SUCCESSFUL HELICOPTER FLIGHT TRIALS WITH AIRBORNE LASER SCANNING TECHNOLOGY TO MEASURE PEAT SWAMP FOREST HEIGHT AND PEAT DOMES IN CENTRAL KALIMANTAN

Dr. H.-D. Viktor Boehm[1], Prof. Dr. Jack Rieley[2], Dr. Suwido Limin[3], Juergen Frank[1] and Mustafa Syafrudin[1]
[1]Kalteng Consultants, Kirchstockacher Weg 2, D-85635 Hoehenkirchen near Munich, Germany and Palangkaraya, Email: ViktorBoehm@t-online.de; www.kalteng.org
[2]University of Nottingham and CIMTROP
[3]University of Palangka Raya and CIMTROP

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SUMMARY

With a high-resolution Airborne Laser Scanner (ALS) the topography of peatlands were measured by a helicopter at the beginning of August 2007. 34 peat drillings were performed between Habering Hurung near to the Rungan and the Katingan River including ALS- and ortho-photo measurements. A 3-dimensional Digital Elevation Model (DEM) has been established for the Kalampangan Channel in Block C of the former Mega Rice Project and for a transect through the Natural Laboratory in the Sabangau National Park, starting from the Sabangau river, passing the base camp and reaching the peat dome. A transect was also analysed between the Rungan and Katingan Rivers. A hydrological model of peatland with biomass of peat swamp Forest (PSF) will be analysed by this modern technology with an elevation resolution of +/-15cm. Illegal channels in Peat Swamp Forest (PSF) were monitored. The first results of ALS- and ortho-photo measurements were presented.

INTRODUCTION

Kalteng Consultants, together with the German company Milan Geoservice GmbH performed several ALS-Helicopter Flight Trials in Central Kalimantan from 5^{th} to 10^{th} August 2007, see Figure 1 (Boehm 2004, 2006; Boehm & Siegert, 2000, 2004; Boehm *et al.,* 1995, 2003). The preparation for this high-technological flight campaign took several months. From ALS-flight on 6^{th} Aug. 2007 with more than 2 hours helicopter flight and 260km length we archived Tracks 17 – 35 for this project. Tracks 17 - 35 were used for calibration over the Palangka Raya airport Tjilik Riwut. The purpose of these trials was to get high-resolution three-dimensional information (Digital Surface Model (DSM) and a Digital Terrain Model (DTM) from the peat landscape in Central Kalimantan of the Ex-Mega Rice Project (EMRP) with knowledge of the topography, the tree-height, the remaining tree-quality, the bio-mass and the peat dome. in that huge peatland area. This information was used to understand better the hydrology and estimate the amount of carbon stored in the peat in combination with peat drillings carried out in July 2007 (Boehm & Sulistiyanto, 2006).

