13th International Peat Congress
8 to 13 June 2008, Tullamore, Ireland

For Section 5: Tropical Peatlands

Peat Dome Measurements in Tropical Peatlands of Central Kalimantan with a high-resolution Airborne Laser Scanner to achieve Digital Elevation Models

by
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ABSTRACT / SUMMARY

With a high-resolution Airborne Laser Scanner (ALS) the topography of peatlands was measured in August 2007 by a helicopter. With this modern technology we achieve a 3-dimensional Digital Elevation Model (DEM), hydrological data, and bio mass data and combined with peat drillings the amount of carbon storage. The ALS-resolution is in elevation (z) +/-15cm and in x- and y-direction 0.5m. Compared to SRTM-images with 90m x 90m x 5m and Landsat-Satellite-images with 30m x 30m (without elevation) we got much better knowledge of peatlands.
DEMs are divided into two types of groups. The Digital Surface Model (DSM) gathers information by Laser Scanner with trees, bridges and house and the Digital Terrain Model (DTM) is filtered using the DSM and shows the topography of landscape without trees, bridges, houses etc. The infra-red Laser sends 100,000 pulses per second and receives many of them in the detector and determines the distance to the different objects.

The study area was the Ex-Mega Rice Project (MRP) Blocks A, B, C, E and the Sebangau National Park between the rivers Sebangau, Rungan and Katingan. Results will be presented only for the area between the rivers Rungan and Katingan at the upper part of Sebangau National Park.

To understand better the situation of that area peat drillings have been done in 4-2006 parallel to the Kalimantan highway along the transect Tangkiling and Kasongan and in 7-2007 from Katingan river to transmigration village Habaring Hurung south of Tangkiling. Results of these peat thickness measurements showed a peat depth up to 8.10 m res. 10.0m. The peat surface with peat dome was measured along the two transects using the ALS technology with 49.1m res. 40.8m. The airborne Laser penetrates the Peat Swamp Forest (PSF) and reaches the peat surface. We measured an average tree height of 35m

The stored peat volume and carbon for the northern Sebangau Catchment and Palangkaraya between Katingan and Rungan rivers up to the border of the heath forest has 7.1 Gm^3 (res. 5.93 Gm^3) peat volume. The content of carbon in 1 cubic meter of peat has been measured and is 154.3kg res. 131kg. We found by ALS-measurements and Peat drillings and interpolation a stored Carbon value of **0.92 to 1.1 Gtons** for this area.

Keywords: Peatland, Peat Dome, GIS, Airborne Laser Scanning, Peat Drilling, Digital Elevation Model, Carbon Storage, Central Kalimantan

INTRODUCTION

Tropical Peatland has been accumulated between the Rivers Rungan and Katingan in Central Kalimantan during the last 10,000 years with more than 3 Mio. ha. Since the 1980s peatland and Peat Swamp Forest (PSF) is being cleared for the construction of the Kalimantan highway between the rivers Rungan (at Tangkiling) and Katingan (at Kasongan). Before then access to that area of peatland was only possible by boat (Sieffermann et al. 1988, Rieley and Page 1997, Boehm and Sulistiyanto 2006). Since then land development projects have taken place in form of human settlements, agricultural activities and plantations, which have greatly increased the risk of peatland fires during the dry season. In 1997, 2002 and 2006 El Niño prolonged the dry season considerably increasing the risk of fire. With the help of Remote Sensing, a Geographical Information System (GIS) and Airborne Laser Scanning (ALS) an exact survey is possible, providing information as changes in the landscapes and the situation of the environment. An integrated planning and management program has been achieved.
Kalteng Consultants has performed together with the German company Milan Geoservice GmbH many ALS-Helicopter Flight Trials in Central Kalimantan from 5th to 10th August 2007. The preparation of this high-technological flight campaign was not easy and took several months. Finally every thing came together like a miracle, e.g. the availability of the ALS-equipment, the procedure at the custom, the availability of the helicopter with an excellent pilot, good weather conditions, the procurement of many recommendation letters and a marvellous team, see Fig. 1.

