SilvaCarbon Activity Report: Regional Training on Remote Sensing and Change Detection

Bangkok, Thailand
November 2015

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Report Date: January 2016

This report was prepared by the U.S. Forest Service, an implementing agency for the interagency SilvaCarbon program. SilvaCarbon agencies:

Acknowledgements

The training summarized in this report was jointly funded by the SilvaCarbon program and the European Commission Joint Research Center (EC-JRC).

The training was organized and conducted in collaboration with the United Nations Food and Agriculture Program and the USAID funded and NASA implemented SERVIR-Mekong Program. The training materials were developed with generous contribution from Boston University.

Contents

Introduction

The SilvaCarbon South and Southeast Asia regional program works with Bangladesh, Cambodia, Indonesia, Lao PDR, Nepal, Philippines, Thailand, and Vietnam to build capacity in measuring, monitoring, and managing forest and terrestrial carbon (see Appendix D for more information about SilvaCarbon). As part of the program's ongoing efforts to assess capacity needs and gaps in the region, participants from previous SilvaCarbon activities expressed interest in a comprehensive training focused on forest cover change detection using open source software.

To address this demand, SilvaCarbon invited the U.S. Forest Service Remote Sensing Application Center (RSAC) (See Appendix F for more information on RSAC) to design and deliver a ten-day regional training on Remote Sensing for Forest Cover Change Detection using free and open source software. The training took place in Bangkok, Thailand from November 9-20, 2015, and was attended by twenty participants representing forestry agencies in Cambodia, Lao PDR, Nepal, and Thailand. The core training materials were leveraged from a Boston University workshop led by Dr. Pontus Olofsson.

Supplemental presentations were delivered by SilvaCarbon partners from the Food and Agriculture Organization of the United Nations (FAO) and the European Commission Joint Research Center (EC-JRC. The training was funded by SilvaCarbon and the EC-JRC ReCaREDD program. ReCaREDD aims at 'Strengthening national and regional capacities for reporting on the mitigation actions of the forest sector'. In Southeast Asia ReCaREDD has particular focus on Cambodia, Lao PDR and Viet Nam. The training component on the JRC IMPACT tool was delivered by A. Langner (JRC). See Appendix E for more information about ReCaREDD.

The training was delivered by Karis Tenneson and Brent Mitchell, two remote sensing specialists from RSAC, with coordination support from Marija Kono of the SilvaCarbon program and Dana Moore of the U.S. Forest Service Office of International Programs (USFS IP).

Training group

Training Objectives

The primary objective of the training was to build participants' capacity in remote sensing in order to strengthen their countries' efforts to monitor forest resources and prepare forestry data for the United Nations Framework Convention on Climate Change (UNFCCC) and Reducing Emissions from Deforestation and forest Degradation (REDD+) reporting. The first week of the training focused on image processing theory and fundamental concepts, land cover mapping, and accuracy assessment. The second week focused on detecting and monitoring landscape change. During the first week participants worked through exercises to create a land cover map with an accuracy assessment, and in the second week they detected and mapped landscape change and designed and implemented a capstone project using data from their countries.

A post-training evaluation and follow-up discussions with participants indicate that the activity was highly successful in building participants' capacity to assist in their ongoing work programs. Evaluation results are summarized in Appendix B.

Training Summary

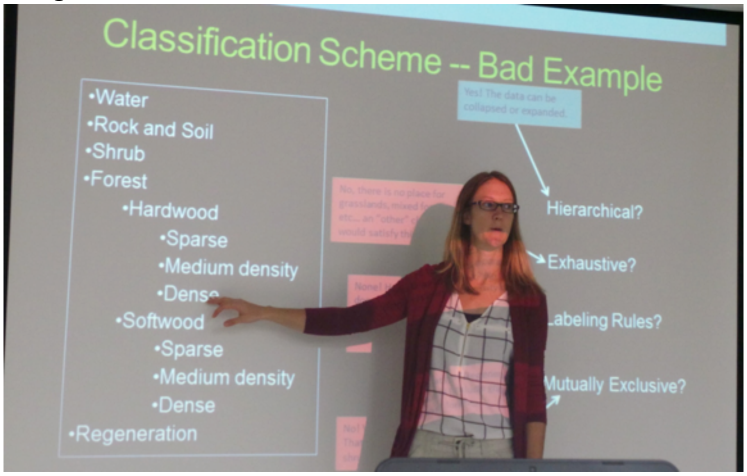
The training was attended by four participants from Cambodia, four from Lao PDR, four from Nepal, and eight from Thailand. In addition, Dewi Anggraini and Peter Cutter from SERVIR-Mekong attended a number of sessions and shared their knowledge and data, including Lidar data for Khao Yai National Park in Thailand. Full list of participants is provided in Appendix C. The Thailand Department of National Parks (DNP) assisted with logistics and hosted the event at Kasetsart University in Bangkok, which had all the amenities needed to conduct a technical training, including internet access to allow participants to work with Google Earth Engine and Google Earth.

The training was designed to use free and open source software. This included the integration of Google Earth Engine and QGIS tools and other open-source software (EC-JRC IMPACT Toolbox) to implement a change detection and accuracy assessment workflow. RSAC worked closely with USFS IP, SilvaCarbon, and Boston Education in Earth Observation Data Analysis (Boston University Department of Earth and Environment), as well as partners from EC-JRC and FAO, to tailor a complete remote sensing workflow and documentation procedures for forest cover change detection that can be used for REDD+ reporting.

