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MULTI-TEMPORAL AIRBORNE LIDAR-SURVEYS IN 2007 AND 2011 OVER TROPICAL PEAT SWAMP FOREST ENVIRONMENTS IN CENTRAL KALIMANTAN, INDONESIA

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SUMMARY

In August 2007 and 2011 we mapped by helicopter different Peat Swamp Forest (PSF) transects with Riegl LiDAR Technology (LMS-Q560) and high-resolution Hasselblad camera in Central Kalimantan, Indonesia. Pairwise comparisons of nearly coincident LiDAR footprints at the Sabangau transect (e.g. 14km) over a period of four years showed canopy height changes up to 12%. On average, the canopy height increased from 15.32m to 17.18m. Additionally, we measured biomass growth with the LiDAR change detection method and subsidence of open degraded peatland. This work could be promising in the framework of the REDD+ (Reducing Emissions from Deforestation and forest Degradation) knowledge of tropical PSF. The LiDAR technology supports the MRV aspect of REDD+ (Monitoring, Reporting, Verification).

KEY WORDS: Peat Swamp Forest, LiDAR, ALS, Kalimantan, REDD.

INTRODUCTION

Peat swamp forests are known for their rich biodiversity and huge amount of underground carbon storage but their areas have been decreasing due to conversion into farm land by excessive draining, illegal logging, shifting cultivation and recently by plantations of palm oil trees on a commercial scale (Boehm & Siegert, 2004). The implications of increasing forest degradation in peat swamp forest environments, their relationships with the occurrence of fires and their impact within global climate systems are still not well understood (Page et al., 2002). Furthermore, the amount of carbon released to the atmosphere due to anthropic interventions in the forest such as logging activities also remains a big challenge (Asner et al., 2005).

The awareness of greenhouse gas emissions from peat swamp forests has created strong political support for reducing emissions from deforestation and degradation (REDD) as well as increasing the interest for understanding such endangered environments from an ecological point of view (Sorensen 1993; Page *et al.*, 2002; Jaenicke *et al.*, 2008). Interventions to the forest may cause changes in water table level leading to subsidence of peat domes, affecting therefore peat decomposition and increasing fire risk and carbon fluxes from peat to the atmosphere (Jauhiainen *et al.*, 2005).

Airborne laser scanning (ALS), also termed airborne Light Detection and Ranging (LiDAR) becomes a good option for monitoring such environments. LiDAR is an optical remote sensing system that measures properties of the scattered light to find range and/or other information of a certain target of interest. The laser emits a light pulse which is scattered (reflected) from the target back to the sensor. By measuring the round trip time of an emitted laser pulse from the sensor to a given surface and its return, the distance from the sensor to the surface is then determined.

Consequently, LiDAR is depended on the distribution of canopy elements on the terrain such as foliage, branches and trunks, as well as the underlying ground surface. In fact, it can directly define the third dimension of forest layers and the relief under dense forest canopies. It is a valuable source for generation of both digital relief models and detailed topographical analysis for peat swamp forests stands.

In August 2007 and 2011, different transects were mapped from a helicopter with Riegl LiDAR technology LMS-Q560 and high-resolution Hasselblad camera H39 supported by field inspection in Central Kalimantan, Indonesia. In this study, the main objectives were: a) to characterize the peat swamp surface using both LiDAR derived terrain and surface models; b) to characterize biophysical property variations along a peat dome transect; and c) to demonstrate the applicability of LiDAR technology to evaluate change detection based on multi-temporal LiDAR acquisition for biomass growth and loss including subsidence.

MATERIAL AND METHODS

Our investigation consists of different LiDAR transects located inside Central Kalimantan Province, Indonesia. A subset of Landsat-7/ETM+ images acquired on August 5, 2007 shows the location of transects (Fig. 1). LiDAR measurements were orthorectified resulting in an elevation accuracy of each Laser beam better than ±0.15m with a root mean square error (RSME) of ±0.5m in both x- and y-directions. The achieved average point density per square metre ranged from 1.4 to 3.0 points (i.e. laser beams). The ground backscattering was responsible for 1 to 3% of the 0.5mrad Laser beams in dense canopy coverage areas of our selected transects. The selected transects represent different relief conditions of peat domes and intensities of forest degradation.