The purpose of these trials was to get high-resolution three-dimensional information from the landscape in form of the topography, to measure the tree-height and to estimate the bio-mass, to get knowledge of the peat dome in that huge peatland area including data of carbon storage, the shape of the river basin Katingan and Rungan, to scan the Tangkiling mountains with Rungan Sari, to scan the Small Scale Gold Mining (SSGM) activities at Galangan, Kereng Pangi near the city Kasongan.
The ALS-data and ortho-photos have been processed and analysed and will be presented here for the upper Sebangau peatland area.

Fig. 1. German-Indonesian ALS team in front of Bell 206-Helicopter in Central Kalimantan: Juergen Frank, Detlef Klante, Suyud, Alam, Viktor Boehm, Jan Giehler and Mustafa Syafrudin

Geographic location of the research site
The Tangkiling District is located to the North of Palangkaraya in Central Kalimantan and has 7 unusual granite hills in the normally flat lowland peat land topography with high annual precipitation. Tangkiling village is located 34 km from Palangkaraya, the provincial capital, on the Kalimantan highway to Sampit. Approx. 45 km away from Tangkiling (79 km from Palangkaraya) is located the city Kasongan capital of the Katingan district on the Katingan river. Between the two rivers a huge amount of peat has been accumulated up to more then

10m depths. In order to estimate the stored carbon and to measure the precise water shed of the peat dome, peat drillings were carried out in spring 2006 with a distance of 500m parallel to the highway with each drilling 200m apart from the road. This research area is located in the northern part of the so called Sebangau Peatland Catchment and reaches up to the boarder between PSF and heath forest.
Landsat ETM images 118-61 acquired on 30 June 1991, on 16 July 2000 and 15 Feb 2003 were compared by using detailed analysis of the region around the Tangkiling granite hills and the black water rivers Rungan and Katingan. These images show major changes in this large remnant of tropical peatland due to high rates of deforestation and fires in 1997, 2002 and 2006 (Page et al. 2002, Boehm et al. 2000, 2003, 2004). The 1991 and 2000 Landsat images show very clearly in different green colours the different PSF types and peat lands, see Fig. 2. With the peat drillings we analyzed the types of peat soil and the peat thickness. The ground survey confirmed the areas of tall and medium PSF showing by different green colours in the Landsat images. Also the peat volume and carbon was estimated in this area. Additionally we used SRTM-Data with the DEM information of approx. 5m in elevation. They were acquired in Feb. 2000 by the Shuttle Radar Topography Mission.

METHODOLOGY

Technical equipments of Airborne Laser Scanning

The following equipments were used during the helicopter flight trials in August 2007.

- Inertial Navigation System (INS)
- Flight Management System (FMS)
- GPS-Antenna L1/2-band located at the helicopter tail boom and a
- DGPS-ground station
- ALS Equipment with Riegl Technology, LMS Q560,
- Several Recorder and a
- Digital RGB camera from Hasselblad with 22 MB pixel
- Power supplies and a mechanical support structure under the helicopter
- Displays in the helicopter

LMS-Q560 Airborne Laser Scanner	
Range	30 - 1500 m
Laser Puls Rate	Up to 100 000 Hz
Laser Wavelength	near Infrared
Beam Divergence	0.5 mrad
Scanner Unit	rot. Polygonmirror
Scanning Type	Parallel Lines
Scanning Speed	5 -160 scans/sec
Measuring Accuracy	±20 mm
Scan angle	± 22.5° and ± 30°
Min. Step Width	0.004° @ 100000 Hz
Wight	20 kg
Power	120 Watt

The Airborne Laser Scanner transmits Laser pulses which will be reflected from the sureface of the earth and received by the Laser Detector.

