GOFC-GOLD Land Cover and GFOI R&D Science Meeting

Summary Report

31 October – 4 November, 2016

The Hague, The Netherlands

Contents

Acronym List

CARL	Communication and Assessment Readiness Levels
COP	Conference Of Parties
ECV	Essential Climate Variable
EEA	European Environment Agency
ESA	European Space Agency
FAO	Food and Agriculture Organization
Fire-IT	Fire Implementation Team
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GFOI	Global Forest Observation Initiative
GLC	Global Land Cover
GOFC-GOLD	Global Observation of Forest Cover and Land Dynamics
GTOS	Global Terrestrial Observing System
ICSU	International Council for Science
IPCC	Intergovernmental Panel on Climate Change
LC-IT	Land Cover Implementation Team
NASA	National Aeronautics and Space Administration
NFMS	National Forest Monitoring Systems
NSO	Netherlands Space Office
REDD	Reducing Emissions from Deforestation and forest Degradation
SDG	Sustainable Development Goals
CBD	Convention on Biological Diversity
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey

Executive Summary

The Science meeting jointly organised in The Hague, The Netherlands by the GOFC-GOLD Land Cover Office and the R&D Coordination component of the GFOI gathered a total of 98 participants throughout the week. Experts in the field of land monitoring from both organizations but also experts from other institutions and policy makers from The Netherlands participated in the event. The Netherlands Space Office was a major sponsor and a host of the meeting.

The GFOI R&D sessions were an opportunity for the R&D Coordination team to present the recent achievements of the R&D component and exchange with participating R&D groups on how the R&D Coordination can support further their activities. A total of 13 GFOI R&D groups (out of 19) was able to present and discuss their work during the GFOI sessions. The discussions held during the sessions led to the development of guidance to countries on how to use biomass data to estimate emission factors, guidance to biomass map developers. An update of the Communication and Assessment of Readiness Level (CARL) framework of the GFOI that is aimed to track progress toward operational forest monitoring systems was also decided.

Sessions on global land cover mapping and validation provided an opportunity to European, Chinese, and American colleagues to present and discuss their most recent research and operational activities towards the production and dissemination of global land cover (GLC) information (processing chains, map products, data portals), the emerging trends (e.g., continuous monitoring rather than static map production), and robust accuracy assessment procedures compliant with international policy requirements. A general consensus among the participants emerged regarding the necessity to agree on a set of standards for the production and assessment of land cover map products. The Secretariat of the Group on Earth Observations (GEO) presented the concept of a web-based platform for land cover mapping. This initiative will be undertaken by the GLC Task of GEO next year.

The morning of the Plenary session entitled "Space for Sustainable Development: the role of Global Land Monitoring" was articulated around panel discussions composed of key land cover product users (World Bank, GCOS, UN GGIM, OECD, and Unilever). The presentations and follow-up discussions allowed the audience the capture their current and emerging land monitoring needs. First, an evolution of the policy context was observed with the advent of the UN Sustainable Development Goals (SDG). Developing processing capabilities (e.g., cloud-based platforms) jointly with the availability of a wealth of Earth observation data (e.g., Landsat, Sentinels) stresses the need to develop more efficient processing methods (e.g., fusion of data streams, uncertainty estimation) to meet the land monitoring needs discussed during the session, notably those aimed to better understand and monitor carbon, water, and energy cycles, but also monitoring sustainable use of land surfaces. Transparency was cited as a key requirements to ensure success of policy processes such as the SDGs and the UNFCCC activities. Participants discussed the opportunity to develop additional LC information-based

indicators to better meet the SDGs, although Parties already raised the issue of having a long list of indicators.

In the afternoon of the Plenary session key stakeholders such as Space Agencies (ESA, NASA), and Dutch companies presented and discussed current land monitoring challenges, ongoing and upcoming Earth observation programmes. The need for a better coordination among institutions involved in capacity building activities was stressed by the Head of the NASA Land Cover Land use Change Programme. A request for clarification on how emission estimates are derived from the Global Forest Watch products, and whether guidance from expert groups (e.g., GFOI) is taken into account, was made. An overlap between some Essential Biodiversity Variables (EBVs) and some Essential Climate Variables (ECVs) was discussed. The need for interaction between the different stakeholders involved in the design of such products was stressed in order to synergise efforts. The advent of micro-satellite constellations for Earth observations was demonstrated by Planet.

Please check the annexes of this summary report for more details on the presentations and discussion points held during the R&D sessions and the Plenary.

Topics and themes the GOFC-GOLD Land Cover Office should focus on during the next coming years

A series of issues and emerging needs were pointed out and discussed. At the same time as the science continues to develop, countries, but private sector are being asked to implement what they can for monitoring land changes. There is a clear need for both practical, actionable advice as the science develops.

- Increase the communication and collaboration between Policy and Science communities to better link evolving needs (i.e. Paris agreement, SDGs) with new Earth Observation opportunities (i.e. Sentinels, dense time series from multiple sensors)
- Maintain research efforts towards the production of land cover products meeting multiple user requirements,
- Keep interaction with Earth observation data providers to ensure data delivered meets the land monitoring needs in the context of an evolving policy context,
- The need for transparency and independent monitoring and assessment to implement the Paris Climate Agreement in land use sector mitigation and adaptation
- Maintain efforts towards scientific consensus for robust map accuracy assessment practices and use of uncertainties in estimation and delivering information,
- Help identification of common needs within and across different policy requirements in order to synergize efforts (e.g., SDGs, ECVs, EBVs, REDD+), addressing the tension between global level comparisons and products and the needs of nations for national level products,
- On SDGs, work further on how LC information can support indicators, including potential synergies across indicators, on the identification of data and indicator gaps, and on how LC information can be used to monitor and mitigate potential adverse effects across indicators,

- Advocate for moving from static and categorical representations of landscapes and change to continuous monitoring of trends in ecosystem health and condition, which requires a long history of consistent well-calibrated observations,
- Advocate for further investment in capacity building activities including development of training materials, organization of training workshops, but also in availability of data and processing capabilities (cloud computing),
- Strengthen partnership of the Land Cover Office with the Netherlands Space Office (NSO) and other Dutch ministries for mutual benefits and to manifest the work of the GOFC-GOLD project office at Wageningen University.

Introduction

The Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) is a coordinated international effort to ensure a continuous program of space-based and in situ forest and land cover observations to better understand global change, to support international assessments and environmental treaties and to contribute to natural resources management. GOFC-GOLD encourages countries to increase their ability to measure and track forest and land cover dynamics by promoting and supporting participation on implementation teams and in regional networks. Through these forums, data users and providers share information to improve understanding of user requirements and product quality.