The processed laser beams were divided into ground surface and overground classes using a terrain-adaptive bare earth extraction algorithm. Later, they were converted in order to digital terrain model (DTM) and digital surface model (DSM), respectively, at a spatial resolution of 1m. Furthermore, at a single date, the difference between the DSM and DTM provided us the canopy tree height model, which also includes the heights of manmade structures. On the other hand, differences between multi-temporal DTMs (e.g. 2011 minus 2007) represents changes of the relief surface whereas the differences in canopy tree height models the forest changes. The peat subsidence was measured with the DTMs for 2007 and 2011.

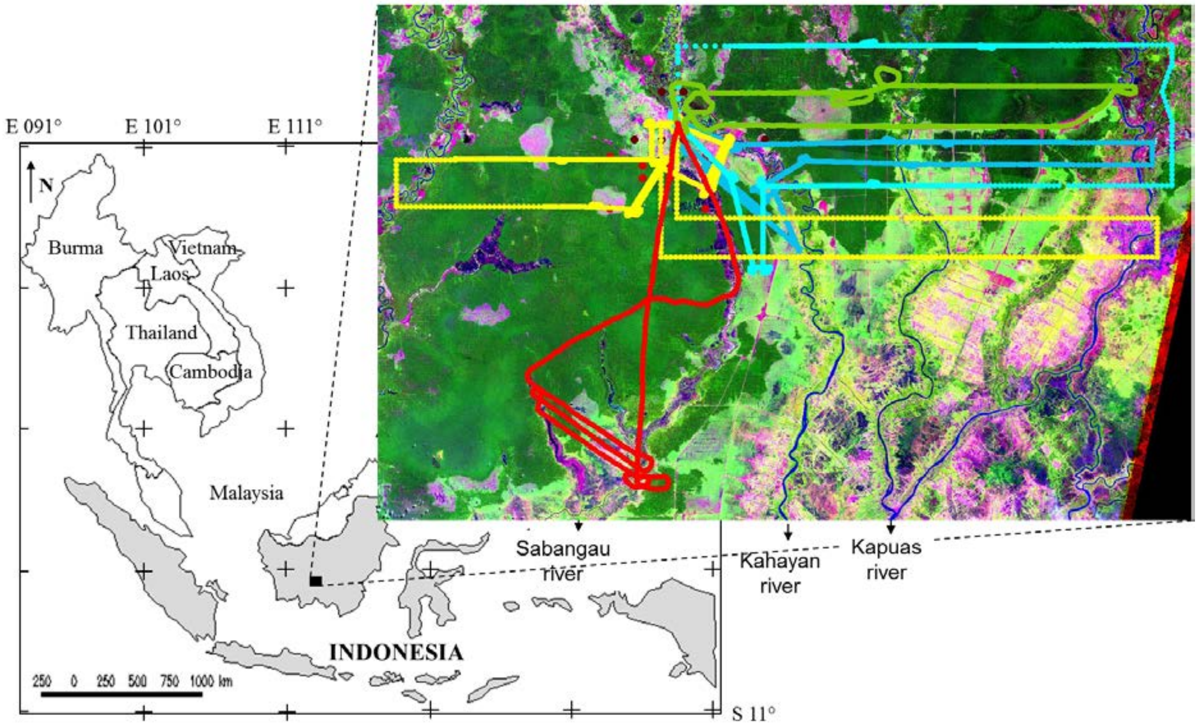

Figure 1. Study Area location with different LiDAR survey helicopter trials.

Observation data were compiled from 51 1-ha sample plots (i.e. 100x100m) with the aim to represent both forest and ground heterogeneity. The sample plots were distributed in the flown acquisition of each LiDAR transect keeping a variable space between two sample plots. We extracted both DTM and DSM values for each measurement transect. In the terrain analysis we only account for the lowest values of the DTM in order to minimize the inclusion of the return signal coming from tree trunks and branches lying on top of the peat surface.

