Joint GFOI / GOFC-GOLD / CONABIO / SilvaCarbon R&D Expert and Capacity Building workshop on: Regional solutions to forest type stratification and characterising the forest state for national forest monitoring and carbon emissions reporting (REDD+ MRV and LULUCF)

Universidad Nacional Autónoma de México
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Summary Report

Organized by:
The Global Forest Observations Initiative (GFOI), the Global Observation of Forest Cover and Land Dynamics (GOFC-GOLD) Land Cover Project Office, the National Commission for Knowledge and use of Biodiversity (CONABIO), Mexico, SilvaCarbon, and the European Space Agency (ESA).

1. Workshop Objectives

The workshop brought together a community of REDD+ monitoring technical experts and regional practitioners to discuss the evolving needs and current state of art on forest stratification mapping. Working group sessions helped identify the gaps and obstacles that hinder progress, and assisted in developing an action plan towards improving the underlying science and national forest monitoring in REDD+ countries.

Specifically, the workshop aimed to:

- Assess the evolving needs from the international level and REDD+ countries for generating and reporting on specific forest types;
- Give regional practitioners an opportunity to present their national and regional forest monitoring systems and discuss the current challenges on decision making and translating what is mapped in reporting;
- Present and share experiences on approaches to mapping nationally relevant forest types;
- Present and share experiences on characterising the forest state (e.g., degradation, regrowth);
- Discuss adequate approaches for product validation and for the related uncertainty assessment in carbon emissions reporting;
- Discuss important gaps and obstacles and opportunities for future improvements documented in an action plan for further R&D and demonstration activities; and
- Synthesize the findings towards improved guidance to countries and REDD+ practitioners.

2. Overview of current national forest monitoring systems (NFMS)

Presentations on Day 1 gave representatives from national agencies an opportunity to share their experiences on operational NFMS and reporting activities. Country specific approaches to forest type stratification and generation of activity data (AD) were reported. The differing approaches, challenges and reporting obligations, specific to each country, became apparent. Countries expressed a desire for greater regional collaboration to allow for discussion of common issues and solutions. SilvaCarbon is partly assisting in this endeavour. A working group session followed where current approaches, obstacles and R&D/satellite data needs were discussed in more detail.

Countries' NFMS typically serve multiple purposes (e.g., LCLU monitoring, biodiversity assessment, GHG inventory, REDD+) and benefit a range of stakeholders. Reporting obligations range from national to international level, and better integration of these is preferable. MINAM (Peru), IDEAM (Colombia) and INPE (Brazil - DETER) have early warning systems. Peru tackles degradation, but regrowth is omitted and presents a key gap in the system. INPE (Brazil) is addressing degradation (DEGRAD) and forest regeneration using TerraClass, and is currently working towards a national LULUCF monitoring system for 2016-2020. CONAP (Guatemala) identifies degradation using the CLASlite method. The ICF is currently developing their NFMS for Honduras, of which, community based monitoring will be a component.

Rather than accounting for all activity classes, countries might be wise to concentrate their sampling on specific activity classes, and so allocate the majority of resources to ensuring high accuracy where needed (i.e., in significant change areas). The system should be tailored to the specific country needs. This focussed effort on key change categories is currently supported by the IPCC.

Different approaches to generating activity data using a time-series of satellite optical data were presented. Primarily Landsat-based, methods exist that use best pixel stacks (e.g., Peru) or temporal composites/mosaics (e.g., Colombia, Mexico, Brazil). The PRODES deforestation monitoring system

(Brazil) uses data from a range of sensors, including Landsat, CBERS, ResourceSat, DMC and SPOT. Honduras, in an early stage of development, is using a variety of methods and data sources (e.g., air photos, RapidEye, Landsat and MODIS).

Change classes are identified by manual interpretation of reflectance data or derivates (e.g., vegetation indices, NDVI, principal components, texture measures) or cross-checking of automated change results. Although resource-intensive, an example from Mexico demonstrated an improvement in user's accuracy of the order of 0.12 to 0.6 for deforestation from manual cross-checking of MAD-Mex (Mexico national system for Monitoring of Activity Data) results. MAD-Mex is applied in Mexico (initial 217 vegetation classes mapped by INEGI and aggregated to 31 classes for GHG inventory and 6 IPCC classes) and Colombia (subsequently aggregated to CORINE classes). Alternative approaches, including semi-automated classification (e.g., random forests - Peru; pixel and object-based classification - Guatemala) are also being investigated. Change is detected on an annual basis (e.g., Colombia, Peru) or in discrete time periods (e.g., Guatemala). Some countries are using high resolution data to improve their LCLU mapping results (e.g., Peru - RapidEye wall-to-wall mapping for 2011; Guatemela - RapidEye for 2012).