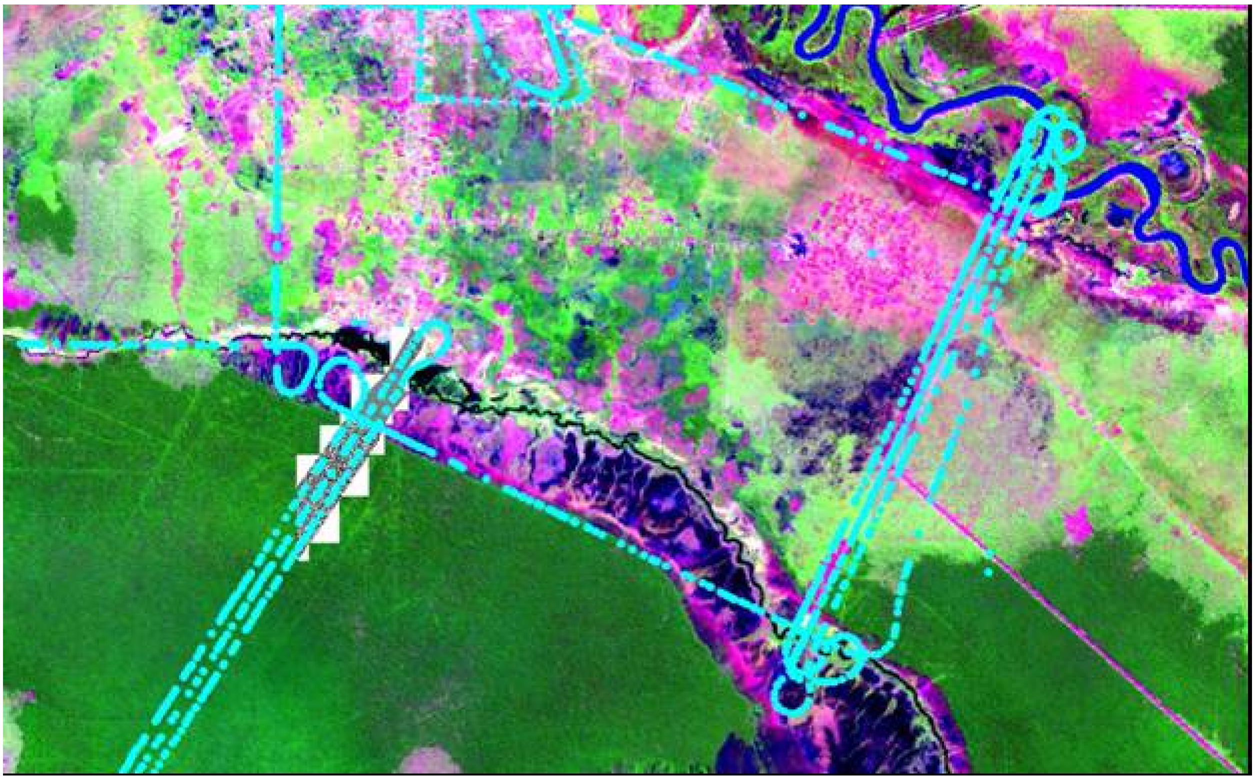

Figure 1 ALS-flight track on 6th August 2007 over Kalampangan Channel-Block C, Sabangau catchment and Nat. Lab. transect superimposed on Landsat image

METHODS

Technical equipment for Airborne Laser Scanning

The following equipment was used during the helicopter flight trials in August 2007: inertial Navigation System (INS), flight management system (FMS), GPS-antenna L1/L2-band, several Recorders and digital RGB camera from Hasselblad with 22 MB pixel resolution, ALS Equipment with Riegl Technology and DGPS-ground station.

Table 1 Parameters of Airborne Laser Scanning System. We used +/- 30° scan angle

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

Calculation of the ortho-metric height, geoid height and ellipsoidal height
There is a definition for the different elevation height.

Orthometric Height = GPS ellipsoidal Height - Geoid Height
http://www.logisticsworld.com/airports.asp?query=PALANGKARAYA&mode=smart

With this definition and values of the internet page of Palangka Raya we calibrated our ALS-data.
http://sps.unavco.org/geoid/

Input Coordinates and GPS Height of PKY:
TJILIK RIWUT (2:13:30S, 113:56:33E, Elev 82 Ft
Latitude = 2.225° S = 2° 13' 30" S
Longitude = 113.9425° W = 113° 56' 33" W and 25m

DEM Data Processing
DEM processing and visualisation needs a lot of knowledge in the area of computing.

The TIN (Triangulated Irregular Network) calculation for the DSM- and DTM product from the ASCII-files can be done with different algorithms, e.g. triangulation with linear interpolation, nearest neighbour, natural neighbour, kriging, etc.

We used the following main SW for our project: GlobalMapper8, Surfer8, ArcView and ArcGIS with spatial analysis, ENVI and IDL, Terra Solid for DSM+DTM, LasEdit and TreesVis for DEM-Videos. Common SW were used additionally: Adobe Photoshop CS2, ACDSEE 9, IranView, Garmin GPS with MapSource-SW, Google Earth Internet, many ALS-SW and Hasselblad-SW

There are many other software for DSM and DTM processing available.