Table 1. Parameter of Airborne Laser Scanning System.
We preferred the +/- 30° scan angle in approx. 500m flight altitude above ground

Peat Drilling and Carbon estimation

We used the normal peat drilling equipment and two Global Positioning Sensors (GPS) and a compass, ref. Boehm et al. 2006, see tracks in Fig. 2. Along the transect Kasongan at km79 to Tangkiling at km34.5 we drilled every 500m parallel to the Kalimantan highway at 200m

distance peat holes to measure the peat thickness. Peat samples from 0 - 20 cm depth and the mineral soil below the peat were taken for pH, C and nutrient analysis to the Analytical Laboratory at Palangkaraya University. Additionally water samples were brought from the seven small rivers crossing the road to the laboratory for pH analysis. Nutrient analysis for the mineral soil was carried out on three samples near Tangkiling area for Rungan Sari and Transmigration area km38.
The UNPAR staff drilled along the transect between river Katingan to transmigration village Habaring Hurung in July 2007. They drilled every 700m peat holes to measure the peat thickness. This area is covered by PSF and has a difficult access. Carbon, C, analysis was carried out on 22 samples and bulk density analysis on 12 samples. pH value of the mineral soil below the peat was analysed for 21 samples along the transect (Sulistiyanto 2004).

	Parameter	Method
1	Peat, mineral soil, and water pH	pH meter
2	C-organic	Loss on ignition
3	Bulk Density	Ring sample
4	N total	Kejhdahl method
5	Available P	P-Bray 1
6	K, Ca, Mg, and Na exchangeable	Ammonium Acetate pH 4.8
7	C E C (Cation Exchange Capacity)	Ammonium Acetate pH 4.8
8	Texture	Pipette method

Table 2. The method used for peat and mineral soil analysis

Data Processing

Land cover classes with peat land and PSF types:

Basic image processing was done using the Remote Sensing Software ENVI4.2. With a GPS points were collected during peat drillings using the waypoint mode of the GPS and during the ALS-helicopter flights we collected the GPS-tracks. With the GIS software ArcGIS 9.2 the peat drilling locations were superimposed to the SRTM and LANDSAT images from 2000 (Boehm & Siegert, 2000, Boehm et al. 2003, 2004, 2006). The analysis was made first by visual interpretation of the satellite images.

ALS-DEM Data Processing

ALS-DEM processing and visualisation needs a lot of knowledge in the area of computing.
We used the following SW for our project:

- GlobalMapper 8 and Surfer 8
- ArcGIS 9.2 with LP360 module
- LasEdit for classification and visualisation
- TreesVis for producing DEM-Videos.

Additionally common SW was used: Adobe Photoshop CS2, ACDSEE, IranView, Garmin GPS with Map Source-SW, Google Earth Internet, different ALS-sensor-SW and Hasselblad-SW. Many other SW are available for DSM and DTM processing.
The geo-referenced raw data were delivered by Milan Geoservice GmbH in ASCII-Format and partly in classified Grid-Format applicable in GlobalMapper and Surfer.
With this data the ALS-tracks were analysed using the common LIDAR exchange format standard LAS-files which is a standard of the American Society of Photogrammetry and Remote Sensing (ASPRS) using the LasEdit SW. This binary file format is an alternative to proprietary systems or the generic ASCII file interchange system used by many companies. The .LAS file format is a binary file format that maintains information specific to the LIDAR nature of the data while not being overly complex. ASPRS has endorsed and strongly supports the use of this standard. Further details are available at www.lasformat.org
The LasEdit SW classification / filtering module Surface Magic was utilized to get the topography (DTM), Fig. 2 and 6. The TIN (Triangulated Irregular Network) calculation can visualize the results for the DSM- and DTM products by LasEdit and very good with LP360 in ArcGis. Both SW can produce cross-section of profiles, e.g. bio mass, display pseudo 3D-presentation and create contour lines for maps. The LP360 module of ArcGis 9.2 is very capable to show the different ALS-tracks geo-referenced.

RESULTS and DISCUSSION

The ALS-technology has been demonstrated in Central Kalimantan successfully. High resolution ALS geo-coded data are available from the helicopter flights beginning of August 2007 with +/-0.5m resolution in x and y and +/-0.15m in z (elevation) which are referenced to the Palangkaraya airport with elevation level of 25.0m. The data were analysed to get the profile of the peat surface and peat dome for topographical and hydrological maps and for estimation of the PSF tree height and for bio-mass calculation. Not all results can be presented in this paper. The ALS is penetrating the PSF with 3% to 5% of the Laser beams, which are enough Laser points for producing topographical maps.
The highest peat dome was determined with 49.1m between Kasongan and Tangkiling res. 40.8m between Katingan and Habaring Hurung and the water surface at the Katingan river at -2.09292° and 113.50867° was 23.1m on the 8.8.2007 15h.