This core workflow was presented at the training, along with several complementary presentations and exercises that highlighted the relevance of considering options that can be elevated to a national level and integrated in current forest monitoring efforts. These included presentations from FAO on: 1) National forest monitoring in the context of REDD+ and beyond by Franz Arnold; 2) an introduction to CollectEarth by Mathieu VanRijn (see Appendix F for more information on Collect and Collect Earth); and 3) the relationship between land cover and land use by Adam Gerrand. Andreas Langner and Hans-Juergen Stibig of EC-JRC prepared a full afternoon session on the EC-JRC IMPACT Toolbox, highlighting possible links to Guidos Toolbox (another EC-JRC tool for map analysis).

In general, the format of the training consisted of short PowerPoint presentations and live demonstrations covering conceptual information followed by hands-on exercises. After key sessions were completed, the instructors recapped the previously covered materials, highlighting elements that the participants had just learned. This gave participants a chance to ask additional questions and gain further clarity on key concepts and processes. Instructors capitalized on opportunities for group discussions, demonstrations, and bonus

exercises to enhance the learning environment, including, for example, a session on lidar data and processing using a local dataset from Thailand.



Background presentations to prepare participants for the exercises

Specifically, participants were trained in:

1. Project planning and best practices for documenting land cover mapping and change detection methods.
2. The use of Google Earth Engine (GEE) to access and export top of atmosphere Landsat scenes and/or cloud free Landsat composites, in areas with persistent cloud cover.
3. The use of QGIS software to classify land cover and land cover changes using random trees modeling with multi-temporal image transforms. RSAC built on a change detection workflow developed for a previous training at Boston University led by Pontus Olofsson. The training included both pixel-based and object-based land cover mapping and change detection methods.
4. Conducting an accuracy assessment of both land cover map and change products using a combination of sampling tool scripts implemented in QGIS and visual interpretation of imagery in Google Earth.
5. The use of EC-JRC's IMPACT Toolbox to unzip, layer stack, convert to top of atmosphere, clip, automatically classify land cover, create land cover segments, and modify the classification results.

See Appendix A for the full training agenda. All training materials, including the manual and presentations, can be accessed online at: https://www.dropbox.com/sh/tl2lc99v16fvzsd/AABJyxtYNUPwbNFhJ5Nwc3a0a?dl=0

Next Steps

Follow-up Support

Training organizers will schedule a series of follow-up support meetings with each agency that participated in the training to discuss challenges they might be facing in implementing their change detection strategy and suggest possible modifications. If the agency's change detection workflow is already underway, the follow-up meetings will instead focus on providing guidance as needed to improve the current workflow. RSAC has funding to provide a limited amount of follow-up support and is available to consult on future efforts.

SilvaCarbon staff will coordinate with the program focal points from the four participating countries to determine how the knowledge gained at the training is being used and identify any implementation challenges. Based on this feedback, specific areas of needed support will be identified and addressed. These efforts will be made in collaboration with other partners in the region as appropriate, depending on the topic.

Answering practical questions was the focus of the training

Create avenues to share new skills

The SilvaCarbon program could design future events in a way that gives participants a chance to practice and demonstrate the new skills they have gained during this training at subsequent regional SilvaCarbon events. For example, the participating countries could prepare an accuracy assessment presentation/exercise for the next GFOI regional workshop on accuracy assessment.

Addressing participant concerns

The concerns in the participant evaluations were primarily related to software and computer issues.

1) Agency computing infrastructure (e.g., access to high speed internet connection and computational power) – Agency computing infrastructure limitations addressed by staff are challenging. Potential remedies include:

- Leveraging resources and expertise made available by collaborative agencies, such as FAO, JICA, EC-JRC and SERVIR-Mekong.
- Using the computational power of Google Earth Engine, which provides cloud side processing and elevates this burden from the users. Other benefits of GEE include the flexibility of working in a scripting environment (once the initial learning curve is overcome), which increases efficiency for fine-tuning methods and reproducing results. Although the use of Google Earth Engine increases reliance on access to the internet and requires a certain comfort level with scripting, it is a viable solution for developing countries and can alleviate some of their current concerns.

2) Software issues – Three potential solutions to the noted software problems have been suggested.

- Run the software from virtual machines. This would allow the trainer to provide each participant with an identical operating system and software environment that had been tested prior to the start of the training. A virtual machine would eliminate interactions with the primary operating system and simplify troubleshooting. However, maintaining and distributing a virtual machine would require a technical approval from the USFS Chief Information Office, which would be difficult. It should be noted that a virtual machine will not overcome hardware (e.g., the processor architecture should be 64 bit compatible) or connectivity limitations. Further, a plan should be in place to ensure the virtual machine is kept up to date over time as software evolves. This is something to keep in mind and discuss for future capacity building with open source software.
- Use other software packages for image classification, such as Google Earth Engine, IMPACT Toolbox, or the QGIS Semi-Automatic Classification plug-in.
- Provide computers in the lab for each student to work on.

3) Language challenges - Challenges associated with learning new material in English can be partially ameliorated by efforts to translate training materials.

4) Communication prior to the training - More detailed instructions and follow-up prior to the training could help to make sure everyone could access the Google Earth Engine software on the first day of the training. Additionally, future activities could require participants to complete a training registration form where they indicate that they have registered for Google Earth Engine and include a copy of the email confirmation from Google.

Future workshop and training offerings

Based on the evaluation forms and bi-weekly check-in responses, there are a number of both software-specific requests and general method topics that participants are interested in learning more about. These are elaborated below.

1) **Advanced training in open source software –** In the course evaluations, 70% of the participants asked for additional training in free and open source software. Some requests were software specific: ten requested lidar training (and carbon estimation methods), five are interested in advanced training on IMPACT and Guidos Toolboxes, four requested advanced QGIS courses, two for advanced Google Earth Engine, and one for CollectEarth.