RESULTS AND DISCUSSION

A subset of the LiDAR data adquired for the Sabangau transect is shown in (Fig. 2). In this figure, the vertical structure of the vegetation is illustrated with detail to the classification of the laser cloud points into ground surface (pink) and vegetation (green) (Fig. 2a). A subset of the LiDAR transect where the vertical structure profile was extracted is shown in (Fig. 2b).

A subset of the orthorectified high-resolution Hasselblad camera shows the base camp at the “Setia Alam” Field Station that is the Orang-Utan Tropical Peatland Project (OuTrop) and the Centre for International Cooperation in Sustainable Management of Tropical Peatland (CIMTROP) primary research site and base camp (Fig. 3a) and the temporary camp at km 8 along that transect (Fig. 3b). The use of high resolution images allows us to identify individual trees as well as the current land use of the region. Such information is very useful for the classification procedures using ALOS/PALSAR and Landsat over the entire area. Interestingly was the identification in situ of small logged areas inside the Sabangau forest used for bat trapping.

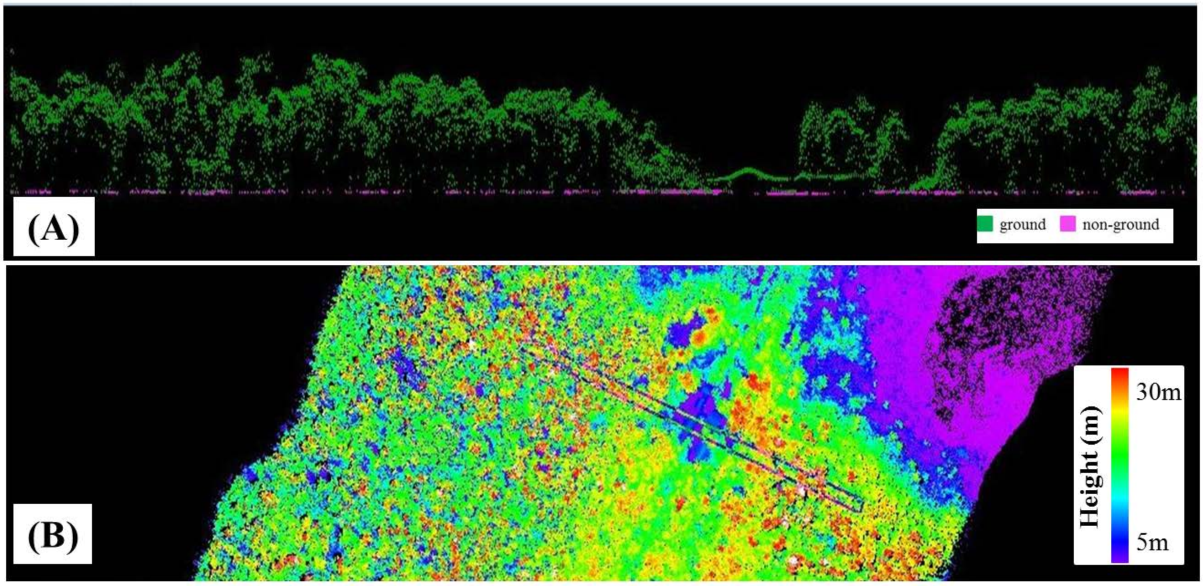

Figure 2. Subset of the LiDAR transects showing the beginning of the Sabangau transect as profiles of trees, huts and ground (A) and the top view of the Sabangau base camp area (B).