Seven small black water rivers are crossing the Kalimantan highway. They have an average pH-value of 3.7. Very shallow peat can be found from km79 to km77.5 and in several locations there is no peat at all. Deep peat can be found from km77 to km76.5. This area is near to the black water river at km76.8. Between km76 and km64, there is fluctuation in peat depth from 0 cm (no peat) to 170 cm peat depth. At km69 are located the holy granite hills of Bukit Tjilik Riwut with 77m altitude, see Fig.2.
The dome shape is between km63.5 and km47. The thickness of peat increases gradually from km62.5 to km54 with the thickest peat depth at km53.5 with 810cm depth, Fig. 2, 3,6,7. At approx. this location the peat dome has also its maximum of 49.1m derived from the ALS-data. After km53.5 the thickness of peat decreases gradually until km47.5 with only 5cm depth. From km47 to km34.5, the thickness of peat is very shallow and several drilling holes had no peat at all, except at km40.5 and km40. On the river side the soil under the peat is sandier and under the rivers themselves are partly clay.
There is a variation on mineral soil types below the peat along the transect Kasongan to Tangkiling. Most of the mineral soil below the peat was sand (quartz sand) and hardpan, only a few places had clay.
The peat itself has in average a bulk density of 0.275 g/cm³ (measured from 12 samples 0 – 20 cm peat depth). The average of C organic content is 56.1% (from 22 samples, from 0 – 20 cm peat depth). From the data above we can calculate that the peat weight in 1 m^3 = volume x bulk density = 1,000,000 cm³ x 0.275 g/cm³ = 275 kg.
The amount of C in 1 m^3 peat = 0.561 x 275 kg = 154.3 kg which is 56.1% of the peat weight of 275kg. Due to the mineral soil below the peat being mainly quartz sand of low fertility, this area is of doubtful utility for agriculture or for plantations. Nevertheless some areas were used along the transect for agricultural purpose especially near Kasongan and near Tangkiling. The peat is there shallow. The degraded PSF has here a canopy height between 20m and 30m. The average height of the trees was confirmed with 24m by ground measurements.

We made 31 peat drillings in the transect Katingan to Habaring Hurung mostly covered by PSF. The peat dome has an altitude of 40.8m at UTM Zone 49 East 799.2km and – South 225.1km, Fig. 2, 5. The dome shape is different compared to the Kalimantan road. The thickness of peat has his biggest value with 10.0m near to the river Katingan. This location is not the same as the peat dome. The total bulk density was measured for this transect by 28 samples with an average of 0.131 gr/cm^3. Shallow peat can be found on this transect at village Habaring Hurung. The average peat thickness is here 3.65m which is much higher than near to the road Tangkiling to Kasongan with cleared peat land. The average tree height along this transect is approx. 30m to 40m near to the peat dome measured by ALS.

The amount of stored peat volume and carbon can be estimated for the northern area of Sebangau Catchment and Palangkaraya between rivers Katingan and Rungan up to the border of the heath forest in the following calculation using the GIS information:

5m to 6m in average x 450x10 Mio m² = 2.25 to 2.7 Gm³ big peat area and 2.5m to 3m average x 1473x10 Mio m² = 3.68 to 4.42 x 10 Gm³ medium peat area, see Fig. 7.
The total sum is for this northern Sebangau Catchment **5.93 to 7.1 Gm³ peat volume.** One m³ peat contains for this peat land 154.3kg Carbon. So we estimated a stored **Carbon value of 0.92 to 1.1x10 Gtons** for this area. This is in line with the calculations of Page et al. 2002 for a bigger area in Kalimantan and other region of Indonesia.
Big peat layers are accumulated in Central Kalimantan between the rivers with up to 10m thickness in the transect between Katingan and Habaring Hurung. The peat layer are shallower down to the Java Sea.