Lidar data processing with FUSION and other open source software – The most requested topic was lidar data, processing, and analysis - with over half of the respondents requesting it as a follow-up training. Of particular interest to many participants, especially those from Thailand and Nepal, to integrate lidar data and field based estimates of carbon stocks to estimate and map carbon storage.

IMPACT and Guidos Toolboxes – Five of twenty participants mentioned that they plan to begin using these Toolboxes to map land cover in their work program, because there is no need to type scripts - it is easy to understand and use. The Forestry Administration of Cambodia staff are interested in testing these tools for the 2016 mapping process.

Google Earth Engine and an Introduction to the Fundamentals of Programming in the Code Editor – There were two requests for advanced training with Google Earth Engine. Generally, based on participant feedback, participants were excited about the Google Earth Engine data library and processing capabilities. An advanced GEE training could focus on the fundamentals of scripting with JavaScript and Earth Engine algorithms in the Code Editor, automation of land cover classification and change detection, and assessing vegetation dynamics (forest degradation and recovery) through the use of scripts. Currently, RSAC is developing material for a Google Earth Engine webinar that provides instruction on these three topics, which could easily be adapted to meet the natural resource management needs of an international audience.

Additionally, the use of GEE for country-wide mapping addresses participant concerns with the computational infrastructure challenges faced by limited department resources. It also allows users to save scripts, quickly replicate results, and increase speed at which methods can be adjusted and or assessed. Although implementing the mapping efforts in GEE would increase reliance on access to (high-speed) internet.

OpenFORIS tools – Four participants listed the CollectEarth and Collect presentation as one of the most interesting topics for the day. Supplementing the change detection training with CollectEarth (a plot-based land assessment tool using remote sensing imagery) and Collect (for field-based forest inventory) training would be a powerful addition to the forest monitoring toolbox of participants. Participants repeatedly expressed the need for a method to address the challenge of using automated mapping techniques to differentiate land cover classes with only very subtle differences in spectral signatures, such as forest land use classes (discerning between native forest and tree crops such as palm oil). A hybrid approach that couples point based estimation with wall-to-wall mapping is one potential method to overcome this challenge and meet basic REDD+ MMRV standards. USFS IP was awarded a grant to integrate some of this material into the existing training material used in this training, in collaboration with FAO.

2) **Time series analysis** – Four requested a training on time series analysis to detect and quantify land degradation.

3) **Accuracy assessment –** Three requested a training focused on planning and conducting accuracy assessments. Participants were briefly exposed to the basics of conducting an accuracy assessment, but this is a topic ripe for a follow up training session as nearly everyone was engaged with excellent follow-up questions after the session. Specific follow-up topics of interest related to accuracy assessment protocols include: 1) general planning considerations (e.g., how to determine acceptable accuracy levels to meet project needs); 2) an exploration of the trade-off considerations when determining the sample design (e.g., what is an appropriate sample size, what are limitations and benefits of random verses systematic plots, etc.); and 3) factors affecting response design decisions (e.g., considerations between field-based data or visual interpretation of satellite imagery).

4) **Integration of multiple data sets to monitor forest resources** – The participants from the Department of National Parks (DNP) Thailand and the Forestry Administration of Cambodia discussed the need to better understand how to integrate data sets, such as Landsat, lidar, ALOS, and Rapid Eye interpretation for forest management projects.

Appendix A – Training Agenda

Remote Sensing and Change Detection Workshop

Bangkok, Thailand / November 9-20, 2015

Objectives:

The objective of this workshop is to build remote sensing capacity for the participants. The first week will focus on image processing theory and fundamental concepts while working through exercises to create a land cover map with an accuracy assessment. The second week will focus on detecting and monitoring landscape change. This training will help countries with their ongoing work, such as preparing the forestry data for the United Nations Framework Convention on Climate Change (UNFCCC) and Reducing Emissions from Deforestation and forest Degradation (REDD) reporting.

Prerequisites (for technical hands-on participants):

Recommended Skills

Workshop participants should have a solid background in GIS concepts and data analysis. In addition a general awareness of remote sensing technology and common workflows would be beneficial.

Data (will be provided by RSAC at the workshop)
For the main data set to be used: two images (a pre and post) will be provided—both will be cloud-free Landsat composites compiled from Google Earth Engine. We will provide a dataset for the workshop exercises. For the Capstone we will have participants modify the Google Earth Engine Cloud Free Composite Script to download imagery for their specific study region (internet connection required for this piece, RSAC will bring a backup dataset along to mitigate any unforeseen limitations with downloading data from GEE). In addition the EC-JRC provided the open-source IMPACT Toolbox together with spatial medium and high resolution satellite imagery.

Capstone Data (Optional)
The workshop will culminate with a Capstone Project in which participants will begin to classify imagery and detect land cover changes in a region of their home country. If there is training data (areas of interest, field data, existing classifications etc.) available to assist with these efforts, participants are encouraged to bring this with them to utilize during the Capstone Project.