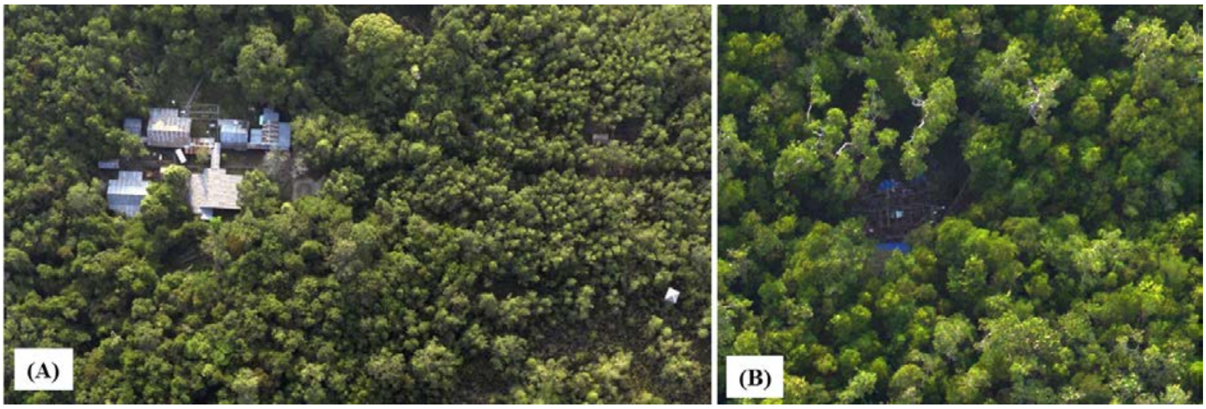

Figure 3. A subset of the orthorectified high-resolution Hasselblad camera for the "Setia Alam" Field Station called base camp (A) and the temporary camp at km 8 (B).

Field measurements at selected physiognomies on the field showed good relationship between diameter at breast height (DBH) and tree height. In general, the relationship increased from riverine to mixed peat swamp forest and tall pole (Fig. 4). Such information will be useful to derived DBH information from LiDAR derived tree canopy height. Afterwards, a better estimate of biophysical parameters is expected. Tree height increases generally from the riverine peat swamp forest to low pole and then to the mixed and tall pole peat swamp forest physiognomies. Although the Sabangau forest was strongly influenced by previous logging activities, the tallest trees were found at higher slopes (Boehm *et al.*, 2010). In this figure, a clear influence of previous logging activities is also confirmed due to the absence of certain DBH and tree height intervals (e.g. DBH > 30cm). Additional information such as plant area index and canopy coveraged extracted from hemispherical photographs will be used for a better description of the peat swamp forest physiognomies towards the transect.