More specifically the primary function of the Land Cover Implementation Team (LC-IT) is to develop and evaluate methods, tools and products for land cover measurements and monitoring using space-borne and in-situ observations. The LC-IT assesses current needs and deficiencies for global and regional monitoring to support global change research, national and regional forest inventories and international policy (i.e. through working with the United Nations Conventions). The LC-IT cooperates with the GOFC-GOLD Fire-IT, Working Groups, and worldwide Regional Networks.

The Global Forest Observations Initiative (GFOI) of the Group on Earth Observations (GEO) fosters actions toward operational national forest monitoring systems (NFMS) that can support REDD+ Measurement, Reporting, and Verification activities. The different Components of the GFOI interact contributing to 1) capture the needs from developing countries toward operational NFMS using remote sensing technologies, 2) identify the R&D gaps and needs and foster synergies among the research partners, 3) facilitate access and use of remote sensing data to countries, and 4) provide guidance and training to countries.

Specifically, the activities of the R&D Coordination component of the GFOI led to the production of strategic reports that identify priority research topics related to the use of remote sensing in NFMS. The R&D Coordination component interacts with the other GFOI components, facilitating access to Earth Observation data to research groups (Space Data Coordination Group Element-3), facilitating the development of training materials on the latest forest monitoring methods (Capacity Building), and advising on the integration of new scientific and technical developments into reports based on their operational level (e.g., Method and Guidance Document, REDD Sourcebook).

In January 2016, the Land Cover Project Office of GOFC-GOLD took the lead of the GFOI R&D Coordination component, thanks to the support of the European Space Agency. Following up on the discussions and outcomes of the last GFOI Plenary and Open Forum[1] (Frascati, Italy, 22-25 February 2016), this joint GOFC-GOLD LC-IT / GFOI R&D Coordination Science meeting aims to provide

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[1] http://www.gfoi.org/2016-gfoi-plenary-and-open-forum/

members of such initiatives, but also external partners such as the SilvaCarbon R&D Programme from the United States Geological Survey (USGS), an opportunity to report on the progress of their work, but also discuss the new and upcoming R&D priorities, and how synergies can be found across the research teams.

Objectives of the Science Meeting

The GOFC-GOLD LC-IT and the GFOI R&D Coordination component co-organized this Science meeting to review the recent accomplishments in tropical forest monitoring in the arenas of research, and implementation in developing countries. Specific activities from the GOFC-GOLD LC-IT, GFOI R&D research groups and its partners were reported. The Science meeting outlined the specific research, applications and development needs that should be targeted by these stakeholders in the future.

The Science meeting was an opportunity for the GOFC-GOLD LC-IT and the GFOI to communicate on its advancements and on its ongoing and potential contributions to a series of international initiatives notably those related to the Sustainable Development Goals (SDGs), and REDD+. In addition the Science meeting enabled the members of the different groups and initiatives to meet other international experts.

The outcomes of the meeting enabled the GOFC-GOLD LC-IT, and the GFOI R&D Coordination group, to provide its sponsors with updated scientific and technical information to support internationally coordinated initiatives such as those from the United Nations Division for Sustainable Development, the United Nations Framework Convention on Climate Change (UNFCCC), or those from the Global Climate Observing System (GCOS), and GEO as a whole.

Detailed objectives of the Science meeting were:

1) Present, discuss, and synthesize the achievements of the GOFC-GOLD LC-IT, GFOI R&D, and partners like Silvacarbon:

- Update on REDD+ and land use sector mitigation/monitoring needs in the context of the recent Paris Agreement (UNFCCC COP-21, fall 2015),
- Engagement with key international initiatives: partners and users: GEO, UNFCCC, UNCBD, GCOS, IPCC, FAO, World Bank FCPF, CIFOR, JRC, ESA, NASA, NSO, USGS, and others.
- Interactions between the GOFC-GOLD LC-IT, the GFOI, and SilvaCarbon,
- Enhance uptake of data and services provided by the European Copernicus Programme for global land cover monitoring on 10-30 m resolution that increases the value of such datasets for national and local users worldwide,
- Strengthen the Dutch role and opportunities of the service sector in the Copernicus Global Land Monitoring activities and use of big data approaches,
- Report progress on biomass estimation, current approaches, and next steps,

- Report progress on priority R&D topics and provision of satellite data for the R&D Programme (SDCG Element-3),

- Develop a Communication and Assessment Readiness Level (CARL) framework for GFOI R&D activities that allows assessment and progress tracking of EO-based methods for National Monitoring Systems,

- Contributions of the GOFC-GOLD LC-IT to the GEO Biological Observing Network,

- Contributions of the GOFC-GOLD LC-IT to the GEO Land Cover and Land Cover Change Task (SB-02), next steps coordination,

- Contributions of the GOFC-GOLD LC-IT to the development of global land cover validation efforts and the development of new databases, next steps coordination,

- Progress on observing Land Cover as an Essential Climate Variable, and new GCOS Implementation Plan,

2) Discuss the new orientations the forest mapping and the global land cover research communities should take after the official launch of the UN SDGs, the outcomes of the UNFCCC COP-21 (Paris Agreement), and the evolving needs for observing land cover as an essential climate variable (ECV).

3) Review of the internal organization and coordination of the GOFC-GOLD LC-IT, and GFOI R&D Coordination component, but also their respective places and roles in the context of emerging needs related to international policy, on-going and emerging needs of the land and forest cover user communities.

The biomass monitoring and the GFOI R&D progress sessions were held in parallel on Monday and Tuesday. These sessions had different objectives. The biomass session was aimed to improve the guidance in the MGD (and related modules) with presentations on day 1 and synthesis discussions on day 2. The GFOI R&D sessions gave the floor on day 1 to R&D groups participating in GFOI to report on the progress of their research activities, in the context of the Communication and Assessment Readiness Level (CARL) framework currently under development within the GFOI. The CARL framework was discussed on day 2. See the summary of the sessions below.