Stratification often uses pre-existing layers related to biogeographic regions, vegetation, climate and elevation, to stratify the forest into homogenous regions (with respect to carbon). A pre-existing map of ecozones is used as the basis for stratification and reporting in Peru. Other inputs include natural regions, physiognomy, vegetation, wetlands and accessibility. Biophysical data (e.g., climate - temperature and precipitation) is used for stratification in Colombia, and which helps explain the variation in carbon distribution. In Colombia, stratification is also undertaken to discriminate degraded and intact forest, for hotspot change detection using high resolution imagery, and for improved emissions estimates. Guatemala uses forest cover dynamics, degradation and enhancement of carbon stocks for stratification. Owing to a large insect attack, Honduras aims to incorporate this in the stratification, taking care not to identify areas as deforestation. Brazil takes a physiognomic approach and classifies altitudinal formations, which are more informative on carbon content.

National forest inventory (NFI) forms an integral part of countries' NFMS. Mexico has a national forest and soil inventory, with a systematic sampling grid across the country. Peru's NFI comprises 7293 plots, of which 1876 are in forest areas. Allometrics and biomass estimates are available for 16 forest types in Colombia. Knowledge of the location and type of disturbance are required for emissions reporting; and yet the latter is often overlooked in countries' NFI. This information may be sourced elsewhere, but is unlikely to have been obtained from a statistical sample.

In Mexico, emissions factors (EFs) are available for all carbon pools (INFyS), however are limited to cases of change from one class to another, and not transitions (e.g., repeat disturbances). In Peru, EFs are available for forest areas only. In Brazil, EFs are taken from an official vegetation map, attributed with carbon contents derived from field measurements extrapolated to vegetation classes.

Current challenges identified by each organisation include:

Mexico

i. Grouping vegetation types for reporting purposes
ii. Change methods for different carbon pools
iii. Estimating above- and below-ground biomass
iv. Land cover and degradation mapping methods

Colombia

i. Consistency of the approach at national level

ii. Shifts in Landsat pixel locations
iii. Terrain effects in surface reflectance data
iv. Uncertainty of forest mask and certainty of change classes
v. How to integrate IPCC approaches

Peru

i. Integration of reporting requirements (NFMS, GHG inventory, national report)
ii. Regrowth mapping

Guatemala

i. Difficult to detect fire impact using remote sensing (surface not canopy)
ii. Upscaling and downscaling methods
iii. Validation methods and lack of ground data
iv. Affordable EO imagery
v. Historic vegetation maps are based on unsupervised classification
vi. Insufficient data processing capacity
vii. High storage capacity needed for backup of data

Honduras

viii. Need cloud-free (<10 %) optical data
ix. Validation scheme
x. Funding for high resolution imagery

Brazil

i. Improve EFs (maps are too generalized and field data are too scarce) and use in reporting on activity data

Other

- Translation of land cover (LC) to land use (LU)

Synthesis of Working Group discussions on 'Evaluation of current approaches in NFMS'

Characterisation of country-specific approaches	Obstacles and limitations	Priority R&D and satellite data needs
	Group 1 (Peru and Colombia)	
Peru EFs: • Forest types based on ecozones map built by NFI • Current EFs from different institutions • Conservative approach - post-deforested areas assumed to have 0 carbon stocks AD: • Landsat mosaic used to classify forest loss - 96% of images are from same year • Semi-auto process for F/NF • SAR used in NRT alert system Validation of AD: • Uses Steven (based on P. Oloffson) sampling design NFI: • 10% of total plots completed • Once 2 cycles ready, stock dif. approach will be applied	EFs: • Lack of historical info on AD • Lack of EFs for post-deforested areas • Lack of info on other C pools besides AGB • Stratification assessment • Integration of field data with maps • Scale of stratification, particularly at boundaries AD: • Stratification of forest classes and accuracy assessment • Lack of accurate information for classification • Cost of data processing tools • Capacity building among technicians	R&D: • Build info on forest management • Definition of degradation and mapping methods • Cost-effectiveness and gain in accuracy at national level when migrating to other sensors (LiDAR/SAR) • Guidelines for mapping dry and Andean forests Satellite data: • VHR for sampling • Sentinel-1/2 • LiDAR