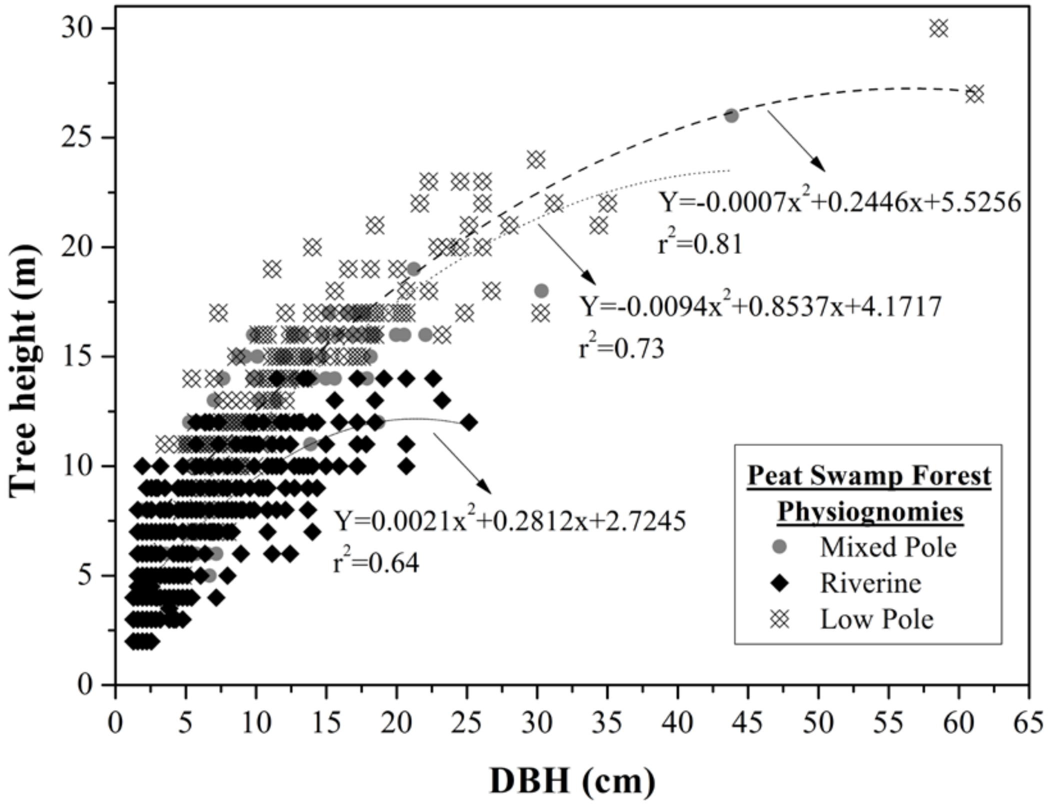

Figure 4. Relationship between DBH and tree height for different peat forest physiognomies along the Sabangau transect.

Pairwise comparisons of nearly coincident LiDAR derived canopy tree height models at the Sabangau transect (i.e. with 14km) in the period of four years showed that canopy height changes up to 12%. In average, the canopy height increased from 15.32m to 17.18m (Boehm *et al.*, 2011). This is a clear indication of the importance of this conservation unit for the regrowth of the peat swamp forest and strongly supports the work conducted by Hoscilo *et al.* (2011) who observed high forest degradation rates outside conservation units in Block C of Central Kalimantan. The research was conducted based on multi-temporal Landsat images and confirmed the importance of the establishment of conservation units in this endangered biome. On the other hand the forest regrowth in some less degradated forest (e.g. some areas at Mawas region) showed a lower regrowth due to lower logging activity in the past.

Besides vegetation and biomass regrowth analysis, subsidence measurements of opened peatland are a major problem for rehabilitation of the ex-the Mega Rice Project (MRP) that was located in Central Kalimantan (Boehm & Frank, 2008). Other researchers used a measuring method based either on strong pillars in the ground or by GPS measurements for such analysis. We proposed here a LiDAR topography change detection method by comparing five sample plots of 50x50m on LiDAR derived DTM for an area in upper Block C, we observed a change detection of 28cm (+/-2.9cm) subsidence in the period of 4 years (i.e. between 2007 and 2011) (Fig. 5). This peatland is relatively near to one channel of MRP. Hence, details of the peat swamp management such as drainage pattern changes caused by the construction of dams are also observed. Finally, a huge subsidence value was found near to the main double channel of MRP in bocks A +B, whose results are expected to be presented during the IPS Congress.

