Degradation. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing.

R&D Group 6:

Organisation: Wageningen University (The Netherlands)

Principal Investigator: D. Hoekman

Study Sites: Mawas, Kalimantan (FCT-BOR-3), Harapan, Sumatra (FCT-SUM-2), Indonesia

Mawas (FCT-BOR-3), Kalimantan, Harapan (FCT-SUM-2), Sumatra, Indonesia

Principal Investigator: D. Hoekman (WUR, The Netherlands)

Site description: Sites dominated by tropical peat swamp forest types (Mawas) and dryland primary and secondary Dipterocarp forest (Sumatra).

R&D objective: Mawas area (BOR-3) – Forest degradation, sensor interoperability, above-ground biomass. Study of dense time-series of Sentinel-1 and TerraSAR-X data to monitor degradation processes (related to fire damage and illegal logging), and study of improved land cover mapping capability of bi-static TanDEM-X data and utility for improved biomass mapping.

Sumatra area (SUM-2) – Forest degradation, sensor interoperability. Study of dense time-series of Sentinel-1 and TerraSAR-X for near-real time highly automated degradation and logging detection.

Primary GFOI Priority R&D Topic(s):

- SAR- and LiDAR-based methods of forest and carbon accounting
- Degradation monitoring using TerraSAR-X

Secondary GFOI Priority R&D Topic(s):

- Hydrology: Mawas area (BOR-3)

Sensors currently used:

- Optical – LiDAR; SAR – ALOS PALSAR, Sentinel-1, TerraSAR-X

Sensors requested:

Sensor	User request	Observation time window	Observation frequency	Observation mode (SAR)	Archive data
Optical					
SPOT5(Take5)	Y	Fixed timeframe	Bi-monthly		2011-2014
VHR Optical					
VHR	Y	2015-2016	Once/month		2014
SAR					
Sentinel-1A	Y	2014-2016	Monthly	1. Dual pol 2. IWS	
TerraSAR-X	Y	2015-2016	Monthly	1. Single pol* 2. Stripmap 3m	N
TanDEM-X	Y	Fixed timeframe			N

**Note for Harapan site (FCT-SUM-2), TSX observation: Stripmap, strip_008, VV pol, Right, Ascending*

Table B.13 – Satellite data requests for Mawas and Harapan (Indonesia) study sites.

Previous R&D: Focussed on the development of dense time-series forest monitoring products using C-band SAR data. Approaches to enhancing information extraction, e.g., multi-temporal speckle filtering were developed. SAR/Optical interoperability and complementarity was assessed for the purpose of detecting logging roads. There was ongoing capacity building with Indonesia on INCAS (the national MRV system).

In situ data: Mawas area (BOR-3): Field data (17 new biomass plots, 2013&2014), aerial photography (2011 and 2014), LiDAR transects (2014).

Sumatra area (SUM-2): Field survey reports at regular basis on position and nature of on-going degradation processes.

Key references:

Schlund, M. F. von Poncet, D.H. Hoekman, S. Kuntz, and C. Schmullius, 2014, Importance of bistatic SAR features from TanDEM-X for forest mapping and monitoring, *Remote Sensing of Environment*, Vol.151, pp.16-28.

Schlund, M. F. von Poncet, S. Kuntz, C. Schmullius, and D.H. Hoekman, 2015, TanDEM-X data for aboveground biomass retrieval in a tropical peat swamp forest, *Remote Sensing of Environment* (in press)

R&D Group 7:

Organisation: KSAT, NMBU, UiT, NLI, Norut (Norway)

Principal Investigator: A.K. Debien, E. Næsset, S. Anfinsen, S. Solberg, J. Haarpaintner

Study Sites: Amani (FCT-TNZ-5), Liwale (FCT-TNZ-6), Tanzania

Amani (FCT-TNZ-5), Liwale (FCT-TNZ-6), Tanzania

Principal Investigator: AK. Debien (KSAT, Norway), E.Næsset (NMBU, Norway), S. Anfinsen (UiT, Norway) , S. Solberg (NFLI, Norway), J. Haaraintner (Norut, Norway)

Site description: Amani ND Site - The Amani Nature Reserve is located in the Eastern Arc Mountains in NE Tanzania. The study area has a size of approximately 80 km^2 and with a range in altitude of almost 1000 m. The area is characterized by very steep slopes and dense tropical rainforest with an extreme biomass density, with maximum observed aboveground tree biomass on the plots around 1200 t/ha. Large fractions of the area are untouched natural forests. Amani is a global biodiversity hotspot.

Liwale ND Site - The Liwale District is located in SE Tanzania. The area under study comprises approximately 15000 km^2, which is a fraction of the legal District of Liwale. Some of the area is farmland, but most of it is Mimbo woodlands, a fairly wet savannah type which is the dominant vegetation type in East-Africa and in a large portion of Africa south of Sahara (9% of the African land area). Mimbo is the most common forest type in Tanzania (approximately 90% of the forested area). The biomass rarely goes above 200-250 t/ha, and biomass densities around 50-100 t/ha are very typical for this vegetation type. The area is subject to rapid land conversion, and especially deforestation must be expected. However, certain areas within the study region have also a fairly stable forest cover due to protection (game reserve).

R&D objective: Quantify the contribution of various types of remotely sensed data to improve precision of carbon estimates and area estimates and changes in such estimates over time. This is fundamental knowledge to help designing cost-effective monitoring systems.

Investigate sensor interoperability and complementarity between optical, C-band SAR and L-band SAR and dense C-band SAR time-series analysis to monitor forest and forest change.

Primary GFOI Priority R&D Topic(s):

- Carbon and carbon change estimation in savannah forest
- Carbon and carbon change estimation in high-biomass tropical rain forest
- Sensor interoperability/complementarity between optical, C-band SAR and L-band SAR
- Optimising information extraction using dense time-series C-band SAR (general forest mapping method improvements)

Secondary GFOI Priority R&D Topic(s):

- Estimation of forest area and change in forest area in savannah forest
- Carbon and carbon change estimation in high-biomass tropical rain forest
- Optimising F/NF change mapping using dense time-series C-band SAR

- Exploiting dense time-series C-band SAR for near-real time forest change detection

Sensors currently used:

- Optical – Landsat, RapidEye, LiDAR
- SAR – ALOS-1/2 PALSAR, RADARSAT-2, ENVISAT ASAR, TerraSARX/TanDEM-X

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
VHR Optical					
VHR	Y	June-Sept and Jan-Feb			
SAR					
Sentinel-1A	Y	All year	Densest time-series possible (Monthly)	1. Dual Pol 2. EWS/IWS 3.	Y
RADARSAT-2	Y	June-Sept and Jan		1. 2. 3.	
ALOS-2 PALSAR-2	Y	June-Sept and Jan		1. HH+HV 2. FBD (default) PLR if available 3.	
TanDEM-X	Y	Fixed timeframe			

Table B.14 – Satellite data requests for Amani and Liwale (Tanzania) study sites.

Previous R&D: Forest cover and change mapping using SAR and optical data, height retrieval and change detection using TanDEM-X data, biomass modelling and biomass estimation and change estimation using LiDAR and other data, and methods development using VHR optical data for detecting degradation.

In situ data: Forest inventory plots in Amani (180) and Liwale (613), land cover and vegetation data, destructive harvesting.

Key references:

Peer-review manuscripts in submission (Remote Sensing of Environment, Remote Sensing, Carbon Balance and Management):

Ene, L.T. et al. (in submission). Large-scale estimation of aboveground biomass in miombo woodlands in Tanzania using airborne laser scanning and national forest inventory data.

Hansen, E.H. et al. (2015). Modeling aboveground biomass in dense tropical submontane rainforest using airborne laser scanner data. Remote Sensing, 7: 788-807.

Hansen, E.H. et al. (in submission). Effects of pulse density on digital terrain model and canopy metrics using airborne laser scanner in a tropical rainforest.

Hansen, E.H et al. (in submission). Impact of field plot size on the efficiency of biomass estimation in a Tanzanian rainforest using airborne laser scanner and interferometric synthetic aperture radar as auxiliary data.

Haarpaintner, J., et al. (Accepted abstract to submit full paper in March 2015). Forest and Forest Change Mapping with C- and L-band SAR in Liwale, Tanzania. ISRSE36

Mauya, E.W. et al. (in submission). Effects of field plot size on prediction accuracy of aboveground biomass in airborne laser scanning-assisted inventories in tropical rain forests of Tanzania.

Mauya, E.W. et al. (in submission). Modelling above ground forest biomass using airborne laser scanner and field inventory data in the miombo woodlands of southern Tanzania.

Næsset, E. et al. (in submission). Mapping and estimating forest area and aboveground biomass in miombo woodlands in Tanzania using data from airborne lasers scanning, Tandem-X, RapidEye, and global forest maps as auxiliary information: A comparison of estimated precision.

Salberg, A. B., Trier, Ø. D., (2012). Temporal analysis of multisensor data for forest change detection using hidden Markov models. In *Proc. IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, pp. 6749-6752

Solberg, S. et al. 2015. Monitoring forest carbon in a Tanzanian woodland using interferometric SAR: a novel methodology for REDD+.Manuscript in submission.

R&D Group 8:

Organisation: HGC (Malaysia)

Principal Investigator: M. Williams

Study Sites: Kokoda (PNG-1), Milne Bay (PNG-2), Yus (PNG-3), Papua New Guinea

Kokoda (PNG-1), Milne Bay (PNG-2), Yus (PNG-3), Papua New Guinea

Principal Investigator: M.Williams (HGC)

Co-investigators: T.Milne (UNSW)

Site description: Conservation areas, primary and secondary forests and forest concession areas in Papua New Guinea. The areas considered have historical (2006) high-resolution airborne SAR data and IFSAR DEM data. HGC has access to ALOS PALSAR II data for these areas through JAXA's K&C Phase IV programme. Additional satellite data would help to achieve the current research and development objectives.

Conservation areas include the Kokoda Track, a site of historic significance to the governments of both Australia and Papua New Guinea. HGC has high-resolution land cover information generated in 2012 from 1.25m resolution airborne SAR data collected in 2006, and recent GeoSAR coverage in 2012, as well as 2011 PALSAR 1 data and 2012 RapidEye data. Also available for the site are X-band DSM and P-band DTM at 5m posting. This area is approximately 25,000 sq km stretching from Port Moresby, across the highlands to Popondetta in the north, and includes a variety of land cover types, including primary and secondary forests, at elevations ranging from lowland to upper montane (> 3000m), large areas of mangrove, plantations (oil palm, teak, rubber, coconut), grassland and subsistence agriculture. Ground truth has been gathered on several occasions and includes estimates of forest biomass derived from variable radius plot samples obtained for various strata in September 2011. Study area centre coordinates: -9.11° latitude, 147.50° longitude.

