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Small-footprint airborne LiDAR technology for REDD+ and MRV application

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Outline / Content

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- Introduction
- Main Objective
- Study Area Description
- Material and Methods
- Results and Discussion
- Final Remarks
- Acknowledgement

Introduction

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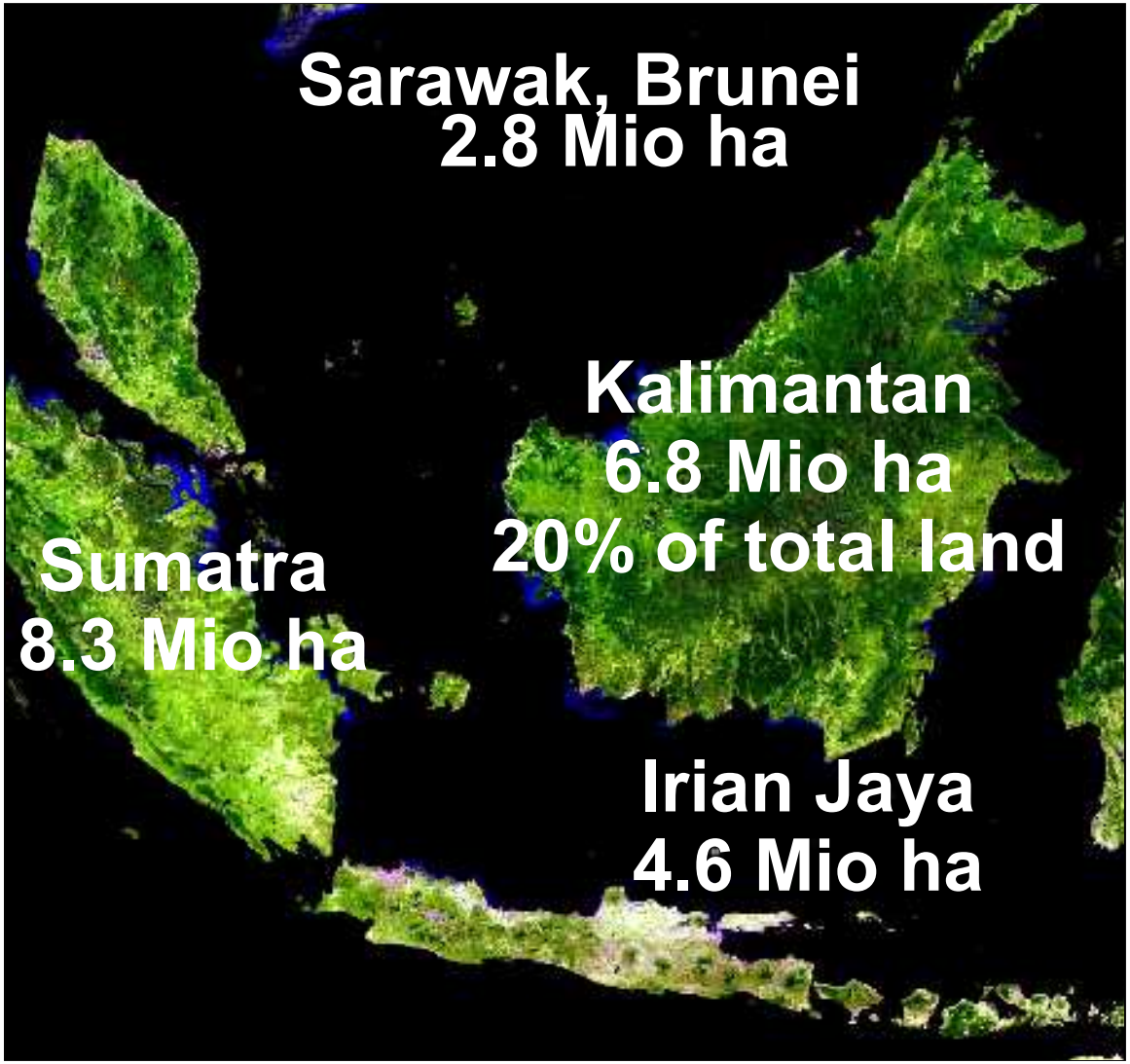

Indonesian Peatlands

- More than 50% of Tropical Peatlands occurs in Indonesia (~20 Mio ha);
- They represent an important carbon pool;
- Approx. 3 Mio ha have been destroyed by fires in Kalimantan (1997/98);

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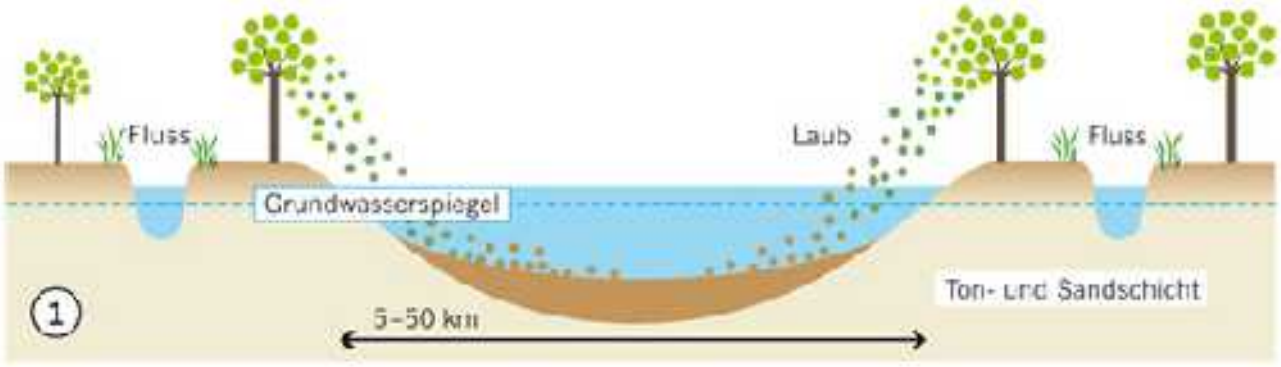
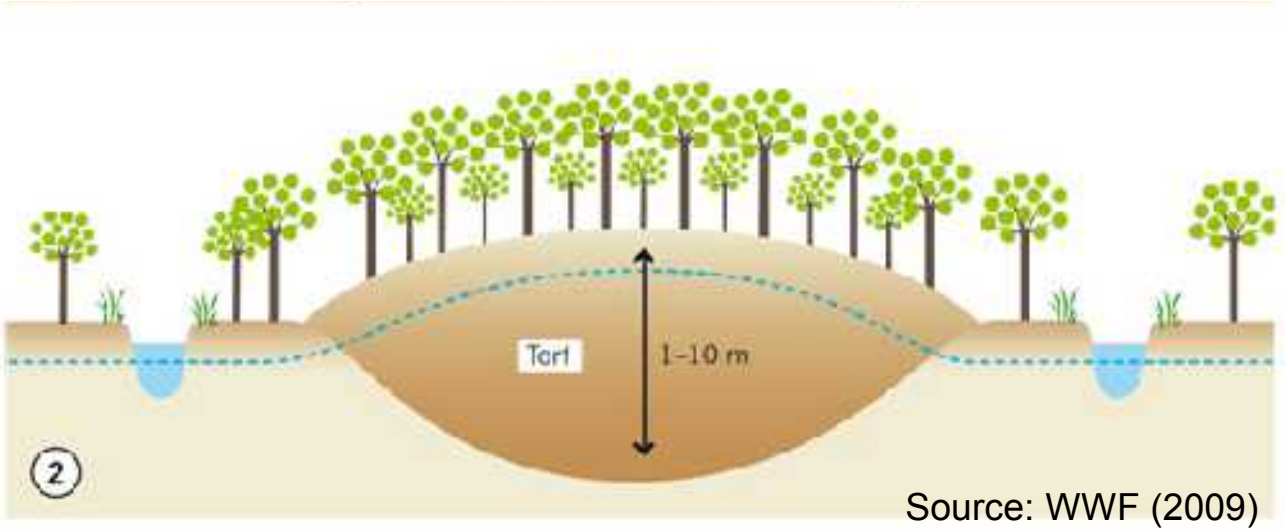


Source: WWF (2009)

Indonesian Peatlands



Source: WWF (2009)

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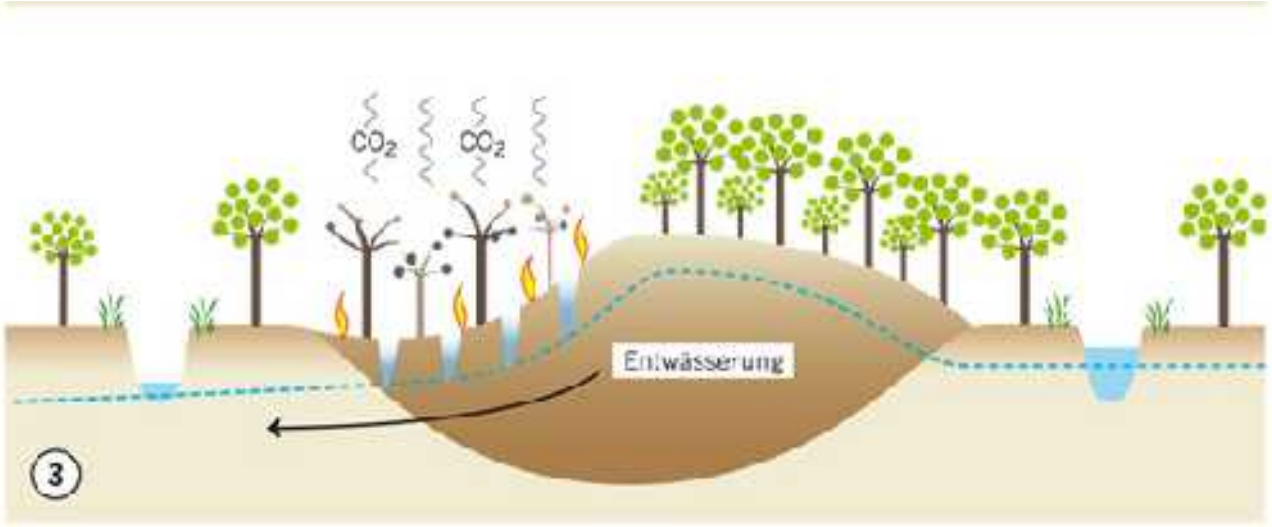

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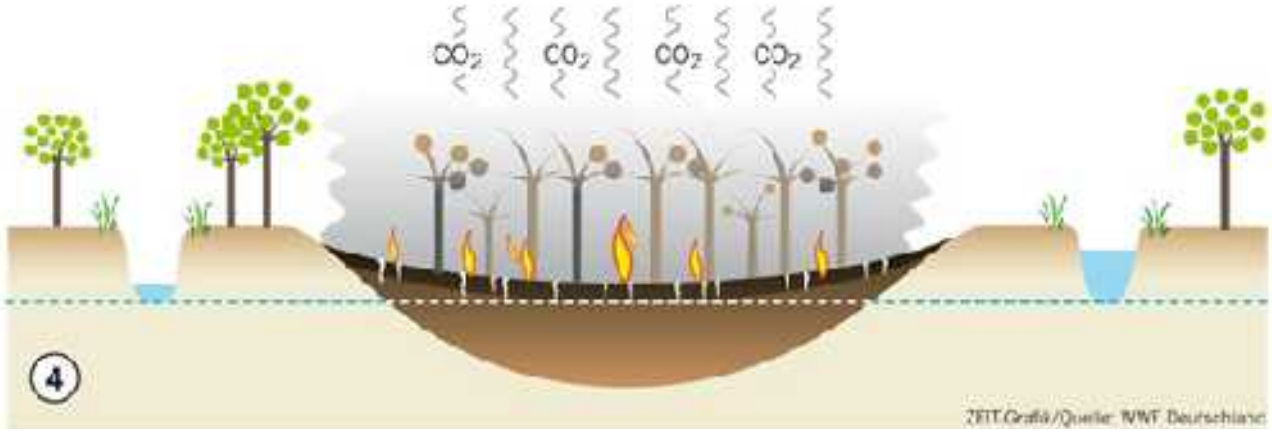
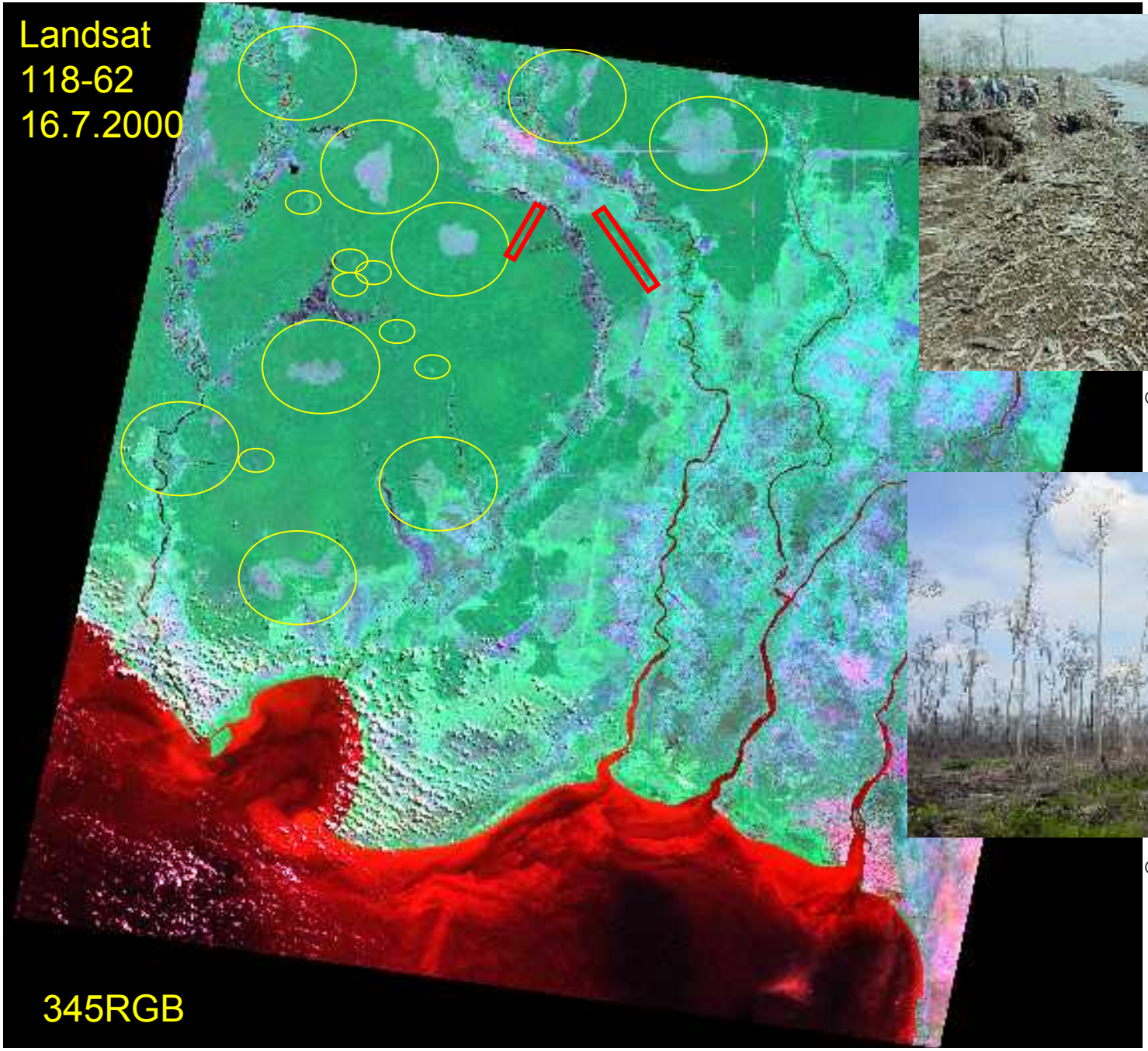


Indonesian Peatlands



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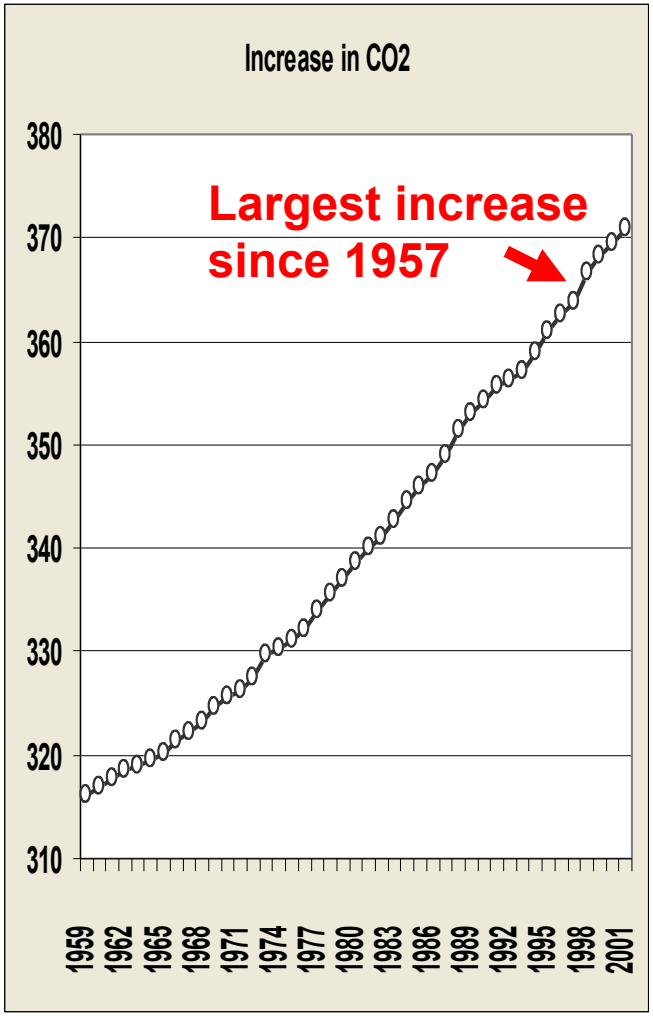
- **Indonesian Peatlands and Climate Change**
  - ✓ Indonesian peat fires in 1997/98 covered 1.5-2.2 Mio ha and emitted 0.81 – 2.57 Gton CO2 (Page et al., 2002)
  - ✓ Equivalent up to 25 years of successful Kyoto implementation