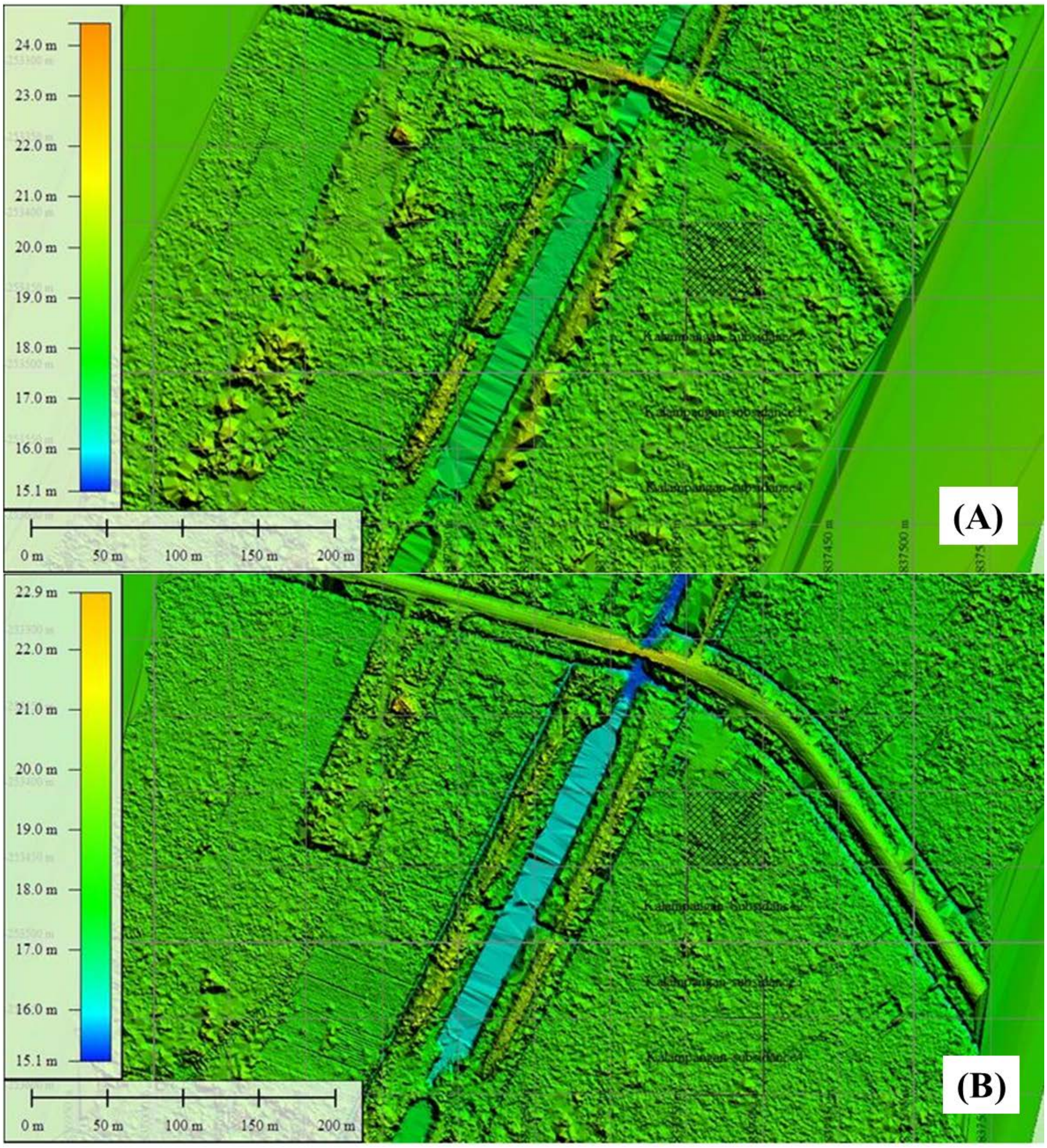

Figure 5. Subsidence LiDAR measurements of 28cm between 2007(A) and 2011(B) in the upper part of Block C.

CONCLUSIONS AND FURTHER WORK

LiDAR measurement is nowadays the most accurate remotely sensed way to characterize peat swamp forest environments at a regional scale. LiDAR data may be used to understand and evaluate peat ground surface and vertical structure of the forest that are required to enable spatial mapping of estimated forest biomass. We intend to estimate forest attributes for peatland at a regional scale using the LiDAR derived attributes and field work data. In order to assure a better coverage of the entire area we intend to explore the potential of the integration of both SAR and optical data for biomass estimation.

Understanding peat swamp forest and their dynamics is important once we consider that the last remnants of peat swamp forest are located in Kalimantan. The region is suffering high rates of deforestation mainly due to the frontier of new pailm oil and pulp and paper plantations. In the coming years, as indicated by political support for reducing emissions from deforestation and degradation (REDD) long-term monitoring of the peat domes will be crucial to quantify changes in carbon stocks of the peat swamp forest, and to evaluate forest growth response to climate and land use change.

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