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Sponsors

GOFC-GOLD Land Cover Office

European Space Agency

Wageningen University Research

Global Forest Observation Initiative

Netherlands Space Office

SilvaCarbon - United States Geological Survey

Access to Presentations

Presentations can be accessed from this page:

http://www.gofcgold.wur.nl/sites/gofcgold-gfoi_sciencemeeting2016.php

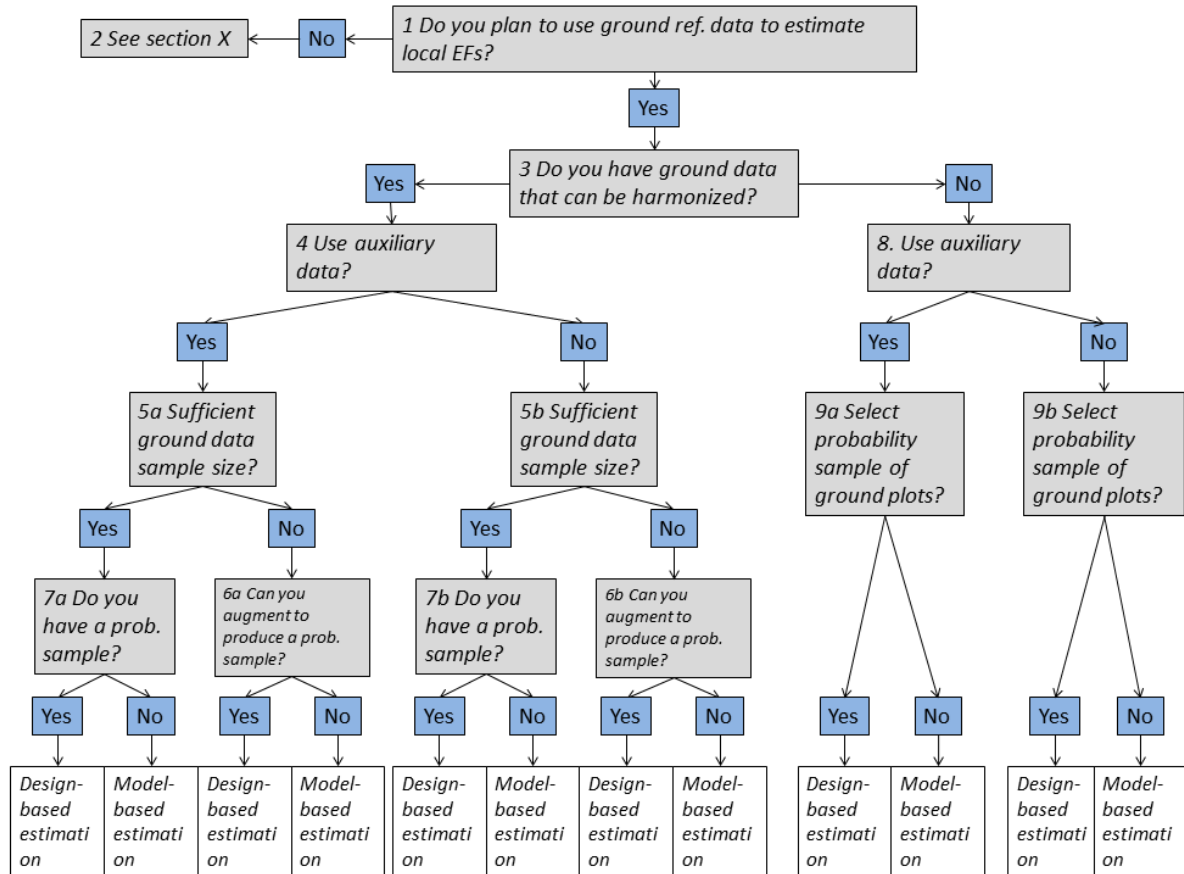## Summary of Sessions

See pages below.

Summary of the Biomass sessions – Day 1&2

Monday, October 31, 2016		
SESSION Introduction, Venue: New World Campus, Room Serendipity		
9.00-9.10	Opening/welcome	Herold
9.10-9.20	GFOI intro	Moad *on behalf of* Harvey
9.20-9.30	GOFC-GOLD and GFOI R&D intro	Mora
9.30-9.40	ESA welcome	Seifert
9.40-9.50	Silvacarbon welcome	Moad
9.50-10.00	Agenda and objectives	Herold/Mora
10.00-10.30 Coffee Break		
SESSION Biomass 1, Venue: New World Campus, Room Innovation Chair: tbc		
Large area biomass mapping progress		
10.30-11.00	Globbiomass: new products and approaches	Schmullius/Santoro
11.00-11.20	The 4th Mission – The need for a global plot based biomass reference	Schepaschenko
11.20-11.40	Linking land trajectories and emissions	Olofsson
11.40-12.00	Integrating Earth Observation and Forest Inventory Data in Quantifying Biomass in Degraded Forests of the Republic of Congo	Olofsson *on behalf of* Hansen
12.00-12.20	Forest height and biomass change 2000-2012 with wall-to-wall InSAR data for Uganda	Solberg
12.20-1.15 Lunch		
SESSION Biomass 2 Venue: New World Campus, Room Innovation Chair: Alan Strahler		
TLS for tropical forest biomass estimation		
1.15-1.35	Various Campaigns with highly portable TLS	Schaaf
1.55-2.15	Biomass and allometry estimation	Disney/Calders
2.15-2.35	Tropical tree biomass estimation in different tropical countries	Bartholomeus
2.35-2.55	TLSIIG activities and synthesis for biomass	Strahler
2.55-3.15	Discussion	
3.15-3.45 Coffee Break		
Emission factors and uncertainties Chair: Chris Schmullius		
3.45-4.05	Addressing Carbon Emissions and Removals from Selective Logging In Support of MRV System Capabilities in Gabon	Saatchi
4.05-4.25	Emission factors for land use change and uncertainty estimation	Herold/de Sy
4.25-4.45	Uncertainty estimation suggestion of options if country has no NFI	McRoberts
4.45-5.05	GlobBiomass: Kalimantan as regional case	Lohberger
5.05-5.25	Estimating biomass and biomass change in different African forest types with different types of remotely sensed data	Naesset
5.25-5.45	Contribution of Trees Outside Forests in carbon stock and Limitations	Pandey

5.45-6.30	Discussion	

Tuesday, November 1, 2016		
SESSION Biomass Synthesis, Venue: New World Campus, Room Innovation		
Chair: Martin Herold		
Introduction/status		
9.00-9.30	Review of MGD modules/progress (incl. For use of global datasets – activity data)	Olofsson
9.30-10.00	Review of progress from Oslo June 2015 incl. decision tree and next steps for guidance	Olofsson/ McRoberts
10.00-10.30	General discussion on progress/guidance on using biomass datasets for national purposes	All
10.30-11.00 Coffee Break		
11.00-12.30	Group/plenary discussions on new guidance	
12.30-1.30 Lunch		
1.30-2.30	Discussion continued	
2.30-3.00	Synthesis session	
3.00-3.30 Coffee Break		

The discussions of the Biomass session led to the development of the following guidance to countries on how to use biomass data to estimate emission factors:

Decision tree flowchart:

1 Do you plan to use ground ref. data to estimate local EFs? — No → 2 See section X; Yes ↓

3 Do you have ground data that can be harmonized?
- Yes → 4 Use auxiliary data?
- No → 8. Use auxiliary data?

4 Use auxiliary data?
- Yes → 5a Sufficient ground data sample size?
  - Yes → 7a Do you have a prob. sample? → Yes: Design-based estimation / No: Model-based estimation
  - No → 6a Can you augment to produce a prob. sample? → Yes: Design-based estimation / No: Model-based estimation
- No → 5b Sufficient ground data sample size?
  - Yes → 7b Do you have a prob. sample? → Yes: Design-based estimation / No: Model-based estimation
  - No → 6b Can you augment to produce a prob. sample? → Yes: Design-based estimation / No: Model-based estimation