Main Objective

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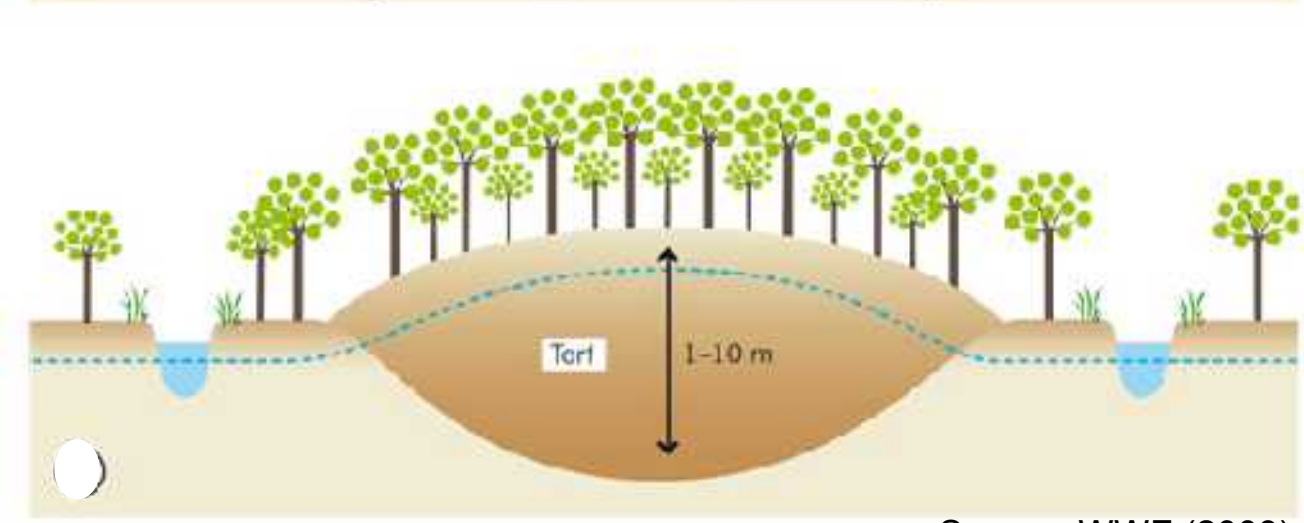
- to evaluate the relationship between tree height and peat dome slope in distinct relief conditions with Airborne LiDAR data in Central Kalimantan (Indonesia);



Source: WWF (2009)

Study Area

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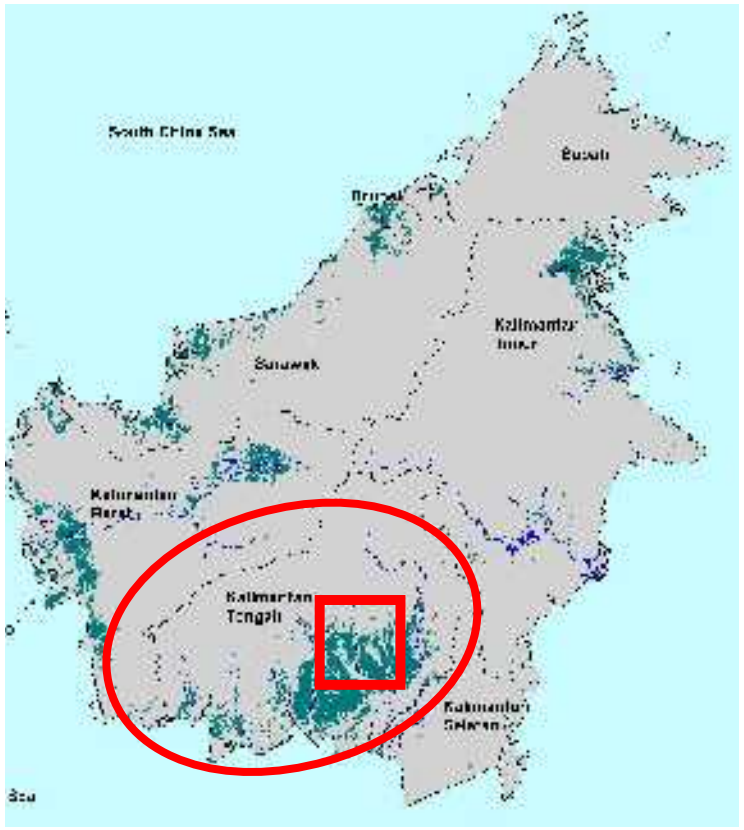

- humid tropical climate (type Af);
- annual rainfall of 3500mm;
- annual mean air temperature of 25°C;
- approx. 25m above sea level;
- mean peat average thickness 4m; max. 12m-15m

Cloud free 60 MODIS mosaic images of Borneo (2003)

Distribution of peat swamp forests in Borneo (2003)

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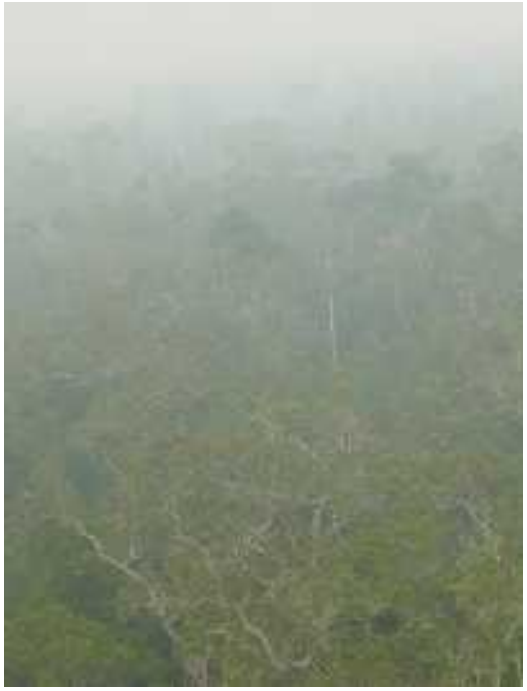
Ex-MRP Peat Swamp forest area:

- Selectively logged prior to year 1998
- Leaf Area Index (LAI) close to 6
- Influenced by drainage channel



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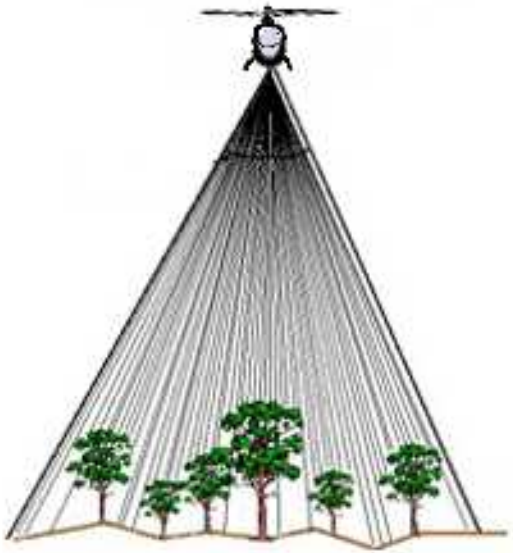
Airborne Laser Scanner



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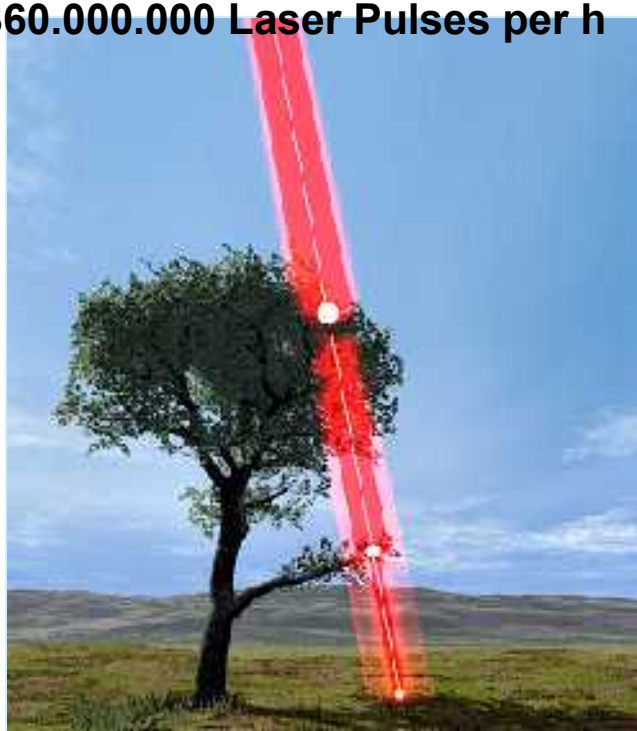
ALS = Airborne Laser Scanning
LiDAR = Light Detection and Ranging

Tree Height Measurement with First (FE), Medium and Last Laser Echo (LE) or with Full Waveform Digitization;

100,000 Laser Pulses per sec or

360.000.000 Laser Pulses per h



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LiDAR data and processing

1) The airborne LiDAR data were acquired from beginning of August, 2007 in Central Kalimantan;

1) The received LiDAR data demonstrates the good usage for REDD+ and MRV for above-ground biomass estimation

2) The Riegl laser-scanner LMS-Q560 was mounted under a Bell 206 helicopter;

1) Small footprint LiDAR data collected for a flight altitude of approx. 500m with a scan angle of 60° with produced a swap-width of approx. 500m (Boehm et al. 2007, 2008);

5) We used for this analysis the first and last pulse Laser echoes only. Full-wave data are available for more detailed biomass analyzes;

6) The Laser scanner had a pulse rate of 66kHz resp. 100kHz with a beam divergence of 0.5mrad or a footprint of approx. 0.25m;

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LiDAR data and processing

7) The ground backscattering in PSF through the canopy was responsible for 1% to 3% of the 0.5mrad Laser beams;

8) The DGPS ref. station was located at the airport of Palangka Raya (25.0m ASL);

9) The position and orientation of the LiDAR system on the helicopter was measured by an Inertial Navigation System (INS) and a GPS located on the tail boom with 256Hz;

10) After the correction of the attitude of the helicopter, the elevation accuracy of each Laser beam was ±0.15m with a root mean square error (RSM) of ±0.5m in both x- and y-direction;

11) The processed laser beams were divided into ground surface and overground classes and converted in order to digital surface model (DSM) and digital terrain model (DTM), respectively, at a spatial resolution of 1m;

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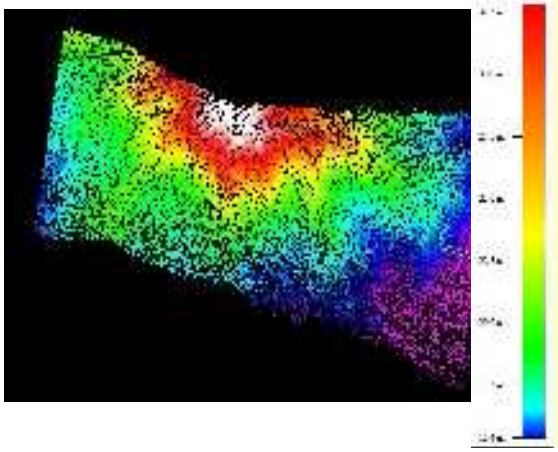

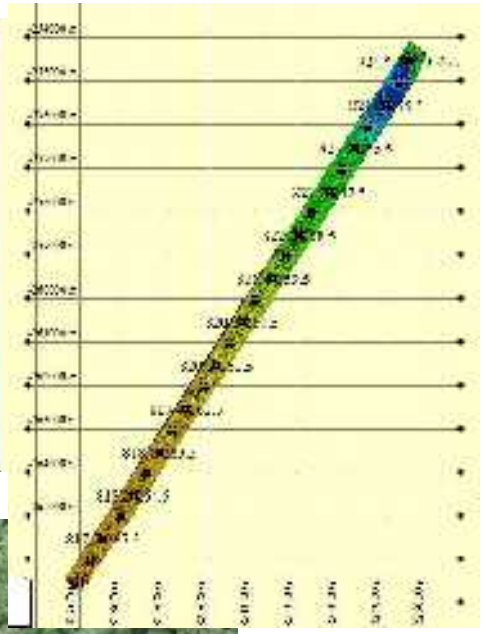

Helicopter with LiDAR + Camera

DTM, Ortho-Photo Track 24

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Statistical Modeling

Eq. 1 $$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - j_i)^2}$$

Eq. 2 $$Bias = \frac{1}{n}\sum_{i=1}^{n}(y_i - j_i)$$

Eq. 3 $$RMSE_r = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - j_i)^2}}{y_m} \times 100$$

Eq. 4 $$Bias_r = \left[\frac{1}{n}\sum_{i=1}^{n}(y_i - j_i)\right] y_m \times 100$$

where: ji is the predicted value, yi is the observed value, ym is the mean of observed value and n is the number of plots in test dataset.

- The relationship between tree height and peat dome slope employed a linear regression analysis (i.e. yj = ax + b);
- The slope value for each sample plot was used as the predictor for tree height determination;
- Complementary we also evaluated the analyses of the residuals (i.e. observed value minus predicted value) and we apply Cook's distance to identify outliers (e.g. flat areas where no slope was observed);

Results and Discussion

Peat Profile

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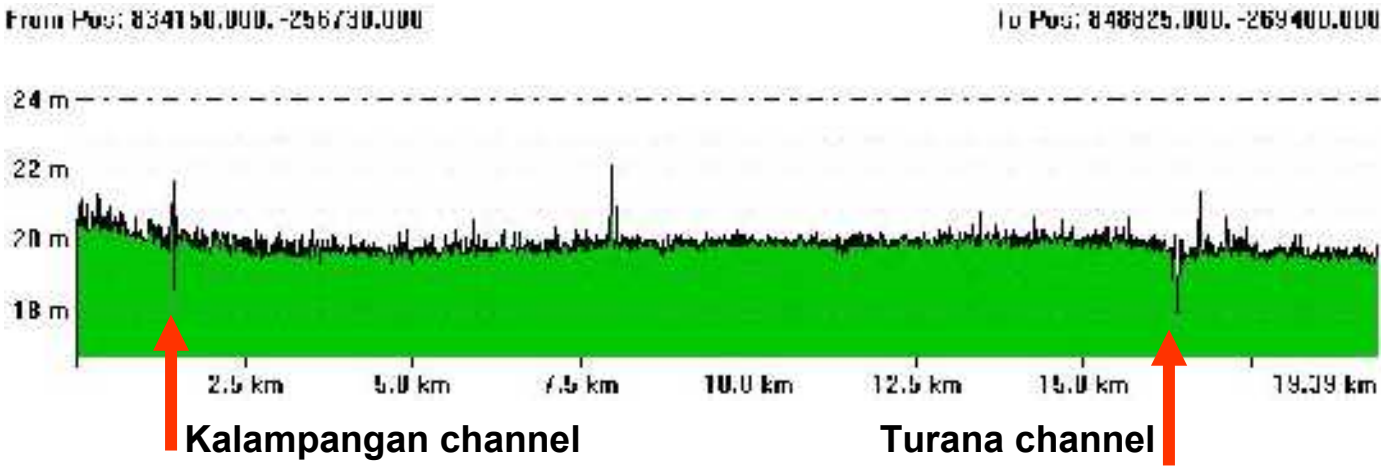
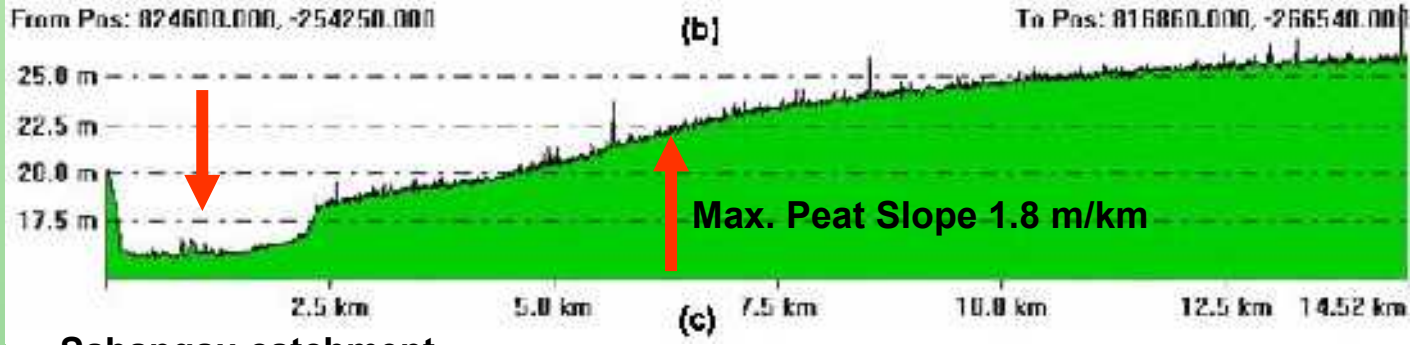
Variations in relief aspects of selected peat surfaces