Software (required locally on all workstations)

- Google Earth Engine (GEE)
  - Google Earth Engine Beta Tester account (register here) and Google Drive (register here)
  - Google Chrome browser, most recent version, (download here)– this is the required interface to access GEE
- Free and Open Source Software: QGIS, Orfeo, IMPACT Toolbox, etc. (we'll provide instructions and support to install these during the workshop)

Hardware (recommended specs…)

- Computer (participants will bring a GIS processing laptop from home unit)
    - Administrative rights to install software on the laptop: We will be installing QGIS and other plugins, so it is important that each participant comes with administrative rights for their laptop.
    - Storage: At least 5 Gigabytes of free disk space
    - RAM: 3 Gigabytes

Agenda, Week 1

Day 1 (Monday):

Introductions, Remote Sensing Overview, and Project Planning

8:30am-12:00pm	• Workshop Introduction and Housekeeping • *Presentation* – Introduction to REDD and IPCC Guidelines
12:00pm-1:00pm	• Lunch
1:00pm-5:00pm	• *Presentation* – Overview of Detecting, Mapping and Quantifying Change (Open to a broader audience - management level) • *Presentation* – Project Planning • *Exercise* – Project Planning Form • Google Earth Engine check-in

Day 2 (Tuesday):

Cloud-free Image Composites Using Google Earth Engine

8:30am-12:00pm	• *Presentation* – Introduction to Google Earth Engine
	• *Exercises* –
	    o Intro to Google Earth Engine (Graphical User Interface and the Earth Engine Playground)
	    o Exploring the Google Earth Engine data repository
	    o Computation and Image Processing

12:00pm-1:00pm	• Lunch

1:00pm-5:00pm	• *Presentation* – Introduction to Google Earth Engine and the Cloud-free Image Composite Script
	• *Exercises* –
	    o Exporting Data
	    o Putting it All Together: Preparing and Exporting a Cloud-free Image Composite

Day 3 (Wednesday):

Overview of Remote Sensing Fundamentals and Image Classification

8:30am-12:00pm	• *Presentation* – Overview of Remote Sensing Theory • *Exercise* – QGIS installation, setting preferences, and image display in QGIS • *Presentation* –Band Ratios, Indices, Image Transformations (tasseled cap and principal component) • *Demo* - Calculating NDVI in Google Earth Engine • *Exercise* – Create Band Ratios, indices, image transformation in QGIS
12:00pm-1:00pm	• Lunch
1:00pm-5:00pm	• *Presentation* – Image Classification, the Land Cover Classification Scheme • *Exercise* – Discuss potential limitations and consider modifications of the IPCC land cover/land use classification scheme • *Presentation* – Review Image Interpretation and Collecting Reference Data • *Exercise* – Collecting Reference Land Cover Data

Day 4 (Thursday):

Image Classification, cont.

8:30am-12:00pm	• *Presentation* –Land Cover Classification Techniques (part I): Supervised Classification Methods • *Exercise* – Run a Random Forest Classification Model on Time 1 Composite • *Exercise* – Qualitative Assessment of Results to Determine Commonly Confused Classes
12:00pm-1:00pm	• Lunch
1:00pm-5:00pm	• *Presentation* –Land Cover Classification Techniques (part II): Improving the Supervised Classification Process and Introduction to Image Segmentation • *Exercise (optional)* – Improve Reference Data and Re-run a Random Forest Classification Model on Time 1 Landsat Composite • *Discussion*

Day 5 (Friday):

Accuracy Assessment and Capstone Prep

8:30am-12:00pm	• *Presentation* – Quantitative Accuracy Assessment • *Exercise* – Quantitative Accuracy Assessment
12:00pm-1:00pm	• Lunch
1:00pm-5:00pm	• *Week Wrap-up*

- *Discussion* - Review and discuss land cover classification process – what works, what are lingering challenges, etc.
- *(Optional)* start on change detection material

Agenda, Week 2

Day 6 (Monday):

Change Detection Introductions

8:30am-12:00pm	• Week II Workshop Introduction and Housekeeping • *Presentation* – Overview: Using Remote Sensing Tools to Detect, Map and Quantify Change • *Presentation* – Basic Change Detection • *Exercise* – Basic Visual Change Detection with Multi-Date Image Layer Stack
12:00pm-1:00pm	• Lunch
1:00pm-5:00pm	• *Presentation* –Automated Change Detection Approaches • *Exercise* – Image Differencing (and PCA) with two date stacks, explore histograms to generate spectral signal change expectations/hypothesis for common land cover transitions, generate reference/training change samples • *Exercise* – Map Changes (train and apply random forest classifier) and visually assess output (qualitative assessment) • *Exercise (optional, time permitting)* – Segment Changes

Day 7 (Tuesday):

Estimating Change and Accuracy Assessment

8:30am-12:00pm	• *Presentation* – Estimating Change Area and Accuracy Assessment • *Exercise* – Estimating Change Area and Accuracy Assessment
12:00pm-1:00pm	• Lunch
1:00pm-5:00pm	• *Presentation* - Recent forest degradation monitoring research results - a future IMPACT Toolbox addition • *Presentation* - Introduction to basic functions of IMPACT Toolbox • *Exercise* - Land cover classification with a Landsat scene using the IMPACT Toolbox: unzipping, layer stacking, TOA conversion, clipping, automatic classification, segmentation, modifications of the classification results. In addition RapidEye scenes are used to explore possible degradation events • *Presentation* - Concluding remarks

Day 8 (Wednesday):

Capstone I

8:30am-12:00pm	• Presentation/Demo - Overview of Sampling for Inventory and Changes • Presentation/Demo - Plot Based Trend Analysis • *Presentation* – Introduce Capstone Assignment
12:00pm-1:00pm	• Lunch
1:00pm-5:00pm	• In Class Work

Day 9 (Thursday):

Capstone II

8:30am-12:00pm	• Quick Check-in & Status Update • In Class Work
12:00pm-1:00pm	• Lunch
1:00pm-5:00pm	• In Class Work

Day 10 (Friday):