Classification of ALS-Data
Automatic Classification
Laser-pulses with negative values e.g. reflections or very high values e.g. birds etc. were deleted from the geo-coded raw data in ASCII-format before the automatic classification process. The DTM filtering/classification of PSF was done semiautomatic with the raw ALS-data:

The parameters for the automatic classification algorithm were determined using special training areas

1. automatic classification of the DTM
2. control of the classification regarding to plausibility and manual processing of the operator of the TIN-surface model (DTM)

Automatic classification and the operational control and modification
Automatic Algorithm
The automatic algorithm for calculating the DTM from the Laser point cloud is based on the analyses of an iterative irregular triangulated net (TIN). Based on some source points of the DTM a rough TIN is calculated and remaining Laser Scanner points are implemented into the TIN. If the new prepared triangles require defined criteria (e.g. fulfilling absolute tilt angles of the new triangles, relative tilt angle to the first triangle area, distance to the first triangle area) these points will be added to the DTM. With this procedure the TIN will become denser and denser, until all points are investigated.

The advantage of this method is that no regular raster data are necessary and the true measured values can be classified. Ditches are remaining and also for areas with large angles this method is good. According to the regional structure up to 95% of the ground points are automatic classified. Depending of the method of the scanned surface, errors in the automatic classification could happen:

- errors of **the first category** (point of the DTM are not classified as DTM e.g. small hills) and
- errors of **the second category** (points not belonging to the DTM e.g. low vegetation).

Normally there are error problems with e.g. bridges.

Semiautomatic operational classification
All data are checked by an operation for its plausibility based on shadowed and colour coded relief models of each point class and additional to the point distribution. If errors of the **first category are found**, the operator can adapt locally the classification algorithm. By adding a clearly defined ground point into the DTM a new triangle grid will be established, which will be the basis of a new, local DTM-TIN. In this simple way missing ground points can be added for the classification. Wrongly classified points of vegetation (error of second category) can be eliminated in a similar method from the DTM. If the semi-automatic procedure leads to bad results, the classification can be done easily manually, e.g. by the help of proper cross-sections.

Peat Drilling and Carbon estimation
We used normal peat drilling equipment and two Global Positioning Sensors (GPS) and a compass. Along the transect from the Katingan River to Habaring Hurung village peat thickness was determined every 700 m. Peat samples from 0 - 20 cm depth and the mineral soil below the peat were taken for pH, carbon and nutrient analysis at the Analytical Laboratory at Palangka Raya University. Table 1 contains the 31 peat drillings with peat thickness, vegetation, location and bulk density (Sulistiyanto, 2004). We estimated two peat area types in the GIS (type1, brown, with 5 to 6m peat depth and type2, yellow, with 2.5m to 3m depth) in order to calculate the peat volume and the carbon stored between the Rivers Rungan and Katingan (Boehm and Sulistiyanto, 2006).

RESULTS AND DISCUSSION

Corrected ALS raw data (geo-coded) are available from the helicopter flights on 6th and 8th August 2007 with tracks 17 - 35 on 6.8.2007 and tracks 191 - 194 on 8.8.2007. Flight tracks 17 and 35 passed the runway of Palangka Raya airport two times, after 2.3 hr flight we received the same elevation of 25.0 m at the reference point where we installed the DGPS. Other ALS flights on other days had the same elevation value of 25.0m for PKY.

Precise ALS-data with +/-0.5m resolution in x and y and +/-0.15 m in z (elevation) were recorded for analysis's of peat swamp forest biomass estimation, topography and hydrology. With the processed DSMs and DTMs the data were used for analysis of the Kalampangan channel, the transect through the Natural Laboratory and the transect between Katingan River and Habaring Hurung village. Filtering and classification was done automatically and using manual controls

The ALS penetrated the PSF, which shows the very good results of the DTMs. The highest peat dome was 40.8m between Katingan River and Habaring Hurung. The visualisation of three dimensional data is not so easy and needs specific SW and skills of the operator. No interrupts of the ALS equipments and other measuring devices occurred during the complete flight path.