The site at Milne Bay / Orangerie Bay has, in addition to high-resolution 2006 and 2012 GeoSAR airborne SAR data, 2010/11 PALSAR 1 data and 2012 RapidEye data LiDAR data for a forested area of around 700 sq km. Forest sample data are also available for the area which has been studied by HGC in collaboration with PNG Forest Authority. Detailed land cover classification for the area is available for 2006 and includes mangrove, primary and secondary forest up to >1000m elevation as well as oil palm plantation, grasslands and subsistence agriculture. Study area centre coordinates: -10.50° latitude, 150.25° longitude.

The Tree Kangaroo Conservation Project site (declared in 2006) is located in the Morobe province on the Huon Peninsula in eastern Papua New Guinea. A rectangular area of interest (AOI) of 623,842 ha surrounding the YUS Conservation Area – with an upper left coordinate, in WGS84 UTM 55S, of 441852 east by 9386513 north, upper right coordinate of 534123 east by 9336786 north, lower left coordinate of 413311 east by 9333049 north and lower right coordinate of 505529 east by 9285208 north – bounds the land cover classification area. Within this AOI, 490,000 ha are terrestrial and the remainder is ocean. The most recent land cover maps for the area are derived from 2010 LANDSAT data.

Additional areas are being considered for forest monitoring studies. These are predominantly in areas with high relief, or at altitude where optical remote sensing provides limited coverage due to clouds. It is most likely that the list of study sites will be extended to incorporate areas in the Western Highlands (Study area centre coordinates: -5.75° latitude, 144.30° longitude) and on the island of New Britain (Study area centre coordinates: -5.80°

latitude, 150.60º longitude). The precise areas will most likely be decided in early March 2015.

R&D objective: Optimising the use of SAR for the detection and monitoring of deforestation and forest degradation, and the recovery of forest biophysical information in Papua New Guinea.

Primary GFOI Priority R&D Topic(s):

- Deforestation and degradation monitoring using SAR

Secondary GFOI Priority R&D Topic(s):

- Support to the development of an MRV/REDD+ system for PNG
- Conservation area monitoring

Sensors currently used:

- SAR – ALOS PALSAR, GeoSAR
- LiDAR
- Optical – RapidEye, Landsat

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
VHR Optical					
VHR	Y	2015-	Monthly		Y (2010, 2014)
SAR					
Sentinel-1A	Y	2015-	As and when available for construction of high-density time-series	1. Dual pol 2. IWS (default mode)	
ALOS-2 PALSAR-2	Y	2015-	Once, more frequent over some areas where available	1. HH+HV 2. FBD (default) Quad-pol if available	N
ALOS PALSAR (archive)	Y			1. HH+HV 2. FBD	Yes 2010+
TerraSAR-X	Y	2015-	Monthly	1. VV+VH 2. Stripmap and Spotlight	Y (2010-2011, 2014)
TanDEM-X	Y	Fixed timeframe	Several interferometric observations	~200 m across track baseline over Milne Bay LiDAR collection area	Y (2011)

Table B.15 – Satellite data requests for Kokoda, Milne Bay and Yus (PNG) study sites.

Previous R&D: Demonstration of airborne SAR (GeoSAR) to generate baseline forest and land cover information, and subsequent monitoring using ALOS PALSAR 1. Methods were developed to estimated biomass/carbon and GHG emissions for tropical forests using forest sample data. Local staff were trained in image analysis and verification. Recovery of forest height information from dual-band InSAR data was demonstrated and compared with LiDAR forest height estimates. Forest change detection was demonstrated using a combination of airborne InSAR and ALOS stereo-optical DEM data.

In situ data: GPS located sites, descriptions and photographs, variable radius plot forest samples..

Key references:

Williams, M.L., Milne, A.K. and Tapley, I.J. The Kokoda Track and Owen Stanley Ranges Remote Sensing Pilot Project. Technical report prepared on behalf of the Department of Environment and Conservation, Papua New Guinea, 15 January 2013. Horizon Geoscience Consulting.

Tadono, T., Williams, M. L. and Hensley, S., *Comparison of Stereo-Optical and Dual-Band InSAR DEMs in Papua New Guinea*, Proc. IEEE International Geoscience and Remote Sensing Symposium, IGARSS 2012

Williams, M.L. and Milne, A.K., *A Remote Sensing Baseline for Land Cover and Forest Above Ground Biomass in Papua New Guinea: Milne Bay Pilot Project, Final Report: Preparation and Analysis of Remotely Sensed Data*, Technical report to Kokusai Kogyo Co., Ltd prepared on behalf of the Forestry Authority, Papua New Guinea, 28 June 2013. Horizon Geoscience Consulting.

Williams, M L, Milne A K, Tapley, J, Reis J, Sanford, M, Kofman, B, Hensley, S, *Tropical Forest Biomass Recovery using GeoSAR Observations*, Proceedings of the International Geoscience and Remote Sensing Symposium, July, Cape Town, 2009.

R&D Group 9:

Organisation: VTT (Finland)

Principal Investigator: T.Häme

Study Sites: Chiapas-1 (FCT-MEX-2), Durango (MEX-8), Mexico, Hyytiälä (FIN-1), Sodanklylä (FIN-2), Finland, Hallormsstadur (ICE-1), Iceland, Pechora-Ilych (RUS-1), Russia

Chiapas (FCT-MEX-2), Mexico

Principal Investigator: T. Häme (VTT, Finland)

Site description: Tropical to sub-tropical landscape with a strong anthropogenic influence. Mixture of forest and cultivated areas. Shifting cultivation common.

R&D objective: To create and test a novel method for forest area and biomass monitoring by combining earth observation and modeling to support assessment of degradation, national forest inventories and forest management with a special reference to carbon balance.

Primary GFOI Priority R&D Topic(s):

- Carbon estimation using SAR/Optical/LiDAR
- SAR/Optical integration for forest degradation assessment
- SAR/Optical interoperability and complementarity studies for LU and change monitoring

Secondary GFOI Priority R&D Topic(s):

- Automation of mapping methods

Sensors currently used:

- Optical – VHR (RapidEye), Landsat, LiDAR
- SAR – ALOS PALSAR, TerraSAR-X, RADARSAT-2

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe			
VHR Optical					
VHR	Y	2007, 2010, 2013, 2015 (2016) cloud free at any time within year OK	Ten small (5 km by 5 km) images/year		

SAR					
Sentinel-1A	Y	Free		1. Dual pol 2. IWS (default mode) 3.	
ALOS-2 PALSAR-2	Y	2015-2016	between bi-monthly to once per year, whole area	1. Dual-pol, Quad-pol 2. Stripmap 3.any but the same	
ALOS PALSAR (archive)	Y	2007-2010	bi-monthly or once per season	1. Dual-pol, Quad-pol 2. Stripmap 3. any	
TerraSAR-X	Y	2015-2016	monthly	1. HH, dual-pol, quad-pol 2. Stripmap 3. any	
TanDEM-X	Y	Fixed timeframe			
COSMO-SkyMed	Y	2015-2016	1-day InSAR pairs if available, monthly	1. (HH,VV) or (HH,HV) 2. Stripmap 3. any	

Table B.16 – Satellite data requests for Chiapas (Mexico) study site.

Previous R&D: FP7 project ReCover, coordinated by VTT; VTT's specific target site was Chiapas

In situ data: Ground plots

Key references:

Antropov, O., Rauste, Y. and Häme, T. 2010. Tropical forest tree height retrieval with TanDEM-X: Algorithm development and accuracy analysis. Proceedings of the ESA Living Planet Symposium, Bergen, Norway, 28 June – 2 July.

Häme, T., Kilpi, J., Ahola, H., Rauste, Y., Antropov, O., Rautiainen, M., Sirro, L., and Bounpone, S. 2013a. Improved mapping of Tropical forests with optical and SAR imagery, Part I: Forest Cover and Ac curacy Assessment Using Multi-Resolution Data, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 6, No. 1, February 2013, p. 74-91.

Häme, T., Rauste, Y., Antropov, O., Ahola, H., and Kilpi, J. 2013b. Improved mapping of Tropical forests with optical and SAR imagery, Part II: Above ground biomass estimation, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 6, No. 1, February 2013, p. 92-101.

Häme, Tuomas; Sirro, Laura; Cabrera, E; Enßle, F; Haarpaintner, J; Hämäläinen, J; de Jong B; Paz Pellat, F; Pedrazzani, D; Reiche, J. 2013c. ReCover: A concept for tropical forest assessment for REDD. Proceedings of the ESA Living Planet Symposium 2013. European Space Agency, ss. 8. ESA Living Planet Symposium 2013, Edinburgh, UK, 9 - 13 September 2013 (ESA SP-722, December 2013)

Sirro, L., Häme, T., Rauste, Y., Antropov, O., Hämäläinen, J., Paz, F., and de Jong, B. 2013. Comparison of optical and SAR data in tropical land cover classification for REDD, Proceedings of the ESA Living Planet symposium, Edinburg, UK, 9-13 September 2013, (ESA SP-722, December 2013), 7 p.

Sirro, L., Häme, T., Rauste, Y., Antropov, O., Hämäläinen, J., Paz, F., and de Jong, B. 2013. Comparison of optical and SAR data in tropical land cover classification for REDD, Proceedings of the ESA Living Planet symposium, Edinburg, UK, 9-13 September 2013, (ESA SP-722, December 2013), 7 p.

MEX-8 Durango, Mexico

Principal Investigator: T. Häme (VTT, Finland)

Site description: Tropical to sub-tropical landscape. Natural and managed forest area.

R&D objective: Improve methods to gain knowledge on the biomass and carbon stocks and predicted future growth of Durango state forest.

Primary GFOI Priority R&D Topic(s):

- Carbon estimation
- SAR/Optical interoperability and complementarity studies

Secondary GFOI Priority R&D Topic(s): N/A

Sensors currently used:

- Optical – Landsat
- SAR – ALOS PALSAR, RADARSAT-2, TerraSAR-X

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc / Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe			
VHR Optical					
VHR	Y	June 15 – Aug 31, years 2010, 2014 & 2015	Ten small (5 km by 5 km) images/year (2014 and 2015 together)		

SAR					
Sentinel-1A	Y	Free		1. Dual pol 2. IWS (default mode) 3.	
ALOS-2 PALSAR-2	Y	2014-2016	between bi-monthly to once per year, whole area	1. Dual-pol, Quad-pol 2. Stripmap 3.any but the same	
TerraSAR-X	Y	2015-2016	monthly	1. HH, dual-pol, quad-pol 2. Stripmap 3. any	
TanDEM-X	Y	Fixed timeframe			
COSMO-SkyMed	Y	2015-2016	1-day InSAR pairs if available, monthly	1. (HH,VV) or (HH,HV) 2. Stripmap 3. any	

Table B.17 – Satellite data requests for Durango (Mexico) study site.

Previous R&D: Research by the University and USDA, NFI by Conafor

In situ data: Temporary and permanent plots

Key references:

Antropov, O., Rauste, Y. and Häme, T. 2010. Tropical forest tree height retrieval with TanDEM-X: Algorithm development and accuracy analysis. Proceedings of the ESA Living Planet Symposium, Bergen, Norway, 28 June – 2 July.

