Joint GFOI/GOFC-GOLD R&D Expert Workshop on approaches to monitoring forest degradation for REDD+
University of Wageningen, The Netherlands – Oct 1-3, 2014

1. Workshop objectives

- Assess the evolving needs from the international level and REDD+ countries for monitoring forest degradation;
- Present and share experiences on approaches to identify and asses different types of degradation for REDD+ monitoring using earth observations, ground-based surveys and proxies;
- Discuss important gaps and obstacles and opportunities for future improvements, documented in an action plan for further R&D and demonstration activities;
- Synthesize the findings towards improved guidance to countries and REDD+ practitioners.

Schedule

Day 1 – Introductory presentations, followed by a session on evolving needs for forest degradation monitoring with key representatives from UCL, FAO, GOFC-GOLD and SilvaCarbon.
Days 1 and 2 – Expert participants were invited to present their approaches to monitoring degradation. Working group discussions focused on evolving requirements, satellite data needs and operational readiness of degradation mapping methodologies, and concept of a national monitoring framework.
Day 3 – Plenary discussion to synthesize findings and prioritize future work.

2. Synthesis on evolving requirements for forest degradation monitoring

Degradation monitoring is still high on the agenda (internationally and nationally), even if measured uncertainties are high. No financial constraints associated to uncertainty of degradation emissions have been defined. Many requirements have been defined. No new UNFCCC/SBSTA negotiations are anticipated on these issues.

Question of importance of degradation:

- Any degradation in intact forests is a loss
- Many processes lead to unsustainable use and persistent decline in carbon stocks in the tropics (although they may be called forest management)
- Sustainable forest management is encouraged in many countries

Different country circumstances should be taken into account:

- Degradation as a common precursor to deforestation in tropical countries, e.g., Indonesia, Brazil
- Some countries may have degradation as a key emission source (low deforestation countries, e.g., Gabon)
- Some countries may have degradation as a stable forest state (i.e., everything is degraded but will not lead to deforestation)

Importance of degradation, degradation risk and current emissions compared to deforestation to be assessed at the national level:

- Developing country: Donors drive the need to assess degradation (FCPT: 10% rule)
- First order estimate (proxies) on what is important tends to be acceptable – choice of methods and approaches
- How compliant with IPCC GPG (key category analysis) – ultimate objective is to report using IPCC GPG
- Here thinking along processes is important
- Define monitoring and capacity building priorities
- Consider high carbon ecosystems and soil pools (particularly peat lands)

Degradation monitoring can target:

- Drivers – offers information on degradation risk (pre-stratification of the territory based on proxies, e.g., infrastructure)
- Quantitative indicators – offers explicit information on degraded land (post-stratification based on carbon changes)
- How to best use stratification – including defining managed land

Time considerations (reporting):

- Emissions reporting under the UNFCCC will be biennial but degradation processes require a T time monitoring to assess degradation persistence
- Defining "areas under recovery" based on time since last disturbance as a way to guarantee mitigation persistence and carbon credit access
- Important of historical land use legacies

Degradation monitoring needs to tackle activity data and emission factors. Ground and remote sensing approaches are best combined. Issues for consideration:

- Consideration of scale – national scale reporting needs. How best to subsample? Wall-to-wall requirements? Implications of choice
- Trade-offs between costs versus accuracy/precision for degradation/carbon monitoring and REDD+ benefits
- New methods and technologies are emerging – need to test and compare in specific case studies. Requirement for good satellite acquisitions and complementary Cal/Val data from high resolution and field survey observations.
- Use simple approach to reflect country realities
- Different monitoring needs appear if we approach REDD+ activities or as land use (forests remaining forests)
    - Monitoring REDD+ activities collectively (apart from deforestation) as forests remaining forests rather than tracking specific REDD+ activities
    - Advantages of estimating REDD+ activities together (more efficient? Simpler and avoids conflicts between activities such as reducing degradation and sustainable management of forests), but some countries might prefer to focus on specific activities
    - Understanding of degradation drivers is important to prioritize for REDD+ strategies
- Long-term monitoring and consistency is key:

- Dynamics in carbon stock changes, inherent cycle issues (logging, fire, shifting cultivation)
- Tracking on a per-parcel basis using time-series

- Differences in monitoring approach:
  - Monitoring degradation vs. impact of reducing degradation (change in change)
  - Two windows in time (not snapshots) are required to measure degradation (starting point and future monitoring)
  - Three windows in time are required for reducing degradation – a reference level that establishes historical degradation, a starting point and future monitoring
  - Methodological consistency is required in historical (reference level) vs. future periods, but data availability can vary
- Important objective to monitoring forests as sinks

National forest monitoring needs are also important, beyond international REDD+ needs, including for example, tracking illegal activities/law enforcement and forest and natural resource management.

3. Forest degradation mapping methods

A diversity of approaches has been applied to map different types of forest degradation (Table 1). Selective logging and clear cuts can be monitored using time-series analysis and spectral unmixing of moderate-VHR Optical and SAR data. Proxies, including logging roads, can be identified on multi-scale Optical and SAR data. Time-series analysis of Optical and L-band SAR data can be applied to monitor the impact of shifting cultivation, agroforestry and grazing. Post-fire disturbance can be mapped by spectral unmixing of time-series moderate-VHR Optical data. Monitoring of forest regrowth is possible using time-series moderate-coarse Optical data, and through the integration of Optical (Landsat) and L-band SAR data. Direct estimates of AGB are possible using modeled relationships between forest inventory, LiDAR, SAR (and InsAR) and/or Optical data.

The majority of methods are still considered in an R&D phase, with larger-scale demonstrations, automation of methods and tuning of algorithms for different forest types needed to semi/operationalise methods in a monitoring context.

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Table 1. Forest degradation mapping methods

Degradation type	EO data type	Sensor	Method	R&D needs
Tree removal Selective logging with infrastructure	VHR Optical	Quickbird	Visual interpretation (VTT)	Sample VHR Opt and w2w Opt/SAR (& ground data/LiDAR) to estimate AGB (VTT)
		RapidEye	Time-series analysis & spectral unmixing (RSS)	
		RapidEye	Calibrated NDVI differences Spectral Mixture Analysis (SIRS)	Transferability to Sentinel-2
	Moderate Optical	Landsat	Structural metrics & change detection (VTT)	
		CBERS-2 Landsat	Soil/Veg fraction ratioing, DEGRAD system (INPE)	Forest disturbance classes Baseline generation
	Moderate – Coarse Optical	Landsat MODIS VCF	Landsat change detection % reduction in canopy cover MODIS VCC (FAO)	Consistent detection of degradation signal Identify appropriate data Thresholds of parameters Certainty of reporting
	L-SAR	ALOS	HV ratio, buffer roads (VTT)	
	C-SAR	RADARSAT-2	Multi-temporal aggregation (VTT)	
	X-SAR	TerraSAR-X	HH ratio, road extraction (VTT)	
		TerraSAR-X (SM VV)	Change detection (WUR)	Automation of methods Tuning of algorithms Precipitation effects Software development
Tree removal Selective logging without infrastructure	VHR Optical	RapidEye	Time-series analysis & spectral unmixing (RSS)	
Tree removal Clearcut	VHR Optical	RapidEye	Time-series analysis & spectral unmixing (RSS)	
	L-SAR	JERS-1 ALOS PALSAR	Time-series analysis (UNSW)	Monitoring methods using ALOS-2
	X-SAR	TerraSAR-X (SM VV)	Change detection (WUR)	Automation of methods Tuning of algorithms Precipitation effects Software development
Shifting cultivation	Moderate Optical	Landsat	Time-series vegetation indices (UNSW)	Seasonality and veg indices
	L-SAR	ALOS PALSAR (FBD)	Time-series (WUR)	
Fire	NFI & Moderate Optical	Landsat	Time-series disturbance & recovery trajectories (ECOSUR)	Relating ground and RS data (ECOSUR)
	VHR Optical	RapidEye	Time-series analysis & spectral unmixing (RSS)	