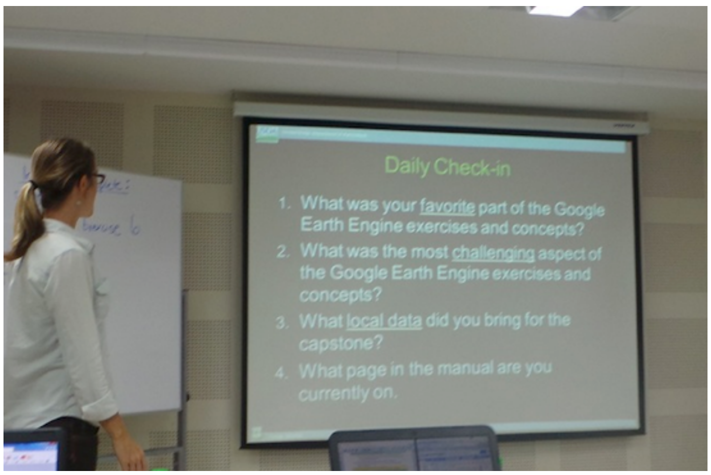
Capstone Conclusions and Workshop Wrap-Up

8:30am-12:00pm	• *Presentation (optional, time permitting)* – Scaling-up Production: discuss how to put all the pieces together, such as merging the classification output for the full country • *Exercise/ demo (optional, time permitting)* – merging capstone subsets into one mosaic
12:00pm-1:00pm	• Lunch
1:00pm-5:00pm	• *Workshop Wrap-up Discussion* – What worked well, what pieces might be more challenging? What are the next steps? • Certificates, Graduation Ceremony

Appendix B – Training Evaluation Results

Overview

We gave participants a chance to provide feedback in many different formats, including one-on-one discussions, an anonymous evaluation at the end of the training, a group discussion and presentation session during the training wrap-up, and written anonymous responses to generic check-in questions twice a week. Overall, the feedback was very positive, and participants appreciated the opportunity to learn about the geoprocessing workflows highlighted in the training and the associated open source tools and software. Trainer observations and self-reported assessments indicate significant advancement in key skills and increased understanding of the covered remote sensing topics (e.g., Google Earth Engine to extract data, land cover classification, mapping forest cover change, and accuracy assessment protocols). Below we provide a synthesis of the most frequently mentioned strengths and limitations of the training.



Collecting feedback and addressing questions was important part of the training

Strengths of the Training

In the final evaluation participants were asked to discuss the strongest aspects of the training. Feedback spanned a wide range. Forty percent of participants discussed the high quality of the training material, instruction, and organization. An additional four respondents (20%) indicated the selection of methods and skills that were applicable and appropriate for the participant and agency goals. Twenty-five percent explicitly mentioned the focus on free and open source software. Thirty percent listed the use and applicability of Google Earth Engine for exploring, pre-processing, and exporting data. The use of QGIS and the well-equipped computer lab were also mentioned. Specific examples are listed below:

1) Excellent training materials – The training manual, class exercises, and schedule with ample time for exercises and discussion were repeatedly listed as very well done. The written materials, particularly the training manual, were particularly appreciated by participants with weaker English skills. There was interest in translating the manual into Cambodian, Laos, and Thai so that the materials could be shared with a wider audience. It is our understanding that SilvaCarbon has funds to complete the translations and the manual will be available in multiple languages.

> *"Some of us had problem with English, but the manual was very good and helped us follow the course. With this step by step approach everydoby can complete work."*
> *"The training give good chance to practice the tols and the manual can help us practise in the office."*

"The tutorials are very helpful to get some clear concepts. For instance, the CART classifier demonstrated with fruit classification was awesome."
"The GEE scripts provided along with clear description which can be customized and adapted for other areas and queries."

2) Applicability of the training to the participants' ongoing work – 90% of participants indicated that the topics were *very applicable* to their job (10% find the content *somewhat applicable*). The usefulness of the materials was rated as *excellent* by 100% of the respondents. 75% indicated that they are *very likely* to directly apply what they have learned to their job (25% are *somewhat likely*). Participants listed a number of specific topics and tools that they plan to use. The most frequently listed was the data processing and export tools in Google Earth Engine, QGIS for spatial analysis, and the ease of the IMPACT Toolbox – specifically because no scripting is required. At the conclusion of the training, participants from each country presented what they found most relevant and what they will apply to their workflow within their department, two examples are included below.

Officers from the Nepal Ministry of Forestry and Soil Conservation indicated they will adopt the presented workflow:

"The workflow that I am interested to implement soon. Get cloud free Landsat composite for two time period, segment them, classify using Random Forest and evaluate accuracy. Use sample plots from FRA to train the model and get additional test sets for evaluation."

Staff from the Cambodia Forestry Administration plan to start adopting parts of the instructed workflow:

"Plan to apply image collection in GEE for next 2016 map produce…. Will be test more on Impact Tool and thinking about it, with part that could apply to our 2016 map."

3) Free and open source software - Participants found the focus on free and open source tools timely and relevant to their agency goals and budget constraints. Many mentioned their plans to share the knowledge gained about these valuable (free) resources with staff in their departments, partnering agencies, and university affiliations. Participants were especially fond of working with Google Earth Engine for exploring, pre-processing, and exporting data. When asked to provide examples of how the participants will use what they learned in their work, ten respondents specified that they will use Google Earth Engine to acquire and pre-process data. Google Earth Engine was also repeatedly cited as one of the strongest points of the training. For example:

"Image collection in GEE because it can save time and we can get cloud free image without atmospheric correction"
"GEE is a very good tool that can dowload very high resolution image free of clouds, we can mosaic the image and use it for small areas as well"

Everyone mentioned the role of free software in their wrap up presentation notes. The participants from Thailand Department of National Parks expressed their interest in slowly phasing out commercial software, while those from the Laos Department of Forestry and the National University of Laos included the budgeting freedom of the Google Earth Engine data downloading process.