Häme, T., Kilpi, J., Ahola, H., Rauste, Y., Antropov, O., Rautiainen, M., Sirro, L., and Bounpone, S. 2013a. Improved mapping of Tropical forests with optical and SAR imagery, Part I: Forest Cover and Ac curacy Assessment Using Multi-Resolution Data, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 6, No. 1, February 2013, p. 74-91.

Häme, T., Rauste, Y., Antropov, O., Ahola, H., and Kilpi, J. 2013b. Improved mapping of Tropical forests with optical and SAR imagery, Part II: Above ground biomass estimation, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 6, No. 1, February 2013, p. 92-101.

Häme, Tuomas; Sirro, Laura; Cabrera, E; Enßle, F; Haarpaintner, J; Hämäläinen, J; de Jong B; Paz Pellat, F; Pedrazzani, D; Reiche, J. 2013c. ReCover: A concept for tropical forest assessment for REDD. Proceedings of the ESA Living Planet Symposium 2013. European Space Agency, ss. 8. ESA Living Planet Symposium 2013, Edinburgh, UK, 9 - 13 September 2013 (ESA SP-722, December 2013)

Sirro, L., Häme, T., Rauste, Y., Antropov, O., Hämäläinen, J., Paz, F., and de Jong, B. 2013. Comparison of optical and SAR data in tropical land cover classification for REDD, Proceedings of the ESA Living Planet symposium, Edinburg, UK, 9-13 September 2013, (ESA SP-722, December 2013), 7 p.

Sirro, L., Häme, T., Rauste, Y., Antropov, O., Hämäläinen, J., Paz, F., and de Jong, B. 2013. Comparison of optical and SAR data in tropical land cover classification for REDD, Proceedings of the ESA Living Planet symposium, Edinburg, UK, 9-13 September 2013, (ESA SP-722, December 2013), 7 p.

Hyytiälä (FIN-1), Sodankylä (FIN-2), Finland

Principal Investigator: T. Häme (VTT, Finland)

Site description: Boreal (Hyytiälä) and northern Boreal conifer dominated managed forest

R&D objective: To reduce the uncertainty in carbon and water balance assessment with the help of earth observation and modeling. Also provision of more accurate up-to-date information on forest parameters.

Primary GFOI Priority R&D Topic(s):

- Carbon and forest resources estimation
- SAR/Optical interoperability and complementarity studies

Secondary GFOI Priority R&D Topic(s): N/A

Sensors currently used:

- Optical – Landsat, GeoEye, Hyperion
- SAR – Sentinel 1

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe			
VHR Optical					
VHR	Y	2007, 2010, 2013, 2015 (2016)	Ten small (5 km by 5 km) images/year		
SAR					
Sentinel-1A	Y	All available OK already		1. Dual pol 2. IWS (default mode)	

ALOS-2 PALSAR-2	Y	2014-2016	bi-monthly or once per season	1. Dual-pol, Quad-pol 2. Stripmap 3. any	
ALOS PALSAR (archive)	Y	2007-2010	bi-monthly or once per season	1. Dual-pol, Quad-pol 2. Stripmap 3. any	
TerraSAR-X	Y	2015-2016	monthly	1. HH, dual-pol. Quad-pol if any 2. Stripmap, also spotlight if any 3. any	
TanDEM-X	Y	Fixed timeframe			
COSMO-SkyMed	Y	2015-2016	1-day InSAR pairs if available, monthly	1. (HH,VV) or (HH,HV) 2. Stripmap, also 1-day InSAR pairs if available 3. any	

Table B.18 – Satellite data requests for Hyytiälä and Sodankylä (Finland) study sites.

Previous R&D: Several studies on boreal forestry, ongoing FP7 project North State, coordinated by VTT

In situ data: Ground plots and stands

Key references:

Antropov, O., Rauste, Y., Ahola, H., and Häme, T. 2013. Stand-Level Stem Volume of Boreal Forests From Spaceborne SAR Imagery at L-Band, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 6, No. 1, February 2013, p. 35-44.

Antropov, O., Rauste, Y., and Häme, T. 2014. Improved retrieval of forest stem volume of boreal forests by combining high resolution optical data and radar-based forest tree height information, Proceedings of ESA Sentinel-2 for Science Workshop, Frascati, Italy, 20-22 May 2014 (to appear), 4 p.

Tuomas Häme, Teemu Mutanen, Annikki Mäkelä, Shaun Quegan, Rune Storvold, Jussi Rasinmäki, Vladimir Elsakov, Jón Atli Benediktsson North state - Enabling intelligent GMES services for carbon and water balance modeling of northern forest ecosystems. Esa Sentinel for Science Symposium, May 2014. 3 p.

Molinier, Matthieu; Häme, Tuomas. 2012. Combining Cellular Phone Images and Wall-to-Wall Satellite Imagery in Forest Management Planning. ESA Sentinel-2 Preparatory Symposium. Frascati, Italy, 23 - 27 April 2012 http://www.congrexprojects.com/docs/12c04_doc/sentine2_poster_session_2a.pdf?sfvrsn=2

Hallormsstadur (ICE-1), Iceland

Principal Investigator: T. Häme (VTT, Finland)

Site description: The site represents an area in a valley between two small mountain ranges. The site belongs to and is managed by the Iceland Forest Service and is one of the largest remaining birch forests in Iceland. Also planted Siberian larch and Russian larch stands are located in the area.

R&D objective: To reduce the uncertainty in carbon and water balance assessment with the help of earth observation and modeling. Also provision of more accurate up-to-date information on forest parameters.

Primary GFOI Priority R&D Topic(s):

- Carbon and forest resources estimation
- SAR/Optical interoperability and complementarity studies

Secondary GFOI Priority R&D Topic(s): N/A

Sensors currently used:

- Optical – Landsat, GeoEye, Hyperion
- SAR – Sentinel 1

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc / Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe			
VHR Optical					
VHR	Y	2007, 2010, 2013, 2015 (2016)	Ten small (5 km by 5 km) images/year		
SAR					
Sentinel-1A	Y	Free		1. Dual pol 2. IWS (default mode)	
TerraSAR-X	Y	2015-2016	monthly	1. HH, dual-pol. Quad-pol if any 2. Stripmap, also spotlight if any 3. any	
TanDEM-X	Y	Fixed timeframe			

COSMO-SkyMed	Y	2015-2016	1-day InSAR pairs if available, monthly	1. (HH,VV) or (HH,HV) 2. Stripmap, also 1-day InSAR pairs if available 3. any	

Table B.19 – Satellite data requests for Hallormsstadur (Iceland) study site.

Previous R&D: Ongoing FP7 project North State, coordinated by VTT

In situ data: plots and stands

Key references:

Antropov, O., Rauste, Y., Ahola, H., and Häme, T. 2013. Stand-Level Stem Volume of Boreal Forests From Spaceborne SAR Imagery at L-Band, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 6, No. 1, February 2013, p. 35-44.

Antropov, O., Rauste, Y., and Häme, T. 2014. Improved retrieval of forest stem volume of boreal forests by combining high resolution optical data and radar-based forest tree height information, Proceedings of ESA Sentinel-2 for Science Workshop, Frascati, Italy, 20-22 May 2014 (to appear), 4 p.

Tuomas Häme, Teemu Mutanen, Annikki Mäkelä, Shaun Quegan, Rune Storvold, Jussi Rasinmäki, Vladimir Elsakov, Jón Atli Benediktsson North state - Enabling intelligent GMES services for carbon and water balance modeling of northern forest ecosystems. Esa Sentinel for Science Symposium, May 2014. 3 p.

Pechora-Ilych (RUS-1), Russia

Principal Investigator: T.Häme (VTT, Finland)

Site description: The site is a nature reserve in Komi republic. site which forms the core of the World Heritage Site Virgin Komi Forests. In the lowlands pine forests, pine forested swamps, and moss swamps dominate, as well as few spruce forests and bogs can be found.The site is a nature reserve in Komi republic.

R&D objective: To reduce the uncertainty in carbon and water balance assessment with the help of earth observation and modeling. Also provision of more accurate up-to-date information on forest parameters.

Primary GFOI Priority R&D Topic(s):

- Carbon and forest resources estimation
- SAR/Optical interoperability and complementarity studies

Secondary GFOI Priority R&D Topic(s): N/A

Sensors currently used:

- Optical – Landsat, GeoEye, Hyperion
- SAR – Sentinel 1

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe			
VHR Optical					
VHR	Y	2007, 2010, 2013, 2015 (2016)	Ten small (5 km by 5 km) images/year		Y
SAR					
Sentinel-1A	Y	Free		1. Dual pol 2. IWS (default mode) 3.	
ALOS-2 PALSAR-2	Y			1. HH+HV 2. FBD (default) 3.	
ALOS PALSAR (archive)	Y	2007-2010	bi-monthly or once per season	1. Dual-pol, Quad-pol 2. Stripmap 3. any	
TerraSAR-X	Y	2015-2016	monthly	1. HH, dual-pol, quad-pol 2. Stripmap 3. any	
TanDEM-X	Y	Fixed timeframe			
COSMO-SkyMed	Y	2015-2016	1-day InSAR pairs if available, monthly	1. (HH,VV) or (HH,HV) 2. Stripmap 3. any	

Table B.20 – Satellite data requests for Pechora-Ilych (Russia) study site.

Previous R&D: Research by the Institute of Biology, Russian Academy of Sciences, cooperation with NASA

In situ data: Ground plots and stands

Key references:

Antropov, O., Rauste, Y., Ahola, H., and Häme, T. 2013. Stand-Level Stem Volume of Boreal Forests From Spaceborne SAR Imagery at L-Band, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 6, No. 1, February 2013, p. 35-44.

Antropov, O., Rauste, Y., and Häme, T. 2014. Improved retrieval of forest stem volume of boreal forests by combining high resolution optical data and radar-based forest tree height information, Proceedings of ESA Sentinel-2 for Science Workshop, Frascati, Italy, 20-22 May 2014 (to appear), 4 p.

Tuomas Häme, Teemu Mutanen, Annikki Mäkelä, Shaun Quegan, Rune Storvold, Jussi Rasinmäki, Vladimir Elsakov, Jón Atli Benediktsson North state - Enabling intelligent GMES services for carbon and water balance modeling of northern forest ecosystems. Esa Sentinel for Science Symposium, May 2014. 3 p.

R&D Group 10:

Organisation: CSIRO, UNSW (Australia)

Principal Investigators: N. Sims, A. Held, A. Mitchell, R. Lucas

Study Sites: Mathinna, Takone and Warra, Tasmania (FCT-AU-1, -2, -3), Robson Creek, Queensland (AU-4), Injune (AU-5), Australia

Mathinna (FCT-AU-1), Takone (FCT-AU-2), Tasmania, Australia

Principal Investigator: A. Mitchell (UNSW, Sydney)

Site description: Eucalypt-dominated wet and dry forest, pockets of rainforest. Agriculture (cropping) and plantations (hardwood/softwood) dominate the rural sector.