8. Use auxiliary data?
- Yes → 9a Select probability sample of ground plots? → Yes: Design-based estimation / No: Model-based estimation
- No → 9b Select probability sample of ground plots? → Yes: Design-based estimation / No: Model-based estimation

1) Biomass maps can be useful in national estimation:
   a. Using biomass maps to improve EF (Oslo w/s flowchart) – similar to gain/loss
   b. Estimating emissions/removals on pixel level – similar to stock change
2) More guidance on the use of biomass maps for country GHG inventory estimations needed; growing evidence of approaches but very few concrete country examples – more demonstration and guidance on how to do uncertainty analysis needed that can underpin better guidance to countries
3) Oslo flowchart could use expansion to include country situations that are progressing towards a collection more ground reference data/NFI
4) Provide guidance towards pixel-based approaches for emissions and removals – not required and do not necessarily comply to IPCC GPG
5) How to combine the spatially explicit biomass (change) estimations together with activity information:
   a. Both have uncertainties that need to be taken into account
6) Idea: first order understanding on what the key uncertainties in the data are and how they affect the emissions estimation … could be put in a decision support tool to explore different uncertainty scenarios in data (sensitivity analysis)
7) Uncertainty assessment should aim to assess effects on overall emissions estimations; understanding of the uncertainties of the various input data is essential to achieve that
8) When choosing data and methods for estimating biomass and EF, considerations on approaches and efforts needed to estimate the uncertainties need to be taken into account:
   a. Designed-based NFI
   b. Biomass maps
   c. Biomass change predictions
   d. Spatially-explicit models: the more complex the model the harder it will be to quantify uncertainty and bias
   e. Need to explain on how to do it/more guidance needed – in many cases this is still a research objective
9) Ranked list of quality/uncertainty metrics with different complexities of providing/estimation uncertainties (different readiness levels of countries)
10) Efforts are (also) needed to improve ground measurements, allometries etc. (i.e. from TLS)
11) Development of a bibliography of methods, examples, case studies, … check if explanation of terms of MGD needs updating

Guidance to data producers

Biomass mapping:

1) Very little usefulness of biomass maps without uncertainties being estimated:
   a. Uncertainties from the model predictions/estimations
   b. Global and regional assessments using independent reference data
   c. More than just r2, need to estimate bias (at scale), i.e. on country level
   d. For both biomass and biomass change estimations
2) Uncertainties should be provided and used in estimation
3) Need to produce more guidance on how to estimate uncertainties
4) Requires ground reference data:
   a. Global reference databases
   b. Data from (regional/national) users (also to adjust estimates/reduce bias)
   c. Reference data availability varies and are scale dependent (plots, ALS)
   d. Reference data are uncertain as well
5) Three satellite missions planned to estimate biomass (BIOMASS, GEDI, NISAR):

a. Option to get away of the one sensor/one map approach, strength is in the combination
b. Potential of these will be limited for REDD+ if not supported by adequate ground reference data for calibration and validation

Reducing uncertainties in ground data:

6) Quality criteria for (re-using) plot data are needed
7) Larger plots tend to be more suited to be integrated with remote sensing estimation, given that many NFIs nowadays aim for small plots, important for countries intending to use both ground and RS data for biomass estimation
8) Potential of terrestrial laser scanning:
    a. Improve allometry for tropical trees, reduce underestimation of biomass for large trees given that many countries are using Chave's equation
    b. Increase transparency and traceability, and ability to produce long-term records of change in canopies and wood damage
    c. Better data to calibrate remote sensing based estimation, plot scale relationships between height, structure and biomass – research topic
    d. Interest for TLS to be tested in/with countries (ie. Guatemala)
    e. TLS community effort to make use of already acquired data across tropics to provide more empirical evidence

Summary of the GFOI-coordinated R&D and CARLs sessions – Day 1&2

Monday, October 31, 2016		
SESSION R&D in support of the GFOI mission - Progress 1, Room Serendipity Chair: A. Rosenqvist		
Programme intro		
10.30-10.50	GFOI R&D Programme: objectives and contributions to GFOI Methods and Guidance	A. Mitchell
10.50-11.10	Reporting requirements and SDCG data provision	A. Rosenqvist
Forest structure and biomass estimation		
11.10-11.30	Forest height monitoring and aboveground biomass variability in Indonesia's tropical forests	F. Siegert (Group 14)
11.30-11.50	Forest structural classification and above ground biomass estimation for Australia	R. Lucas (Group 11)
11.50-12.10	Integration of remote sensing data with ground plot information for MRV	A. Lister (SilvaCarbon)
12.10-1.15 Lunch		
SESSION R&D in support of the GFOI mission - Progress 2, Room Serendipity Chair: A. Mitchell		
Forest monitoring and generation of activity data		
1.15-1.35	Automated wide-area forest change monitoring with Sentinel-1 and TerraSAR-X	D. Hoekman (Group 6)
1.35-1.55	Combining SAR and optical time series for monitoring tropical forest change	J. Reiche (Group 4)
1.55-2.15	Forest monitoring techniques with Forestry Thematic Exploitation Platform to support REDD+	T. Haeme (Group 9)
2.15-2.35	Forest, land cover and forest change mapping with SAR from ENVISAT/ALOS to Sentinel1/ALOS-2 in the Mai-Ndombe district, DRC	J. Haarpaintner (Group 17)
2.35-2.55	A prototype MRV system for a sub-region in Colombia compliant with IPCC approach for securing activity data	P. Olofsson (Group 3)
2.55-3.15	Inventory and remote sensing based assessments of forest degradation	R. McRoberts (USFS)
3.15-3.45 Coffee Break		
SESSION R&D in support of the GFOI mission - Progress 3, Room Serendipity Chair: B. Mora		
Forest degradation and disturbance monitoring		
3.45-4.05	How useful is forest canopy change detection for forest degradation monitoring?	F. von Poncet (Group 15)
4.05-4.25	Sentinel4REDD - Sentinel-1/2 time series for REDD+ product generation	C. Thiel (Group 18)
4.25-4.45	Near-real time forest disturbance monitoring in Gabon from 2015 to 2016 using a combination of Landsat and Sentinel2 imagery	C. Sannier (Group 2)
4.45-5.05	Mapping tropical deforestation and land use change using time-series and large area image compositing	D. Pflugmacher (Group 13)
5.05-5.25	SAR-time series analysis and future opportunities with the NISAR mission	J. Kellndorfer (Group 3)
5.25 Closing of the session		