"GEE is an appropriate machine to obtain the data set especially the images that no budget require for data (images)"

Limitations of the Training

Participants were also asked about the limitations of the training at the conclusion of the training. Their concerns were primarily related to software and computer issues and language challenges. Four topics emerged and are discussed below:

1) Agency computing infrastructure (e.g., access to high speed internet connection and computational power) – some of the tools demonstrated during the training require a good internet connection and high power processing computers, which at this point is unavailable at the offices of some of the participants. However, there was also recognition that these tools are very powerful and there is a need to access high speed internet to take advantage of the tools' data processing and access capabilities. For example, in their wrap-up discussion the participants from the Forestry Administration of Cambodia mentioned:

> "*Mosaic scene that download from GEE not combine in one file, and can't save direct to local Machine. So take time to download from Google Drive to Local Machine and merge in QGIS…. Easy and fast to find satellite Imagery and image mosaic and much opportunity to get cloud free image*"

The participants from the Nepal Ministry of Forestry and Soil Conservation wrote:

> "*However, for application on actual work some key limitations could be*
> - *Computational challenges (could be due to machine/memory or the tools themselves). For example: segmenting whole landsat scene….*
> - *Internet connection- when it comes to using tools such as Google Earth Engine*."

2) Software issues – Users encountered difficulty with permission levels, operating system differences (Windows 7, 8, and 10), available storage, and conflicts with other installed software. For example, there were issues with QGIS operability with newer versions of Microsoft Operating Systems (8 and 10). Additionally, there were some challenges with machines that had older versions of some of the software packages or libraries installed. Examples of issues related to this included environment variables pointing to the wrong gdal or python libraries. Finally, some participants had computers that could only run 32 bit software installs, as opposed to 64 bit.

> *"Software (QGIS) conflict with Window and that sometime stop me to practice the tools and especially run the model"*

3) Language challenges – four participants mentioned the challenge of learning in English when it is not their native language. However, they indicated that the written materials were helpful in overcoming this barrier. There was interest in translating the training manual for an in-house reference and for future trainings.

> *"English language is difficult, but it's good to have the manual to follow step by step and learn"*

4) Communication prior to the training – Three respondents indicated they would have liked to have more information prior to the training. Two were interested in knowing more about the software requirements and one was interested in knowing how technical the training material was, specifically the use of scripting in portions of the exercises. Many of the participants did not follow through to complete Google Earth Engine registration process.

Appendix C – Participants List

	Country	Name	Title	Organization	E-mail address
1	Cambodia	Ms. Hout Naborey	GIS & RS technical staff	Forestry Administration, MAFF	houtnaborey@gmail.com
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3	Cambodia	Mr. Preap Sam	Chief, Afforestation Office	Forestry Administration, MAFF	sam_preap@yahoo.com
4	Cambodia	Mr. Net Norin	GIS & RS technical staff	Forestry Administration, MAFF	netnorint@yahoo.com
5	Lao PDR	Mr. Soukanh Bounthabandid	Deputy Director, Forest Inventory and Planning Division	Department of Forestry, MAF	soukanh09@gmail.com
6	Lao PDR	Mr. Phouthone Komkieng	Technical staff	Department of Forestry, MAF	phouthon2011fipd@gmail.com
7	Lao PDR	Mr. Somxay Phaophongsavath	Technical staff	Department of Forestry, MAF	somxay1986@gmail.com
8	Lao PDR	Mr. Daovorn Thongphanh	Graduate Student	National University of Lao	daovornth@yahoo.com
9	Nepal	Mr. Prakash Singh Thapa	Assistant Forest Officer, REDD Implementation Centre	Department of Forest Research and Survey	seasoniof@gmail.com
10	Nepal	Ms. Sangita Shakya	Assistant Cartography Officer	Department of Forest Research and Survey	sangita_bajra@yahoo.com
11	Nepal	Mr. Shiva Khanal	Remote Sensing Officer	Department of Forest Research and Survey	khanalshiva1@gmail.com
12	Nepal	Mr. Bimal Khumar Acharya	Assistant Research Officer	Department of Forest Research and Survey	dangalibimal@gmail.com
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Appendix D – About SilvaCarbon

Overview

SilvaCarbon is an interagency technical cooperation program of the U.S. Government (USG) to enhance the capacity of selected tropical countries to measure, monitor, and manage forest and terrestrial carbon, and more accurately estimate greenhouse gas (GHG) emissions resulting from changes in land use, forest cover, and forest degradation. SilvaCarbon helps advance Reducing Emissions from Deforestation and Forest Degradation (REDD+) and other climate change mitigation and development initiatives by working with technical teams at government agencies in partner countries to design and implement credible landscape monitoring systems and GHG inventories that feed into international reporting frameworks such as the United Nations Framework Convention on Climate Change (UNFCCC).

Drawing on the strengths of USG technical agencies and partners from academia, non-governmental organizations, and industry, SilvaCarbon builds capacity by supporting direct technical assistance, hands-on training, workshops and study tours, South-South cooperation, and applied research.

The program engages the following twenty-five countries through a combination of bilateral and regional activities, research partnerships, and in-country technical advisors:

> Africa: Cameroon, Democratic Republic of Congo, Gabon, Republic of Congo, Zambia
> Americas: Belize, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru
> Asia: Bangladesh, Cambodia, Indonesia, Lao PDR, Nepal, Philippines, Thailand, Vietnam

Organization and Funding

SilvaCarbon is cooperatively managed by eight USG agencies: the U.S. Agency for International Development (USAID), U.S. Department of State, U.S. Forest Service (USFS), U.S. Geological Survey (USGS), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and Smithsonian Institution. Program implementation is led by USFS, USGS, EPA, and NASA.