R&D objective: Extend methods development using SAR and sensor synergy (SAR/Optical/LiDAR) for deforestation and degradation monitoring and retrieving estimates of AGB. Comparison of methods and retrieval accuracies over semi-arid, temperate and tropical forests in conjunction with other research groups.

Primary GFOI Priority R&D Topic(s):

- Integration of SAR and Optical data for degradation assessment
- Above Ground Biomass (AGB) estimation using SAR, Optical and LiDAR data

Secondary GFOI Priority R&D Topic(s):

- Compare methods and retrieval accuracies for different forest types and biomes (semi-arid-temperate-tropical)

Sensors currently used:

- Optical – Landsat
- SAR – ALOS PALSAR, RADARSAT-2

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
VHR Optical					
VHR	Y	2015-	Monthly	N/A	Y (2010, 2014)
SAR					
Sentinel-1A	Y	2015-	Bi-monthly	1. Dual pol 2. IWS (default mode)	
ALOS-2 PALSAR-2	Y	2015-	Bi-monthly	1. HH+HV 2. FBD (default)	N

TerraSAR-X	Y	2015-	Monthly	1. VV+VH 2. Stripmap and Spotlight	Y (2010-2011, 2014)
TanDEM-X	Y	Fixed timeframe	Max		Y (2011)

Table B.21 – Satellite data requests for Mathinna and Takone (Tasmnia, Australia) study sites.

Previous R&D: Previous studies focussed on the interoperability of time-series optical (Landsat) and SAR (ALOS PALSAR) data for forest information monitoring. SAR-SAR (C- and L-band) interoperability and complementarity was also assessed for forest and land use cover mapping. Training manuals were developed on SAR processing, forest information extraction and verification (http://www.crcsi.com.au/Research/Radar-Research-Facility/Forest-Carbon-Tracking-using-Radar).

In situ data: GPS located sites with species, land use, age, visual estimates of tree height and cover, and photographs.

Key references:

Mitchell, A.L., Tapley, I., Milne, A.K., Williams, M.L., Zhou, Z-S., Lehmann, E., Caccetta, P., Lowell, K. and Held, A. C- and L-band SAR interoperability: Filling the gaps in continuous forest cover mapping in Tasmania. *Remote Sensing of Environment*, In Press, Corrected Proof, Available online 15 May 2014.

Lehman, E., Caccetta, P., Lowell, K., Mitchell, A., Zhou, Z-S., Held, A., Milne, A.K. and Tapley, I. In Press. SAR and optical remote sensing: assessment of complementarity and interoperability in the context of a large-scale operational forest monitoring system. *Remote Sensing of Environment*.

Lehmann, E.A., 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*, 50, 1: 55-67.

Warra (FCT-AU-3), Tasmania, Australia

Principal Investigator: A. Held/N. Sims (CSIRO, Canberra/Melbourne)

Site description: Warra is a TERN supersite dominated by tall Eucalypt forest. The site also comprises areas of moorland, temperate rainforest, riparian and montane conifer forest and scrubs.

R&D objective: Our primary R&D objective is to examine the potential for retrieving forest canopy profile information from a combination of radar and high resolution optical image data. Success would provide a lower cost alternative to LiDAR data, and may enable REDD+ activities to be differentiated. The selection of two sites will enable us to test the potential of these methods in a range of forest conditions. The Warra site has been the location of earlier studies examining combined radar and optical image data.

Primary GFOI Priority R&D Topic(s):

- Methods of forest disturbance monitoring

- SAR-Optical interoperability and complementarity studies

Secondary GFOI Priority R&D Topic(s):

- Effect of forest disturbance on soil CO_2 fluxes
- Ecology of Eucalypt forests
- Long-term impact of management vs. natural disturbance

Sensors currently used:

- Optical - Landsat, SPOT
- SAR – ALOS PALSAR

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe	max		N
VHR Optical					
Worldview2	Y	Apr-Dec 2015	1	default	N
SAR					
Sentinel-1A	Y	Apr-Dec 2015	max	1. Dual pol 2. IWS (default mode) 3.	
RADARSAT-2	Y	Apr-Dec 2015	max	1.Quad Pol 2.Wide Fine 3.	N
ALOS-2 PALSAR-2	Y	Apr-Dec 2015	Monthly	1. HH+HV 2. FBD (default) 3.	N
TerraSAR-X	Y	Apr-Dec 2015	max	1. VV+VH 2. Stripmap 3.descending	N
TanDEM-X	Y	Apr-Dec 2015	max	1.default 2.default 3.ascending	N

Table B.22 – Satellite data requests for Warra (Tasmania, Australia) study sites.

Previous R&D: Warra was established as a Long-term Ecological Research (LER) site in 1998. It is a hub for intensive, multi-disciplinary research to understand the fundamental ecological processes in Eucalypt forests and the long-term effects that management has on those processes in contrast with natural disturbance. LiDAR and hyperspectral campaigns have been flown. Flux tower measurements are ongoing.

In situ data: Flux tower measurements, hydrology, meteorology, continuous forest inventory plots (CFI), species lists, baseline long-term vegetation monitoring plots, permanently marked plots.

Key references:

Burrows, R.M., Magierowski, R.H., Fellman, J.B., Clapcott, J.E. et al. 2014. Variation in stream organic matter processing among years and benthic habitats in response to clearfelling. *Forest Ecology and Management*, 327: 136-147.

Lehmann, E.A., Caccetta, P., Lowell, K., Mitchell, A., Zhou, Z.-S., Held, A., Milne, T., & Tapley, I. (2015). SAR and optical remote sensing: Assessment of complementarity and interoperability in the context of a large-scale operational forest monitoring system. Remote Sensing of Environment, 156, 335-348

Robson Creek (AU-4), Queensland, Australia

Principal Investigator: A. Held/N. Sims (CSIRO, Canberra/Melbourne)

Site description: Robson Creek is a TERN supersite dominated by tropical rainforest.

R&D objective: Our primary R&D objective is to examine the potential for retrieving forest canopy profile information from a combination of radar and high resolution optical image data. Success would provide a lower cost alternative to LiDAR data, and may enable REDD+ activities to be differentiated. The selection of two sites will enable us to test the potential of these methods in a range of forest conditions. Forest cover conditions at the Robson Creek site are most similar to those of tropical regions in other countries.

Primary GFOI Priority R&D Topic(s):

- Carbon estimation related to forest disturbance
- SAR-Optical interoperability and complementarity studies

Secondary GFOI Priority R&D Topic(s):

- Ecosystem monitoring
- Carbon and water balance experiments
- In-stream water quantity and quality measurements and O_2 flux energy

Sensors currently used:

- Optical - Landsat
- SAR – ALOS PALSAR

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc / Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe	max		N
VHR Optical					
Worldview2	Y	Apr-Dec 2015	1	default	N
SAR					
Sentinel-1A	Y	Apr-Dec 2015	max	1. Dual pol 2. IWS (default mode) 3.	
RADARSAT-2	Y	Apr-Dec 2015	max	1.Quad Pol 2.Wide Fine 3.	N
ALOS-2 PALSAR-2	Y	Apr-Dec 2015	Monthly	1. HH+HV 2. FBD (default) 3.	N
TerraSAR-X	Y	Apr-Dec 2015	max	1. VV+VH 2. Stripmap 3.descending	N
TanDEM-X	Y	Apr-Dec 2015	max	1.default 2.default 3.ascending	N

Table B.23 – Satellite data requests for Robson Creek (QLD, Australia) study sites.

Previous R&D: The Robson Creek supersite builds on more than 40 years of research on monitoring the physical and biological status of rainforests in far north Queensland. LiDAR and hyperspectral campaigns have been flown at this site.

In situ data: Flux tower, forest dynamics plot, tree structural measurements, weather station, soil and water quality sensors, gauging station, logging bore.

Key references:

Bradford, M.G., Metcalfe, D.J., Ford, A.J., Liddell, M.J. et al. 2014. Floristics, stand structure and above ground biomass of a 25 ha rainforest plot in the Wet Tropics of Australia. Journal of Tropical Forest Science, In press.

Injune (AU-5), Queensland, Australia

Principal Investigator: R. Lucas (UNSW)

Site description: The Injune Landscape Collaborative Project (ILCP) is an internationally recognised super-site for the development of new ground- and remote sensing based algorithms for retrieving biophysical attributes and detecting change in, for example, biomass and structure, in response to environmental (e.g., drought, wild fire) and anthropogenic (e.g., clearing) change. The landscape is largely comprised of woodlands and open forests.

R&D objective: Extend methods development using SAR and sensor synergy (SAR/Optical/LiDAR) for deforestation and degradation monitoring and retrieving estimates of AGB. Use time-series data to better understand and quantify ecosystem response to natural and human drivers.

Primary GFOI Priority R&D Topic(s):

- Forest disturbance monitoring methods using time-series SAR, optical and LiDAR data
- Sensor synergy for improved estimates of Above Ground Biomass (AGB)

Secondary GFOI Priority R&D Topic(s):

- Compare methods and retrieval accuracies for different forest types and biomes (semi-arid-temperate-tropical)
- Ecological change monitoring in response to natural and anthropogenic induced change

Sensors currently used:

- Optical - Landsat, CASI, air photography
- SAR - ALOS-1/2 PALSAR, AIRSAR.
- LiDAR - TLS and airborne

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
VHR Optical					
VHR	Y	2015	Monthly		Y (2010-)
SAR					
Sentinel-1A	Y	2015	Bi-monthly	1. Dual pol 2. IWS (default mode	
ALOS-2 PALSAR-2	Y	2015	Bi-monthly	1. HH+HV 2. FBD (default)	N
ALOS PALSAR (archive)				1. HH+HV 2. FBD	Y (2010-)

TerraSAR-X	Y	2015	Monthly	1. VV+VH 2. Stripmap and Spotlight 3.	Y (2010-)
TanDEM-X	Y	Fixed timeframe	Max		Y (2010-)

Table B.24 – Satellite data requests for Injune (QLD, Australia) study sites.

Previous R&D: The long term remote sensing observations at multiple scales have involved airborne (e.g., LiDAR, CASI, AIRSAR) and spaceborne (e.g., ALOS PALSAR) sensors operating in different modes, with their interpretation supported by on-ground measurements at tree and stand level. These data have, and continue to provide an unprecedented opportunity to better understand ecosystem response to change, and also unique opportunities for calibration and validation of new spaceborne sensors (e.g., ALOS-2 PALSAR-2) and derived products (e.g., regrowth and biomass maps).

In situ data: Forest mensuration data including trunk diameters, tree heights, crown sizes. Allometrics for a range of species.

Key references:

Schmidt, M., Lucas, R.M., Bunting, P., Verbesselt, J. and Armston, J. (2014). Multi-resolution time-series imagery for forest disturbance and regrowth monitoring in Queensland, Australia. *Remote Sensing of Environment*, 158, 156-168.