<u>Colombia</u> EFs: • Forest types based on Holdrige lifezones, precipitation and topography • Current EFs from different institutions • Post-deforested C stocks used from IPCC default values to build EF AD: • Landsat composite imagery - data from each year • Semi-auto process for F/NF Validation of AD: • Sample increased in deforestation areas • Visual classification of images for Val NFI: • 15% of sample completed • Stock difference method once NFI is ready		
Characterisation of country-specific approaches	**Obstacles and limitations**	**Priority R&D and satellite data needs**
Group 2 (Mexico and Brazil)		
• No standardization in methods adopted by different countries - scale, semantics, data input • May lead to difficulty in comparison of reports (likely stems from IPCC broad criteria and guidelines for NFMS and consequently MRV) • Approaches inherit previous mapping initiatives, not specifically designed for MRV • Resource limitation hampers the development of MRV specific approaches by institutional resistance • Basic approaches may be different in nature, e.g., mapping vs. forest inventory makes these differences more acute • Transition requires definition of methods and software, which increases the complexity of the problem • Indicators should be standardised rather than methodology, for the sake of producing significant info	• Confusion of LC prevalence over LU as monitoring object - suggest include in MGD • Have RS data but very few ground observations of LU and biomass measurements • Institutionally, some countries don't have a single authority over LULC info collection, dissemination and use • Lack of continuity due to government shift is limiting - GFOI and UNFCCC may help by pointing out deterioration of internal capacity • Resistance to adopt GFOI guidelines due to previous experience or internal contradiction among institutions • Delay in implementation of carbon market discourages countries to put effort in NFMS and MRV capacity development	R&D: • Access to cloud infrastructure to gain time in processing archival data • Adaptation capability is necessary to make better use of available algorithms and cloud computing • Need to complement RS data with local info on drivers of LUC to maximise use of data and achieve sounds MRV - requires cooperation among internal institutions, horizontally and vertically in government structure - will improve reporting and mitigation efforts Satellite data: • Availability of at least >1 view/year is necessary to exploit temporal dimension - increases demand over cooperation of commercial data provider

• Regional standardization should prevail over global (semantics) • Alignment of methods should be pursued among countries with greater communication and sharing of methods/results • Carbon gain should have equivalent relevance as carbon loss • Production of metadata and inter-country comparisons (comparable reporting) should be pursued		
Characterisation of country-specific approaches	**Obstacles and limitations**	**Priority R&D and satellite data needs**
Group 3 (Guatemala and Honduras)		
<u>Guatemala</u> • Forest carbon maps derived annually 2001-2010 by different approaches and data • 2500 ground samples collected. • Destructive method for generation of allometric equations. Currently one equation for bradleaf forest, two for conifers. • Generation of maps of forest height planned, but approach is still not clear. • . No approach available for identification of illegal logging.	**<u>Guatemala</u>** • Forest maps not generated in a timely manner • Comparability of maps generated by different methods difficult • Validation of maps – especially degradation – is a problem. Not enough field data available.	**<u>Guatemala</u>** • Separation between anthropogenic and non-anthopogenic changes
<u>Honduras</u> • 2012 used for Reference Level • National forest definition 10% canopy cover • 2014 national coverage by RapidEye used for generation of first forest map. Released 2016. • Plans for second RapidEye coverage in 2017 but no funds for purchase	**<u>Honduras</u>** • Difficulty to measure current national forest definition (10% cover). REDD definition is 30% (and 2m height for dry forest and mangroves, 4m for other forst types) • Cost of commercial data major obstacle as not sustaibanle in long-term.	**<u>Honduras</u>** • Separation between anthropogenic and non-anthopogenic changes • How to correctly identify forest according to a given (cover+height) definition • Currently relying on commercial satellite data (RapidEye). Suggestion to switch to Landsat/Sentinel-2

3. Forest type stratification and change mapping methods

Day 2 gave presenters an opportunity to outline their experiences in forest stratification mapping and characterisation of forest state, including deforestation and degradation indicators. A working group session followed, where current approaches to forest type stratification and change monitoring were discussed, and the key gaps and obstacles to operational use and R&D/satellite data needs were identified.