LiDAR-DTM profile area in:



(a) Turana channel
Block C
Track 041a

Remark:
different x- and y-scales



Sabangau catchment

(b) Sabangau transect
Track 025

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LiDAR Transects

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Variations of relief aspects of selected peat surfaces

Table 1. Summary of the three LiDAR transects under study

Peat area transect	River level	Peat dome	Used trans. length	Max. slope (m / km)	Avg. avg. tree height	Avg. max. tree height
Block C -Turana (a)	15.5m	**20m**	19.5km	**0m/km**	**11.2m**	**27.2m**
Sabangau km256S (b)	15.5m	**26m**	12km	**1.7m/km**	**14.0m**	**29.4m**

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Tree Heights

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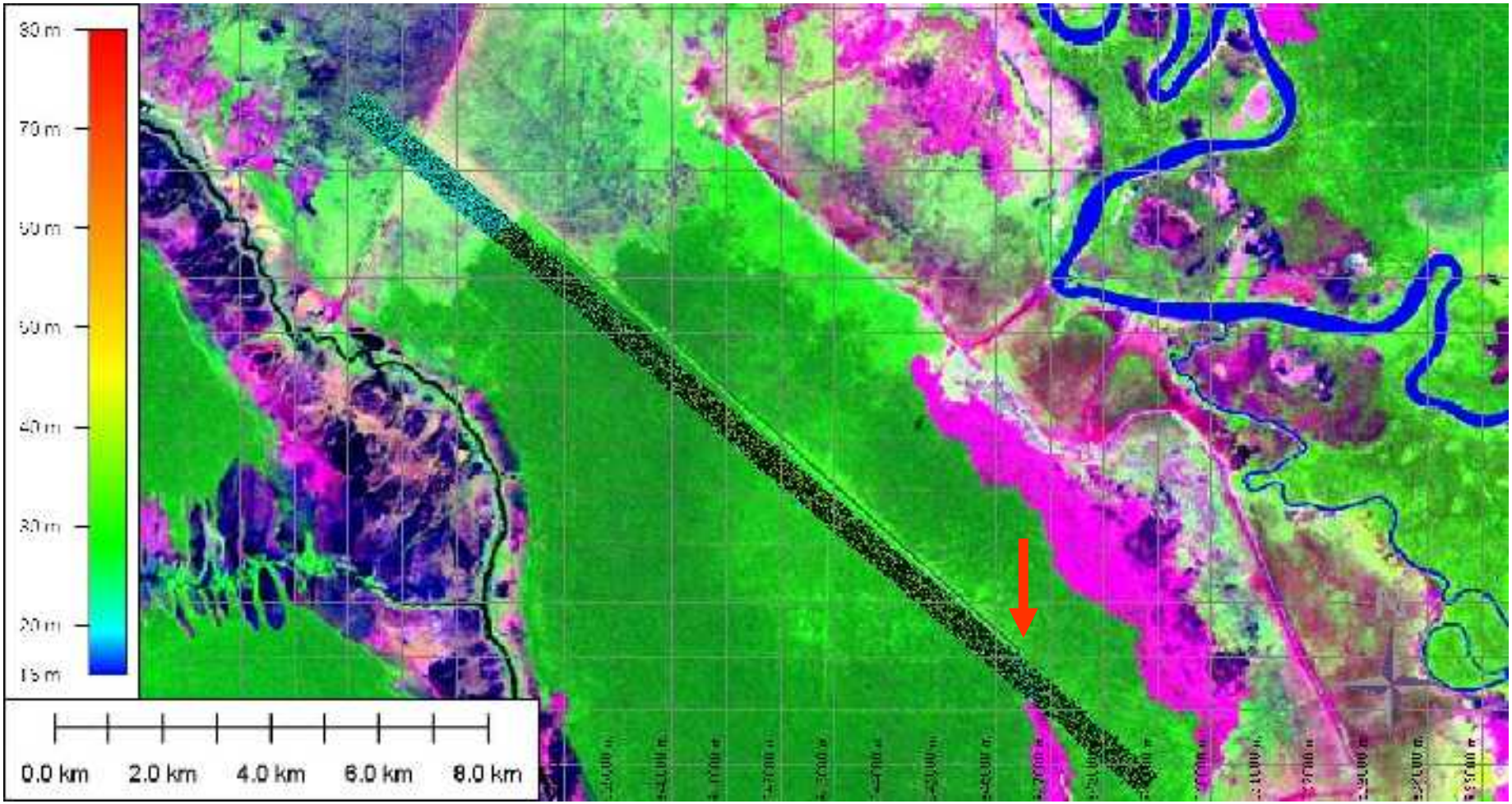

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Track 41a parallel to Turana channel, DSM

Results and Discussion

LiDAR-DSM Tower 1

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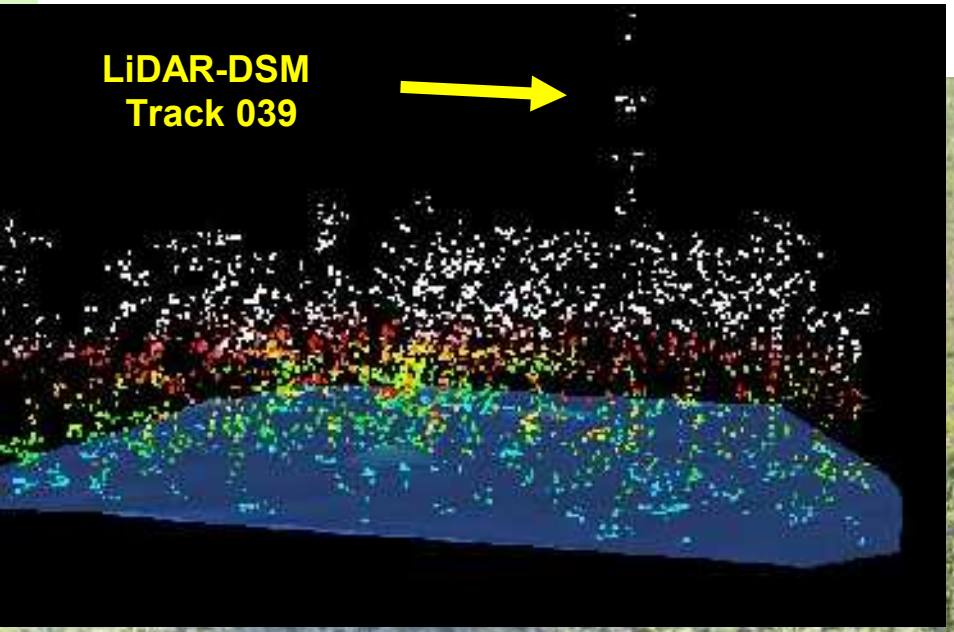
Block C-Turana channel: -2.346° +114.03641°, -259670m S, 837755m E, UTM, WGS84, Zone 49S



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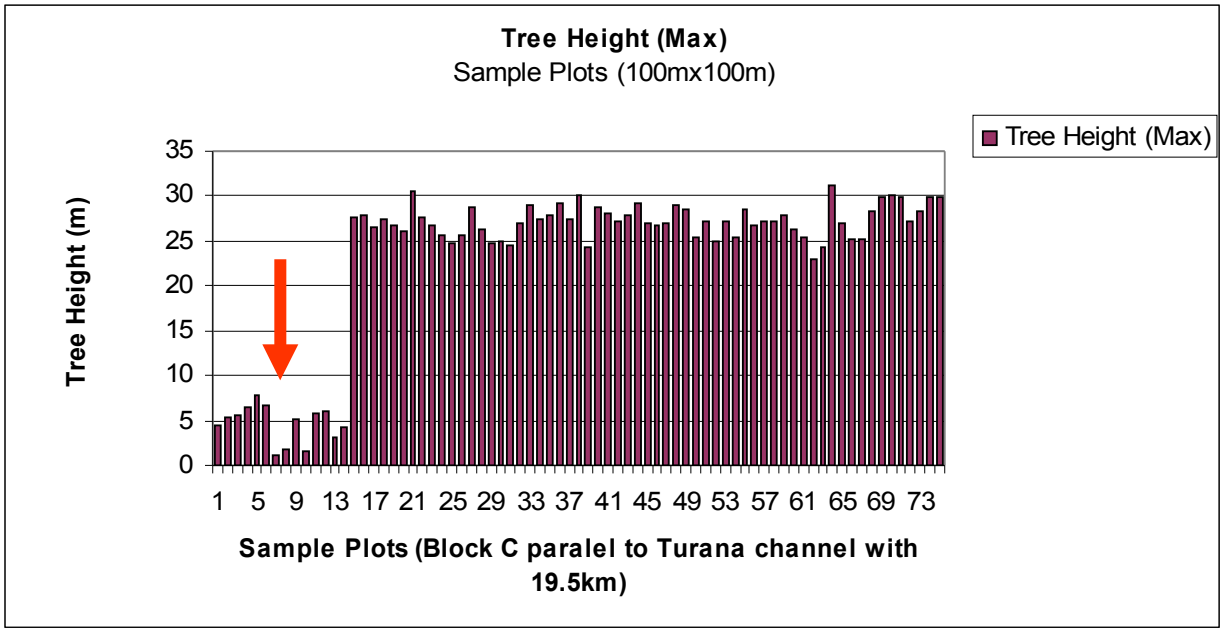
Clear cut



Maximum tree height for 75 sample plots,
each 100mx100m parallel to Turana channel,
Averaged maximum tree height 27.2m

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Tree Heights

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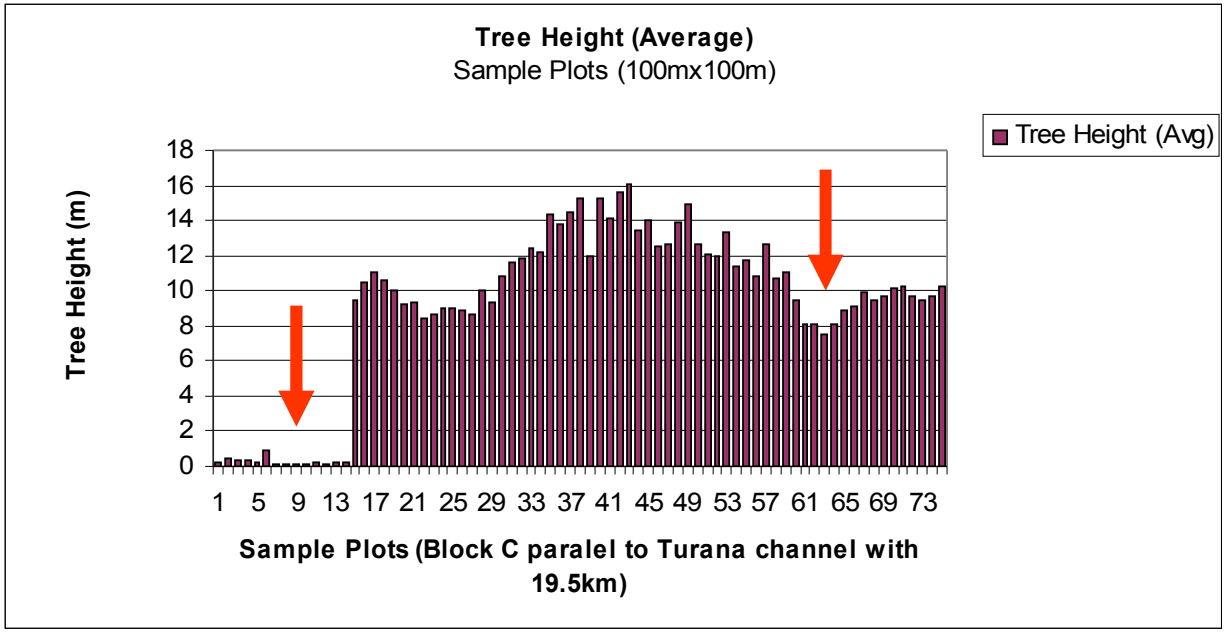
Clear cut **Turana channel**



Average tree height for 75 sample plots,
each 100mx100m parallel to Turana channel,
Averaged average tree height 11.2m

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Tree Heights, AGB-biomass

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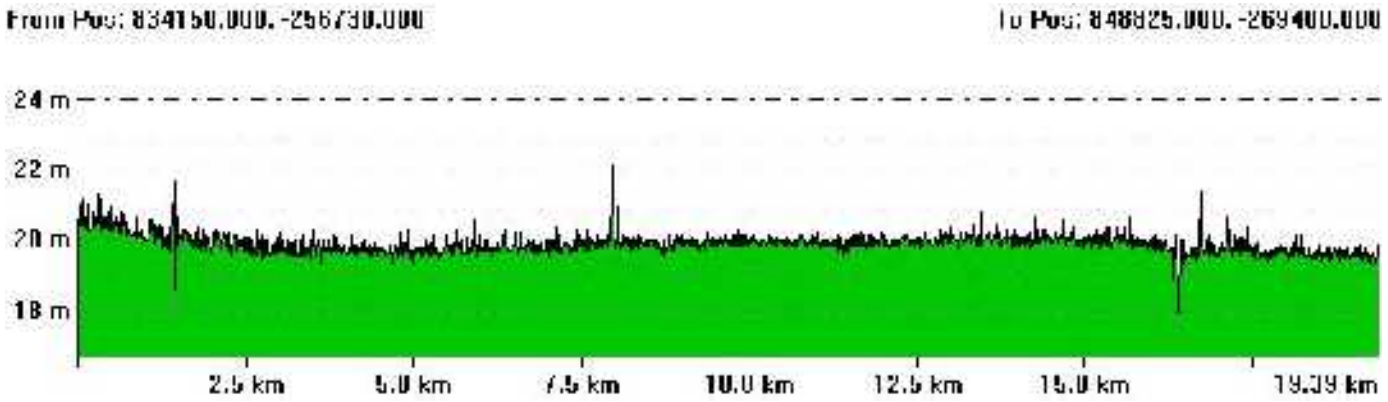
Turana channel

Transect

Tree Height

Classification



Above-Ground Biomass (AGB) in Mg/ha for 75 sample plots,
each 100mx100m parallel to Turana channel,
ranged from 85 to 390 Mg/ha
using regression formular AGB = 0.378 * h(avg)²
after Lefsky et. al 2001

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Tree Heights, AGB-biomass

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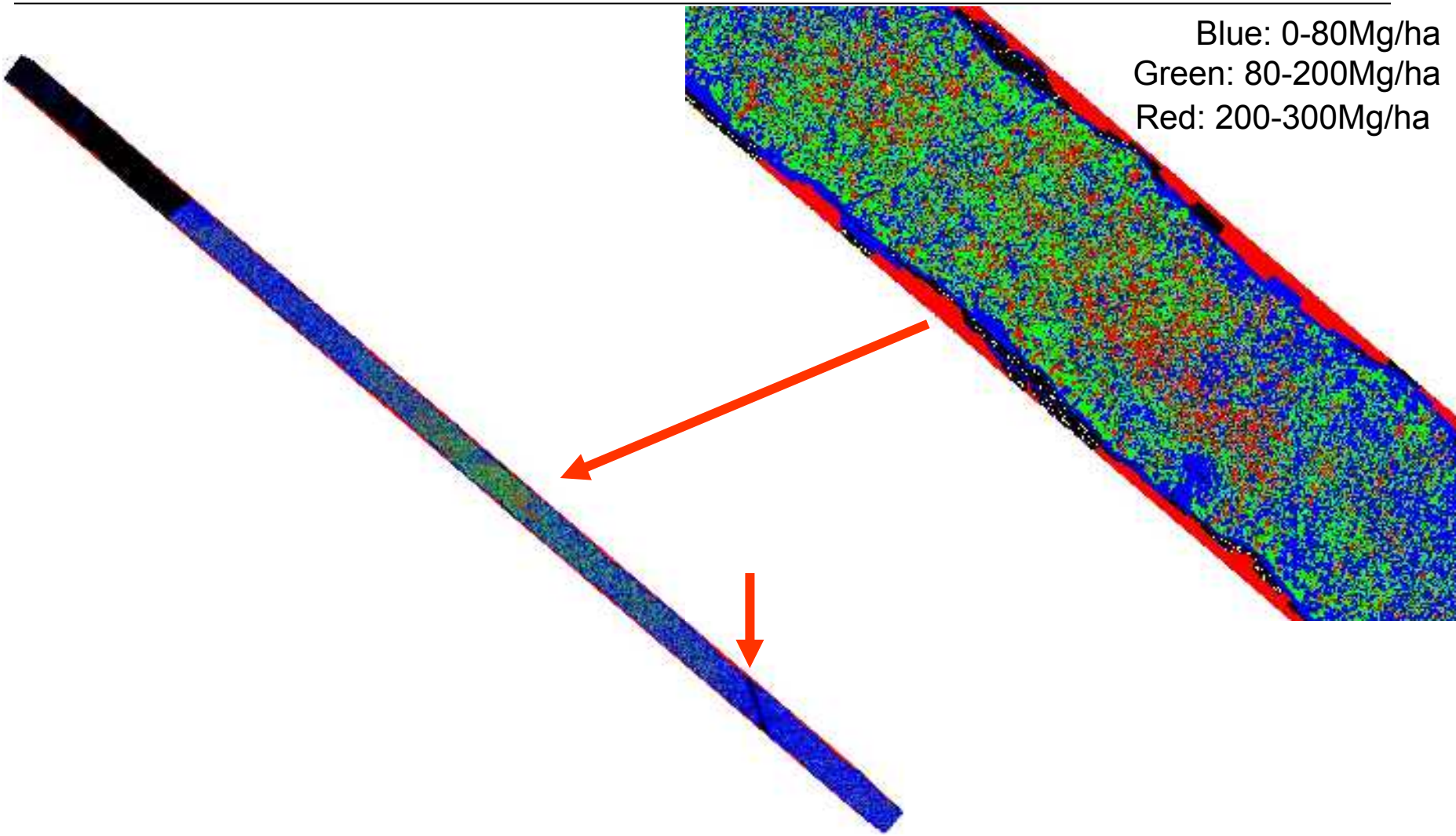