L**ucas**, R.M., Clewley, D., Accad, A., Butler, D., Armston, J., Bowen, M., Bunting, P., Carreiras, J., Dwyer, J., Eyre, T., Kelly, A., McAlpine, C., Pollock, S. and Seabrook, L. (2014). Mapping forest growth and degradation stage in the Brigalow Belt Bioregion of Australia through integration of ALOS PALSAR and Landsat-derived Foliage Projective Cover (FPC) data. *Remote Sensing of Environment* 4(8), 2236-2255 (citations 1).

Lucas, R.M., Armston, J., Fairfax, R., Fensham, R., Accad, A., Carreiras, J., Kelley, J., Bunting, P., Clewley, D., Bray, S., Metcalfe, D., Dwyer, J., Bowen, M., Eyre, T., Laidlaw, M. and Shimada, M. 2010. An evaluation of the ALOS PALSAR L-band backscatter – above ground biomass relationships Queensland, Australia: Impacts of surface moisture condition and vegetation structure. *IEEE Journal of Selected Topics in Applied Earth Observation and Remote Sensing*, 3, 4: 576-593.

Lucas, R.M., Lee, A.C., Armston, J., Carreiras, J., Viergever, K. Bunting, P., Clewley, D., Moghaddam, M., Siqueira, P., and Woodhouse, I. (2010). Quantifying Carbon in Wooded Savannas: The Role of Active Sensors in Measurements of Structure and Biomass. In: *Ecosystem Function in Savannas: Measurement and Modelling at Landscape to Global Scales*, Eds. M.J. Hill and N.P. Hanan, Taylor and Francis (in press).

Bunting P, Lucas R.M., Jones, K and Bean A.R. (2010). Retrieval of the forest communities through the clustering of individual crown. *Remote Sensing of Environment* (In Press)

Bunting, P., Labrosse, F., and Lucas, R.M. (2010). A multi-scale, multi-resolution hierarchical approach to automatic tie point identification for multi-modal image registration. *Image and Vision Computing*, 28(8) pp 1173-1238.

Bunting, P., He, W., Zwiggelaar, R. and Lucas, R.M. (2009). Combining textural and hyperspectral information for the classification of tree species in Australian savanna woodlands. In: *Lecture Notes in Geoinformation and Cartography: Innovations in Remote Sensing and Photogrammetry*, Eds. S. Jones and K. Reinke, Springer, 19-26.

De Grandi, F., Lucas, R.M. and J. Kropacek (2009). Analysis by wavelet frames of spatial statistics in SAR data for characterizing structural properties of forests. *IEEE Transactions Geoscience and Remote Sensing*, 7, 2, 9-507.

Lucas, R.M., Bunting, P., Paterson, M. and Chisholm, M. (2008). Classification of Australian Forest Communities Using Aerial Photography, CASI and HyMap Data. *Remote Sensing of Environment*, 112, 2088-2100.

Lucas, R.M., Lee, A.C. and Bunting, P.J. (2008). Retrieving forest biomass through integration of CASI and LiDAR data. *International Journal of Remote Sensing*, 29(5), 1553- 1577.

Lucas, R.M., Mitchell, A. and Bunting, P. (2008). Hyperspectral Remote Sensing of Tropical and Subtropical Forests. In*: Hyperspectral Applications in Forestry*. Ed. M. Kalascka (Wiley).

Lucas, R.M., Accad, A., Randall, L., Bunting, P. and Armston, J. (2008). Assessing human impacts on Australian forests through integration of airborne/spaceborne remote sensing data. In: *Patterns and Processes in Forest Landscapes: Multiple uses and sustainable management*, pp. 213-240, Ed. R. Lafortezza, J. Chen, G. Sanesi and T.R. Crow, Springer.

Lucas, R.M., Lee, A.C. and Milne, A.K. (2007). Integrated airborne campaigns: The lessons from PACRIM II. *Asian Geophysical Journal*, 7(2), 75-81.

Armston, J., Scarth, P., Phinn, S. and Danaher, T. (2007). Analysis of multi-date MISR measurements for forest and woodland communities, Queensland, Australia. *Remote Sensing of Environment*, 107(1-2), 287-298.

Lee, A.C. and Lucas, R.M. (2007). A LiDAR-derived canopy density model for tree stem and crown mapping in Australian forests. *Remote Sensing of Environment*, 111, 493-518.

Lucas, R.M., Cronin, N., Lee, A., Witte, C. and Moghaddam, M. (2006). Empirical relationships between AIRSAR backscatter and forest biomass, Queensland, Australia, *Remote Sensing of Environment*, 100, 388 - 406.

Lucas, R.M., Cronin, N., Moghaddam, M., Lee, A., Armston, J., Bunting, P. and Witte, C. (2006). Integration of Radar and Landsat-derived Foliage Projected Cover for Woody Regrowth Mapping, Queensland, Australia, *Remote Sensing of Environment*, 100, 407-425.

Lucas, R.M., Lee, A. and Williams, M. (2006). The role of LiDAR data in understanding the relationship between forest structure and SAR imagery. *IEEE Transactions in Geoscience and Remote Sensing,* 44(10), 2736-2754.

Tickle, P.K., Lee, A., Lucas, R.M., Austin, J. and Witte, C. (2006). Quantifying Australian forest and woodland structure and biomass using large scale photography and small footprint Lidar. *Forest Ecology and Management*, 223 (1-3), 379-394.

Bunting, P. and Lucas, R.M. (2006). The delineation of tree crowns within CASI data of Australian mixed species woodlands, *Remote Sensing of Environment,* 101, 230-248.

Liang, P., Moghaddam, M., Pierce, L. and Lucas, R.M. (2005). Radar backscatter model for multi-layer mixed species forests. *IEEE Transactions on Geoscience and Remote Sensing.* 43(11). 2612-2626.

Moffiet, T., Mengersen K., Witte C., King R., Denham R. (2005). Airborne laser scanning: Exploratory data analysis indicates potential variables for classification of individual trees or forest stands according to species. *ISPRS Journal of Photogrammetry and Remote Sensing*. 59, 289-309.

Lucas, R.M., Moghaddam, M. and Cronin, N (2004). Microwave scattering from mixed species woodlands, central Queensland, Australia. *IEEE Transactions on Geoscience and Remote Sensing*, 2142-2159, October, 2004.

Rosenqvist, A., Milne, A.K., Lucas, R.M., Dobson, C. and Imhoff, M. (2003). A review of remote sensing technology for support to the Kyoto Protocol. *Environment, Science and Policy*, 441-445.

Lucas, R.M., Milne, A.K., Cronin, N., Witte, C. and Denham, R (2000). The Potential of Synthetic Aperture Radar (SAR) Data for Quantifying the Above Ground Biomass of Australia's Woodlands. *Rangeland Journal*, 22, 124-140.

R&D Group 11:

Organisation: Natural Resources Canada, Canadian Forest Service (CFS, Canada)

Principal Investigators: André Beaudoin, Ron J. Hall

Study Sites: North West Territories (CAN-1), (CAN-2), Canada

North West Terratories (CAN-1, CAN-2), Canada

Principal Investigators: A.Beaudoin, Ron J. Hall (CFS, Canada)

Co-investigators: Hao Chen, Don. Leckie (CFS, Canada)

Site description: Large pitot region (470,000 km^2) in a poorly inventoried portion of the Northwest Territories in Canada (northern boreal forests). The large pilot region is to be covered only with 25m ALOS-1/2 PALSAR mosaics. Otherwise, two smaller sites 1 and 2 have been defined for Sentinel-1, TandemX and ALOS-1/2 PALSAR FBD and Radarsat-2 acquisitions (both archived and future ones).

R&D objective: Large area study: develop and test methods to best use the multi-annual 25m ALOS-1/2 PALSAR and Landsat mosaics for optimal biomass and fire mapping in difficult northern boreal forests due to environmental disturbances affecting radar backscatter; provide recommendations towards the future use of ALOS-2/PALSAR mosaics required to update the biomass and fire maps to more current conditions.

Local studies over two test-sites: develop and test multi-sensor methods suited to map key forest attributes (biomass, volume, height and crown closure) along with fires in poorly-inventoried northern boreal forests using multi-source optical and SAR remote sensing imagery (optical: Landsat; SAR: ALOS-PALSAR, Radarsat-2; Sentinel-1A and TandemX), land cover maps and ground inventory plots along with LiDAR samples as surrogates to inventory plots. On-going and proposed CFS work allows addressing some of the key GFOI Priority R&D topics while fulfilling Canada's forest attribute mapping needs with emphasis in poorly inventoried boreal forests.

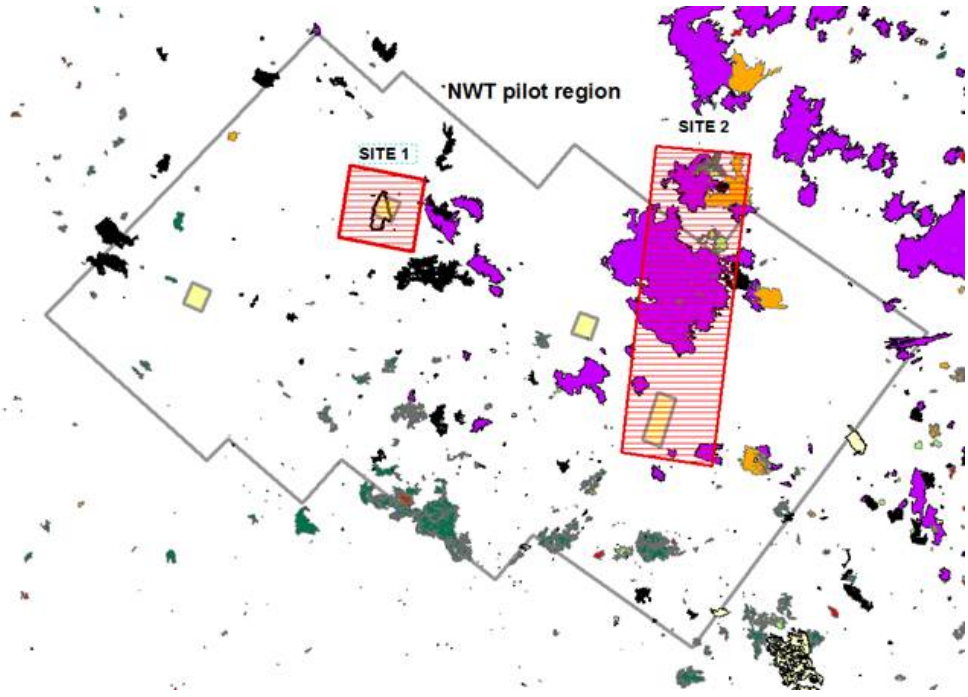

Figure B.7 North West Territories Pilot Region and location of study sites 1 and 2, Canada.