		RapidEye	Calibrated NDVI differences Spectral Mixture Analysis (SIRS)	Transferability to Sentinel-2
Agroforestry	VHR Optical	Aerial survey Quickbird	Coarse digitizing of defoliation & colour change (CSIRO)	Integration of independent datasets
	Moderate-Coarse Optical	Hyperion Landsat MODIS		
Grazing	NFI & Moderate Optical	Landsat	Time-series disturbance & recovery trajectories (ECOSUR)	Relating ground and RS data
Forest regrowth	Moderate Optical	Landsat	Time-series reflectance trajectories (UNSW)	
	Moderate – Coarse Optical	Landsat MODIS	Temporal reflectance trajectories 'VegMachine' VMAT, BFAST algorithm (CSIRO)	Calibration to absolute change?
	SAR/Opt synergy	ALOS PALSAR Landsat	Threshold intensity and FPC (UNSW)	Transferability to other savannah woodlands
Direct AGB estimates - Quantitative	Forest inventory & Optical	Landsat	Time-series disturbance & recovery trajectories (ECOSUR)	Relating ground and RS data
	LiDAR & forest inventory (+Opt/SAR)	LiDAR RapidEye Landsat	Carbon stock mapping using forest inventory, LiDAR and Opt LU map (RSS)	Forest inventory design Allometrics Correlating Field & RS data Uncertainty analysis Usefulness of SAR data
		LiDAR	Gain/loss method (USDA-FS)	Precision/bias
		LiDAR Landsat ALOS PALSAR TerraSAR-X	Carbon densities by LU type – adjusted Baccini AGB & Opt/SAR LU (CIFOR)	Transferability to SPOT Methods for discriminating peat lands
		Terrestrial LiDAR	Echidna, VEGNET – plant area index (CSIRO)	
	L-SAR	ALOS PALSAR & AVNIR	Regression analysis with field/LiDAR data (VTT)	Statistical sampling framework Practical affordable methods
		ALOS PALSAR	Regression analysis, validated by VHR Opt & forest inventory (SIRS)	
	X-SAR	TanDEM-X SRTM	InSAR height difference & AGB, validated using forest inventory & LiDAR (NFLI)	DEM correction C- to X-band Modelling & field AGB Seasonality, leaf on/off

4. Satellite data requirements and operational readiness

The satellite data requirements for monitoring broad-scale (e.g., from fire and logging) and fine-scale degradation (e.g., selective logging) are summarized in Table 2. More subtle degradation features require higher resolution data, such as VHR Optical or X-band SAR. Optical imagery should be acquired in leaf-on periods. Dry season imagery, and at least dual polarisation, is typically required for SAR. Data processed at higher levels (e.g., radiometrically and geometrically calibrated) would benefit end-users.

Table 2. Satellite data requirements for monitoring forest degradation

Degradation type	Sensor	Mode (if any)	Pref acq. time window	Temporal frequency	Proc. level	Notes
Broad-scale degradation (fire/logging)	Landsat, S-2	V, NIR, SWIR	Leaf on season	1 cloud free seasonal coverage	BoA reflectance/cloud masked	
	L-band	FBD	At dry season	3 obs/year	Cal, ortho, atm corr	2 obs could do as well vs. 'wet' acq.
	C-band	IWS (dual pol)	At dry season	3 obs x 2 times/year	Cal, ortho, atm corr	Logging roads as proxies
	X-band	3D TDM, WS TSX	Leaf on season	At least once/year	Cal, ortho, atm corr	
Fine-scale degradation	VHR (0.5 – 6.5 m)	V, NIR, SWIR	Leaf on	Min 2, Pref 4/year		
	X-band	3 m SM		At least once/year	Cal, ortho, atm corr	
		3D TDM		At least once/year	Cal, ortho, atm corr	