Track 041a is parallel to Turana channel, estimation of Above Ground Biomass (AGB)

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Tree Heights, AGB-biomass

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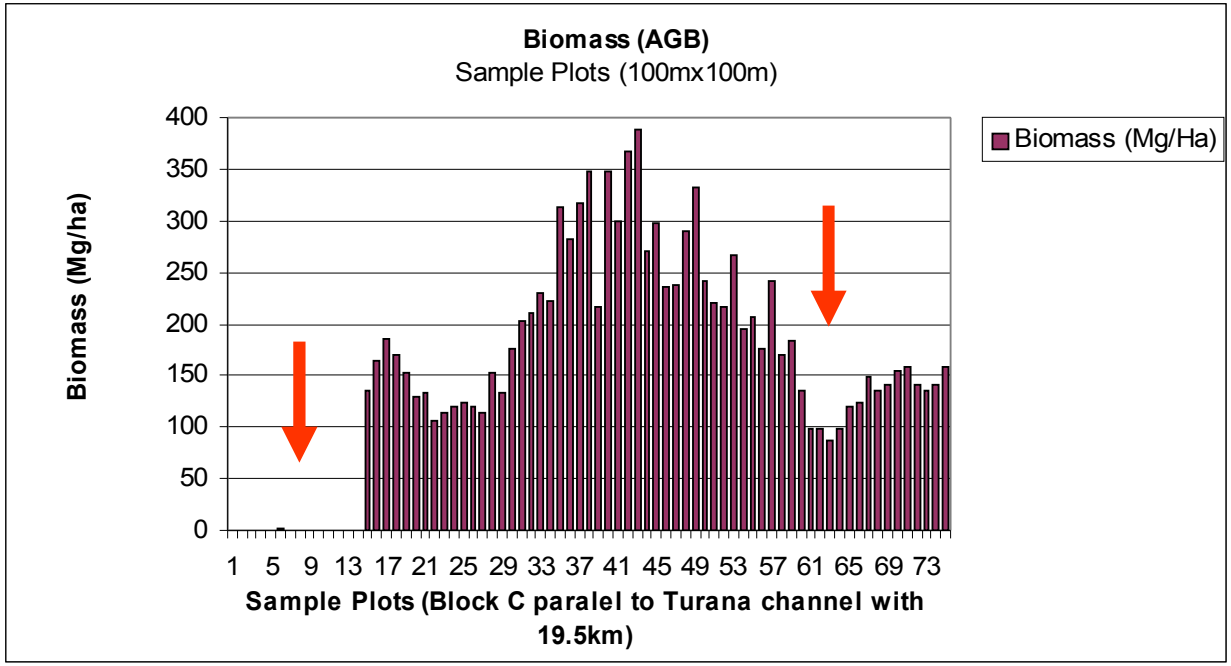
Clear cut **Turana channel**



Above-Ground Biomass in Mg/ha for 75 sample plots, each 100mx100m parallel to Turana channel, ranged from 85 to 390 Mg/ha

using regression formular AGB = 0.378 * h(avg)²

after Lefsky et. al 2001

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Results and Discussion

Tree height vs Slope

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Aerial Photo of Kereng Bangkirai and Camp Nat. Laboratory taken on 6.8.2007

CIMTROP camp with fires from 2006 in catchment

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Tree height vs Slope

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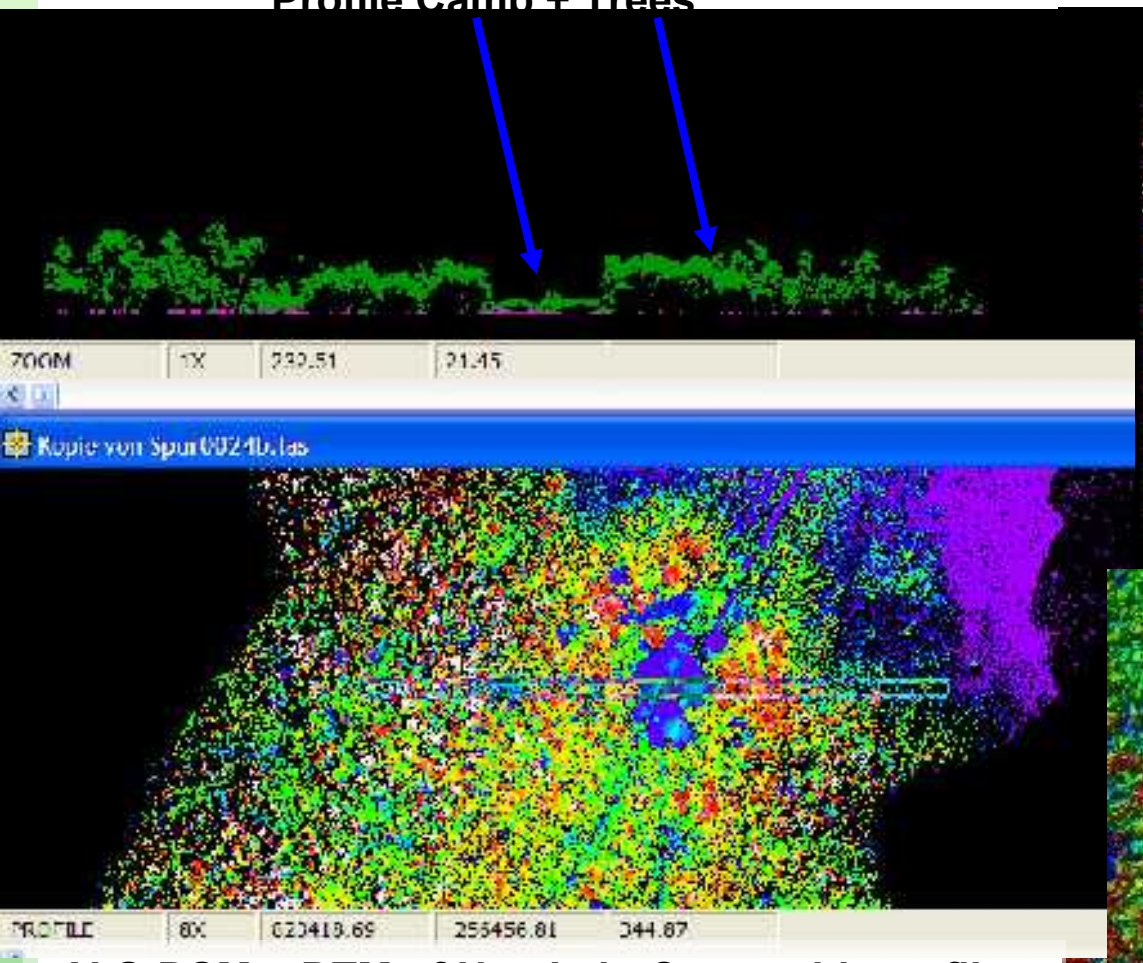
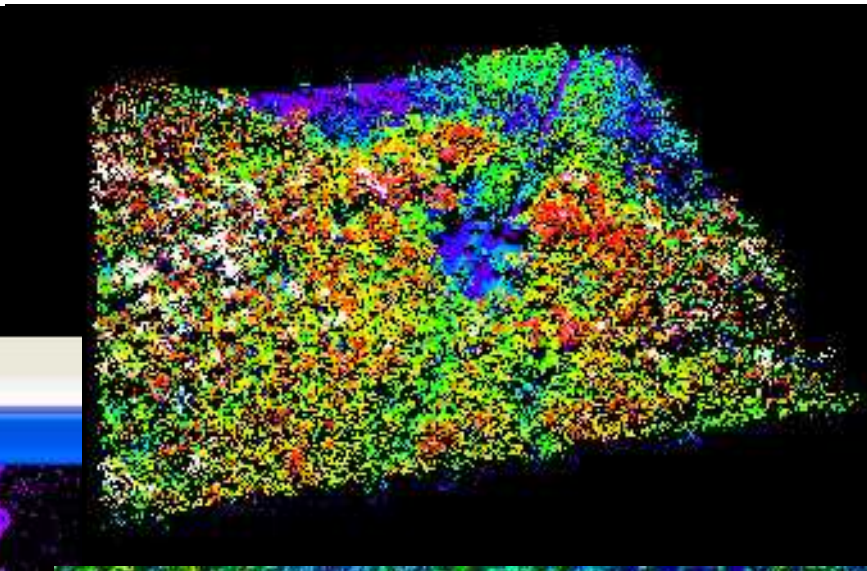
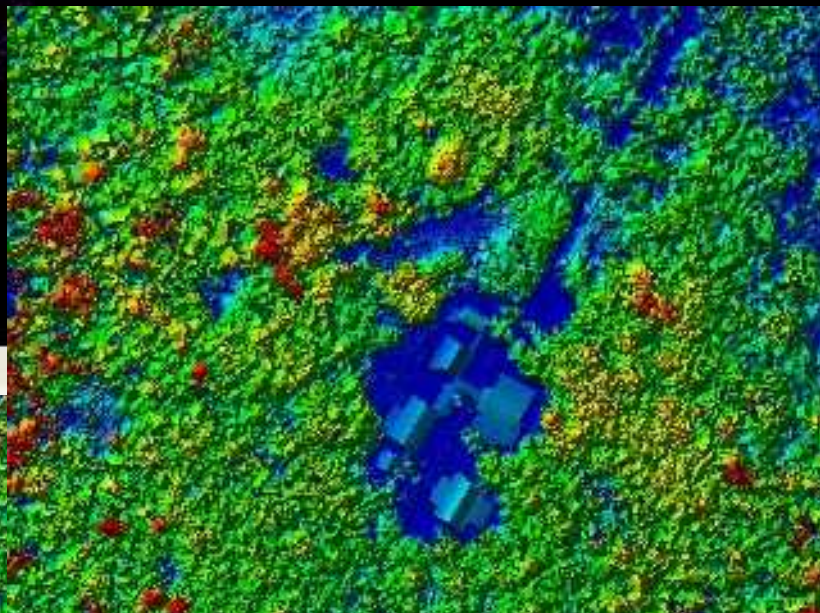
Profile Camp + Trees







ALS-DSM + DTM of Nat. Lab. Camp with profiles and 3D-presentation, Each tree can be resolved and analysed

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Tree height vs Slope

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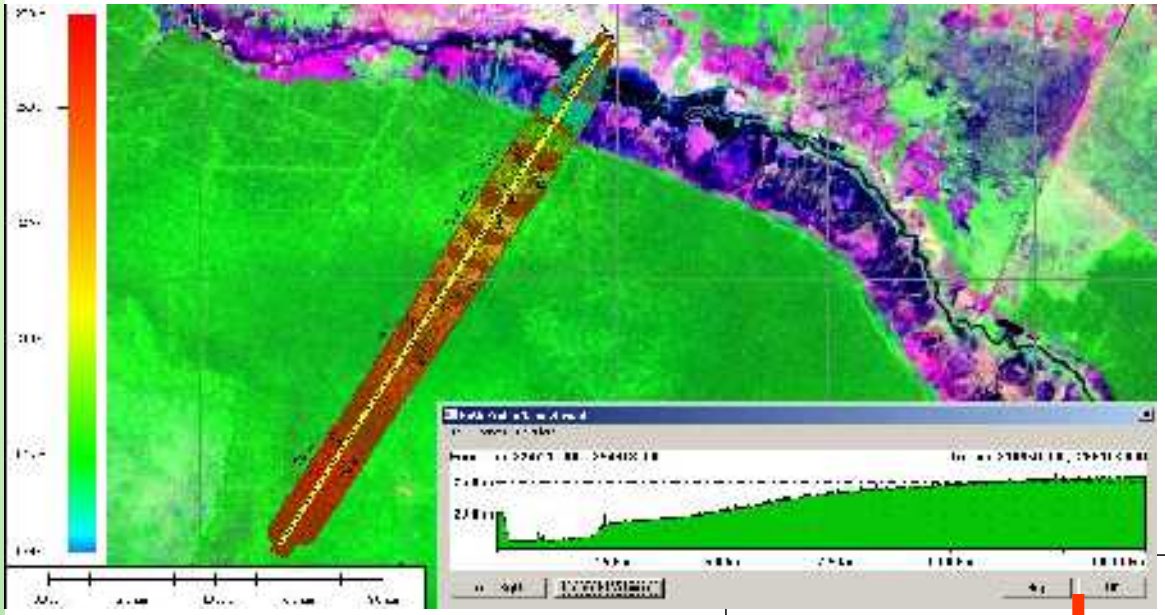
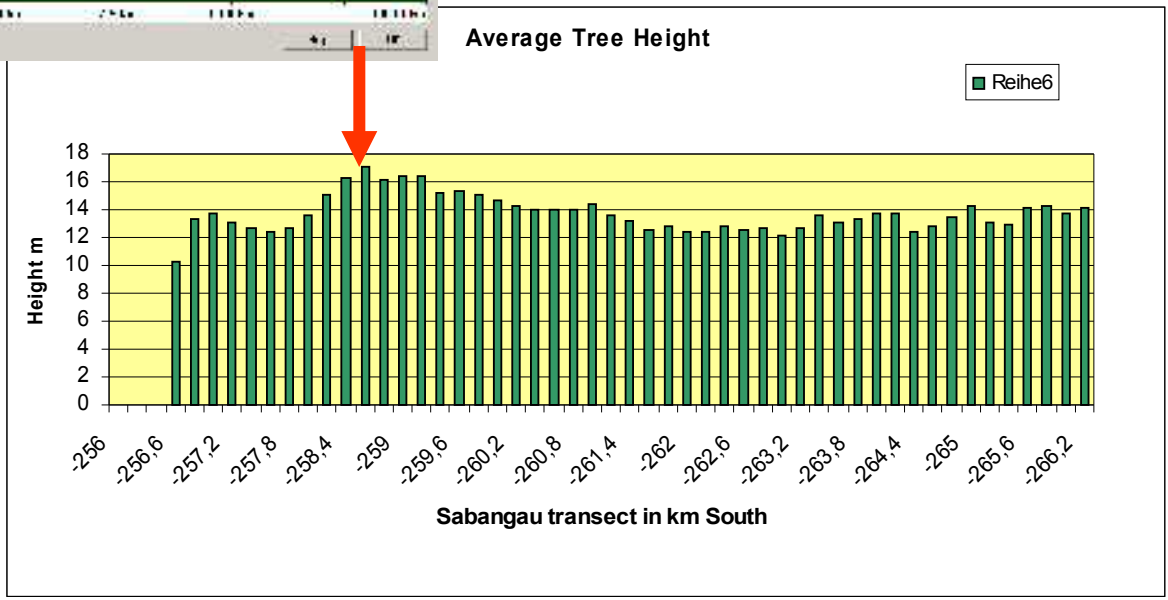


Sabangau Cimtrop Transect,
Peat Swamp Forest
DTM with 1m contour lines
18m (15m) to 26m
PSF 10 years not logged
1997 - 2007

Average Tree Height without terrain

Samples of track 025 taken approx. 400m away from transect



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Results and Discussion

Tree height vs Slope

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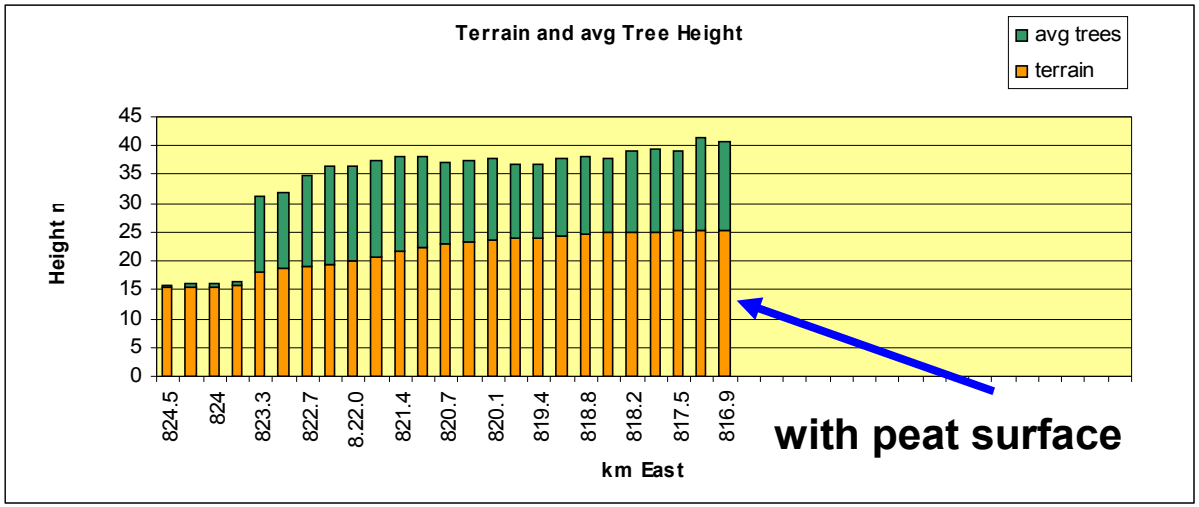