ACKNOWLEDGEMENTS

The funding for the ALS-flights, the peat drillings and peat analyses at UNPAR was provided by Kalteng Consultants. The authors wish to thank Dr. Suwido Limin, Dr. Yustinus Sulistiyanto and their teams from UNPAR. Additional we would thank company Milan Geoservice GmbH with Operator Jan Giehler and Equipment Integrator Detlef Klante for the technical part of the ALS-flight campaign and M. Mustafa Syafrudin for good cooperation during the ALS-flight campaign.

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FIGURES

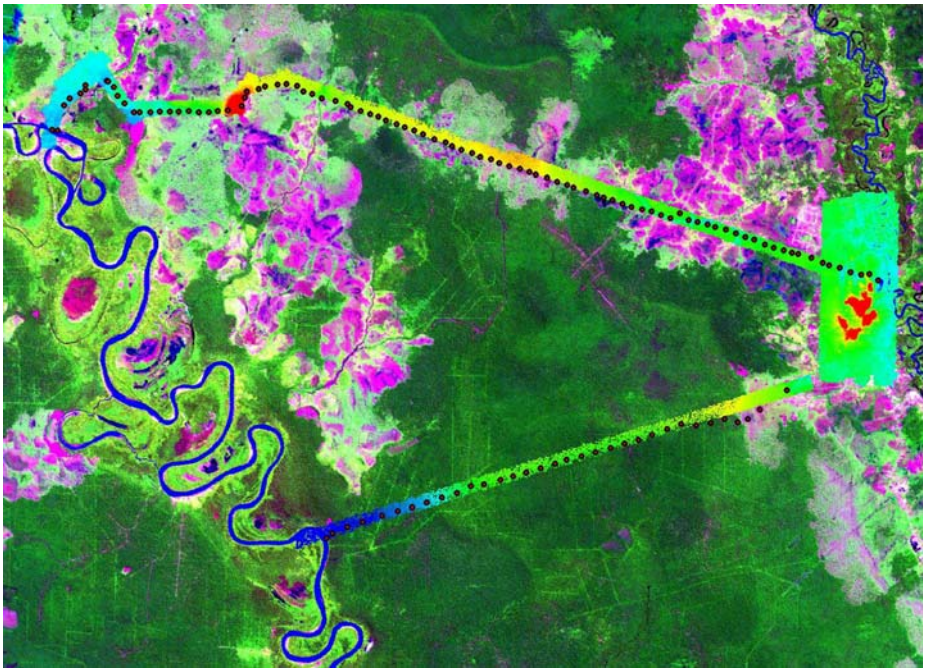

Fig. 2. ALS-Tracks from 8.8.2007 showing the topography (DTM, classified) of peatland and peat-drillings between rivers Katingan left and Rungan right superimposed on a Landsat-image 2000. The peatland elevation is presented in different colours; red is high and blue low. The ALS penetrates the canopy and produces 3% - 5% return pulses through PSF. ALS-Track widths is approx. 500m.