Forest type stratification mapping is largely undertaken using semi-automated approaches and using a variety of medium to high resolution satellite optical and, less frequently, SAR imagery. Historical vegetation maps are often available, compiled from a variety of data sources and issued at different scales. Reference data typically collected in the field or compiled from visual interpretation of high to VHR satellite imagery. The accuracy of forest type mapping decreases with an increasing number of classes.

A structural classification of forests produces classes that are more relevant to carbon stocks. In Mexico, forest type classification is based on the ecological and floristic affinities of plant communities. Successional stage classification is also applied in Colombia using structural data. In Australia, forest stratification is based on height (ICESat GLAS) and cover (joint segmentation of ALOS PALSAR and Landsat persistent green fraction). In South Africa, woody vegetation cover is mapped using a combination of LiDAR, SAR and field data.

At the global scale, UMD are producing the vegetation continuous field (VCF) layers. Forest stratification is attempted at global scale through the integration of ICESat GLAS height and Landsat-based forest cover maps. Dominant strata are associated with an AGB value using GLAS heights.

Other approaches attempt to estimate the above-ground biomass (AGB) of forests, and so stratify on the basis of homogeneity of biomass/carbon content. FSU demonstrated the potential for improved AGB estimates by random forest modelling applied to multi-sensor data (RMSE 14.3 t/ha for tropical dry forest). A wall-to-wall map of AGB in Mexico was produced (RMSE of 27.2 t/ha). In South Africa, AGB estimates are obtained by random forest modelling of LIDAR and ALOS PALSAR data, and through the integration of GLAS and MODIS VCF products, and multi-frequency SAR data.

Degradation is high on the list of R&D priorities and countries continue to struggle with the definition, mapping and reporting method. Drones are being used in Colombia, flown over managed areas at different times of year to capture localised change. VTT use a time-series of Landsat red reflectance to detect and map degradation. New roads are detected using SAR texture features and buffered to map selectively logged areas. Conversely, regrowth is as high a priority, and the combination of ALOS PALSAR and Landsat data to differentiate degradation and regrowth stages is a promising technique being applied in Australian forests.

Forest cover change monitoring is typically applied at country scale using a time-series of optical (Landsat) data. MAD-Mex is an operational, wall-to-wall satellite-based monitoring system, that uses the Landsat archive and a sampling approach to assess historical deforestation and degradation rates. Global forest cover change maps have been generated by analysing multi-temporal trends in Landsat time-series data (UMD). The IT infrastructure needs are high to process such high data volumes. Time-series of C- and L-band SAR have also been used to detect changes in forest cover. Reference data should be attributed with the driver of change for better explanation of deforestation estimates.

Synthesis of Working Group discussions on 'Stratification and change in forest land and emissions reporting'

Group 1: Evaluate current approaches to forest type stratification for emission reporting
• Use of existing mapping layers (biogeographic regions, vegetation, climate, elevation etc) • Stratification based on biomass distribution • Attempts to include degraded forest to improve emissions estimates • Varying emphasis of NFI sampling strategy; EFs limited for transition classes
Group 2: Evaluate current approaches to monitoring forest state and change within forest land, and discuss how it is used to emissions and/or national forest reporting

- In case some areas are difficult to access, potential solution (NFI approach) - (i) Building stratum with sampling intensity lower in difficult stratum (social, high, slope etc.), and (ii) Photo interpretation.
- Possibility to acquire VHR data above plots and impute field measurements to features identified in RS/biophysical data.
- Issue of defining degradation: persistent loss of carbon within forest land; time component; primary to secondary forest.
- If NFI available, then stock-change method becomes appropriate.
- Possibility to incorporate gain-loss features into stock change approach - use NFI plots to build emission factors and use RS to estimate change.

Group 3: Identify key gaps and obstacles to operational (widespread) use and priority R&D and satellite data needs

Stratification, forest type and change:

- Post-classification analysis is not the way, but still countries are comparing maps
- Importance of time-series analysis acknowledged, but more research is needed to bring it to country level. Recommendation to provide a suite of open source algorithms at an operational level
- The tools that the science community are developing are not easy to implement. Countries are often overwhelmed with new information. Processing intensive.
- Value of the systems have to move beyond C reporting to include climate change planning and adaptation.