Table 2 shows the variation in peat thickness and mineral soil below the peat from the transect Katingan River to Habaring Hurung. Shallow peat can be found on this transect. The dome height is 40.8 m above sea level at UTM Zone 49, 799.2 km East and – 225.1 km south. The thickest peat is 10 m near to the River Katingan. This location is not the same as the centre of the peat dome.

The total bulk density was measured along this transect and was 0.131 g cm^{-3} (Table 2). The peat volume and amount of carbon stored was estimated for the northern part of the Sabangau River catchment and Palangka Raya between the Rivers Katingan and Rungan up to the border with the heath forest as follows:

5m to 6m average thickness x 450 x 10 $Miom^2$ = 2.25 to 2.7 Gm^3 big peat area and 2.5m to 3m average x 1473x10 Miom[r1]^2 = 3.68 to 4.42x10 Gm[r2]^3 medium peat area. The total volume for the northern Sabangau Catchment is 5.93 to 7.1 Gm^3. One m^3 of this peat contains 154.3 kg carbon so the total amount of carbon stored in this area is 0.92 to 1.1x10 Gt[1].This is in line with the calculations of Page *et al.* (2002) for a bigger area in Kalimantan and Indonesia.

[1] Gt = gigatonne = t x 10^9

Table 2 Habaring Hurung - Katingan Transect

No	Peat Thickness (m)	Elevation (m)	Water Table (cm)	Coordinate Point	Bottom Layer	Vegetation	Bulk density (g / cm ^{3})	
End of Road				S02^{0}01’30,5”; E113^{0}43’02,0”			0- 50 cm (surface)	Above Bottom layer
1	1.70	31	17	S02^{0}02’03,0”, E113^{0}42’17,7”	Granite	Fern, Karamunting, Burnt		
2	2,40	41	3	S02^{0}02’17,8”, 113^{0}41’58,6”	Granite	Tumih, Fern, burnt	0.204	0.130
	3,25	55	17	S02^{0}02’22,9”, 113^{0}41’41,6”	Granite	Hangkang>20 m high, mixed forest		
4	3,30	42	2	S02^{0}02’18,2”, 113^{0}41’20,6”	Granite	Tumih,burnt, gerunggang	0.1777	0.128
5	3,50	50	31	S02^{0}02’23,9”, 113^{0}40’57,5”	Granite	Fern, burnt		
6	5,10	51	15	S02^{0}02’28,3”, 113^{0}40’34,4”	Granite	Hangkang>20 m high, mixed forest	0.144	0.112
7	3,30	49	10	S02^{0}02’27,0”, 113^{0}40’09,5”	Granite	Mixed forest, hangkang		