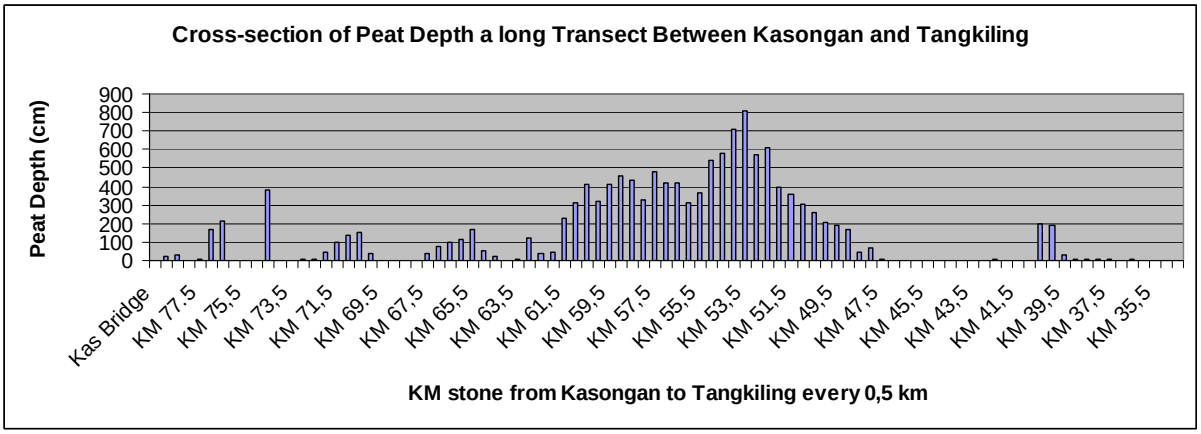

Fig. 3. 91 measurements of peat depth along the Kalimantan highway Kasongan to Tangkiling between the rivers Katingan and Rungan. At km 53.5 is the peat depth 8.10m and there is also approx. the peat dome measured by ALS.

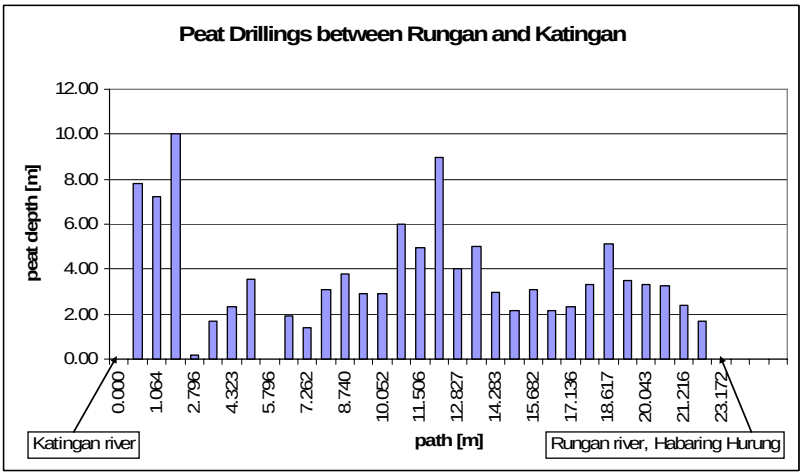

Fig. 4. 31 measurements of Peat depth along the Katingan to Habaring Hurung-transect: Peat depth variation between 10m and shallow peat layer.

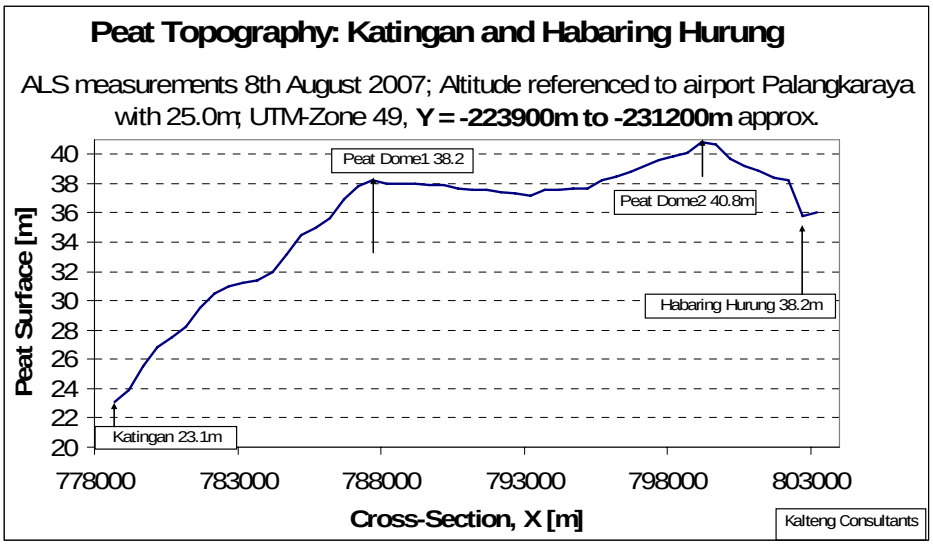

Fig. 5. ALS-DTM x-cross-section (24.5km long) between river Katingan and village Habaring Hurung (y=7.3km). The Peat dome has an altitude of 40.8m, referenced to PKY airport with 25.0m