Satellite data needs and obstacles:

- High cost of data and access to data. HR data is needed (not for wall-to-wall mapping) for hot spot and validation.
- Countries not clear on Sentinel-1/2 acquisitions and data distribution.
- Access to ALOS PALSAR data (South Africa). Commercial data policy is an impediment.
- Internet access, data storage and infrastructure are major obstacles for countries
- Staff and institutional arrangements the responsibility of countries
- Cloud usage is a good solution but still needs to be proven as a potential solution to the countries without losing autonomy of their system.

4. Monitoring tools and approaches to validation

There are few GHG emissions estimation tools in circulation. Australia's FULLCAM (CSIRO) is one such system that enables full tracking of forest carbon pools and dynamics. The system has been adapted to run in Indonesia (INCAS) and provides a Tier 3 level system. Input data comprises spatial data, annual forest cover change, biomass, growth rates and information on LU management. Annual forest cover change maps were produced by LAPAN using a time-series of Landsat data. Reference data were sourced from local experts and existing maps. Burnt and peatland areas are accounted for in the modelling. GHG emissions results were produced for each province and for total country, and fulfilled the various reporting obligations.

Through the process of implementation in Indonesia, some limitations of FULLCAM were identified. The models are hard-coded and some of the data requirements are rigid. Organic soils (peat) are significant in Indonesia, but not included as a pool in FULLCAM. Some types of events, e.g., enrichment planting and thinning response, cannot be modelled. Overall, the system performance is limited for spatial modelling in northern hemisphere forests.

The carbon budget model (CBM-CFS3) used by Canada is an operational, national monitoring system for reporting on carbon dynamics. It adopts that IPCC gain-loss method. Amongst its advantages are scale-independency, use of spatially explicit data from multiple sources, flexibility to extend with new data, and accounting for all carbon pools. The second generation of tools, GCBM-FLINT, incorporates new science modules, and has been tested in Canada and Mexico.

The optimal data integration tool should allow the user to estimate, monitor and project GHG emissions with flexibility to adopt country specific data and models. Further, the outcomes should guide the development of mitigation actions.

A new initiative 'MOJA', proposed by CFS and colleagues, aims to provide a flexible data integration system for estimating and reporting on GHG emissions. The concept is for a generic suite of tools that can access global datasets and integrate with country specific models for customised reporting and policy scenarios. A prototype system is under development in Kenya (SLEEK). Further information can be found here: http://moja.global.

Reference data

Stratification for REDD is not a stand-alone product; it is multi-purpose, both supporting and increasing the precision of emissions estimates in different categories. Often different sampling intensities need to be accommodated. Reference data is not 'truth', but is of higher accuracy than map data. It can be collected by field measurements (NFI), or from interpretation or careful classification of remote sensing data. Reference data should always be acquired using a probability sampling design to produce estimates that satisfy IPCC GPG.

Synthesis of Working Group discussions on 'Validation of forest type and change products"

Current approaches to validating forest types	Obstacles and limitations	Guidance, priority R&D and satellite data needs
	Group 1 (Peru and Colombia)	
Colombia • Sampling intensity focussed on high risk (deforestation) areas • Reference data from careful classification of Landsat data • Local (plot-based) EFs • Annual reporting **Peru** • Sampling frequency in strata based on instances of change • Reference data based on time periods • Reference data submitted - now have to report on this (time interval to be determined) • Reference data from RapidEye (external agency)	• Unrealistic expectations of donor on confidence interval • EFs usually stable but can have large variance • Errors in allometrics • Error propagation • More resources needed to build adequate reference data sample size • Conflicting advice	• How to deal with missing reference data • Defining best frequency of reporting • Trade-off between cost of acquiring reference data & achieving small confidence intervals in low deforestation countries • Donors should be aware of scientific & technical underpinnings to achieve set objectives
Current approaches to validating forest types	**Obstacles and limitations**	**Guidance, priority R&D and satellite data needs**
	Group 2 (Mexico and Brazil)	
• Sample based validation in selected areas • PRODES uses 3 independent interpreters & a vote to assess accuracy • LCC validation needs to identify presence/absence and type of change	• Implementation of recommendations on reference data • Cost of validating LCC • Temporal resolution of change makes validation costly & ambiguous • Consistency when using	• Agreement & transparency on relevant type of change • Assessment of relevance of products, thresholds at which change is detected & their consistency over time • Use of biomass products • Crowd sourcing of change