Primary GFOI Priority R&D Topic(s):

- Demonstrate the use of JAXA's 25m ALOS PALSAR mosaics for wide-area mapping–develop guidance. Provide advice to JAXA on how ALOS-2 mosaics could be improved for optimal use.
- Investigation of environment and climate effects on accuracy of retrieval of forest structure/biomass estimates.

Secondary GFOI Priority R&D Topic(s):

- Further development of data fusion and trend analysis methods using multi--sensor data (biomass and fire mapping)
- Transferability of methods to newly launched and upcoming sensors, e.g. Sentinel-1/2, ALOS-2

Sensors currently used:

- Optical – Landsat
- SAR – ALOS-1/PALSAR mosaics 2007-2010, Radarsat-2
- LiDAR: airborne and spaceborne (ICESAT-GLAS)

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
SAR					
Sentinel-1A	Y	May-Sept	Bi-monthly	1. 2. IWS Asc 3.	Y
ALOS-2 PALSAR-2*	Y	May-Sept	Bi-monthly	1. 2. FBD 3. Asc	Y (ALOS-1/2*)
TanDEM-X	Y	Fixed timeframe	Several interferometric observations		

** 2014/2015ALOS-2 PALSAR 25m mosaics would be required for large area mapping across all the NWT area.*

**ALOS-2 PALSAR-2: 4 consecutive frames along orbit required to cover CAN-2.*

Table B.25 – Satellite data requests for Canada study sites.

Previous R&D: On-going work in NWT led by Ron Hall in partnership with the Government of NWT Forest Resources to map forest inventory attributes and fires using Landsat imagery.

- On-going work across Canada led by André Beaudoin on the use of 25m ALOS-1/PALSAR Global mosaics 2007-2010 for biomass mapping in partnership with Canadian Space Agency
- National mapping of NFI forest attributes based on MODIS 250m composites kNN imputation led by André Beaudoin (completed, Beaudoin et al. 2014); kNN will be used to impute forest attributes across the pilot-region and using the various imagery sources requested.

In situ data: Inventory ground plot data; LiDAR coverage; land cover map; database of burned areas.

Key references:

Beaudoin, A.; Bernier, P.Y.; Guindon, L.; Villemaire, P.; Guo, X.J.; Stinson, G.; Bergeron, T.; Magnussen, S.; Hall, R.J. 2014. Mapping attributes of Canada's forests at moderate resolution through *k*NN and MODIS imagery. Can. J. For. Res. 44:521-532.

Hall, R.J. R.S. Skakun, A. Beaudoin, M.A. Wulder, E.J. Arsenault, P.Y. Bernier, L. Guindon, J.E. Luther, and M.D. Gillis. 2010. Approaches for forest biomass estimation and mapping in Canada. DVD pp. 1988-1991 in Proc. 2010 IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2010), Honolulu, Hawaii, USA. July 25-30, 2010

Healy, S.P., P.L. Patterson, S. Saatchi, M.A. Lefsky, A.J. Lister and E.A. Freeman. 2012. A sample design for globally consistent biomass estimation using lidar data from the Geoscience Laser Altimeter System (GLAS). Carbon Balance and Management 7: 10, 9pp.

R&D Group 12:

Organisation: RSS, Humboldt University, Airbus DS Geo GmbH (Germany)

Principal Investigators: F. Siegert, P. Hostert, F. von Poncet

Study Sites: Central Kalimantan (KAL-1), South Sumatra (SUM-1), Indonesia, Novo Progresso (BRA-2), Brazil, Kabo (SUR-1), Suriname, Malinau (MAL-1), Indonesia, Mahafaly (MAD-1), Madagascar

Central Kalimantan (KAL-1), Indonesia

Principal Investigator: F. Siegert (RSS, Germany)

Co-investigators: S. Englhartm, J. Franke, U. Ballhorn, P. Navratil

Site description: The study site (2°18'S – 2°30'S/113°50'E – 114°23'E) is located in the Sebangau National Park and the Block B of the Ex-Mega Rice Project (MRP) area. The dominant vegetation in this area is tropical peat swamp forest. The underground peat dome can reach up to 20 m deep and consists of waterlogged plant detritus which has accumulated over millennia. Thus these peat domes constitute gigantic carbon storage (up to ten times more than the overlying forest) and through intense anthropogenic disturbance are responsible for enormous emissions. The area has been continually degraded through both legal and illegal wood harvesting, drainage and fires. Wood harvesting permits have been allocated in this area beginning at the end of the 70's up until cir. 1997. The worst degradation of this ecosystem was caused by the Ex-Mega Rice project, initiated by the Indonesian government in 1996 to convert 1 million hectares of forest into rice fields for transmigrants. As part of the project 4000 km of drainage canals were dug, opening up large areas for more easy access and consequently led to further plundering of wood resources. A large part of the study site is located in Sebangau National Park, which was designated in 2004. Since this area is protected, a lower amount of change in forest height and biomass is expected. This is in contrast to the Block B area, where intensive illegal harvesting occurs, and thus a large amount of change may be anticipated.

R&D objective:

- Methods for enhanced aboveground biomass estimation
- Methods for forest degradation monitoring

Primary GFOI Priority R&D Topic(s):

- Aboveground biomass and change
- Forest degradation (especially logging

Secondary GFOI Priority R&D Topic(s): N/A

Sensors currently used:

- Optical - Landsat, RapidEye
- SAR – TerraSAR-X, ALOS PALSAR (1&2)
- Airborne LiDAR

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Y	Fixed timeframe			
SPOT1-5 (archive)	Y	Jul-Oct	2		Y
SAR					
Sentinel-1A	Y			1. Dual pol 2. IWS (default mode) 3.	
ALOS-2 PALSAR-2	Y	June-Nov	1	1. HH+HV 2. FBD (default)	Y
TerraSAR-X	Y	June-Nov	1	1. HH+HV, VV+VH 2. Stripmap, Scansar 3.	Y
TanDEM-X	Y	Fixed timeframe			Y

Table B.26 – Satellite data requests for Central Kalimantan (Indonesia) study site.

Previous R&D:

- Aboveground biomass estimation

In situ data:

A huge amount of field inventory data (n=250) is available for this area which was collected between 2008 and 2014. Additional field inventories area planned for 2015.

In forested areas, three circular nested plots with radii of 4 m, 14 m and 20 m were recorded. Inside each nest, trees of a certain diameter at breast height (DBH) were measured depending on degradation intensity: 2 cm to 10 cm or 5 cm to 20 cm (within the 4 m radius), 10 cm to 20 cm or 20 cm to 50 cm (within 14 m radius), and greater than 20 cm or 50 cm (within 20 m radius). In regrowth areas, rectangular plots of 20 x 50 m² were used and all saplings and trees within this area were recorded.

Within both plot types, the following parameters were recorded: DBH, tree height and tree species. Tree species data were used to obtain estimates of wood density from databases

provided by Chudnoff (1984), World Agroforestry Centre (2011) and IPCC (2006). If the tree species could not be identified, an average specific wood density for Asian tropical trees of 0.57 Mg m-3 was applied (Brown, 1997).

Key references:

Englhart, S., Keuck, V., and Siegert, F. 2011 Aboveground biomass retrieval in tropical forests – The potential of combined X- and L-band SAR data use. Remote Sens. Environ. 115, 1260–1271.

Kronseder, K., Ballhorn, U., Böhm, V., and Siegert, F. 2012 Above ground biomass estimation across forest types at different degradation levels in Central Kalimantan using LiDAR data. Int. J. Appl. Earth Obs. Geoinf. 18, 37–48.

Englhart, S., Keuck, V., and Siegert, F. 2012 Modeling Aboveground Biomass in Tropical Forests Using Multi-Frequency SAR Data – A Comparison of Methods. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. 5, 298–306.

Englhart, S., Franke, J., Keuck, V., and Siegert, F. 2012 Aboveground biomass estimation of tropical peat swamp forests using SAR and optical data. In, 2012 IEEE International Geoscience and Remote Sensing Symposium. IEEE, pp. 6577–6580.

Franke, J., Navratil, P., Keuck, V., Peterson, K., and Siegert, F. 2012 Monitoring Fire and Selective Logging Activities in Tropical Peat Swamp Forests. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. 5, 1811–1820.

Jubanski, J., Ballhorn, U., Kronseder, K., and Siegert, F. 2013 Detection of large above-ground biomass variability in lowland forest ecosystems by airborne LiDAR. Biogeosciences 10, 3917–3930.

Englhart, S., Franke, J., Keuck, V., and Siegert, F. 2013 Carbon stock estimation of tropical forests on Borneo, Indonesia, for REDD+. In, LULC in Europe: practices and trends.

Englhart, S., Franke, J., Keuck, V., and Siegert, F. 2014 Carbon Stock Estimation of Tropical Forests on Borneo, Indonesia, for REDD+. In, Manakos,I. and Braun,M. (eds), Land Use and Land Cover Mapping in Europe. Springer Science+Business Media Dordrecht, pp. 411–427.

South Sumatra (SUM-1), Indonesia

Principal Investigator: F. Siegert

Co-investigators: S. Englhart, J. Franke, U. Ballhorn, P. Navratil

Site description: This study site (1°45'S – 3°14'S/102°4'S - 104°53'E) comprises different ecosystems such as mangrove forest, peat swamp forest and tropical lowland forest, which is the most species-rich ecosystem in Indonesia. These forests are characterized by their upper canopy tree density, consisting mainly of dipterocarps (Dipterocarpaceen) of which cir. 60% are endemic. The tropical lowland rainforest differs from peat swamp forests in that the trees are higher, which are generally 45 m tall but can reach up to 60 m. Peat swamp forests are characterized by tree heights reaching 20-30 m, dependent upon the soil conditions, reaching a maximum of only 45 m.

R&D objective:

- Extensive aboveground biomass estimation based on field inventory and airborne LiDAR
- Forest degradation assessment

Primary GFOI Priority R&D Topic(s):

- Aboveground biomass
- Forest degradation and deforestation

Secondary GFOI Priority R&D Topic(s):

- Historical and recent fire burned scar assessment
- Biodiversity

Sensors currently used:

- Optical - Spot
- Airborne LiDAR

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT1-5 (archive)	Y	Jan-Dec	3		Y
SAR					
Sentinel-1A	Y	Apr-Nov	2	1. Dual pol 2. IWS (default mode) 3.	Y
ALOS-2 PALSAR-2	Y	Apr-Nov	1	1. HH+HV 2. FBD (default) 3.	Y
ALOS PALSAR (archive)	Y	Apr-Nov	1	1. HH+HV 2. FBD (default)	Y
TerraSAR-X	Y	Apr-Nov	1	1. VV+VH 2. Stripmap 3.	Y
TanDEM-X	Y	Fixed timeframe			

Table B.27 – Satellite data requests for South Sumatra (Indonesia) study site.

Previous R&D:

In situ data:

Field inventory in this study site will be acquired in collaboration with the GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) within the BIOCLIME (Biodiversity and Clime Change) project. The field inventory is planned to be conducted in April 2015. Therefore the number of field inventory plots cannot yet be estimated.