Tuesday, November 1, 2016		
SESSION 3 Communication & Assessment Readiness Level framework (CARL), Room Serendipity Chair: B. Mora		
9.00-10.00	CARLs and relevance to GFOI R&D	B. Mora
10.00-10.30 Coffee Break		
10.30-11.30	Break out group discussions on CARLs	All
11.30-12.30	Synthesis discussion on CARLs	All
12.30-1.30 Lunch		
1.30-2.15	SilvaCarbon R&D activities	A. Moad
2.15-3.00	Update of GFOI R&D priority topics	B. Mora
3.00-3.30 Coffee Break		
SESSION GFOI **R&D teams**, Venue: New World Campus, Room Serendipity Chair: A. Rosenqvist / A. Mitchell		
3.30-5.30	GFOI R&D coordination component meeting - outcomes of the GFOI review by James Baker, - how can R&D coordination component better assist R&D groups? - how can R&D coordination component stimulate donors to support R&D activities? - how to improve coordination and contribution with other components? -activities for next phase: annual report, meetings/workshops	GFOI R&D groups
5.30 Closing of the day		

The GFOI sessions constituted the first meeting of the research groups participating in the GFOI R&D Programme, which is set out to progress GFOI Priority R&D Topics towards operational status for inclusion in future updates of the GFOI MGD. Ten of the 18 GFOI R&D groups participating in the programme were represented at the meeting.

Anthea Mitchell (UNSW) provided an overview of the GFOI R&D Programme, the MGD and the Priority R&D Topics Review. Ake Rosenqvist (soloEO) presented GFOI Space Data Coordination (SDCG) and the SDCG Element-3 strategy document which comprises detailed descriptions of the R&D group projects, information on the distribution of satellite data from CEOS space agencies and the terms of references for participation in the GFOI R&D Programme.

Group leads were asked to provide feed-back on the GFOI R&D Group terms of references:

- Groups agree to undertake research focused on one or more of the GFOI Priority R&D Topics;
- Certify that the satellite data provided are used for non-commercial research purposes only;
- Comply with the data policy and data restrictions related to every dataset requested;
- Coordinate the project execution;
  - Provide a project timeline and milestone dates;
  - Ensure, to the best of their ability, that their project has sufficient funding and resources to complete the planned research within the stated timeframe;

- Publish the results of the research project and appropriately acknowledge the GFOI and the data sources;
- Submit to GFOI R&D and SDCG, on request, the results and methods used;
- On a best effort basis, attend annual GFOI R&D science workshops to present results;

The R&D groups presented updates on the status of their research projects within the Communication & Assessment Readiness Level (CARL) framework (see next section below for more information). Note that not all presenters reported their work in this framework. Levels in [brackets]: CARL level categorised (R&D: 1-2; Pre-operational: 3-4; Operational: 5-6):

- Nested approach for Near-Real Time (NRT) deforestation monitoring over wide areas and degradation mapping in small hotspot areas with Sentinel-1 and TerraSAR-X. Monthly (24-days) Sentinel-1 (Cvv+Cvh) data at dual-polarisation required. (D. Hoekman).
- Dense time-series of TerraSAR-X (High Resolution SpotLight mode, Xvv or Xhh) data used to detect the removal of individual trees in degradation hotspot areas (D. Hoekman) and map persistency of changes in the forest canopy over 6 years (F. Poncet).
- Extreme high variability of above-ground biomass (ABG) levels in peat swamp forests. Models using LIDAR (by drones) and SAR data used to generate large-scale ABG maps Regional-scale (Kalimantan-wide) ABG maps (<200 t/ha, 86 t/ha MSE) generated by ALOS 25m mosaics, SRTM-30 and Lidar transects (F. Siegert). [CARL 3-4]
- Development of InSAR and Pol-InSAR techniques (RADARSAT-2, Sentinel-1, TerraSAR-X, TanDEM-X) for measurement of tree height in tropical forests (F. Siegert).
- Optical-SAR interoperability approach to national-scale (Australia-wide) mapping of ABG and structural vegetation classes using Landsat-derived "Persistent Green" index and ALOS (Lhh+Lhv) (R. Lucas). [CARL 4]
- Bayesian optical-SAR interoperability approach for NRT monitoring using Landsat (NDVI), Sentinel-1 (Cvv) and ALOS-2 (Lhh+Lhv) (J. Reiche).
- Forest/Land Cover and forest change maps generated DRC province. Comparison of Landsat GFC, Sentinel-1 and ALOS-2 (J. Haarpaintner).
- Development of integrated multi-temporal processing chains for Sentinel-1 and Sentinel-2 data for delineation of forest cover, forest cover change and degradation (C. Thiel). [CARL 1]
- Development of a National Forest Monitoring system (Gabon) for mapping of Forest Cover, Forest Cover Change and NRT monitoring using cloud-free Landsat composites (C. Sannier). [FC/FCC – CARL 5-6; NRT – CARL 3-4]
- Development of a prototype monitoring system compliant with IPCC Approach 3 for securing activity data (Colombian Amazon). CCDC/YATSM method based on dense time series of Landsat data (P. Olofsson).

J. Kelldorfer (Earth Big data) presented an overview of NISAR mission and the SEPPO system, an open source software package for automation of large volume SAR, optical, and lidar data processing.

T. Haeme (VTT) provided an update on the ESA Forestry Thematic Exploration Platform (TEP).

R. McRoberts (USFS) discussed LIDAR-assisted estimation of degradation parameters and A. Lister (also USFS) presented some practical aspects of integrating field plot data with remote sensing.

Dmitry Schepaschenko from IIASA (not present), asked us to report on the Forest-Observation-System.net project. The data being collected as part of this project will be available for free and help accuracy assessment of GLC maps at country-level.
http://forest-observation-system.net/

Session on Communication & Assessment Readiness Level (CARL) framework

The session aimed to present and discuss the Communication & Assessment Readiness Level (CARL) framework proposed by the GFOI to help researchers, countries, data providers, and donors to understand the readiness of methods and tools for tropical forest monitoring, and where efforts should be put when no method is readily available for operational implementation. The CARL framework is built upon the concept of Technical Readiness Levels (TRL) developed by NASA in the 1980's.

The first attempt to apply the CARL framework by speakers on Monday afternoon showed the current version lacks levels (currently six) to rate appropriately methods. For example, a method was complying partially with Level 3 and partially with Level 4. More importantly, Josef Kellndorfer pointed out the fact an Application Readiness Level (ARL) framework, developed also by NASA, was developed based on the TRL framework. We decided to work on an adaptation the ARL framework that complies with our specific needs since it is considered by a part of the community as a standard. Break out groups worked on the adaptation of the definitions of the nine levels of the ARL framework based on the characteristics reported in the six levels of the CARL framework. A updated version of the CARL framework could not be achieved at the end of the session. A consolidation work is being performed by the coordination team (MGD and R&D coordination components). The consolidated version should be ready early 2017, after a review by GFOI R&D participants.