The operational readiness of EO sensors for monitoring forest degradation and direct estimates of AGB is summarized in Tables 3 and 4 respectively. Methods development has largely focused on the use of VHR Optical, X-band SAR and LiDAR data, but with few large area demonstrations (Table 3). GFOI will submit requests to satellite operators to acquire VHR Optical and X-band SAR over nominated study sites in support of further R&D. A key recommendation to TanDEM-X operators is to continue with the TanDEM-X mission, and implement a background mission over tropical forest areas (at least one coverage within mission constraints) to assist with R&D. Methods have been developed and tested using moderate resolution Optical and C-band SAR data. There has been limited methods development using L-band SAR. Recommendations to ESA are required to support future acquisitions of C-band SAR.

Direct estimates of AGB have been demonstrated using LiDAR, SAR, InSAR and VHR Optical data, but with few large-area demonstrations (Table 4). LiDAR-assisted biomass estimation using wall-to-wall Optical or SAR data is a promising technique. InSAR height differencing is possible using SRTM and TanDEM-X, with further refinements possible using future TanDEM-X data. L-band SAR retrieval of AGB is limited to below 150 t/ha. VHR Optical texture measures have met with some success.

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Table 3. Operational Readiness of EO sensors for monitoring forest degradation

Data source	Technical capabilities/ sensitivity	Global data coverage	Length of Time series	Methods developed and tested	Large area demon-strations	Country operational examples	Capacity implications
Optical moderate (Landsat/S2)	Severe degradation	Yes	(1972) 1984+				
L-band moderate (ALOS 1/2)	Severe degradation	Global 2obs/yr Trop 4obs/yr	1995 & 2007-2010 & 2014+	No	No	No	Systematic observations already in operations
C-band moderate (S1, ASAR, ERS, RADARSAT-2…)	1. Detection of logging activities 2. Large scale degradation 3. Improved LCC 4. Fire	Regional data required. Need for recommendation for ESA	Time series exist over selected FCT ND sites. (bi-monthly required)	Mature R&D example in Central Kalimantan	Central Kalimantan	No	Need to provide recommendation to ESA
Optical Fine (SPOT, Rapideye, …)	Possibility to simulate S-2	Requests required					
VHR (RapidEye)	1. Detection of logging activities 2. Hot-spot monitoring 3. Improved LCC 4. Fire	Yes (patchy)	2002 (SPOT5)/2009+ (RapidEye)	Several examples	No	No (Guyana?)	
X-band fine (TSX, COSMO)	1. Detection of logging activities 2. Hot-spot monitoring 3. Improved LCC 4. Fire	Requests required	No	Yes	No	No	GFOI to submit requests over GFOI SS
X-band TanDEM-X	Estimation of height change	Yes (2 times)	2011+	Yes	No	No	TSX back in TDX mode March 2015
LiDAR airborne	Estimation of height and structure	No	No	Yes	Yes	Yes (for biomass stock)	High technical capacity needed, cost and logistics constraints

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Table 4. Operational Readiness of RS based Direct biomass and biomass change estimates[1]

	Methods developed and tested	Large area demon-strations	Country operational examples	EO data availability Pre-2000 / since-2000 / today / future
Terrestrial LiDAR	Yes			Sample-based to assist field observations
Airborne LiDAR[2]	Yes	Yes		Mostly sample-based, some recent examples of country wall-to-wall coverage (e.g. Gabon…)
InSAR height differences	Yes			Global coverage available for 2000 (SRTM) and 2014 (TanDEM X available since 2010, seamless global coverage for 2014)
SAR Backscatter derived AGB[3]	Yes			L band based (patchy coverage for 90s with JERS, global coverage for 2006-2011 with ALOS 1, ALOS 2 since 2014) limited to AGB below 150 t/ha
VHR optical texture based	Yes			Suitable for a sample-based approach, examples in Amazon and Congo basin

5. Forest degradation data sources: activity data, emission factors, proxies

Data sources for generating activity data, emission factors and proxies are summarized in Table 5. Optical data at Landsat-like resolutions (30 m or better) is required to detect most types of degradation, and so generate activity data. Data acquired by L- and C-band SAR are also useful to some extent. VHR Optical (5 m or better) or X-band SAR is required for detection of subtle degradation features. Activity data relating to fuel wood and charcoal and forest grazing is mostly not detectable using remote sensing.