8	2,35	50	22	S02^{0}02’35,0”, 113^{0}39’46,4”	Granite	Mixed & tall forest	0.133	0.123
9	2,14	54	26	S02^{0}02’44,5”, 113^{0}39’21,9”	Granite	Mixed & tall forest		
10	3,10	47	19	S02^{0}02’52,0”, 113^{0}38’59,3”	Granite	Mixed & tall forest	0.198	0.092
11	2,15	47	16	S02^{0}02’58,7”, 113^{0}38’36,7”	Granite	Mixed & tall forest		
12	2,95	46	38	S02^{0}03’05,7”, 113^{0}38’14,0”	Granite	Mixed & tall forest	0.160	0.150
13	5,0	55	29	S02^{0}03’12,9”, 113^{0}37’49,7”	Granite	Mixed & tall forest		
14	4,04	49	25	S02^{0}03’19,5”, 113^{0}37’26,8”	Granite	Tumih, pandan, mixed forest	0.181	0.133
15	9,0	49	42	S02^{0}03’25,5”, 113^{0}37’02,2”	Clay	Mixed & tall forest		
16	4,95	40	24	S02^{0}03’32,1”, 113^{0}36’44,0”	Granite	Mixed & tall forest	0.196	0.112
17	6,0	52	30	S02^{0}03’39,4”, 113^{0}36’20,5”	Clay	Mixed & tall forest		
18	2,91	50	27	S02^{0}03’46,6”, 113^{0}35’56,9”	Sand	Mixed & tall forest	0.177	0.104
19	2,90	49	30	S02^{0}03’52,3”, 113^{0}35’35,4”	Sand	Mixed & tall forest		
20	3,76	53	52	S02^{0}03’59,4”, 113^{0}35’14,4”	Sand	Mixed & tall forest	0.156	0.099
21	3,06	43	65	S02^{0}04’05,8”, 113^{0}34’48,5”	Sand	Mixed & tall forest		
22	1,39	45	60	S02^{0}04’09,2”, 113^{0}34’26,5”	Sand	Pandan, mixed forest	0.153	0.097
23	1,95	43	70	S02^{0}04’20,3”, 113^{0}34’03,6”	Sand	Mixed & tall forest		
24	0	52	-	S02^{0}04’28,4”, 113^{0}33’39,0”	Sand	Bintangor≤15 m, lampesau, jambu-jambuan, tumih, gerunggang, orchid	-	-
25	3,56	34	55	S02^{0}04’36,1”, 113^{0}33’14,7”	Clay	Mixed & tall forest		
26	2,34	41	35	S02^{0}04’43,4”, 113^{0}32’51,3”	Clay	Mixed & tall forest	0.151	0.093
27	1,70	47	35	S02^{0}04’50,0”, 113^{0}32’28,0”	Granite	Mixed & tall forest		
28	0,16	52	-	S02^{0}04’57,3”, 113^{0}32’01,8”	Sand	Mixed & tall forest	0.149	0.115
29	10,0	34	22	S02^{0}05’07,7”, 113^{0}31’30,5”	Clay	Mixed & tall forest		
30	7,24	35	50	S02^{0}05’15,3”, 113^{0}31’05,7”	Clay	Mixed & tall forest	0.155	0.120
31	7,80	27	15	S02^{0}05’25,6”, 113^{0}30’40,6”	Clay	Mixed & tall forest		
Katingan River				S02^{0}05’34,5”, 113^{0}30’31,2”				
						Average	0.1556	0.107
						Average total	0.131 g/ cm ^{3}	