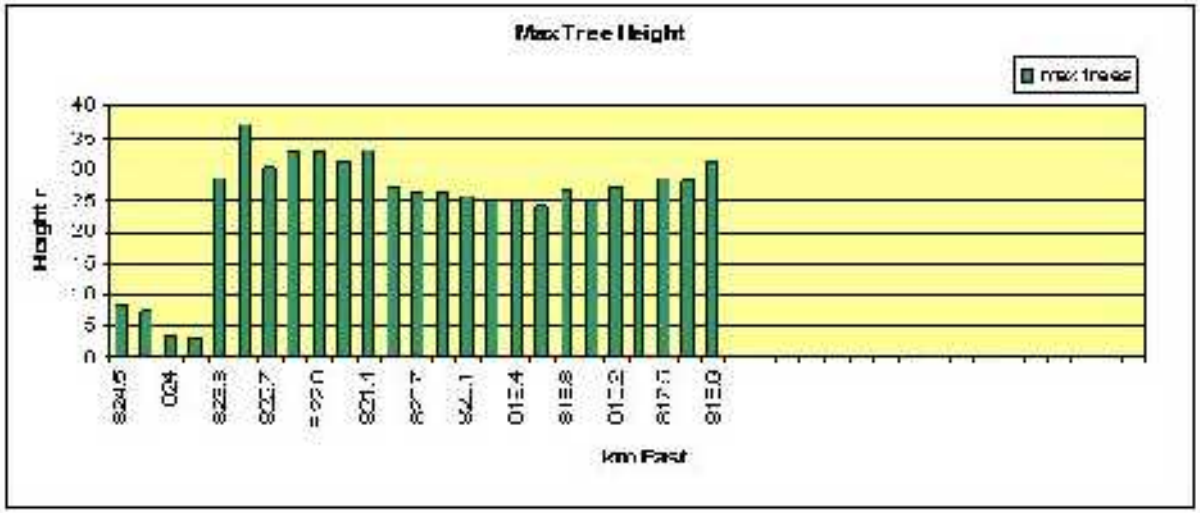

Max. tree height with up to 37.3m at the slopes to the peat dome here at km822. Sabangau ALS-DTM Track24 with **peat dome of 26m**

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Averaged tree height without the peat surface. A strong relation between tree height and peat slope is existing. At km822.3 we have the highest averaged trees with 17.1m. A lot of water and good soil nutrition's are here available. At km819.4 we found the lowest averaged tree height value with 12.6m. The tree heights increases to the dome, may be caused by not to strong logging. No railway transect in the last three ALS measurements. The steepest peat surface is at km 822 with 0.7m-0.8m for 600m path length, that are approx. **0.17% max. slope.**
=> Good nutrients and permanent water saturation related with the permeability, interflow, water storage capability and nutrient availability **in the peat slope/dome.**

The average of averaged tree height of the 12km is 14.6m. ©

Results and Discussion

Tree height of camp area

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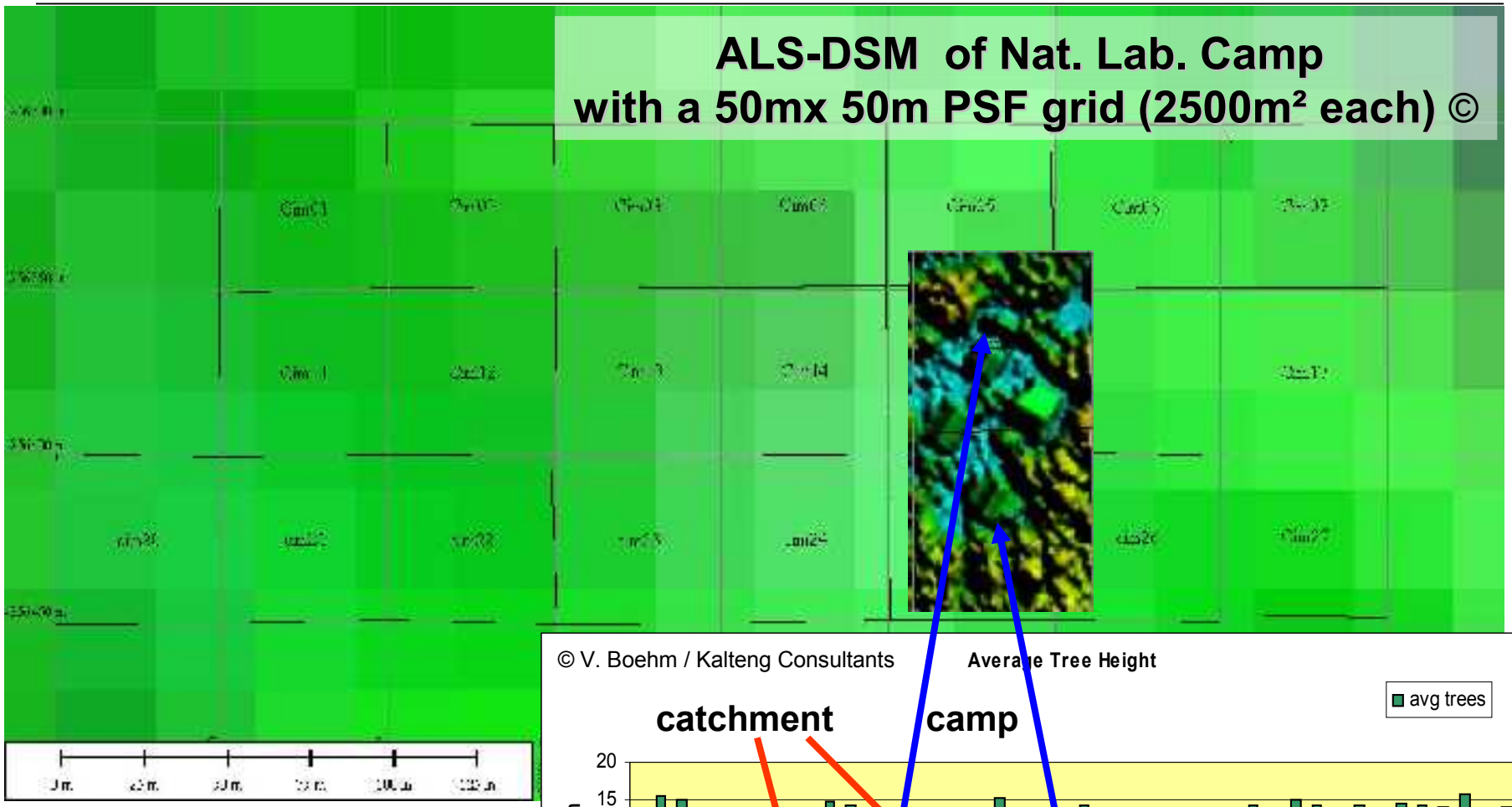
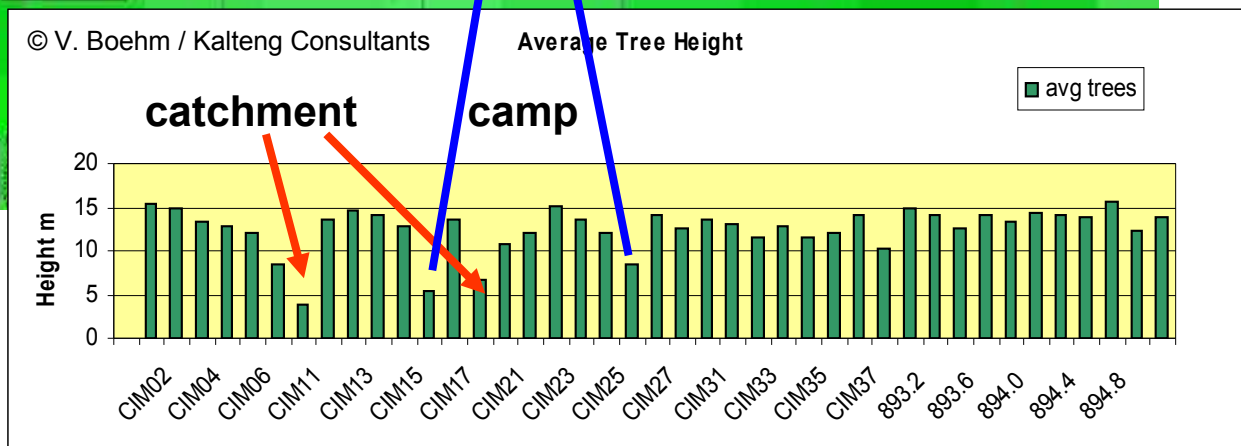
ALS-DSM of Nat. Lab. Camp with a 50mx 50m PSF grid (2500m² each) ©





Averaged tree height of each 50m x 50m sample

AGB ~ a $(h_{(avg)})^2$ Mg/ha ©

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Tree height, AGB-biomass

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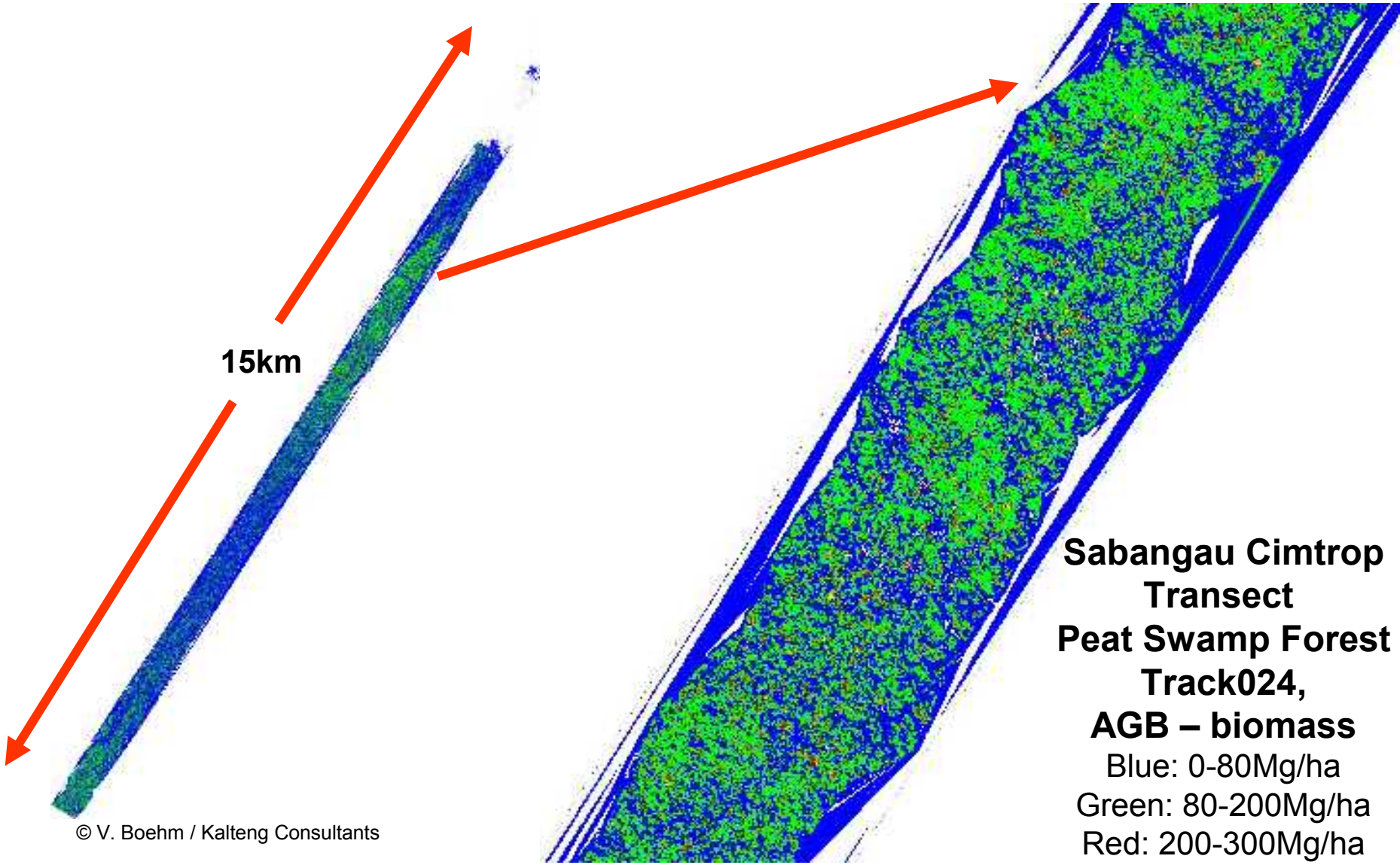

Sabangau Cimtrop Transect
Peat Swamp Forest
Track024,
AGB – biomass
Blue: 0-80Mg/ha
Green: 80-200Mg/ha
Red: 200-300Mg/ha

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LiDAR-DSM Tower 2

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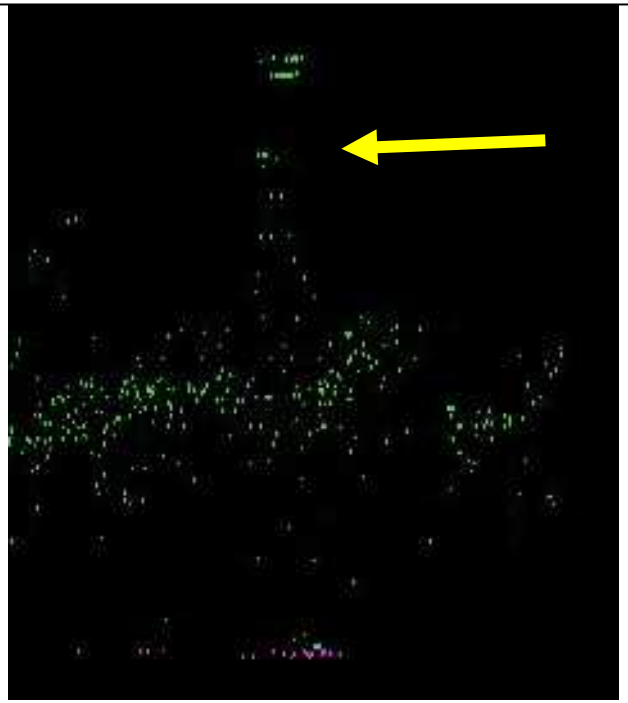

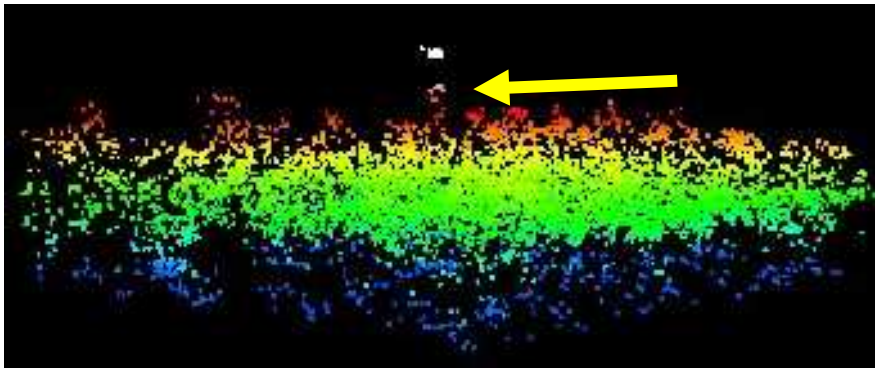

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Japanese Tower at CIMTROP at 823073m E, -257187m S

Results and Discussion

Tree height vs Slope

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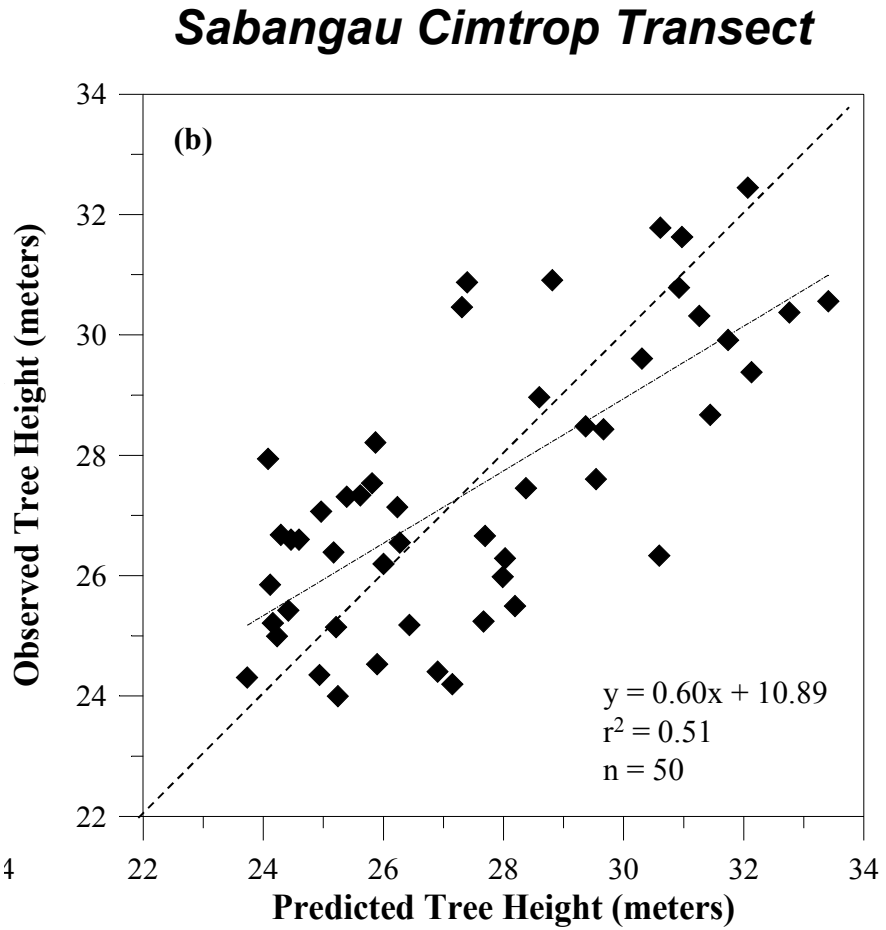

Relationship between observed and predicted tree height (validation dataset). The LiDAR and statistical attributes include validation dataset for Sabangau transects.