SilvaCarbon is a U.S. contribution to the Global Forest Observations Initiative (GFOI), a body of the intergovernmental Group on Earth Observations (GEO). GFOI supports countries' access to and application of Earth observation data for national forest monitoring systems. SilvaCarbon leads the capacity-building component of GFOI.

Funding for SilvaCarbon is provided through the USAID Sustainable Landscapes Program (Bureau for Economic Growth, Education, and Environment); the U.S. Department of State Office of Global Change (Bureau of Oceans and International Environmental and Scientific Affairs); in-kind contributions from other SilvaCarbon member agencies; and contributions from USAID Missions in participating countries.

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Appendix E - About ReCaREDD Project

The project ReCaREDD

The lead objective of the project ReCaREDD (Regional Capacities for REDD+) is to enhance the ability of institutions in partner countries to report on forest degradation, in a reliable and cost-efficient manner. Where assessing a percentage of carbon loss per ha (relative to previous carbon carrying capacity) proves too difficult, it would at least help identifying forest area exposed to degradation and deriving proxy estimates of associated carbon fluxes.

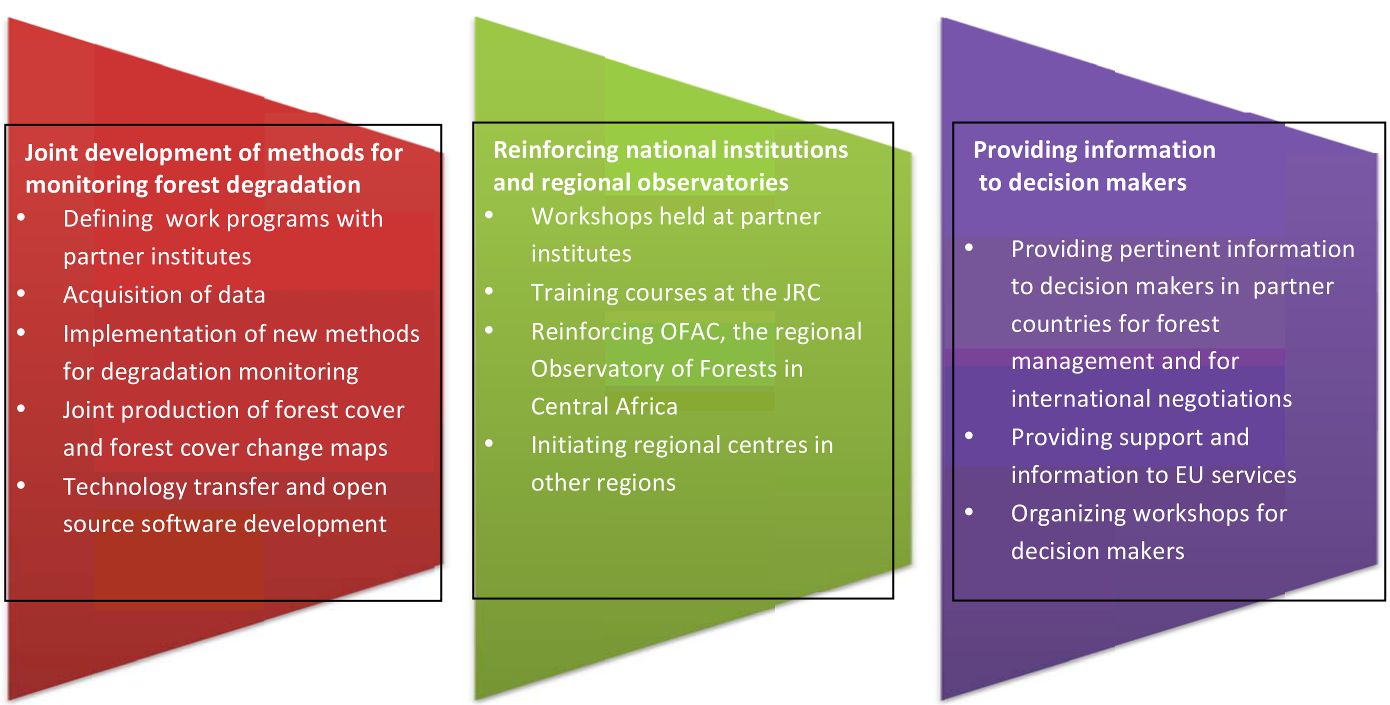
Further objectives are to develop, share and adapt appropriate monitoring methods and to provide direct assessments of the status and evolution of tropical forest cover in support to forest policies and national and international negotiations on emission reductions and biodiversity conservation (UNFCCC, CBD). The project is funded by the European Union (Thematic Program Environment and Natural Resources) and implemented by 10 experts from the Joint Research Centre of the European Commission, based in Ispra (Italy). A dozen partner countries will be involved, the majority in Africa.

The principal activities of the project

The ReCaREDD project aims to respond to these challenges by:

- joint methodological developments for monitoring forest degradation,
- actions to strengthen capacity including training and workshops at national or regional levels,
- strengthening the Forest Observatory of Central Africa (OFAC) or creating new regional observatories, as appropriate,
- and providing thematic analysis to decision-makers in the EU and partner countries.

The project is organized in three complementary pillars with sub-activities which are detailed in the figure below.



Focus Countries

For the initial phase, methodologies and satellite imagery will be tested in 'Focus Countries'. These 'Focus Countries' include:

- in Africa: Cote d'Ivoire, Cameroon, Rep. of Congo., Dem Rep. of Congo, Tanzania and IGAD countries
- in Southeast Asia: Cambodia, Laos and Vietnam
- in South America: Colombia

Institutions from other tropical countries are welcome to access methodologies and forest monitoring tools developed by the project, as well as to contribute and participate in workshops organized by the project ('Associated Countries').