CONCLUSIONS

This paper provides beside the ALS-technology, information on peat thickness in the Sabangau National Park. The amount of carbon in 1 m^3 peat was estimated to be 154.3 kg which is 56.1% of the peat weight of 275kg. Calculation of the amount of carbon in the northern area of the Sabangau catchment between Kasongan and Tangkiling, using peat thickness measurements and GIS technology was approximately 10 Gt. Owing to the nature of the mineral soil below the peat being mainly quartz sand of low fertility, this area is of doubtful utility for agriculture or for plantations. Future work could be carried out on that area with more peat drillings spread over the area of interest to get more accurate results of the peat volume and the amount of carbon.

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Appendix (Additional Figures)

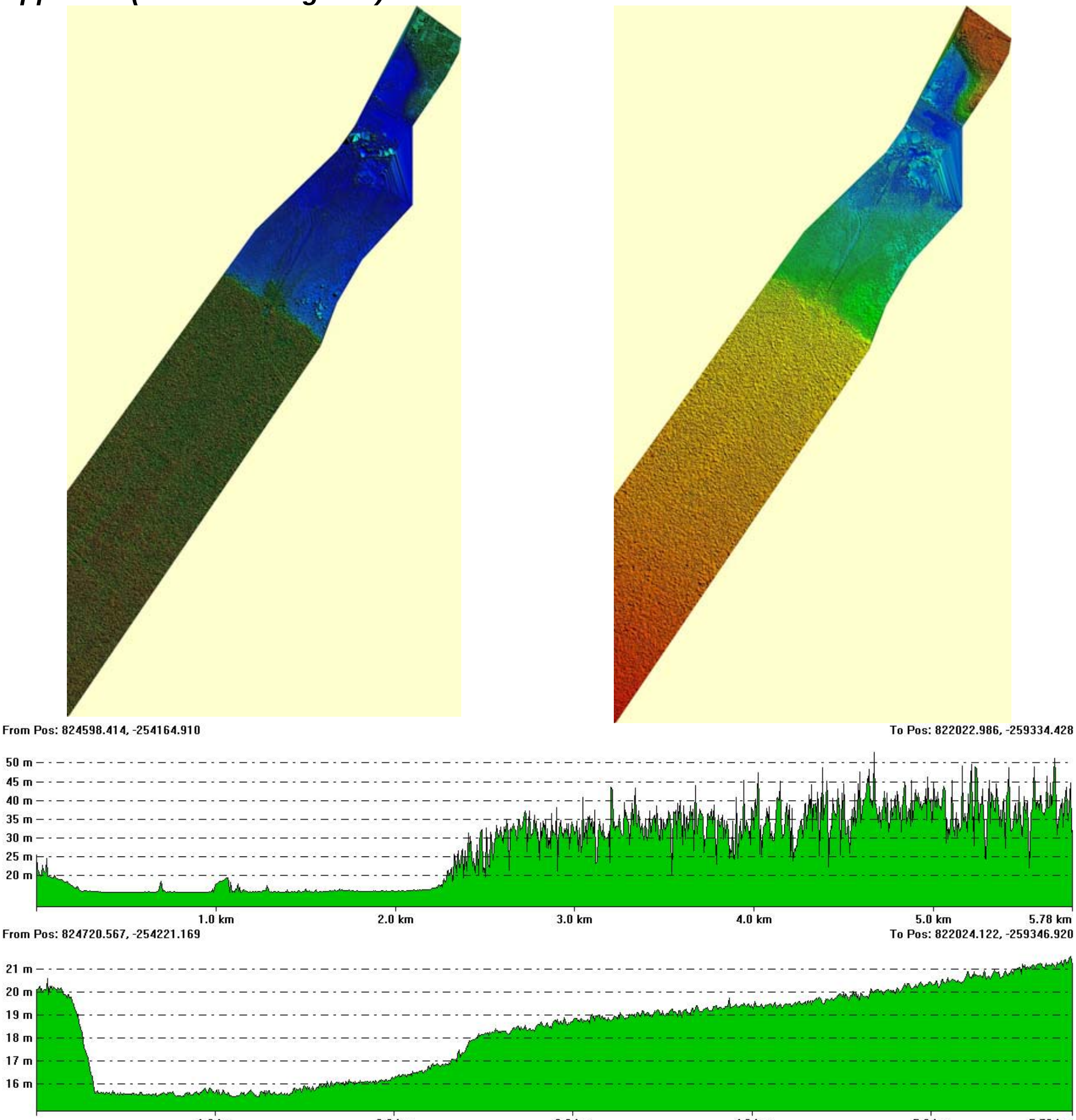

Figure 2 ALS-DSM (above left) and DTM (above right) and cross-sections of transect Nat. Lab. and Sebangau Catchment with PSF: colours shows the difference in elevation; above DSM- and below DTM-cross-section. (Note the different elevation scales). DTM cross-section shows for a 3.2km transect that the peat surface increases by approx. 3.2m (Altitude referenced to PKY-Airport with 25m, values in UTM-Zone49)