Sample-based approaches utilizing NFI, permanent sample plots or LiDAR are typically the best source of emission factors. However, remote-sensing approaches, combined with field sampling, may assist in deriving emission factors for degradation involving tree removal, shifting cultivation and fire. Data sources for proxies can include a range of ancillary datasets, e.g., forest concessions, land use plans, harvest data and forest growth models, and GIS layers (transport/settlements).

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[1] As appropriate to gain-loss (emission factor) or stock change

[2] Method also applicable to activity data for gain-loss

[3] Method also applicable to activity data for gain-loss

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Table 5. Forest degradation data sources
Technology Reference Levels: TRL1: Methods developed and tested; **TRL2:** Large area demonstration; **TRL3:** Country operational examples

Indicator / process	Sub-type	Data sources: Activity data	Data sources: Emission factors	Data sources: proxies
		*IPCC default values may be applicable throughout, especially for non-key categories. Defaults and country-specific data should not be combined without consideration of consistency issues		
Tree removal	Clearcut	Optical: 30m or better (TRL3) SAR L (TRL2) or C (TRL1) band	**Sample based:** • Repeated NFI or permanent plots (TRL3) • Field sampling: disturbed vs. undisturbed areas (TRL3) • Terrestrial LiDAR (TRL2) **RS combined with field observations (NFI or bespoke):** • Height changes: airborne LiDAR (TRL2), InSAR height differences (TRL1) • Backscatter derived AGB estimates (TRL1) • VHR Optical texture based AGB model (TRL1)	Forest concessions boundaries Land use plan Harvest estimates combined with growth estimates Settlements transport network (road, rivers)
	Selective w. infrastructure	Optical: 30m or better (TRL3) SAR L (TRL1), C (TRL1) or X (TRL1) band		
	Selective w.o. infrastructure	Optical: 5m or better (TRL2) SAR X (TRL1) band		
Forest area affected by shifting cultivation	Areal expansion	Optical: 30m or better (TRL3) SAR L (TRL2) or C (TRL1) band		Settlements transport network (road, rivers) Forest concessions boundaries
Fire	Fire scars	Optical: 30m or better (TRL3) SAR L (TRL2) or C (TRL1) band		Forest concessions boundaries? Land use plan? Settlements transport network (road, rivers)? Data from local communities and stakeholders? Fuel loads?
	Ground Fire	Optical: 5m or better (TRL2) SAR X (TRL1) band		
Forest area affected by agroforestry (crop under tree cover)		Optical: 5m or better (TRL1)	**Sample based:** • Repeated NFI or permanent plots (TRL3) • Field sampling: disturbed vs. undisturbed areas (TRL3) • Terrestrial LiDAR (TRL2)	Land use plan Settlements transport network (road, rivers)
Fuel wood and charcoal		Mostly not detectable from RS		Population consumption per capita Forest growth potential GIS model

Forest grazing		Mostly not detectable from RS		Livestock estimates and consumption rates Forest growth potential GIS model
Forest regrowth[4] (clearcuts, logging roads, fire scars)		Optical: 30m or better (TRL2) SAR L (TRL2) or X (TRL1) band[5]	**Sample based:** • Repeated NFI or permanent plots (TRL3)	Previous disturbance from activity data

6. Designing a national framework for degradation monitoring

The start of a first order assessment of degradation:

- What degradation processes are active?
- How important are they? (ideally in GHG units) – also in relation to deforestation
- Flow chart of questions:
  - Ask for importance of key degradation processes
    1. Timber extraction
    2. Fuel wood use
    3. Fire affecting forests
    4. Shifting cultivation
    5. Grazing
  - Derive at risk areas (i.e., using roads, concessions, infrastructure) , or even areas affected (can be coarse)
  - Guide to use available national data, or alternatively global datasets for first order estimates
- Guidance on which degradation processes can be considered important to be addressed (i.e., in terms of REDD+ policy) and potential focus of monitoring