• Adjust classifier for regional differences • Assess plausibility of LC objects by analysing spatial patterns and likelihood of change • Aim to reduce commission error	interpreters	observations
Current approaches to validating forest types	**Obstacles and limitations**	**Guidance, priority R&D and satellite data needs**
Group 3 (Guatemala and Honduras)		
• Field data to assess map accuracy, opportunistically collected • No information on forest loss yet • Available data that fit probability-based sample models: Landsat time-series (Honduras), orthophotos, RapidEye & Landsat (Guatemala)	• Commercial data constraints • Resources - personnel • Validation is not a priority so capacity not established	• Need to emphasise validation as a core component internally • Priority implementing good practice methods with available data • Recognition of fine scale of LU change which requires VHR data for estimation/validation

5. EO systems for forest monitoring

On the afternoon of Day 3, EO systems for forest monitoring were discussed, including a new proposal for a global high resolution satellite constellation.

With sub-metre resolution the domain of commercial satellite data providers, and the cost impediment of RapidEye and SPOT data, there exists a potential gap in low-cost satellite data in support of operational forest and REDD+ monitoring and reporting. CONABIO have proposed a possible solution in the form of an 8-satellite constellation (6 sun-synchronous and 2 equatorial orbits) that would provide global coverage of land systems and based on the Landsat model (i.e., open access). The proposed specifications include a 125 km swath, 2.5 m panchromatic, 5 m multispectral and 2 thermal channels. Access to such a system would encourage industry development (value-adding services), and hopefully inspire countries to implement operational monitoring strategies to inform policy and decision making.

The following data sources were flagged as highly relevant to countries in ongoing development of their NFMS:

- **ALOS-1/2 PALSAR-1/2** - Global L-band SAR mosaics (25 m) are available for download free of charge from JAXA (2007-2010, 2015+). Systematic acquisitions over all regions of the world 4-6 times/year at 10m resolution. Pan-tropical zone in addition covered 9 times/year at 50m resolution. Standard (non-mosaic) data commercial only.
http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm
- **SAOCOM-1A/B** - L-band SAR, scheduled launch in 2017 (1A) and 2018 (1B), 16-day repeat cycle. Dedicated national observation strategy for Argentina and global background mission with all countries in the pan-tropical zone acquired 4 times/year at 10-30m resolution. Free and open data access is anticipated from CONAE (Argentina).
http://www.conae.gov.ar/index.php/english/satellite-missions/saocom/introduction
- **BIOMASS** - P-band SAR, scheduled launch 2021. Complex observation strategy, tuned specifically for tomography, and providing support for global carbon budgets.

http://www.esa.int/Our_Activities/Observing_the_Earth/The_Living_Planet_Programme/Earth_Explorers/Future_missions/Biomass

- **GEDI** - LiDAR mounted on the International Space Station, scheduled launch in 2019. Will provide global, high resolution observations of forest vertical structure to support carbon balance and biodiversity assessment.
  http://science.nasa.gov/missions/gedi/

6. Concluding discussions

The workshop provided a forum for both scientists and practitioners to engage in technical discussion on current methods, limitations, obstacles and future needs of NFMS and, in particular, forest stratification monitoring and reporting.

Evolving needs at international level and REDD+ countries

Countries placed varying emphasis on their emissions reporting system, with reporting focussed on specific change classes rather than encompassing all. Technical solutions for NFMS exist, however, implementing these is the challenge. Countries need to develop good practice using available data. Maintenance of an NFI, although resource-intensive, should be given a high priority, and further extend to disturbance type and EFs for other carbon pools. Cost-effectiveness of monitoring tools is paramount, and the benefits of certain technology (SAR/LiDAR) and the gain-loss vs. stock-change approach should be well demonstrated. Satellite VHR data are often requested for collecting reference data; where cost is limiting, alternative approaches that satisfy IPCC GPG should be sought. IT infrastructure needs are high to cope with large data volumes, and there are moves towards cloud-based systems.

