Forest Monitoring in Indonesia: Using an extensive LiDAR data set to map forest carbon stock and logging impacts

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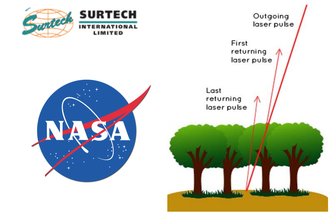

Introduction

Around the world, governments are establishing **national forest monitoring systems (NFMS)** that use a combination of remote sensing and ground-based forest carbon inventory approaches to estimate anthropogenic forest-related greenhouse gas emissions and removals. The creation of a reliable, transparent, and comprehensive NFMS is currently limited by a dearth of relevant data that are accurate, low-cost, and spatially resolved at subnational scales. In this project, we are developing, evaluating, and validating several critical components of an NFMS in **Kalimantan, Indonesia**, focusing on the use of LiDAR and radar imagery for improved carbon stock and forest degradation information. We aim to evaluate sensor and platform tradeoffs systematically against *in situ* investments, as well as provide **detailed tracking and characterization of uncertainty** in a cost-benefit framework. While our work focuses at the subnational scale for Kalimantan, we are targeting these methods for applicability across broader geographies and for implementation at various scales.

Project Goals and Objectives

Our two primary **project goals** are to:

1) assist REDD+ stakeholders by **contributing relevant data products**; and
2) develop **improved methods** that are useful across regions and are cost effective to map biomass, deforestation and carbon loss from deforestation and degradation

These goals will be met through **three objectives**:

a) develop an uncertainty tracking system for NFMS;
b) map carbon emissions associated with forest degradation from timber harvesting using LiDAR and radar; and
c) produce improved wall-to-wall forest carbon stock maps using LiDAR, radar, and optical data.

Task Overview

1. **Collect airborne LiDAR data** from 25 transects across Kalimantan and an additional six sites in logging concessions where extensive field measurements have been (COMPLETED);
2. In the field, measure **forest structure and biomass** and estimate forest **carbon flux associated with logging** (six regions) (COMPLETED);
3. Relate **LiDAR to forest carbon** in multiple types of forests, including logged areas (ONGOING);
4. Calibrate PALSAR, Landsat, & MODIS data to the field and LiDAR observations to **map forest carbon stocks across Kalimantan and estimate carbon emissions associated with logging** (COMING SOON);
5. Create **software tools to track uncertainty** from the field sampling and measurements through final wall-to-wall maps (ONGOING);
6. Conduct a complete **assessment of the trade offs** (i.e. cost vs. accuracy) in using field inventories, LiDAR, radar, and optical data to produce accurate forest carbon maps. (COMING SOON);

LiDAR Data Across Kalimantan

LiDAR provides a 3-D representation of the forest and is useful for estimating carbon content across a full range of forest types and conditions. Our algorithms extract from these point clouds tree counts, gaps, gap sizes, and relative vegetation density (useful for logging analysis), as well as tree heights and biomass distributions.

LiDAR observations have been collected over 104,000 ha of forest across Kalimantan between 18 October and 30 November 2014 by the Jakarta-based company Surtech. The data are collected in strips 250-500 m wide with a pulse density ranging from 4 ppm to 10 ppm. Data are delivered as LAS point cloud files and have accompanying aerial photos at a resolution of approximately 7 cm.

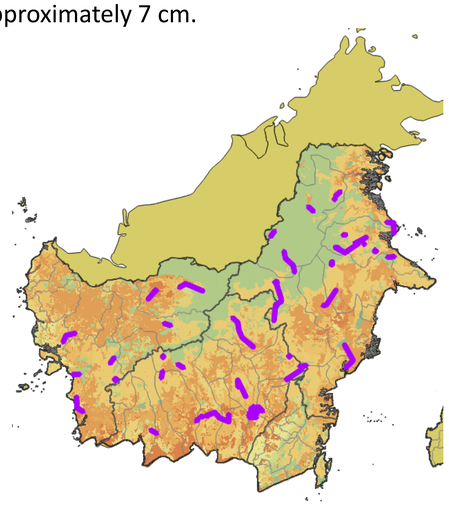

Figure 1: Our 2014 LiDAR campaign covers 104,000 ha across the Indonesian portion of the island of Borneo (i.e. Kalimantan)

The conversion of raw LiDAR observations into useful information on forest structure requires an intensive, multi-stage processing routine. Traditionally, this processing has been achieved with expensive commercial software packages. One of our objectives in this project has been to achieve high quality results using an open source processing pipeline, accessible to all without requiring expensive licensing. We have achieved this objective by integrating ***pdal ground*** and ***points2grid*** (***p2g***), allowing complete pipelines of classification, filtering, and DEM generation.

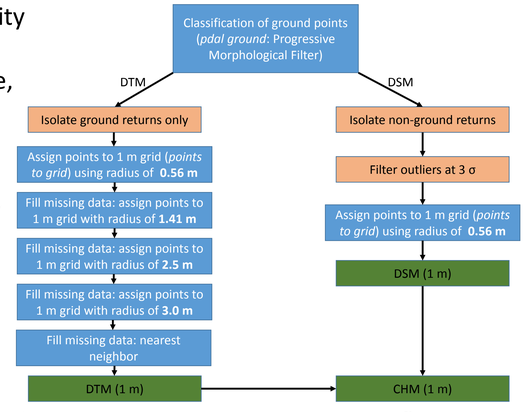

Figure 2: Open Source LiDAR processing flow.

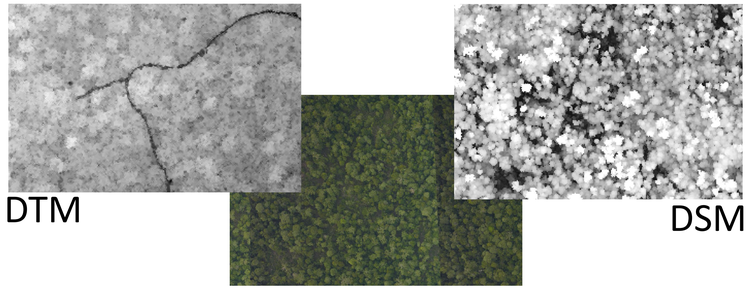

Figure 3: DTM and DSM results from the Mawas region of Central Kalimantan

We have collected two types of field measurements in Kalimantan:

1) Forest structure for above ground biomass estimation including plot measurements of diameter at breast height (dbh), tree height, and canopy dimensions.
2) Estimate of forest carbon loss due to logging, including the biomass extracted as the timber log, the biomass of the remaining crown and stump left behind, trees killed due to incidental damage of timber operations, and biomass cleared for the creation of logging roads, skid trails and logging decks.

Figure 4: We are collating and standardizing field observations of biomass and logging impacts from across Kalimantan for calibrating and validating the LIDAR.

Team

Our core project team includes scientists from seven institutions in three countries. We have experts in forest carbon science and remote sensing disciplines . Collaborations include the Indonesian space agency (LAPAN) and the Tropical Forest Foundation. We established collaboration with ongoing and recently completed forest carbon projects in the region to continue to build upon the successes achieved to date.