Results and Discussion

Tree height vs Slope

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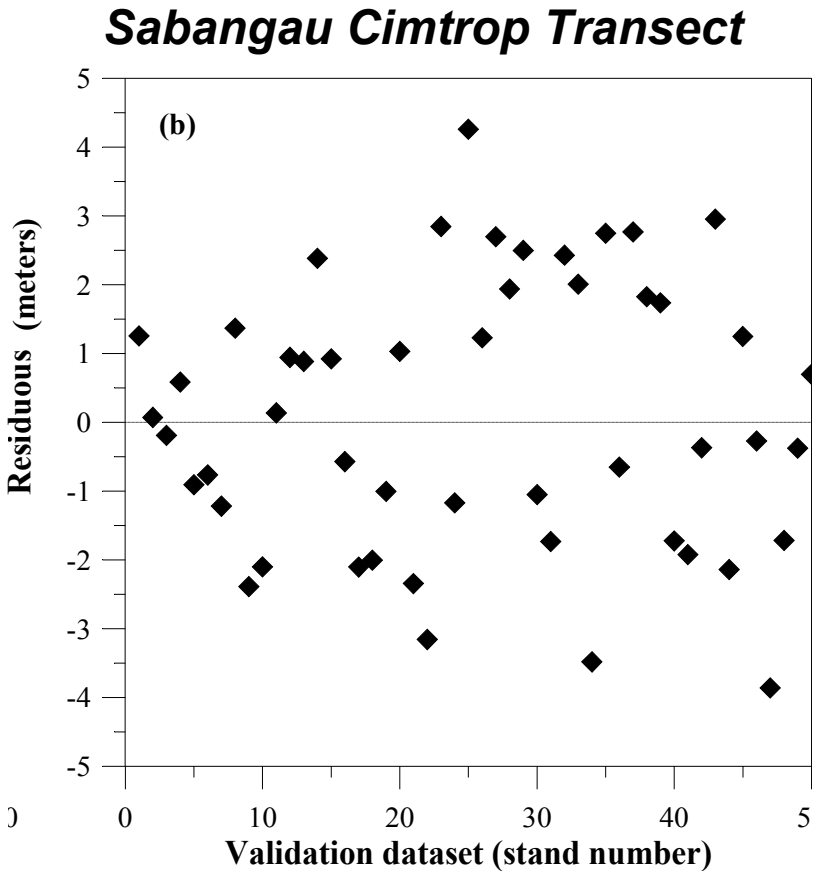

Residuous obtained from the difference of observed and predicted tree height. The statistical attributes include validation dataset for Sabangau transect. Positive and negative values indicate in order over- and underestimation of the tree height.

Results and Discussion
Hampangan REDD+ project

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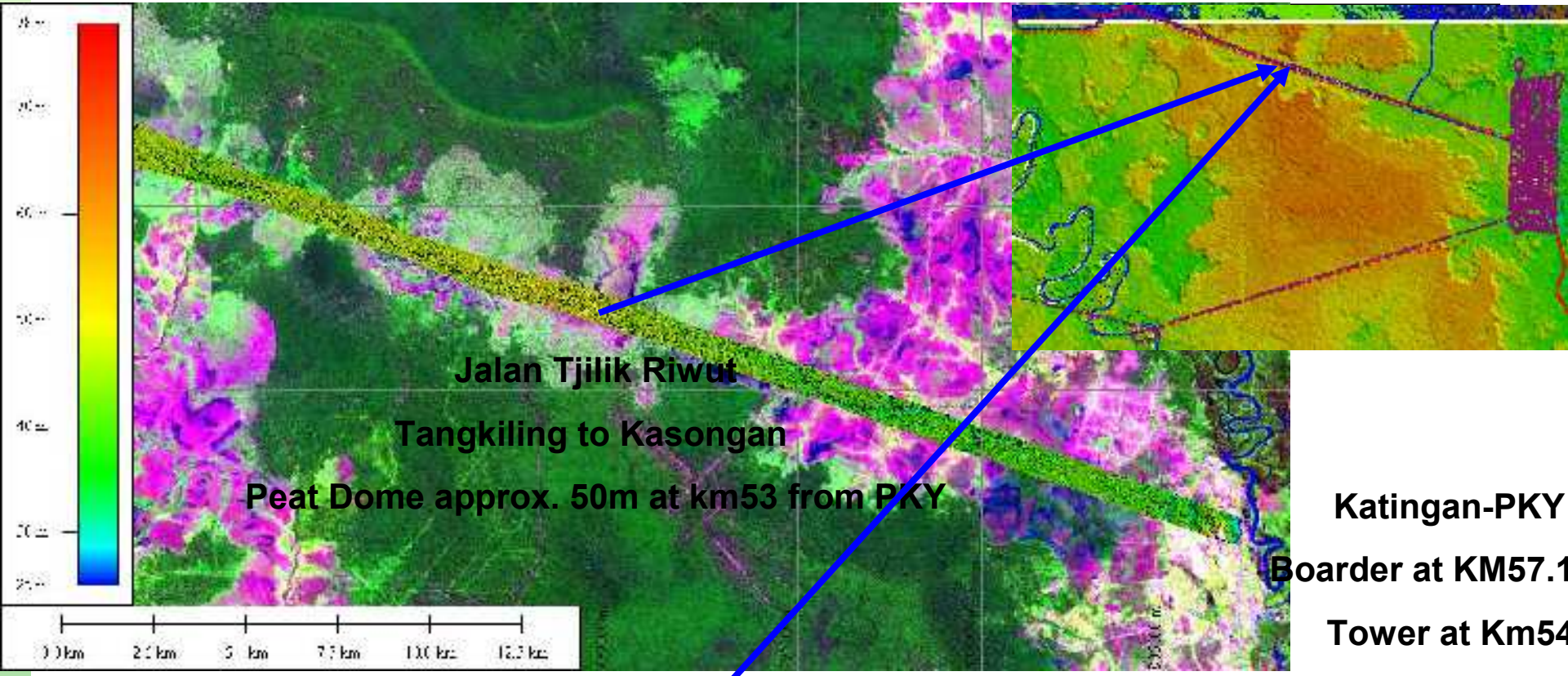

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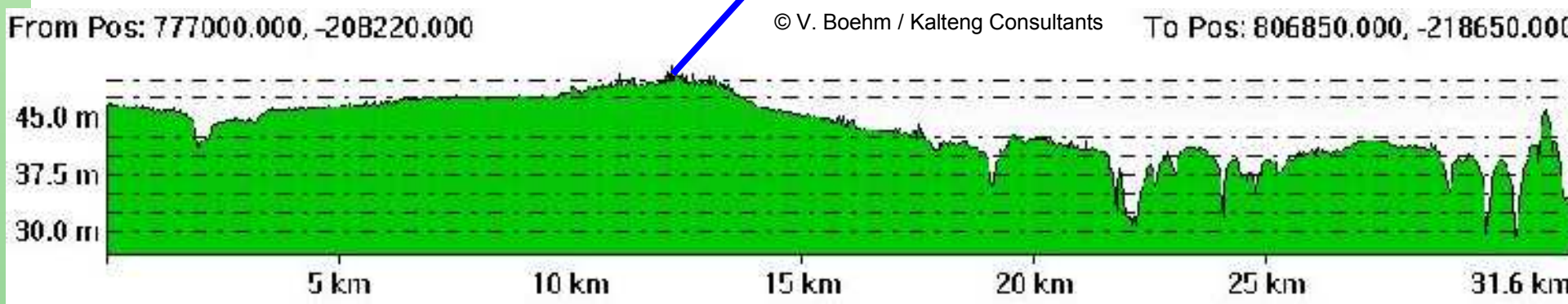

Results and Discussion

Hampangan REDD+ project

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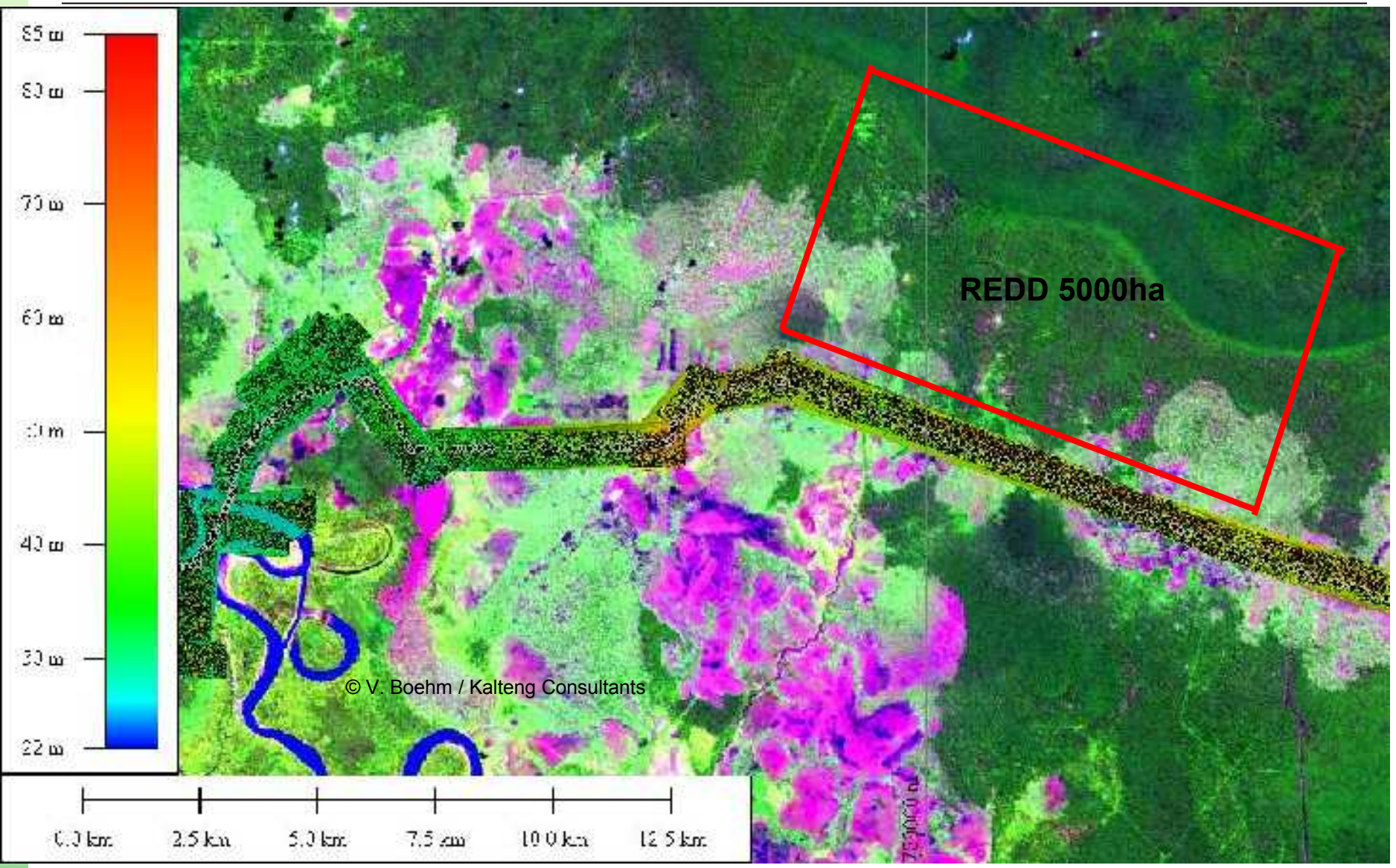

Results and Discussion
Hampangan REDD+ project

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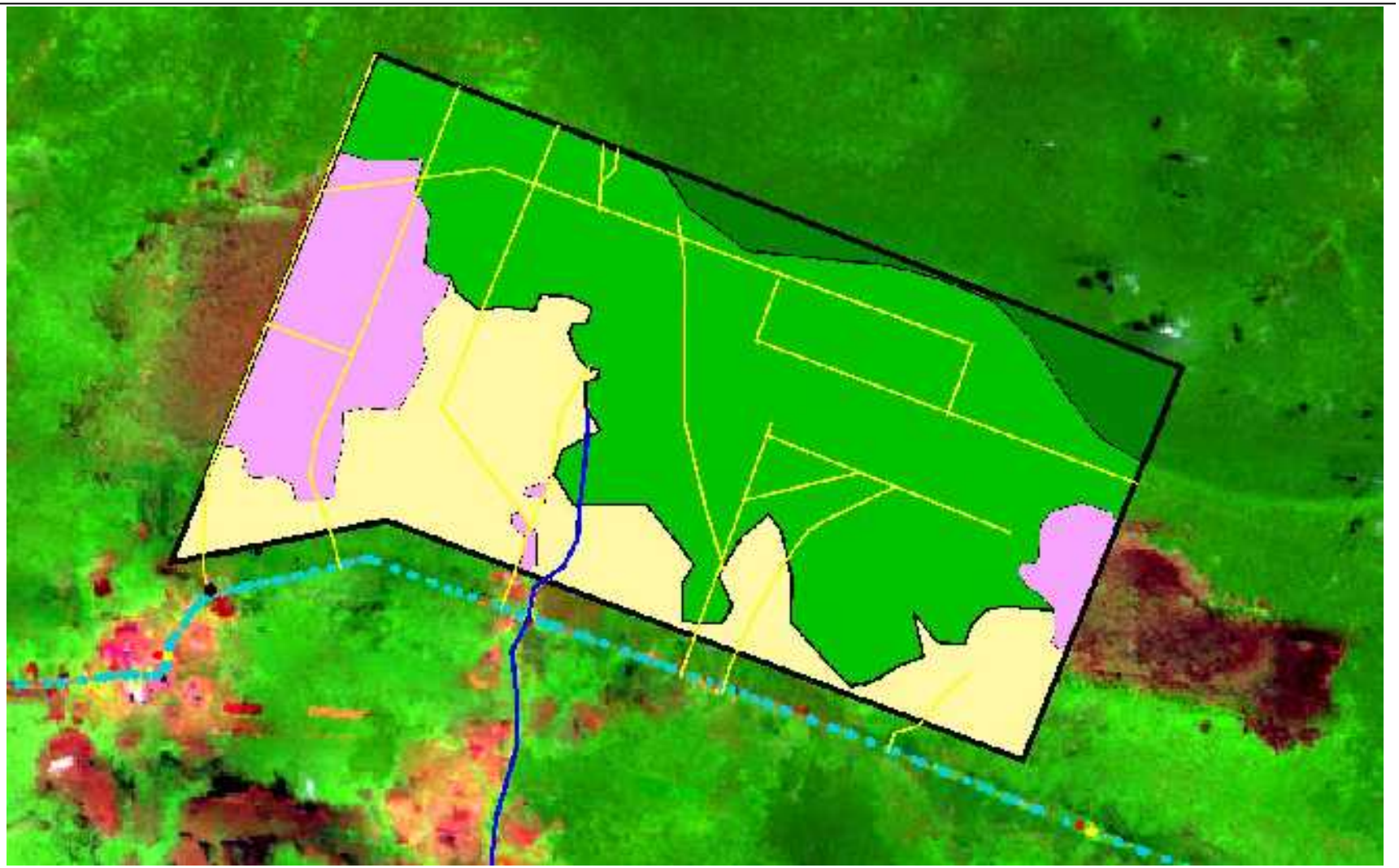

dark-green = primary/secondary forest, 282ha; green = degraded forest, 2920ha; blue = river; yellow = main logging roads;sandy = clear cut and shrubs, bushland,1898ha; pink = fires 2002; black point = UNPAR-building

Results and Discussion
Hampangan REDD+ project

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- *For the proposed Hampangan REDD+ project LiDAR data would be very helpful to analyse by multi-temporal measurments growth and loss of biomass*

- *With LiDAR technology single tree detection is possible and therefore the above-ground biomass (DSM – DTM) can be estimated*

- *Peat dome can be found with LiDAR technology*

- *Storage of carbon amount can be measured combinded with peat drillings*

- *With LiDAR data Radar-data can be calibrated, Forest Inventory, Topographic Maps, find illegal logging channels in PSF, Flood Plain Mapping, Environmental Protection,*
Peat Growth and Peat Loss measurement (multi-temporal)