Specific comments made during the discussion:

- Consider institutional context: clear mandate given by government,
- Be conservative when rating methods,
- Apply V2 of CARL framework on examples presented on Monday afternoon sessions (Richard Lucas, Florian Siegert, Christophe Sannier),
- Provide country circumstances (forest type, etc) when rating a method, readiness may vary from one place to another,
- Make sure the scale component is included in the adapted ARL framework (NASA ARL framework does not mention this parameter) but consider also other parameters as a measure of progress,
- Need to develop a body of experts that validates the ratings of the method,
- Milestone approach from NASA ARL should be kept. Need to define milestones specific to our needs,
- Richard Lucas proposed to map methods across the different forest biomes indicating which and where methods are tested and implemented. Avoid rating methods chosen by countries (no country level information), but inform countries on readiness of methods tested and implemented in similar forest conditions and circumstances.

General discussion on activities of the R&D Coordination component

The GFOI sessions were concluded with an R&D Coordination component meeting to discuss issues related to the GFOI R&D Programme.

Pontus Olofsson (MGD author) invited R&D groups to author MGD modules on mature R&D topics for possible inclusion in future updates of the MGD.

It was also suggested that R&D group members could support the GFOI Capacity Building component by development of training materials and exercises. To assure consistency and avoid confusion however, such efforts should be coordinated closely with SilvaCarbon.

• Alex Moad from USFS presented an overview of the SilvaCarbon R&D activities and it was agreed that closer collaboration between the GFOI and SilvaCarbon R&D programmes would be mutually beneficial;

• It was also recognized that several organisations and initiatives, such as the World Bank FCPF and NASA LCLUC SERVIR, have activities which partly overlap with GFOI and SilvaCarbon interests and with which closer linking should be investigated;

• Proposed a new R&D topics:

> o Forest restoration monitoring. Tracking land use history, dynamic indicators and forest restoration monitoring (R. Lucas);
>
> o Methods of better utilising dense time-series for generating activity data, including spatial/temporal segmentation (P. Olofsson);
>
> o Multi-temporal filtering of SAR signal to preserve the degradation signal (C. Thiel)

• In order to better track the progress of each R&D topic, Richard Lucas also suggested the designation of Topic Leads, tasked to monitor and coordinate similar research between groups. This could also include mailing list to inform R&D groups and facilitate exchanges on progress;

• The possibility of data sharing (with the exception of commercial data) to test algorithms in different forest types was discussed;

• Johannes Reiche proposed the organisation of side events at scientific conferences which GFOI R&D group members typically would attend, such as e.g. the ISRSE, IGARSS, and AGU, to meet and discuss GFOI R&D matters;

• Brice Mora mentioned that a special session on GFOI R&D is planned for ISRSE-37 in South Africa (May, 2017) and invited group members to submit abstracts;

Summary of the Plenary session – Day 3

"Space for Sustainable Development: the role of Global Land Monitoring"

Wednesday, November 2, 2016		
Policy Workshop on GOFC-GOLD support to international policy requirements Venue Ministry of Economic Affairs, Room Veegenszaal Chair: Janetos		
Opening		
9.00-9.10	Welcome Dutch Ministry of Economic Affairs and Netherlands Space Office	Beukeboom/ Grim
9.10-9.40	Overview and review of GOFC-GOLD land cover activities	Herold/Janetos
GOFC-GOLD support and evolving requirements		
9.40-9.50	Worldbank FCPF	v.d. Linden
9.50-10.00	WMO / GCOS	Eggleston
10.00-10.10	GFOI	Moad *on behalf of* Harvey
10.10-10.50	Panel discussion	Janetos (moderator)
10.50-11.15 Coffee Break		
11.15-11.25	Land monitoring needs for SDGs	Scott
11.25-11.35	OECD needs	Hascic
11.35-11.45	Needs for sustainable supply chains (Unilever)	Vis
11.45-12.30	Panel discussion	Janetos (moderator)
12.30-1.30 Lunch		
Afternoon session Venue Ministry of Economic Affairs, Room Veegenszaal Chair: Mora		
New opportunities		
1.30-1.45	Summary of international policy requirements	Mora
1.45-2.00	NASA LCLUC programme	Gutman
2.00-2.15	US Silvacarbon and collaborations with GFOI	Wilson
2.15-2.30	ESA and Sentinels	Seifert
2.30-2.45	Global Forest Watch: Making remote sensing science transparent, accessible and applicable to the policy community	Petersen
2.45-3.00	GEO BON activities	Skidmore
3.00-3.15	Dutch service sector presentation (Satelligence)	Schut
3.15-3.30	Planet's contribution to forest monitoring	Rosso
3.30-4.00 Coffee Break		
Discussion on future GOFC-GOLD strategy		
4.00-4.15	Summary of presentations	Janetos/ Woodcock
4.15-5.15	Discussion on how policy requirements evolve and how to respond to them	All
5.15 Closing of the session and drinks		

We report the main points discussed during the Plenary of the Science meeting. Most important points reported in bold letters.

Panel discussions (morning session)

- GOFC-GOLD was created 20 years ago as a project of CEOS and has become a focal point for global forest and land monitoring
- **Evolving policy context for land monitoring: climate change, ecosystem services, and now Sustainable Development Goals**
- Rapidly evolving environment stresses the need for GOFC-GOLD and GFOI to strengthen further link between its activities and country / societal needs
- Growing trend: moving from land cover to land use information, and land management
- Need for free open access of Earth Observation data for research but also to support business opportunities and services
- **The era of big data notably geospatial data increases further the need to improve land monitoring methods**
- Long time series of observations needed to understand and monitor climate change, notably to help untangling different parameters and effects
- Global-scale land cover products getting routinely produced
- **Transparency is key to ensure success of policy processes**
- **Importance to develop community consensus (standards, procedures) and guidance**
- Need for improved access to data, higher time frequency, and accuracy in detecting changes
- **Need for land cover, land use information and other Earth observation-based data streams to understand global scale carbon, water, energy cycles**
- Monitoring change in forests is an important component to mitigate climate change, research still needed to reach this goal
- Global Forest Observations Initiative (GFOI) is a key stakeholder that works on providing support to countries on developing national forest monitoring systems
- **GFOI identified need for GOFC-GOLD to enhance trans-national research collaborations**
- Monitoring solutions needed also for restoration (regeneration), local communities have to be involved
- **Challenge to fuse different data streams (EO, socio-economic data)**
- **Uncertainty in (change) estimates is a challenge, notably for result-based finance schemes. (World Bank)**
- **Sustainable Development Goals: Goal 15: Life on Land, need for land cover time series, 15.1.1 Forest area as a proportion of forest land. Obtaining reliable information is a challenge**
- **OECD** needs Earth observation-derived evidence to support policy making, among these: land cover, land use change, soil information at global scale (quantify conversion from natural to non-natural environments, incl. fragmentation), <100m spatial resolution, annual. No dataset available do date that meets these requirements
- **Unilever** developed a sustainable living plan with 3 pillars on improving health and well being, reducing environment impacts, enhancing livelihood. Standards, indicators and certifications developed to support these specific objectives. Private sector develops its own set of indicators and remote sensing data is needed also here
- Detailed data needed for impact assessment livelihoods, productivity, biodiversity
- **Earth observation data needed for monitoring of vegetation canopy, foliage analysis, plant water stress (Unilever)**
- Countries have started to report on SDG, report recently submitted to the United Nations