Specific R&D needs were identified as follows:

- Mapping methods for degradation and regrowth
- Understanding secondary forest dynamics
- Mapping methods for dry and Andean forests
- Automation of methods (hybrid systems that use human interpreters and intelligent computing)
- Need for better data-model integration tools to estimate emissions
- Methods for emissions estimates in other carbon pools (beyond AGB)
- Development of structurally robust allometrics

Guidance and capacity building

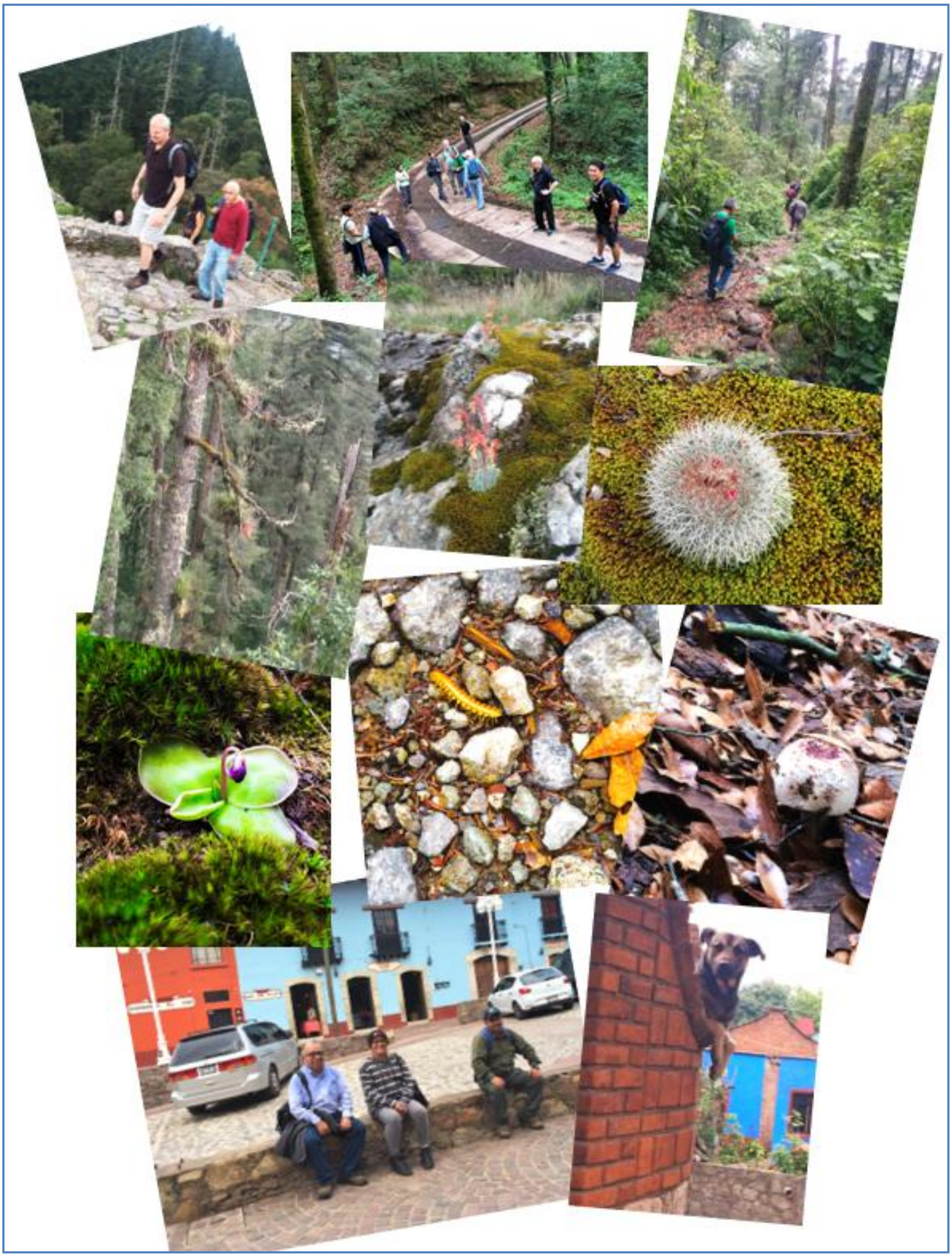
Guidance is still needed on forest stratification and validation scenarios. Advice on monitoring frameworks and how to maximize NFI and other ground surveys is desirable. Options exist for dealing with non-standard conditions (e.g., missing observations), however, this is neglected in guidance materials. The procedure and requirement for assessment of error propagation should be considered. Information is needed on data-model integration tools, what the available options are, and their advantages/ disadvantages. Awareness and training in use of open source/free software should be provided where applicable (e.g., RSGISLib.org, moja global, F-TEP). An interest for citizen science/crowd-sourcing approaches was expressed, however the topics were not tackled during the workshop. The GOFC-GOLD REDD sourcebook provides information (concepts and case studies) on these topics. The GFOI should present, discuss, and provide guidance on available tools for emission estimation and reporting such as INCAS, FullCAM, CBM-CFS3 and moja global.