Results and Discussion

Fires 1 + 2 of 2006

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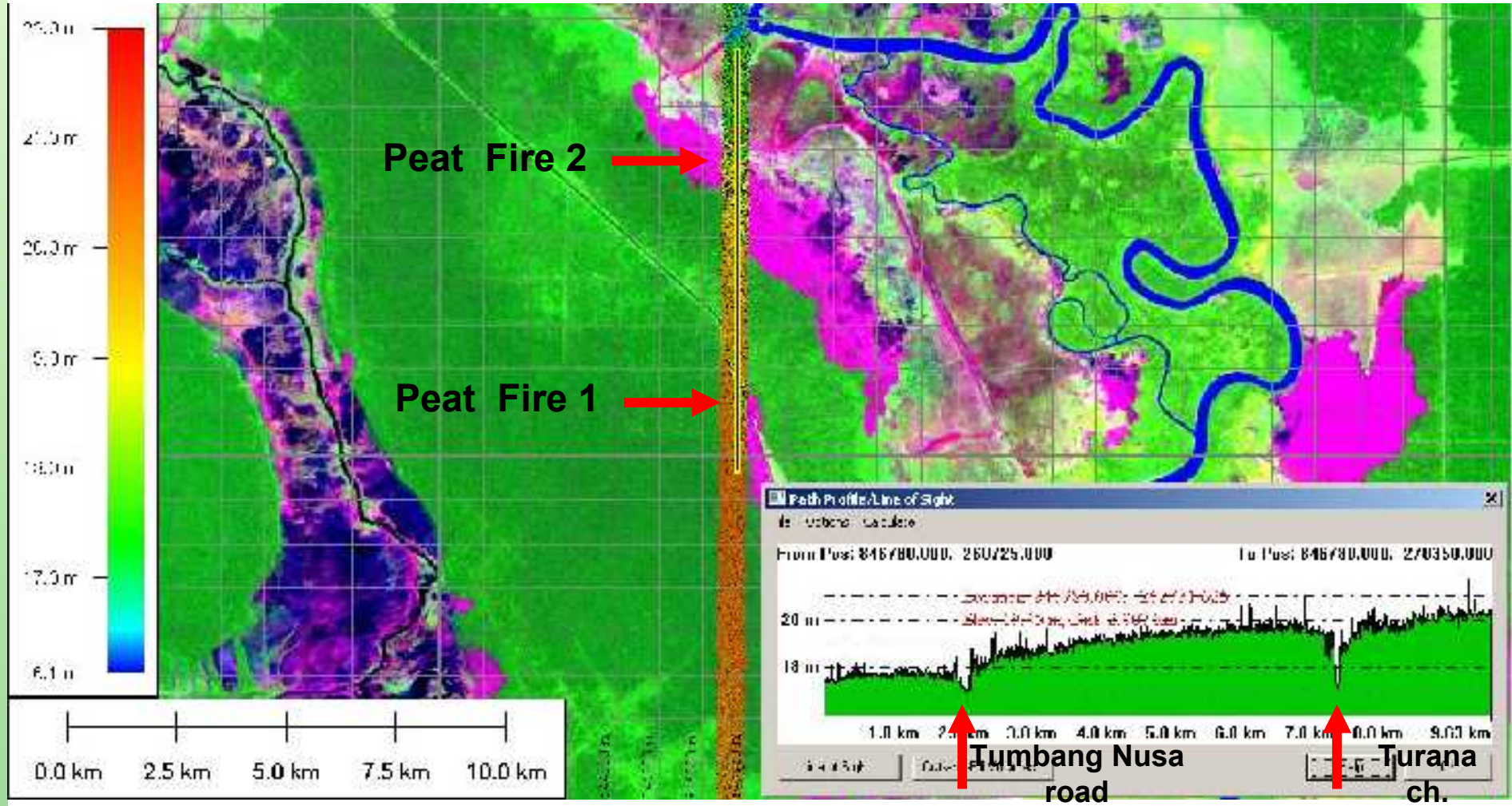
Two fire area from 2006 near Tumbang Nusa and Turana channel



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LiDAR-DTM + Landsat 2007 and two fire area from 2006; DTM-profile

Results and Discussion

Fire1 2006, Turana channel

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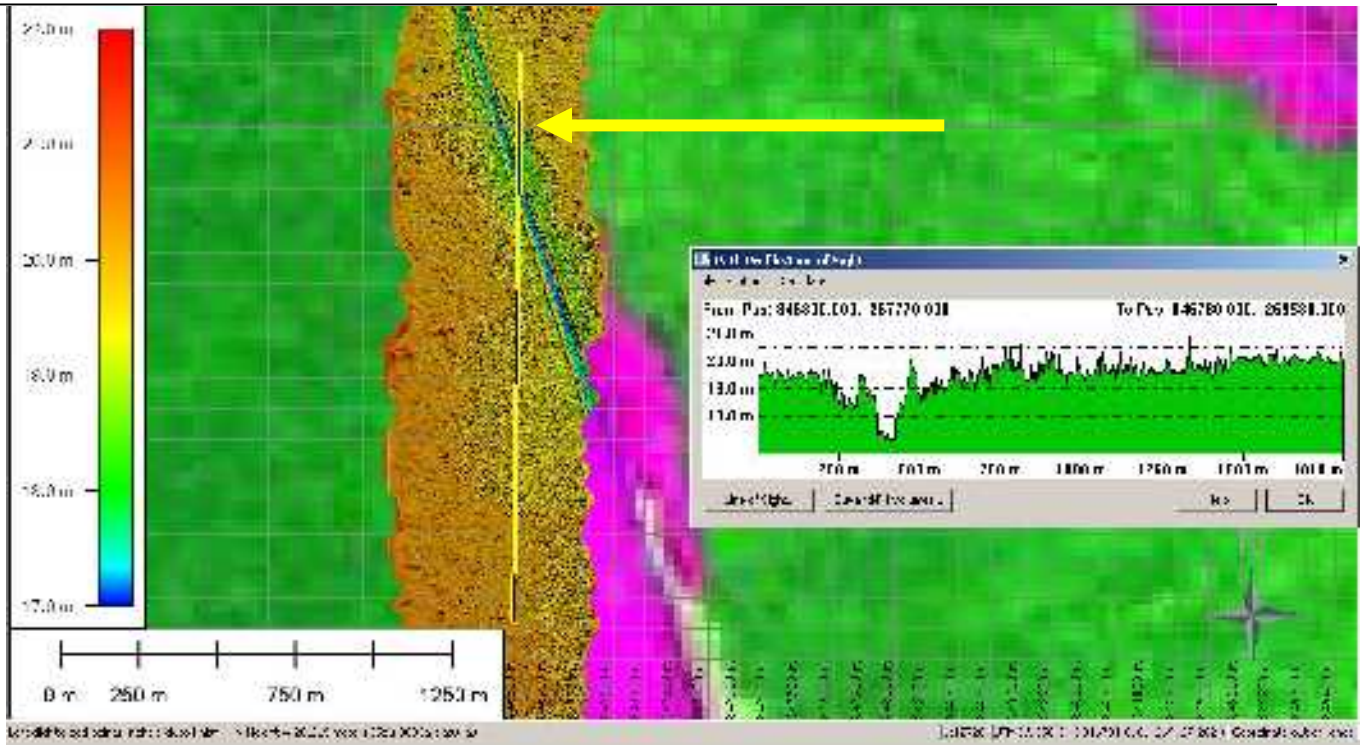
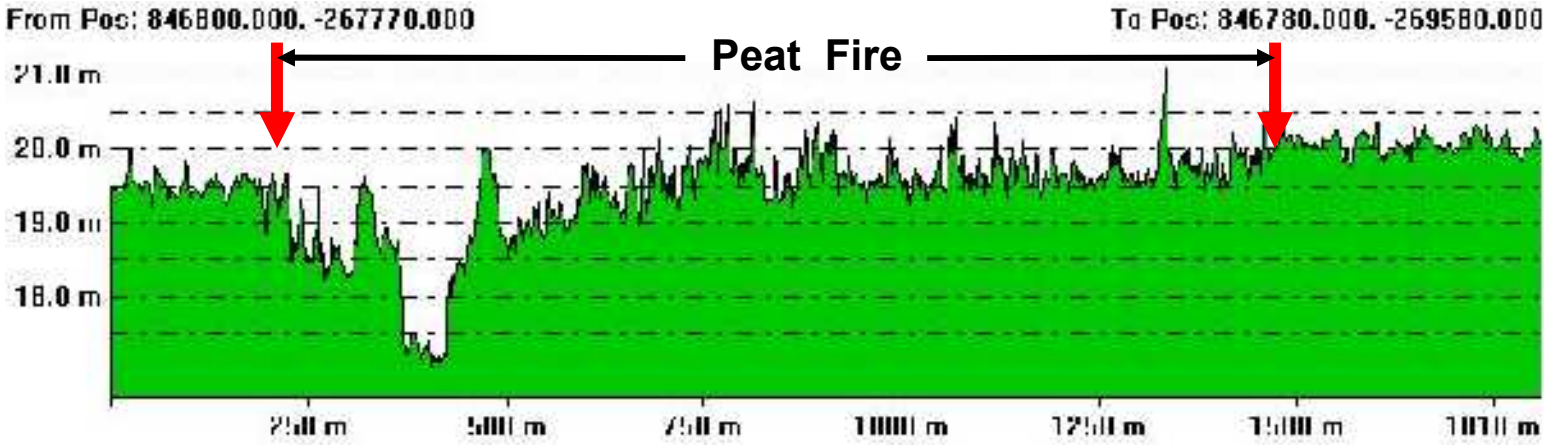
LiDAR-DTM + Landsat 2007

Turana channel

Peat Fire 2006 approx. 30cm





Results and Discussion

Fire1 2006, Turana channel

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Ortho-Photo 1534, Peat Fire

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Ortho-Photo 1531, Turana channel

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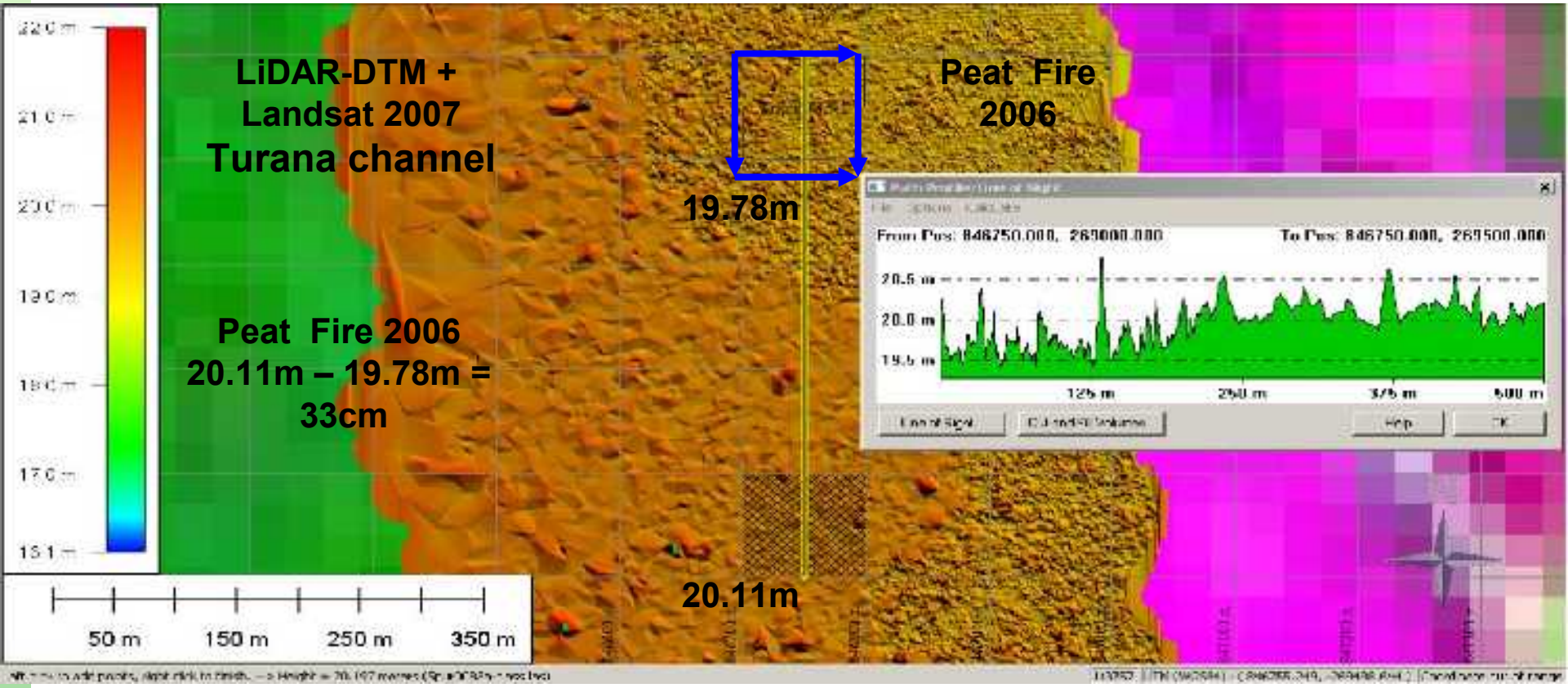

LiDAR-DTM + Landsat 2007 and Turana fire area from 2006; DTM-profile and 100m x 100m digitizer tool, 20.11m – 19.78m = 33cm fire depth

Results and Discussion

Fire2 2006, Tumbang Nusa

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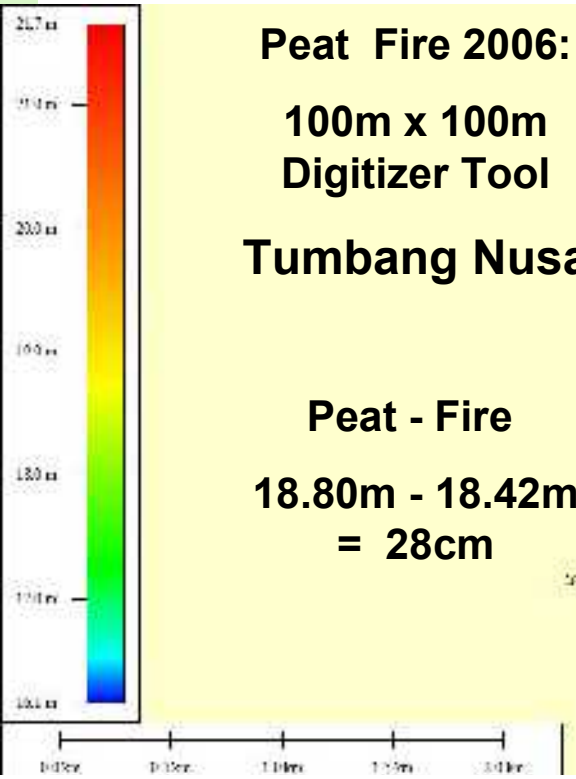
Peat Fire 2006:

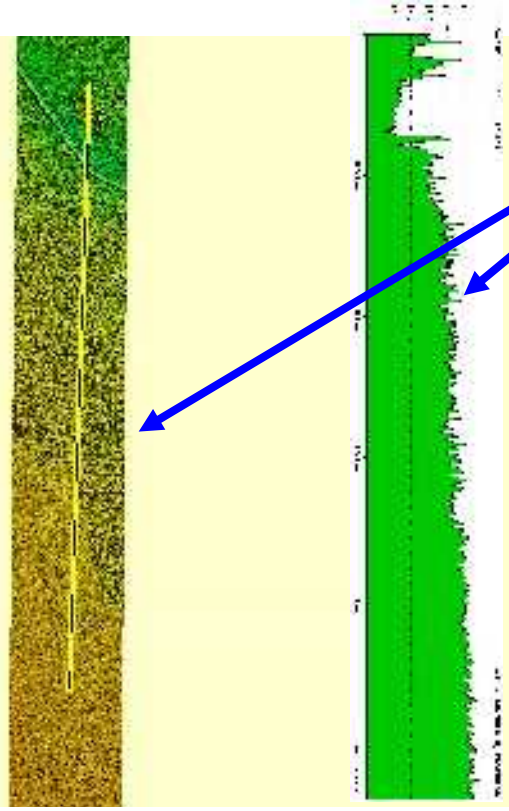
100m x 100m Digitizer Tool

Tumbang Nusa

Peat - Fire

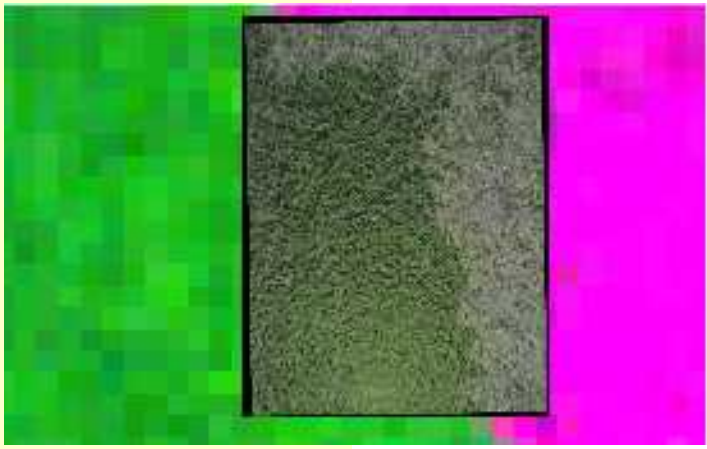
18.80m - 18.42m = 28cm





Peat Fire 2006 approx. 30cm

Ortho-Photo + Landsat 2007 Peat Fire 2006 approx. 30cm



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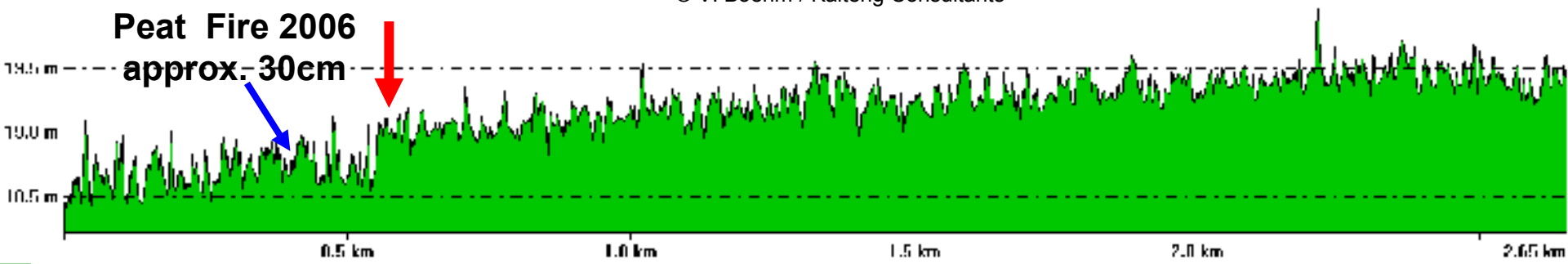
Peat Fire 2006 approx. 30cm