- **Additional SDG indicators needed, notably on food production efficiency although countries complain this is too much already. Addition of a few more is discussed, likely not more than 20-30. Consistency needed also for the indicator list**
- **Key issue of uncertainty in the data SDG indicators are based on. Cost efficiency issue may be unsolvable**
- How do we improve communication between policy makers and scientific community and data producers? UN GGIM promotes a community of experts to help augment input of geospatial information to SDG indicators.
- Need to invest in pedagogy, to inform on relevance of statistical indicators, associated uncertainty
- **SDG: need to share technology (e.g., open source software tech.) to help countries**
- Need to agree on definition of phenomenon you want to monitor (e.g., deforestation, degradation), but more importantly need to estimate associated uncertainty of estimates, and ensure consistency in measurements across time

Land monitoring stakeholders (afternoon session)

- Several capacity development initiatives by NASA LCLUC projects in SE Asia,
- Landsat-Sentinel Team under NASA LCLUC, with partnership with ESA, jointly with research labs, and other Space agencies (DLR…)
- **Many stakeholders in field of capacity development including SERVIR, SilvaCarbon, GOFC-GOLD, FAO networks, coordination done but needs to be developed further, to avoid duplications, improve efficiency (expert availability, costs)**
- SilvaCarbon capacity development activities supports several countries to establish NFMS, forest inventory, remote sensing, GHG reporting, and advancing research also. No funding of R&D in the future
- Sentinel-1 and -2 constellations as part of Copernicus Programme provide higher time frequency observations for land monitoring which is key over cloudy regions, no rolling archive policy, data always available, restrictions on number of scenes to be downloaded
- ESA working on facilitating access to data via Thematic Exploitation Platforms (e.g, Forests) with cloud computing IT solutions
- Global Forest Watch (GFW) promotes transparency, support near-real time action (against deforestation)
- **Clarification needed on how emission estimates are derived from GFW products and whether guidance from some expert bodies taken into account**
- **GEO BON works on biodiversity-related issues. Aichi Targets difficult to achieve because of complexity (ambiguity, difficulty to quantify…).**
- Gaps in biodiversity monitoring capacities. Other GEO activities related to GE BON (e.g., GFOI)
- **Essential Biodiversity Variables (EBV) built on Essential Climate Variables, EBV developed to support Aichi Targets**
- **Remote sensing EBVs have been developed and overlap with some ECVs. Need for interaction between the different stakeholders involved n the design of such products incl. GOFC-GOLD, GFOI**
- GEO BON in-a-Box concept to facilitate access to tools, e.g., Biodiversity sourcebook joint project between GOFC-GOLD and GEO BON
- **Planet provides Earth observation data from RapidEye constellation but also 120 micro-satellites**
- **Near real time change detection: sensor interoperability is a current challenge**
- Satelligence (Dutch company) points out the challenge of connecting science with concrete applications that answer questions from various users

- Remote sensing data useful; to monitor changes but also to prevent changes, e.g., of oil palm plantations in unsuitable areas
- **Monitoring challenges: atmospheric corrections (optical data), and rain showers (radar data)**
- **Know what you are using: providing easy access to data may lead to misuse, wrong interpretations in some case**

Synthesis points reported by Curtis Woodcock and Tony Janetos

Common threads:

- There is room for improvement in communications between the policy and science communities. From the policy perspective it is important to clarify information needs and the science community needs to clarify capabilities. The goal is to minimize differences, and ultimately to manage expectations.
- For assessments of various kinds, there is a clear preference for information on change relative to information that characterizes any single time.
- There is an ongoing tension between the desire for global level comparisons and products and the needs of nations for national level products.

Other:

- Continuity and access to observations are the key to monitoring, and we are headed into a golden era of observations at spatial scales relevant for land monitoring. The space agencies are doing their job and it is time for the science community to step-up.
- In the context of sustainable development goals and indicators, we need to move from static and categorical representations of landscapes and change to continuous monitoring of trends in ecosystem health and condition, which requires a long history of consistent well-calibrated observations.

General discussion points

- GOFC-GOLD achieved its original purpose: develop capacity to observe Earth from space and make data available
- There is a need for an active dialogue to support the SDG. GOFC-GOLD is interested to contribute to it
- There is a need to push for transparency in monitoring and reporting processes (UNFCCC, and SDG)
- There is a need to invest further in capacity building,
- Science needs to be made further actionable. Use cases have demonstrated this is possible (e.g., early detection of illegal logging)
- Community-based monitoring can be complementary to Earth observation data

Summary of the Global Land Cover Mapping, Monitoring, and Validation Sessions – Day 4

Thursday, November 3, 2016		
SESSION Global Land Cover Mapping Activities, Venue Ministry of Economic Affairs, Room Zijlstrazaal Chair: Herold		
9.00-9.20	ESA CCI Global Land Cover time series	Defourny
9.20-9.40	Land cover mapping activities from Tsinghua University	Yu
9.40-10.00	Globeland30	Chen
10.00-10.20	Copernicus Global Land Service	Smets (VITO/JRC)
10.20-10.50	*Coffee Break*	
10.50-11.10	GEO Global Land Cover strategies and activities	Geller
11.10-11.30	Boston university efforts	Woodcock/Olofsson
11.30-11.50	USGS land cover mapping activities	Woodcock (Loveland)
11.50-12.10	Advancing global land cover monitoring	Hansen
12.10-1.30 Lunch		
SESSION Global Land Cover Validation, Venue Ministry of Economic Affairs, Room Zijlstrazaal Chair: McRoberts		
1.30-1.50	Report on CEOS Cal/Val activities	Herold/Olofsson
1.50-2.10	GlobeLand30 products validation	Chen
2.10-2.30	Copernicus Global Land Services - LC validation	Tsendbazar
2.30-2.50	ESA CCI Land Cover and land cover change validation strategy	Defourny
2.50-3.20 *Coffee Break*		
3.20-3.40	IIASA GeoWiki land cover map accuracy assessment activities	See
3.40-3.50	USGS land cover map validation efforts	Olofsson (Loveland)
3.50-4.10	Boston efforts	Olofsson/ Woodcock
4.10-5.45	Discussion / WG towards more joint and agreed efforts	All
5.45 Closing of the session		

Global land cover mapping efforts

Pierre Defourny from UC Louvain, Belgium, presented the current activities of the Land Cover Climate Change Initiative project. Annual GLC maps are now being produced based on time-series data. The AVHRR archive is used to produce LC maps that go back to year 1992. R&D activities are ongoing to aim for 10m Sentinel-2 based LC products with Africa used as a test case.