Develop a national framework for monitoring degradation:

- First order assessment should provide at least qualitative assessment of which and where degradation processes are happening and are most important
- Need to link degradation monitoring to that of deforestation
- Two basic choices:
  - Aggregated – a method that monitors all relevant degradation within forests combined:

[4] Applies to any of the processes in the table (post-disturbance dynamics)

[5] Post disturbance dynamics using time series for the purpose of estimating areal extent

1. Remote-sensing monitoring lead:
    - Recommended for countries with limited data and capacities
    - Combination of moderate resolution time-series and higher resolution data, complementary to forest area change monitoring
    - Focus on activity data and initially use standard/regional/global emission factors
    - Limitation – some very small-scale changes may not be detected (but are certainly less important)
    - Potential to use available data and sampling design for field measurements to estimate emission factors using activity data (i.e., for areas of activities and risks) or coarse categories (intact, modified, planted)
2. Ground-based monitoring lead:
    - Most relevant for countries that have good ground-based monitoring program and capacities
    - REDD+ can move faster than it takes to do (two) NFIs or a comprehensive national ground-based monitoring program
    - Can lead to use stock/change method, but gain/loss is starting point (requires activity data)
    - Explore/use/expand upon available data, including: expand suite of attributes, geographic coverage, measure additional variables, increase frequency (time) or intensity (space) of measurements
    - Requirement to capture degradation impacts, incorporate in stratification
    - Use of remote sensing data in stratification helpful to enhance estimation and reduce costs

- Disaggregated – a method that tracks specific degradation processes:
    1. Need to clearly define and disaggregate different processes, in particular the degree of removals varies, areas affected and how it can be observed
    2. This method is most useful if focus is on few, specific degradation types and some data and capacities are already available for these
    3. Tuned approaches can be efficient
    4. Use table of group 2 (data and operational readiness)

Pros and cons of aggregated for disaggregated approach:

- Policy guidance – requires separation of different processes and drivers (in terms of setting priorities and results); is largely national requirement
- Country circumstances – make use of available data and capacities may lead to specific method choice
- Aggregated approach methodologically simpler and potentially more precise for international IPCC reporting

7. Action plan

Priorities for further work

The following conclusions were made during the final day plenary discussion:

- Important messages:
  - Degradation monitoring is asked for by donors
  - Emissions by degradation may be small compared to deforestation
  - Degradation is an important indicator or precursor for further forest loss
  - Information/understanding of forest disturbance is important for many reasons/users
- Develop/test concepts for multi-stage process of step-wide improvements for estimating degradation emissions
- Respond to the need for first order estimation for countries: look at case studies and synthesize
- Gap assessment based on group 2 (satellite data and operational readiness) and 3 (data sources) tables
- Define a set of priority sites and compare different methods:
  - Coordinated satellite data acquisitions
  - Requires strong support from ground measurements for degradation
  - Opportunities to move to larger area demonstrations

Observation requests to SDCG: Multi-sensor campaign

Collectively, there is a need for improved access to optimum datasets, comprising dense, ongoing time-series of optical and SAR imagery. In response to the CEOS SDCG development of the Element-3 data strategy 'Data Supply in support of GFOI R&D', it is recommended that the SDCG liaise with relevant space agencies and data providers to launch a coordinated acquisition campaign that aims to address (a selection of) key R&D topics identified during the current workshop.

To capitalize on previous research, it is proposed to take advantage of the coordinated multi-sensor observations undertaken 2009-2011 over the GEO Forest Carbon Tracking (GEO-FCT) National Demonstrator countries and, where feasible, focus R&D activities on Validation Sites in the former NDs that are still active, or relevant to re-activate. But as the geographical focus of GFOI is broader than the 11 countries/regions covered with in the GEO-FCT, and a wider range of R&D topics are being considered, new study sites may also be considered if proper justification can be provided. Access to archive data acquired over GEO-FCT countries is therefore sought and space agencies that contributed to the FCT campaign are encouraged to provide (the GFOI R&D coordinators) with detailed information about the satellite data acquired over the NDs.