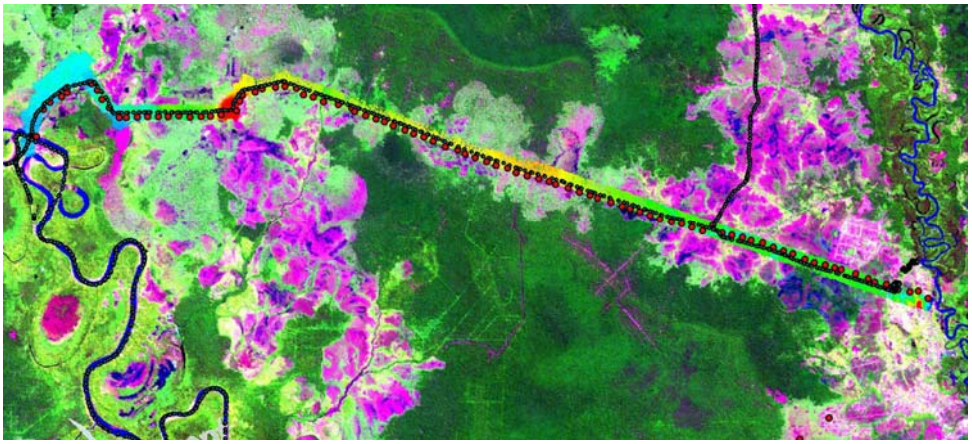

Fig. 6. ALS-Tracks as LAS-presentation, reaching from river Rungan (right side) along transect road to Kasongan superimposed on a Landsat-image. The ALS-LAS-data are classified and show the DTM as topography with contour-lines in 3m steps starting from Rungan with 20.8m up to 49.1m at peat dome km53.2km, reference to PKY airport with 25.0m. The peat dome is at km53.2 in the middle, which can be located by the yellow reddish colour of the DTM. Km69 shows the Bukit Tjilik Riwut.

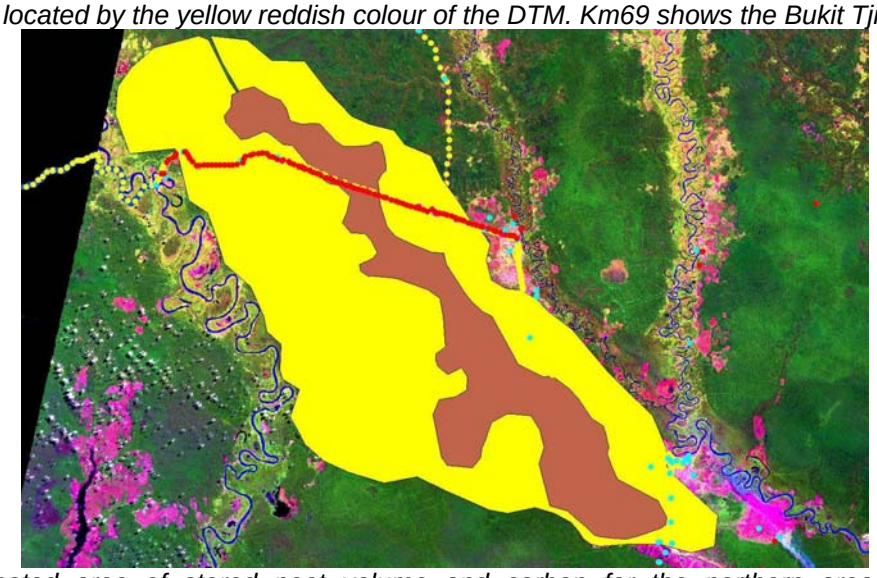

Fig. 7. Estimated area of stored peat volume and carbon for the northern area of Sebangau Catchment and Palangkaraya between rivers Katingan and Rungan between the PSF-border to the heath forest analysed in the Landsat image from 1991 with two types of peat thickness (brown 5 to 6m and yellow 2.5 to 3m). Tangkiling and Kasongan area and locations near the rivers are not included in the estimation!