Le Yu presented activities related to the Landsat-scale GLC products developed at Tsinghua University, China. Map products are available from: www.fromlc.net. The portal an access to data but also tools to produce LC maps.

Jun Chen from National Geomatics of China (NGCC) presented the GlobeLand30 portal. It is possible to geotag changes based on crowdsourcing technology, generate land cover statistics for a given region. Efforts have been put on mapping water bodies, and change in mangroves. NGCC works on the development of a GLC map for year 2015, but also the development of maps for the 1970's and 1980's. Prof. Jun Chen advocated for a joint portal for data sharing.

Bruno Smets from VITO, Belgium presented the Copernicus Global Land Service that aims to deliver annual LC information at global information for free. A special attention will be put on the validation of the LC products. Project realised in collaboration with IIASA and Wageningen University.

Greg Scott (UN Statistics Division) presented on behalf of Gary Geller (GEO Sec.) a project aimed to synergise efforts among the main developers of LC information in order to develop an online on-demand land cover mapping service. Identified challenges are: designing a system flexible to accommodate different user needs, develop a workable cloud-based system (data cube), and the validation should be considered seriously. On that point, partnership with already existing initiatives like IIASA LacoWiki should be considered.

Curtis Woodcock presented LC monitoring activities from Boston U. based on Landsat data. A new paradigm has been introduced related to the necessity to monitor change continuously instead of detecting change between two specific distant points in time. Time-series analysis can be used also to detect trends such declining forests, land use change cycles in cropland, growth, phenology, and stress. Cropland landscapes remain a challenge.

Curtis Woodcock presented on behalf of Tom Loveland (USGS) the LCMAP project based on time-series analysis method developed at Boston U. The project delivers notably multiple LC, LC change, LC condition products.

Matt Hansen from U. of Maryland presented forest monitoring projects in tropical countries based on the Global Forest Watch products, and crop monitoring in the United States. Matt Hansen emphasized the fact that LC and LU mapping at global-scale is maturing, interest is shifting from LC change to LC condition monitoring, and the use of ancillary data sources (e.g. lidar, SAR) can be used for calibration and alleviate limitations of optical observations.

Accuracy assessment of GLC products

Martin Herold from Wageningen U. presented important points to consider for accuracy assessment of GLC products, and emphasized the need to develop a community consensus on accuracy assessment practices, notably on the response design.

Chen Jun presented a project from GEO to develop a collaborative validation platform for 30m GLC data products. Specifications are still under discussion within the GEO community. A prototype of such a system is available here: www.glcval.geo-compass.com.

Nandika Tsendbazar (Wageningen U.) presented avenues on better use of existing GLC reference dataset and the validation approach for the CGLOPS project (part of the Copernicus Global Land Service).

Pierre Defourny (UC Louvain, Belgium) presented the strategy for map accuracy assessment of the LC-CCI project, based on a maximum of 13,000 sampling units developed via a user interface for interpretation, and a network of experts. Work performed for different time periods. Accuracy assessment procedure not completed yet. Calls for an update of CEOS Cal/Val LC standards, and synergy among stakeholders.

Linda See from IIASA presented a validation campaign (cropland) based on the GEO-Wiki platform. The new tool is named LACO-Wiki. http://www.laco-wiki.net/.

Pontus Olofsson (Boston U.) presented a stratified estimation procedure combined with a time series-based approach to land monitoring, in the context of the GHG inventories as defined by the IPCC. The approach presented aims to account for the bias inherent to the model used to produce the estimates, and produce confidence intervals around such estimates.

Curtis Woodcock presented on behalf of Tom Loveland (USGS) the validation activities of the USGS. Information is available on http://landcover.usgs.gov/glc.

General discussion points

- An agreement among several participants of the session was found on the necessity to develop a common set of criteria to develop generally usable sample data.

- One issue to overcome for global-scale dataset lies in the necessity to detect small-scale classes like change.

- Option to combine permanent and temporary (movable) sample plots should be investigated. The issue of combining systematic grids of permanent plots with "moving locations" of temporary plots was also raised at the SilvaCarbon research workshop in Washington, DC, in September 2016. Alex Moad and Ron McRoberts have agreed on a project to address that issue.

- Another issue raised concerns the practicalities of using jointly datasets acquired with different sampling and response designs. Hopefully that problem will go away with time in tropical countries with the development and implementation of consistent sampling designs.

- The GLC mapping community needs to analyse also the adequacy of existing GLC products to support indicators of the SDGs.

- For the sake of statistical rigor, distinguishing between the two kinds (or purposes for) "sample data" may be appropriate. When the sample data are used for model development or calibrations, there really are no requirements such as probability samples and complete harmonization. However, when the sample data are used as reference data for assessing bias and uncertainty, then the data requirements are quite rigorous: generally probability samples (unless model-based inference is used); harmonization with respect to factors such as date of acquisition, measurement protocols, minimum diameter thresholds, plot sizes; etc.

- The optimization of sampling designs and plot configurations for use with remotely sensed data: nearly all boreal and temperate NFIs were developed before remotely sensed data came to be available and widely used. Unfortunately, those NFIs have a lot invested in their sampling designs and plot configurations and are reluctant to change them with the result that they will always be sub-optimal relative to the use of remotely sensed data. For tropical inventory and monitoring programs, we have the luxury of developing them with remotely sensed data in mind.

- Regarding GLC map products, there do need to be some rigorous assessments of the use of biomass maps for enhancing estimation of emissions factors. For global land cover/use products to estimate activity data, a few papers have been published (Sannier et al, 2016, RSE 173: 326–338; Næsset et al, 2016, RSE 175: 282–300; McRoberts et al, 2016, CJFR 46: 924-932), but more are certainly needed. Ron McRoberts is reluctant to include the "fully integrated models" in the same category as global land cover/use and/or biomass maps, because it is not clear exactly how they can be used. However Ron is open to understanding.

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