Key references:

Englhart, S., Keuck, V., and Siegert, F. 2011 Aboveground biomass retrieval in tropical forests – The potential of combined X- and L-band SAR data use. Remote Sens. Environ. 115,.

Kronseder, K., Ballhorn, U., Böhm, V., and Siegert, F. 2012 Above ground biomass estimation across forest types at different degradation levels in Central Kalimantan using LiDAR data. Int. J. Appl. Earth Obs. Geoinf. 18, 37–48.

Englhart, S., Keuck, V., and Siegert, F. 2012 Modeling Aboveground Biomass in Tropical Forests Using Multi-Frequency SAR Data – A Comparison of Methods. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens. 5, 298–306.

Englhart, S., Franke, J., Keuck, V., and Siegert, F. 2012 Aboveground biomass estimation of tropical peat swamp forests using SAR and optical data. In, 2012 IEEE International Geoscience and Remote Sensing Symposium. IEEE, pp. 6577–6580.

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Englhart, S., Franke, J., Keuck, V., and Siegert, F. 2014 Carbon Stock Estimation of Tropical Forests on Borneo, Indonesia, for REDD+. In, Manakos,I. and Braun,M. (eds), Land Use and Land Cover Mapping in Europe. Springer Science+Business Media Dordrecht, pp. 411–427.

Novo Progresso (BRA-2), Brazil

Principal Investigator: Prof. Dr. Patrick Hostert

Co-investigators: Prof. Dr. Björn Waske, Dr. Patrick Griffiths

Site description: Tropical forest site situated on one of the most active deforestation frontiers in the Brazilian Amazon. Land use is dominated by forest clearing and conversion, extensive cattle farming and some agriculture. Site generally features high land use dynamic. Publically available forest inventory data and management plans for licensed forest plots where selective timer extraction occurs (AUTEF sites). The latter provide a unique opportunity for developing methods capable of detecting selective logging using optical and/or SAR time series data. Due to the relatively long land use history in the site's proximity, extensive areas of secondary and regenerating forests over a wide range of ages exist.

R&D objective:

Primary GFOI Priority R&D Topic(s):

- Forest degradation / Selective logging
- Proxy methods for reporting degradation and/or enhancement of carbon stocks
- Satellite sensor interoperability

Secondary GFOI Priority R&D Topic(s):

- Forest/non-forest and land use change

Sensors currently used:

- Optical - Landsat, Rapid Eye, MODIS, VHR
- SAR – TerraSAR-X (StripMap, 6 Beam ScanSAR, Staring Spotlight), Radarsat-2 (Standard, Dual)

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
Optical					
SPOT5(Take5)	Yes	Fixed timeframe			
SPOT1-5 (archive)	Yes				Yes
VHR Optical					
VHR	Yes	Dry season	1-2 images per dry season		Yes
SAR					
Sentinel-1A	Yes			1. Dual pol 2. IWS (default mode) 3.	No
ENVISAT ASAR (archive)	No				No
ALOS-2 PALSAR-2	Yes	May 2015 – May 2016	Each revisit (14 days), or monthly	1. HH+HV 2. FBD (default) 3. Ascending or Descending	Yes
TanDEM-X	Yes	Fixed timeframe		VV+VH 2. Stripmap	

Table B.28 – Satellite data requests for Novo Progresso (Brazil) study site.

Previous R&D: The German Federal Ministry of Economy and Infrastructure funded project SenseCarbon (BMWi; project no. 50EE1254, 04/2013 – 03/2016) investigates the potential of Sentinel-1 and Sentinel-2 type data for forest change and biomass proxy mapping using surrogate archived data (Landsat, ASAR, ERS, Radarsat). Methodological cornerstones are image compositing and automated large area mapping as well as time series analyses.

The German Government funded Brazilian–German cooperation project "Carbon sequestration, biodiversity and social structures in Southern Amazonia" ("CarBioCial", fundedby the German Federal Ministry of Research and Education (BMBF; project no. 01LL09021)) focuses on sustainable forest management and conserve biodiversity since 4 years . Inventory plot data, soil carbon information, hydologic fluxes can be provided by CarBioCial.

In situ data: Several field trips were conducted in the region by the research groups at Humboldt-University Berlin and Free University Berlin as well as by collaborating partners. Data from AUTEF sites (see site description) providing forest inventory data and management plans, specifically with regard to selective logging. Additionally products of the Brazilian Amazonian forest monitoring programs are available (DETER, PRODES, etc.).

Key references:

Müller, H., Rufin, P., Griffiths, P., Barros Siqueira, A.J., &Hostert, P. (2015). Mining dense Landsat time series for separating cropland and pasture in a heterogeneous Brazilian savanna landscape. Remote Sensing of Environment, 156, 490-499.http://dx.doi.org/10.1016/j.rse.2014.10.014

Rufin, P., Müller., H., Pflugmacher, D., Hostert, P. (in review). Land Use Intensity Trajectories on Amazonian Pastures derived from Landsat Time Series. International Journal of Applied Earth Observation and Geoinformation.

Kabo (SUR-1), Suriname, Malinau (MAL-1), Indonesia, Mahafaly (MAD-1), Madagascar

Principal Investigator: Felicitas von Poncet (Airbus DS Geo GmbH)

Co-investigators: Prof. Dr. M. Köhl (University of Hamburg)

Site description:

Suriname: Kabo test site and concession areas in Suriname's „forestry belt"–Coordinates of the lower left corner of a central plot are lat: 5.255928°N / long: -55.766823°E.

The Kabo test site with a size of 30 ha is located in the forestry belt of Suriname, which comprises natural forests in the northern part of the country where forest management and harvesting activities are carried out. The Kabo test site is part of a long-term experiment which has been implemented in 1978 providing georeferenced terrestrial data of more than 16,000 single trees. The test site consists of three different replications, each representing a different harvesting intensity. Assessments were conducted in 1983, 2000 and 2012/2013 resulting in a chronosequence of stand structure development and disturbances. The very detailed ground data is intended to be used as reference for validating remote sensing products such as change detection and reference mapping.

In addition, data from concession areas will be assessed and analyzed before and after harvesting activities for change detection. Disturbances in stand structure due to logging will be analyzed. The specific concession areas have not been chosen yet, therefore the exact

position and coordinates are still unknown. Nevertheless, the concession areas are also located in the forestry belt.

Indonesia: Reduced Impact Logging (RIL) and conventional logging (CL) concession areas in the Malinau District - Center coordinates are lat: 3.0217°N / long: 116.3601°E.

The study sites in Indonesia are part of the Forests and Climate Change Programme (FORCLIME) by the BMZ, GIZ and the Indonesian Ministry of Forestry (KEHMUT), located in the Malinau District of North Kalimantan. Two test sites have been established in order to compare different logging types (reduced impact logging – RIL, and conventional logging – CL) each one representing one type of logging. Both areas have a size of +/- 100 ha. A pre-logging inventory was carried out in March/April 2014. Logging in the conventional logging area has just started recently. The start of post-logging inventory is expected for September.

Madagascar:

The study site is located on the Mahafaly Plateau in semi-arid south-western Madagascar –

Center coordinates of the sample plots are 24.0304°S / 43.7651°E.

The natural vegetation consists of a dry spiny forest with a high rate of endemic plant species. In the framework of the BMBF funded project SuLaMa (www.sulama.de) a forest inventory was carried out in 2011 on 286 georeferenced sample plots (total area of 10.8 ha) along a gradient from undisturbed to highly disturbed natural vegetation. On 40 % of those sample plots, additional inventories were carried out in 2008 and 2014. These terrestrial data can be used to assess to what extent remote sensing data can be used to reliably map forest structures and disturbances of dry forest ecosystems.

R&D objective: MRV system under the scope of REDD+

Primary GFOI Priority R&D Topic(s):

- General forest mapping method improvements (reducing uncertainty)
- Near-Real Time forest change indicators mapping
- Forest stratification
- Degradation/Enhancement of C stocks

Secondary GFOI Priority R&D Topic(s):

- "Deriving forest degradation products and field validation from VHR data"
- "Use of SAR data for mapping degradation"
- "Assessment of the relationship among definitions of degradation, degree of degradation that can be detected, associated accuracies, and useful kinds of remotely sensed data"

Sensors currently used:

- Optical - Rapid Eye to simulate Sentinel-2
- SAR – TanDEM-X bistatic mission data from global archive/ TerraSAR-X

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
VHR Optical					
VHR	Y	03/2015-10/2015	2 times in obs. window		Yes, 05-10/2011
SAR					
Sentinel-1A	Y	03/2015-10/2015	1/month	1. Dual pol 2. IWS (default mode) 3,	
ALOS-2 PALSAR-2	Y	03/2015-10/2015	1/month	1. HH+HV 2. FBD (default) 3.	

Table B.29 – Satellite data requests for Kabo (Suriname), Malinau (Indonesia) and Mahafaly (Madagascar) study sites.

Previous R&D:

REDD+ LULUCF/ Forestry projects by Airbus DS Geo GmbH (former Infoterra GmbH)

- Synergy of TerraSAR-X/TanDEM-X missions with Sentinel-2 for forest benchmark and degradation monitoring; planned demonstrators: Indonesia, Surinam, Ghana (funded by DLR (2014-2016, Coordinator: Infoterra, Partner: Universität Hamburg)
- CimateKIC FOREST: TanDEM-X & TerraSAR-X support to estimate carbon stock and its change; planned demonstrators: French Guiana, Cameroon, Gabun, Brazil (a European consortium funded by the EIT Climate KIC and composed by seven institutions including AIRBUS DS Geo GmbH & SAS, LSCE, AMAP, NPL and ONF International and CDC Climat; http://www.climate-kic.org/projects/fully-optimised-and-reliable-emissions-tool-forest/)
- Mawas Reserve, Kalimantan Tengah: R&D project on estimation of forest structure parameters of tropical peat swamp forests with bistatic TanDEM-X data (Project of Infoterra GmbH and Dr. Dirk Hoekman, University of Wageningen supported by BOS Foundation (SAB))
- Develop monitoring system for Illegal logging detection Para, Brasil (led by University of Wageningen in cooperation with SEMA, 2013- ongoing): Infoterra supports data acquisition scheme optimization and gathers continuous TerraSAR-X data flow for development.
- Ghana develoPPP (2012-2013): Supporting Ghana in forest monitoring based on German remote sensing technology, PPP of GIZ and Infoterra GmbH. Capacity building in forest degradation monitoring in the context of REDD+ using TerraSAR-X and TanDEM-X.