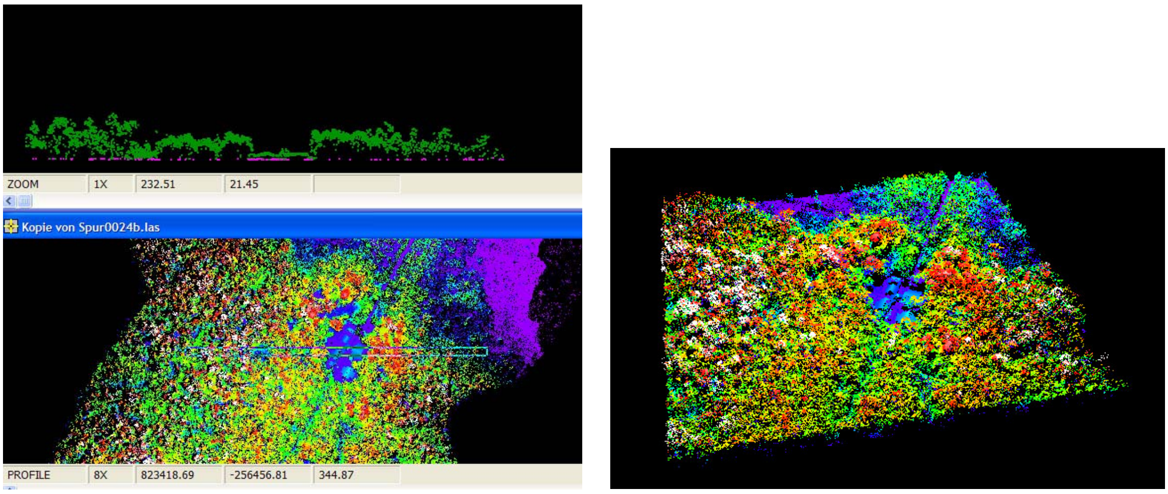

Figure 3 ALS-DSM from Nat. Laboratory with camp, see cottages (grid 1km x 1km, above left); same area now as DTM (above right). Single tree detection is possible with ALS Laser cloud, see below, cross-section of DSM at camp area presented as profile, x-, y-, with z-scale in colour and a pseudo-3D display (lower right)

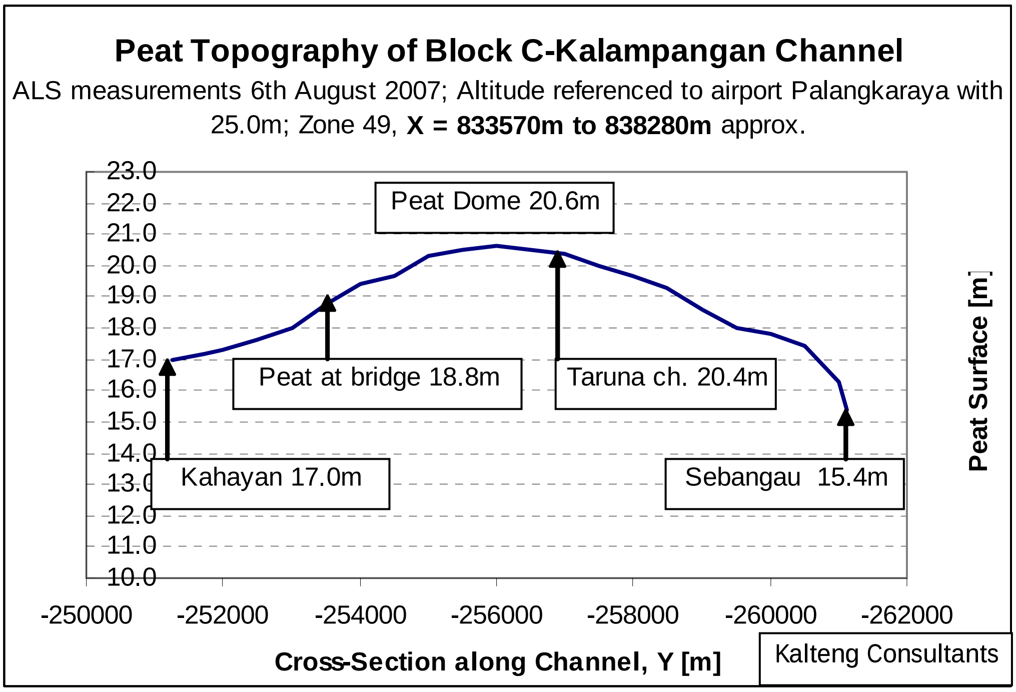

Figure 4 ALS-DTM-Y-cross-section (9.87km) of Kalampangan Channel approx. 11km long between rivers Kahayan and Sebangau (X=4.7km), Peat dome with 20.6m, referenced to PKY airport with 25.0m