At the policy level, the timeframe for reporting should take into account the significance and temporal dynamics of the changes observed in forest land. Donors need to better understand the scientific underpinnings of the systems and be realistic in their requests to countries. Internally, institutional arrangements and maintaining consistency of the NFMS in the face of changing staff/ government/policy is paramount. The NFMS should also go beyond climate change mitigation, and consider adaptation strategies and sustainable development goals.

Proposed action plan

- The benefits of regional collaboration and building solutions together - SilvaCarbon taking a lead role
- Development of modules/update of the GFOI Methods & Guidance Document (MGD) to present and discuss:
  - options for forest stratification
  - available tools for emissions estimation and reporting
- Incorporate aforementioned country R&D needs into future R&D plan
- Closer collaboration between GFOI R&D and Capacity Building components

Field excursion - El Chico National Park



Annex A. Workshop participants

Name	Affiliation	Country	Email
Gregorio de Angeles	COLPOS University	Mexico	gangelesperez@gmail.com
Susana Rodríguez Burticá	Humboldt Institute	Colombia	drodriguez@humboldt.org.co
Natalia Malaga Duran	MINAM	Peru	nmalaga@minam.gob.pe
Gustavo Galindo	IDEAM	Colombia	gusgalin@gmail.com
José Gildardo Galvez	MARN	Guatemala	jggalvez@marn.gob.gt
Amaury Gutierrez	CONABIO	Mexico	
Tuomas Häme	VTT	Finland	tuomas.hame@vtt.fi
Matt Hansen	UMD	USA	mhansen@umd.edu
Tom Harvey	GFOI	Italy	tom.harvey@gfoi.org
Arturo Victoria Hernández	INEGI	Mexico	arturo.victoria@inegi.org.mx
Melanie Kolb	UNAM	Mexico	kolb@igg.unam.mx
Werner Kurz	NRCan	Canada	Werner.Kurz@NRCan-RNCan.gc.ca
Adalberto Lopez	CONAP	Guatemala	alopez@conap.gob.gt
Roberto Martinez	CONABIO	Mexico	
Renaud Mathieu	CSIR	South Africa	RMathieu@csir.co.za
Ron McRoberts	USDA Forest Service	USA	rmcroberts@fs.fed.us
Jorge Morfin	FAO - CONAFOR	Mexico	jemorfinr@gmail.com
Marcela Olguin	CEC	Mexico	marcela.olguin2@gmail.com
José Luis Ornelas	INEGI	Mexico	jose.ornelas@inegi.org.mx
Gerson Perdomo	ICF	Honduras	gperdomo@icf.gob.hn
Rainer Reissl	CONABIO	Mexico	rainer.ressl@xolo.conabio.gob.mx
Eduardo Rojas	MINAM	Peru	erojas@minam.gob.pe
Christophe Sannier	SIRS	France	christophe.sannier@sirs-fr.com
Michael Schmidt	CONABIO	Mexico	michael.schmidt@conabio.gob.mx
Carmen Meneses Tovar	CONAFOR	Mexico	cmeneses@conafor.gob.mx
Anthea Mitchell	UNSW	Australia	a.mitchell@unsw.edu.au
Brice Mora	GOFC-GOLD/WUR	Netherlands	brice.mora@wur.nl
Erick Palacios	CONABIO	Mexico	
Ake Rosenqvist	soloEO	Japan	ake.rosenqvist@soloEO.com
Michail Urbazaev	FSU	Germany	mikhail.urbazaev@uni-jena.de
Dalton Valeriano	INPE	Brazil	dalton@dsr.inpe.br
Sylvia Wilson	USGS/SilvaCarbon	USA	snwilson@usgs.gov