- Mangrove Reforestation success control using TerraSAR-X (Feasibility study 2012 for Livelihoods Fund- carbon investment fund founded by Danone in 2008)
- TerraSAR-X support to DeforestAction Earthwatchers in Borneo (2012) project of GMES award winner Geodan: Empowering world citizens in tropical forest monitoring via the integration of Earth Observation, social media, human computation and collaborative intelligence); Infoterra contribution: TerraSAR-X NRT support to combat illegal logging; http://video.esri.com/watch/1651/earthwatchers
- DeCoverII: Consolidation of national GMES Land Monitoring Core service integration scheme with existing topographic mapping programme. Focus on TerraSAR-X based method devel-opment for land use & land cover change detection /ATKIS update (funded by DLR 2010-2012).
- FOR-X (funded by DLR 2008-2010, Coordinator RSS, Partner Infoterra GmbH): Synergetic use of Ter-raSAR-X and ALOS PALSAR for mapping of deforestation, forest degradation and biomass in tropical rain forest in the context of Kyoto reporting.
- COIN (Carbon inventory): Development of an optimized survey design and monitoring concept combining SAR data and terrestrial surveys to support sustainable carbon offset projects in the forestry sector (in cooperation with SFM consultants & TÜV Süd)
- INVENT: 'Development and validation of a concept for the operational use of radar derived in-formation for commercially oriented boreal forest INVENTories (in cooperation with CESBIO, StoraEnso, Jaakko Pöyry, SFM consultants)
- RACOON: Radar-based CO2 -modeling of temperate forests for forest certification (in cooperation with CESBIO)

REDD+ LULUCF/ Forestry projects by University of Hamburg

- Improvement of the Economic Sustainability of Natural Forest Management in the Tropics (partner countries: Vietnam, Nepal, Suriname)
- Participatory research to support sustainable land management on the Mahafaly Plateau in south-western Madagascar – SuLaMa
- Reducing emissions from deforestation and forest degradation (REDD) - Qualitative and quantitative assessment of changes of tropical forests
- GHG - "Reducing emissions from deforestation" (REDD) as an option for climate protection: Combined inventory methods for the assessment of forest area development in Madagascar
- COIN (Carbon inventory): Development of an optimized survey design and monitoring concept combining SAR data and terrestrial surveys to support sustainable carbon offset projects in the forestry sector (in cooperation with Prof. Dr. Köhl/ SFM consultants & TÜV Süd)

In situ data:

Suriname – Inventory data from the Kabo test site with the size of 30 ha. The data set contains information of more than 16,000 single trees from assessments in 1983, 2000 and 2012/2013.

Indonesia – Pre- and post-logging inventory data of RIL and CL study sites with a size of +/- 100 ha each. A pre-logging inventory was conducted in March/April 2014.

Madagascar - Inventory data from assessments in 2011 on 286 georeferenced sample plots (total area of 10.8 ha). On 40 % of those sample plots, additional inventories were carried out in 2008 and 2014.

Key references:

Köhl, M., T. Baldauf, D. Plugge, J. Krug (2009): Reduced Emissions from Deforestation and Forest Degradation (REDD): a Climate Change Mitigation Strategy on a Critical Track, Carbon Balance and Management, 4(10) doi:10.11.1186/1750-0680-4-10

Köhl, M., Lister, A., Scott, C.T., Baldauf, T., Plugge, D., 2011: Implications of sampling design and sample size for national carbon accounting systems Carbon Balance and Management 6:10, doi: 10:1186/1750-0680-6-10

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Plugge, D., Köhl, (2012): Estimating Carbon Emissions from Forest Degradation: Implications of uncertainties and area sizes for a REDD+ MRV system. Canadian Journal of Forest Research 42 (11): 1996-2010.

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Michael Schlund, Felicitas von Poncet, Steffen Kuntz, Hans-Dieter Viktor Boehm, Christiane Schmullius & Dirk H. Hoekman (2015): WorldDEMTM data for canopy height and aboveground biomass retrieval in a tropical peat swamp forest (in preparation).

Schlund, M, F. von Poncet, S. Kuntz, C. Schmullius & D.H. Hoekman (2014): TanDEM-X data for aboveground biomass retrieval in a tropical peat swamp forest. Remote Sensing of Environment 158, 255-266.

Schlund, M, F. von Poncet, D.H. Hoekman, S. Kuntz & C. Schmullius (2015): TanDEM-X data for above ground biomass retrieval in a tropical peat swamp forest. Remote Sensing of Environment 158, 255-266.

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Schlund, M., V. Herrera-Cruz & F. von Poncet (2014): Synergetic use of TanDEM-X and RapidEye to support object based Land Use/Land cover Mapping. – South-Eastern European Journal of Earth Observation and Geomatics 3 (2), 595-600.

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Peterson, K.& F. von Poncet (2013): TerraSAR-X Based Monitoring of Mangrove Reforestation in Senegal: A Feasibility Study. Verlag der Österreichischen Akademie der Wissenschaften, 2013.

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Ullmann, T., Lumsdon, P., von Poncet, F., Esch, T., Lang, O., Tinz, M., Kuntz, S., & Dech, S. (2012). Application of quadpolarimetric TerraSAR-X data for landcover characterization in tropical regions – A case study in south Kalimantan, Indonesia. IEEE international Geosience and Remote Sensing Symposium (IGARSS), 22-27 July 2012, 5133-5136.

Kuntz, S., F. von Poncet, D. Weihing & M. Schlund (2012): Use of TerraSAR-X very high resolution imagery for forest degradation monitoring. – Poster on ForestSAT 2012, 11-14 September 2012, Oregon State University, Corvallis, Oregon, USA.

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Poncet, F. von, B. Mayhew & M. Schlund (2011): TerraSAR-X support for geo-database update. – Poster at 4th TerraSAR-X Science Team Meeting, 14 – 16 February 2011, Oberpfaffenhofen, Germany.

Schlund, M. & F. von Poncet (2011): TerraSAR-X Daten zur Unterstützung der Aktualisierung von Geodatenbanken. In: Seyfert, E. (Hrsg.): Publikationen der Deutschen Gesellschaft für Photogrammetrie, Fernerkundung und Geoinformation e.V. Band 20. 31. Wissenschaftlich-Technische Jahrestagung der DGPF. Potsdam: Deutsche Gesellschaft für Photogrammetrie, Fernerkundung und Geoinformation (DGPF), 389-399.

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Leyk, S. & M. Koehl & F. von Poncet (2002): Application of Future TerraSAR Data for Improvement of Forest Resource Assessments. ForestSAT Symposium , Edinburgh, August 5-9 2002.

R&D Group 13:

Organisation: (South Africa)

Principal Investigators: Renaud Mathieu

Study Sites: Lowveld Savannas (SA-1), Eastern Cape Thickets (SA-2), South Africa

Lowveld Savannas (SA-1), South Africa

Principal Investigators: Renaud Mathieu

Co-investigators: R.J. Scholes, S. Archibald, G. Asner, C. Schmullius, H. Baltzer, B. Erasmus

Site description: The central and southern part of the Kruger National Park and the adjacent populated landscapes to the west – approximately 23° 55′ S to 25° 14′ S and 20° 51′ E to 32° 00′ E

R&D objective: To measure vegetation attributes, including woody plant cover, height, biomass and phenology and their change over time due to use, management, climate and ecological dynamics, both inside and outside of protected areas

Primary GFOI Priority R&D Topic(s):

- Forest degradation – due to fuelwood harvesting, human settlement expansion, elephants and fire
- Mapping forest types – predominantly low biomass open savannas, but also high biomass plantations and natural afromontane forests

Secondary GFOI Priority R&D Topic(s):

- Integration between Optical, SAR and Lidar sensors
- Uncertainty and accuracy assessment

Sensors currently used:

- Optical - SPOT5, Landsat, Modis, MISR, CAO hyperspectral, repeated national aerial photography (~ 1m GSD, ~ 5 yearly, initially B&W but 4-band colour since ~1980)
- SAR - ALOS PALSAR. TanDEM-X, TerraSAR-X

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
SAR					
ALOS-2 PALSAR-2	Y		Bi-monthly	1. HH+HV 2. FBD (default)	
TerraSAR-X	Y		Monthly	1. VV+VH 2. Stripmap	

Table B.30 – Satellite data requests for Lowveld Savannas (South Africa) study site.

Previous R&D: Various maps of woody vegetation parameters; studies associated with the changes in woody biomass as a result of increasing elephant numbers, intensifying land use outside the KNP and changes in fire frequency and intensity. Three Carnegie Airborne Observatory campaigns combining airborne lidar and hyperspectral sensors covering large areas at high resolution.

In situ data: Several hundred ground plots, typically ~30x30 m to 100x 100 m, using a variety of methods. Several tens of walked transects, kilometres long, with individual marked trees, repeated every few years. Flux tower operational since 2001. Allometry for key species.

Key references:

Archibald, S. and R.J. Scholes.2007. Leaf green-up in a semi-arid African savanna – separating tree and grass responses to environmental cues. Journal of Vegetation Science 18, 583-594.

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Verstraete, M.M., Hunt, L.A., Scholes, R.J., Clerici, M., Pinty, B., Nelson, D.L. 2012. Generating 275 m Resolution Land Surface Products From the Multi-Angle Imaging SpectroRadiometer Data. IEEE Transactions on Geoscience and remote sensing, 1 – 10.

Eastern Cape Thickets (SA-2), South Africa

Principal Investigator: To be determined

Co-investigators: M. Powell, K. Smart, G. Asner, R. Scholes

Site description: The subtropical thickets at the interface between savannas, arid shrublands and coastal forests in the area north of Port Elizabeth. Approximately 33° 25′ S to 33° 48′ S and 25° 20′ E to 26° 00′ E

R&D objective: Carbon sequestration in thickets, especially in relation to restoration of degraded sites; thicket structural and compositional complexity in relation to the cosnservation of rare species.

Primary GFOI Priority R&D Topic(s):

- Forest degradation and restoration
- Mapping forest type – a very dense, low-growing succulent forest (thicket) with high carbon storage potential (for an arid landscape)

Secondary GFOI Priority R&D Topic(s):

- Satellite interoperability
- Uncertainty and Accuracy

Sensors currently used:

- Optical - SPOT5, Landsat, Modis, MISR, CAO airborne hyperspectral+Lidar

Sensors requested:

Sensor	User request	Observation time window	Observation frequency (Times per month?)	Observation mode (SAR) (1. Polarisation? 2. Stripmap or widebeam? 3. Asc and/or Desc?)	Archive data Yes/No? (Time window?)
SAR					
ALOS-2 PALSAR-2	Y		Bi-monthly	1. HH+HV 2. FBD (default)	
TerraSAR-X	Y		Monthly	1. VV+VH 2. Stripmap	

Table B.31 – Satellite data requests for Eastern Cape Thickets (South Africa) study site.

Previous R&D: Mapping of thicket distribution, plot-scale estimates of biomass, some work on growth rates

In situ data: 150 ground plots, Allometry for key species.

Key references:

Mills, A.J. and Cowling, R.M. 2009. Below-ground carbon stocks in intact and transformed subtropical thicket landscapes in semi-arid South Africa. Journal of Arid Environments. doi:10.1016/j.jaridenv.2009.07.002

Mills, A.J. and Cowling, R.M. 2006. Rate of carbon sequestration at two thicket restoration sites in the Eastern Cape, South Africa. Restoration Ecology 14, 38-49.