Project Resources

The project duration is scheduled for four years (November 2013 to October 2017). A team of experts at the JRC will be involved in the project implementation, including 4 permanent Scientific Officers (one general plus three regional coordinators), 5 non-permanent Scientific Officers and one External Service Provider. The total budget amounts to 5 Million Euros.

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Appendix F –Open Foris initiative and tools

About Open Foris

Open Foris is an FAO-led initiative to develop, share and support specialized software tools required by countries and institutions to implement multi-purpose forest inventories. It is a set of free and open-source software tools that facilitates flexible and efficient data collection, analysis and reporting. These tools are used to support countries in gathering, producing and disseminating reliable information on the state of forest resources that is vital to decision makers and other stakeholders. Emphasis is placed on building sustainable capacity through the free sharing of all tools, documentation and source-code, thus promoting self-sufficiency, transparency and vendor independence. In addition, being open-source means Open Foris software's inner workings are open to review by peers, promoting higher quality tools and encouraging and facilitating partner contributions.

The initiative was created under the FAO-Finland Forestry Programme in collaboration with FAO's support to National Forest Monitoring and Assessment (NFMA) and the UN-REDD Programme to address the growing need for accurate and timely information on the state of forest resources and their use and users. Applying FAO's broad experience in forest monitoring, Open Foris addresses cross-cutting needs through a set of highly flexible, easy-to-use software tools. Through FAO's global network of partners and experts, tools are designed, tested, applied and improved to ensure they are relevant and provide real value to beneficiaries.

Open Foris tools are being built to support the entire inventory lifecycle, from needs assessment, design, planning, field data collection and management, estimation analysis, and dissemination. Remote sensing image processing tools are included, as well as tools for international reporting such as for REDD+ Measurement Reporting and Verification (MRV) and FAO's Global Forest Resources Assessment (FRA).

Not all stakeholders have the same needs and capacity. To address this, Open Foris is not designed as a single program or database, but rather as a set of software tools and standards which may be mixed and matched to best fit user needs. Where applicable, open standards are used, guaranteeing maximum interoperability with existing local, national and international systems and infrastructure. Application of standards also facilitates data portability, guaranteeing data is accessible independent of future technology decisions.

Open Foris software tools

A) Open Foris Collect

Open Foris Collect is the main entry point for data collected in field-based inventories. It provides a fast, easy, flexible way to set up a survey with a user-friendly interface. Collect handles multiple data types and complex validation rules, all in a multi-language environment.

B) Open Foris Geospatial Toolkit

Open Foris Geospatial Toolkit is a collection of command-line utilities for processing of geographical data. It aims to simplify the complex process of transforming raw satellite imagery for automatic image processing to produce valuable information. It is particularly useful for processing big amounts of raster data, and provides a wide range of functionalities including image manipulation, statistics, segmentation and classification. The tools have been tested mainly in Ubuntu Linux environment although can be used with other linux distros, Mac OS, and MS Windows (Cygwin) as well. Most of the stand-alone programs use GDAL libraries and many of the scripts rely heavily on GDAL command-line utilities.

C) Open Foris Calc

Open Foris Calc is a robust tool for data analysis and results calculation. The input data and metadata come from Open Foris Collect and Calc provides a flexible way to produce aggregated results which can be analyzed and visualized through the open source software Saiku. Calc allows expert users to write custom R modules to perform calculations working with a variety of sampling designs.

D) Collect Earth

Collect Earth is a tool that enables data collection through Google Earth. In conjunction with Google Earth, Bing Maps and Google Earth Engine, users can analyze high and very high resolution satellite imagery for a wide variety of purposes, including:

- Support multi-phase National Forest Inventories
- Land Use, Land Use Change and Forestry (LULUCF) assessments
- Monitoring agricultural land and urban areas
- Validation of existing maps
- Collection of spatially explicit socio-economic data
- Quantifying deforestation, reforestation and desertification

E) Collect Mobile

Collect Mobile is a fast, intuitive and flexible data collection tool for field-based surveys. This Android app allows the completion of complex data structures, such as biophysical, socio-economic or biodiversity surveys. Its many features include:

- On-the-fly validation to improve data quality
- Handling of large lists of species or other attributes
- Geo-location through embedded GPS
- Integration with Collect for data management, analysis and export to commonly used formats
- Processes inputs and calculates attributes for quality control in the field

Further information

Food and Agriculture Organization of the United Nations, Forestry Department: http://www.fao.org/forestry/en/

Open Foris: http://www.openforis.org/home.html

Appendix G – About RSAC

The Remote Sensing Applications Center (RSAC) is a national technical service center of the USDA Forest Service. The mission of RSAC is to provide the Forest Service with the knowledge, tools, and technical services required to use remote sensing data to meet the agency's stewardship responsibilities. At RSAC, a structured program of work creates science-based information that supports the assessment and monitoring of natural resources.

Program Areas

The RSAC is organized into the following four program areas:

Remote Sensing Evaluation, Application & Training (RSEAT)

The Remote Sensing Evaluation, Application & Training program evaluates new remote sensing technologies and integrates promising technologies into Forest Service business functions.

Rapid Disturbance Assessment & Services (RDAS)

The Disturbance Assessment & Services program provides tactical and strategic support to Forest Service units and external partners in response to disturbance events.

Resource Mapping, Inventory & Monitoring (RMIM)

The Mapping, Inventory & Monitoring program provides operational remote sensing support and analysis services to help meet internal and interagency programmatic assessment and monitoring needs.

Enterprise Data & Services (EDS)

The Enterprise Data & Services program coordinates with Forest Service and USDA CIO organizations and agency technology users to evaluate and provide enterprise remote sensing technology and data.

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