In terms of new data acquisitions, both to extend the time-series of satellite data for R&D over GEO-FCT Validation Sites and to build new data series over additional target sites, systematic acquisition of optical, L-band and C-band SAR data will be requested. Access to TerraSAR-X and TanDEM-X data is requested by specific users. VHR optical data is requested on a sampling basis for cal/val.

The GFOI R&D coordinators will work with research teams to develop the acquisition requests to feed into the SDCG Element-3 plan. Table 6 summarizes the data requests received to date from workshop participants.

Table 6 Satellite data requests for R&D related to forest degradation

Study site	Data needs: Optical	Data Needs: SAR	Specific R&D topics	PI
Warra Robson Ck (Australia)	SPOT5Take5, Landsat, Sentinel-2	Sentinel-1, ALOS-2 PALSAR, TerraSAR-X	Ecosystem monitoring, carbon & water balance experiments, soil CO_2 flux	N.Sims/A.Held (CISRO)
Mathinna Takone (Australia)	Landsat, RapidEye	Sentinel-1, ALOS-2 PALSAR, TerraSAR-X/TanDEM-X	Activity data, degradation assessment, carbon estimation	A.Mitchell (UNSW)
Mato Grosso (Brazil)	Spot5Take5, Sentinel-2	Sentinel-1	Forest degradation assessment due to selective logging & fire	D.Valeriano/Y.Shimabukuro (INPE)
Mbäiki (C Afr Rep)	Spot5Take5		Forest degradation from selective logging, subsistence agriculture and fire	C.Sannier (SIRS)
(Gabon)	Spot5Take5	ALOS-2 PALSAR	Intense forest degradation and deforestation since establishment of oil palm plantation	C.Sannier (SIRS)
Hyytiälä Sodankylä (Finland) Hallormsstadur (Iceland) Chiapas Durango (Mexico) Pechora-Ilych (Russia)	Pleiades, Landsat, Spot5Take5	Sentinel-1, ALOS-2 PALSAR, TerraSAR-X/TanDEM-X, Cosmo-SkyMed	Carbon & forest resources estimation	T.Häme (VTT)
(Guyana)	VHR, Sentinel-2, SPOT	ALOS-2 PALSAR, ENVISAT ASAR	Mining & shifting agriculture/rotational farming	P.Bholanath (GFC)
(Guyana)	Spot5Take5		Deforestation and degradation monitoring	M.Herold (WUR)
Kafa BR (Ethiopia)	Spot5Take5		Community based forest monitoring	M.Herold (WUR)
Mawas Harapan (Indonesia)	VHR	TerraSAR-X	Forest/carbon accounting, degradation monitoring	D.Hoekman (WUR)

Amani Liwale (Tanzania)	VHR	ALOS-2 PALSAR, RADARSAT-2, TanDEM-X	Carbon estimation in savannah forest	A.K.Debien (KSAT), E.Naesset (NFLI)

Next Steps

- Any further request from workshop participants for satellite data for R&D should be forwarded to Ake/Anthea
- Integrate User Requests in CEOS SDCG Strategy Document for R&D (Element 3) – Ake/Anthea
- Forward input/recommendations to SDCG/Space agencies for dedicated multi-sensor acquisition campaign – Ake
- Workshop presentations and report included on GFOI R&D website – GFOI Office
- Draft Technology Review paper on state-of-the-art methods of sensor synergy, with contributions from workshop participants – Anthea
- Facilitate contributions to GFOI Methods and Guidance Documentation and GOFC-GOLD Sourcebook, pending success of R&D – Ake/Anthea and Martin/Brice
- Workshop participants are invited to attend and present research outcomes at the GFOI Annual Science Meeting (to be scheduled in 2015)

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Annex A. Workshop participants

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