Results and Discussion

Fire2 2006, Tumbang Nusa

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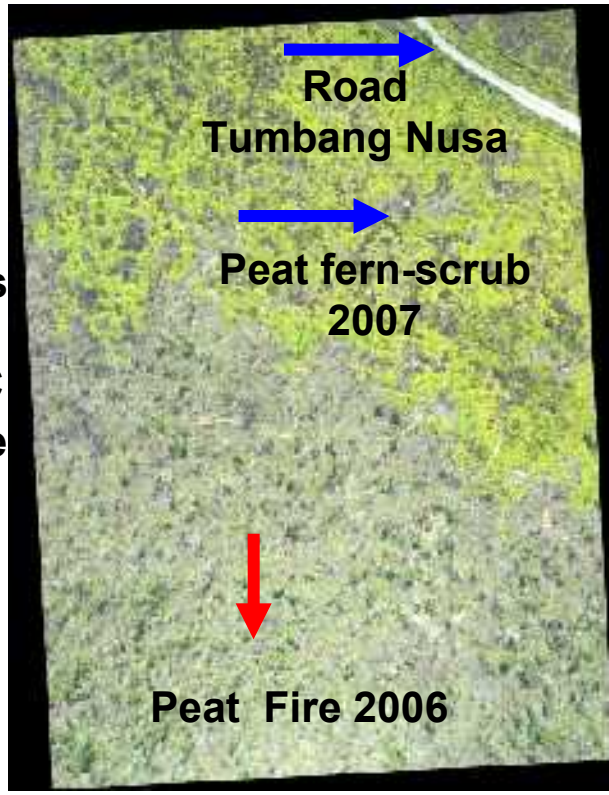
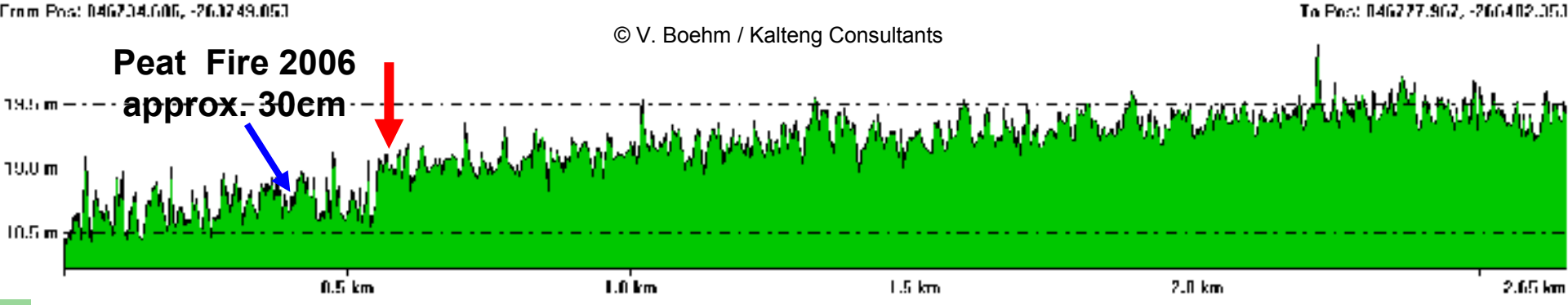
The 2006 fires on the two areas in Block C showed a fire depth varying from 15cm to 30cm. An extrapolation of the fire damages was done using ancillary Landsat scenes of 2007 to the entire Block C and approx. 150 Mio ton of C were release to the atmosphere in 2006.

Ortho-Photos
+ LiDAR-DTM

Tumbang Nusa





Results and Discussion

Fire3 2002, Kalampangan-Turana

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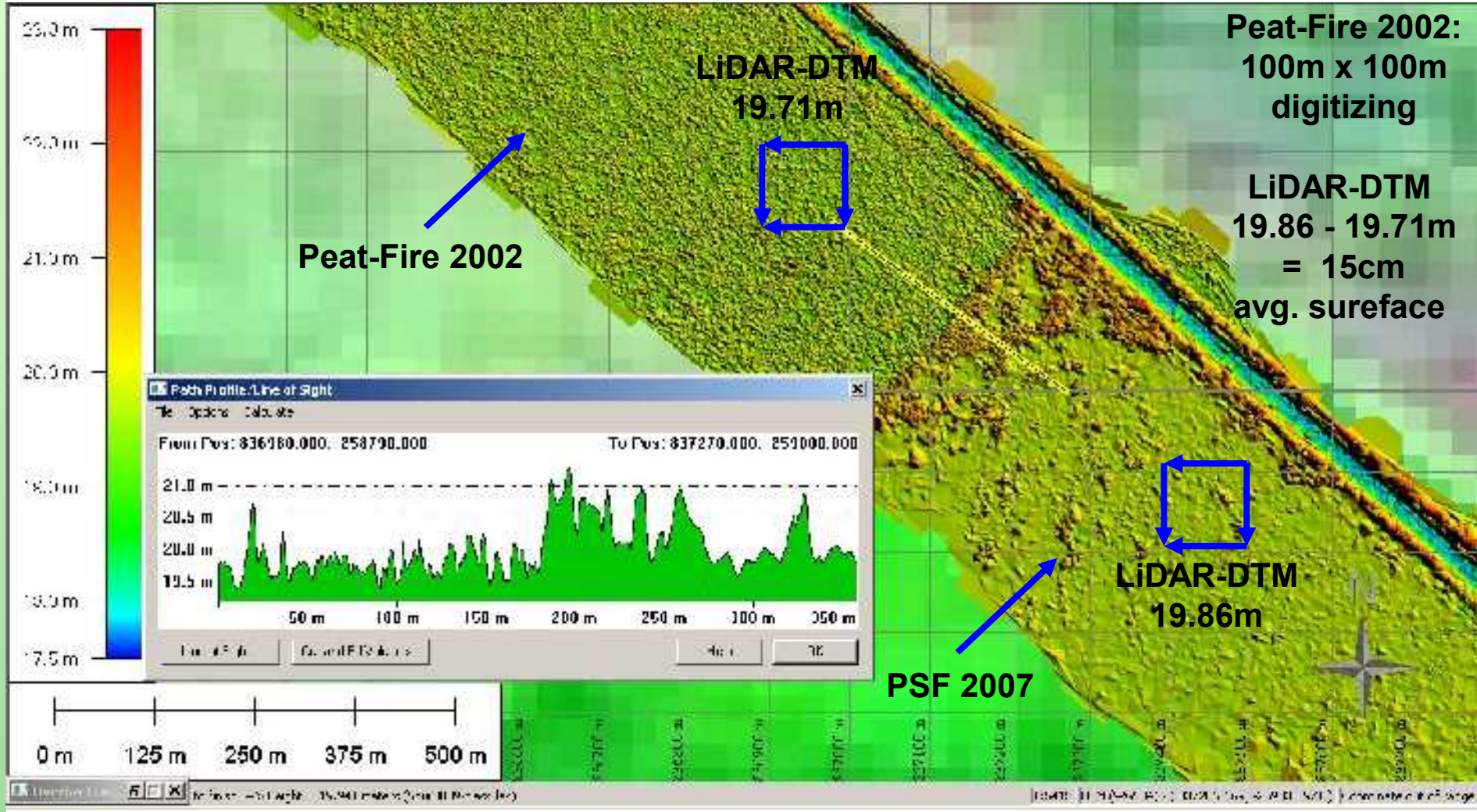

Peat Fires of 2002 here analysed with 15cm, using a 100m Grid (1ha) digitizer tool, Track 039 near Turana channel

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Results and Discussion

Fire3 2002, Kalampangan-Turana

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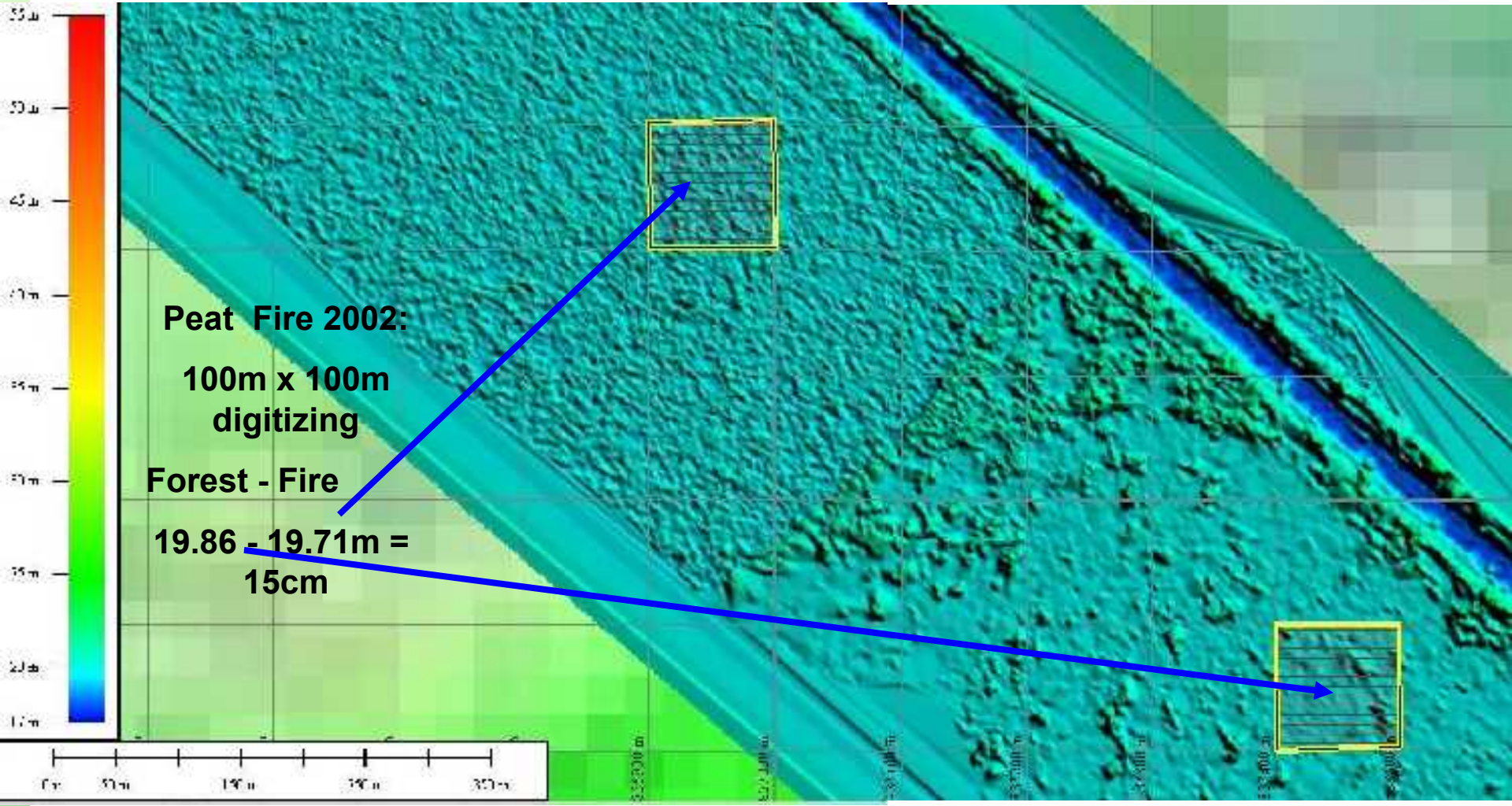

Peat Fires of 2002 here analysed with 15cm, using a 100m Grid (1ha) digitizer tool, Track 039 near Turana channel

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Results and Discussion

Processing => Forest Maps

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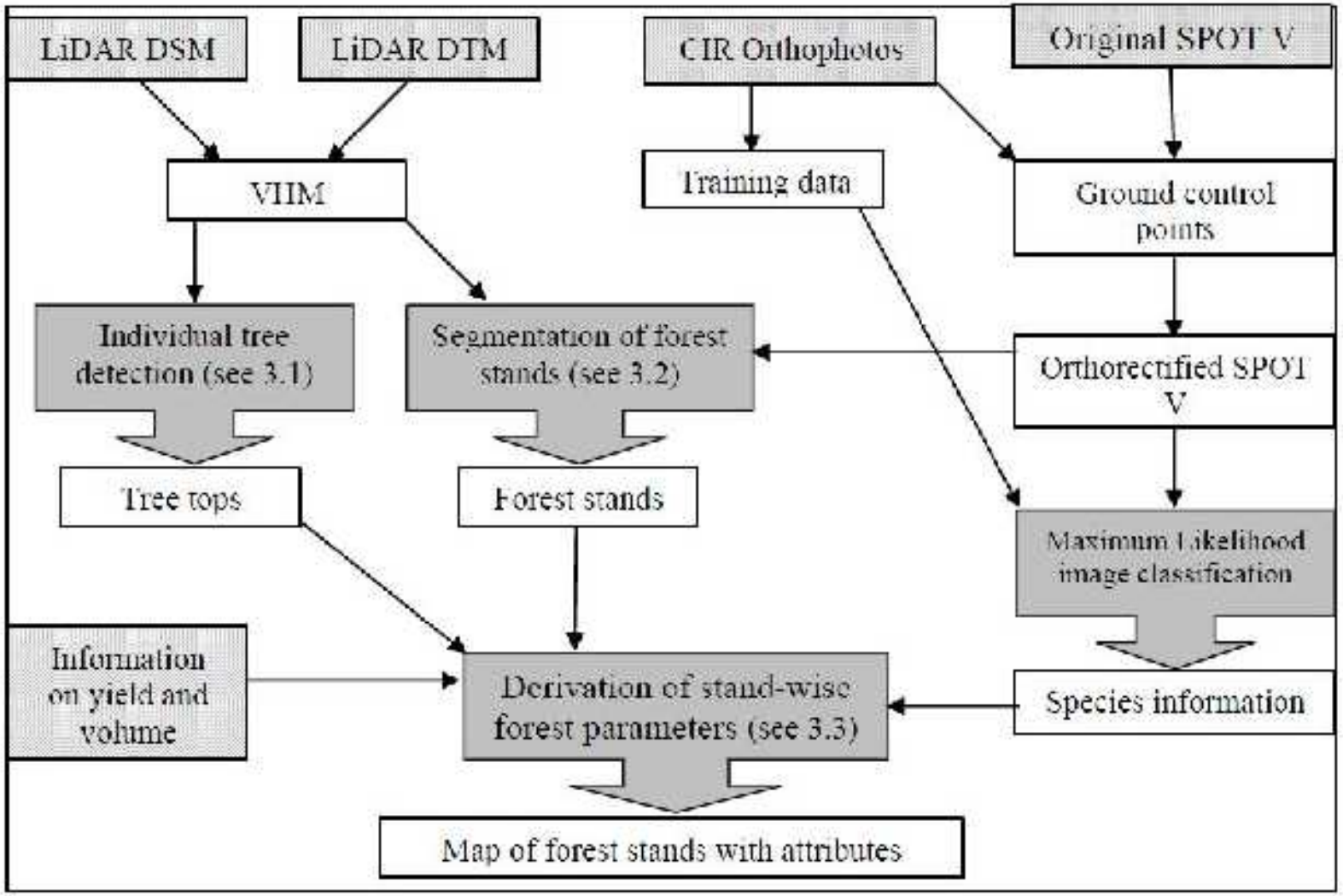

Digital Map of forest stands, © Joanneum Uni Graz, Austria, VHM Vertical Height Model

Final Remarks

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✓ We found out that our analysis were affected by past selective logging activities reducing our linear regression results significantly; especially at Mawas km238 location;

✓Our results are useful to assess the dependence of biophysical properties (e.g. above ground biomass + REDD) with peat dome slope in peatlands environments;

✓ Good nutrients and permanent water saturation related with the permeability, interflow, water storage capability and nutrient availability in the peat slope/dome;

✓ Further research is still necessary in order to test the dependence of other biophysical parameters and feature selection techniques for LiDAR data in different vegetation types in Indonesia as well as field work campaigns;

✓ In spite of the technique used for dependence assessment, interesting results will be probably achieved with the additional use of new LiDAR measurements over the area, e.g. in 2011 regarding change detection of biomass, peat fires etc;

Future Work

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- ✓ New LiDAR measurements in Central Kalimantan (Indonesia);
- ✓ Field work activities for the determination of LAI, Tree Crown Coverage, Above Ground Biomass, REDD and in-situ tree height measurements;
- ✓ Merging of both Ortho-Photographs with LiDAR data;
- ✓ Integration with both Optical and SAR data; Multisensorics;

Acknowledgements

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Thank you!!!