Monitoring of land use change and GHG emissions on peatlands

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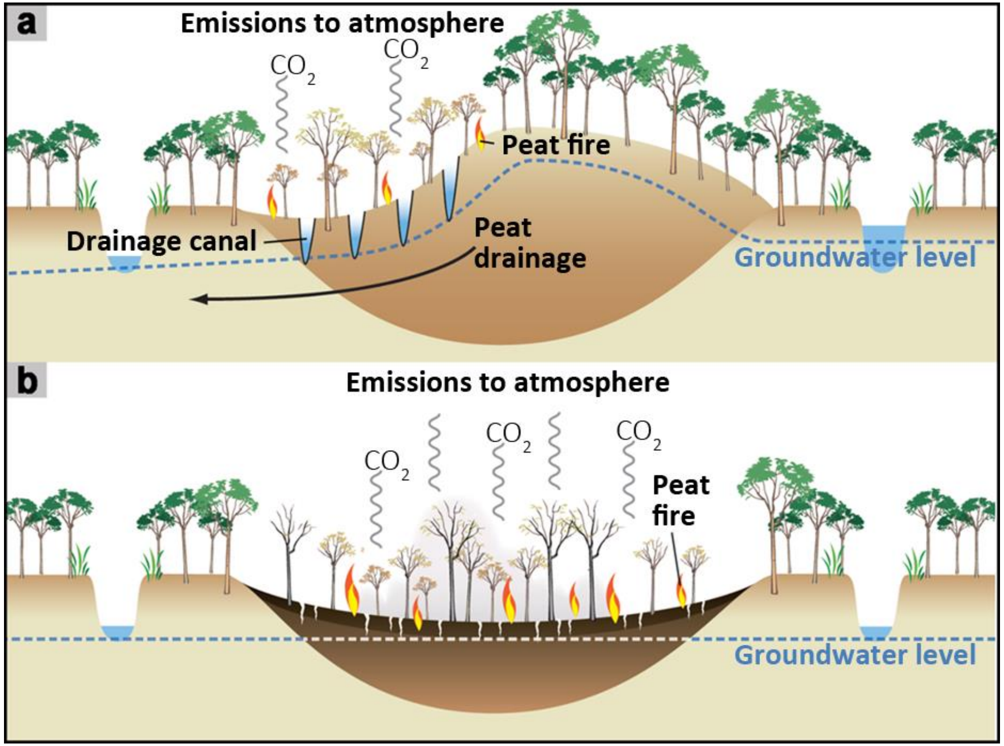
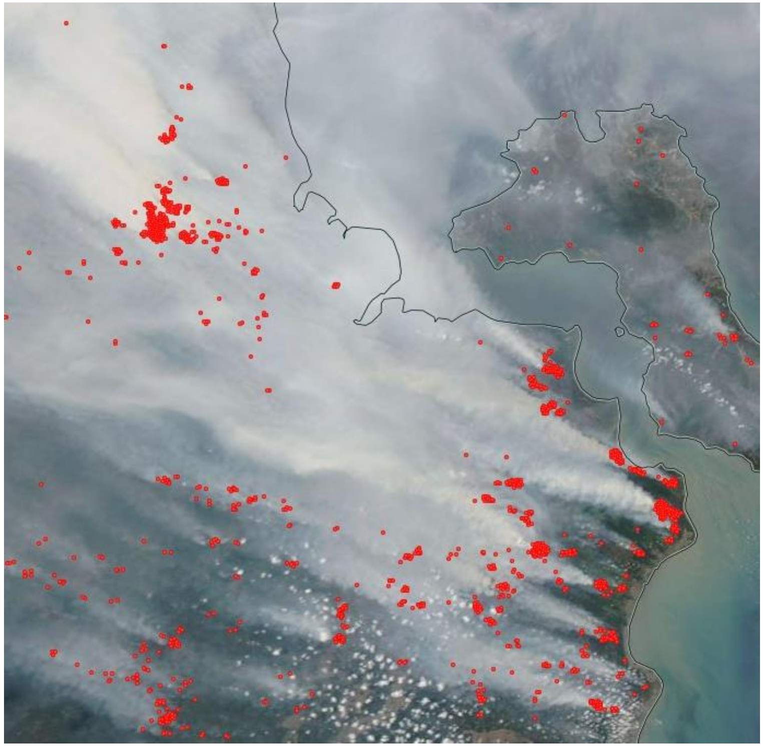
Outline

- Assessment of GHG emissions recurrent from peatland fires
- Planning of peatland rehabilitation by remote sensing
- Firebird & TET: A new satellite system for Near real time monitoring of fires

GHG emissions from peatlands



(WWF, 2009; modified)



Assessment of GHG emissions recurrent from peatland fires

Global Change Biology

Global Change Biology (2016), doi: 10.1111/gcb.13186

Variable carbon losses from recurrent fires in drained tropical peatlands

KRISTINA KONECNY[1,2], UWE BALLHORN[2], PETER NAVRATIL[2], JUILSON JUBANSKI[2], SUSAN E. PAGE[3], KEVIN TANSEY[3], ALJOSJA HOOIJER[4], RONALD VERNIMMEN[4] and FLORIAN SIEGERT[1,2]

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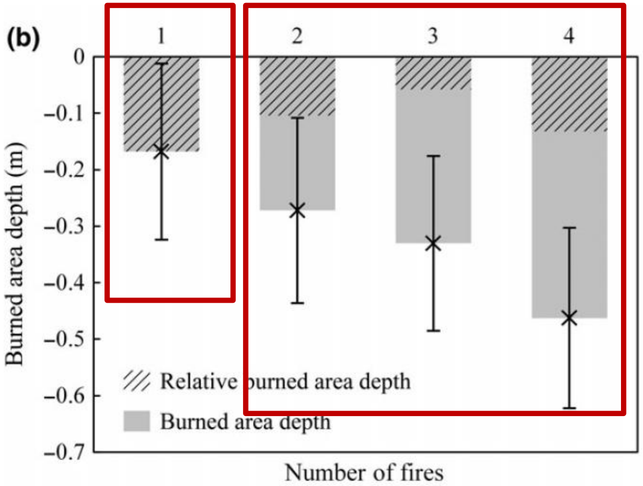


Fire event	First fire	Second fire	Third fire	Fourth+ fire
Average relative burned area depth (m)	-0.17	-0.10	-0.06	-0.02
Mass of peat fuel (t ha^{-1})*	206	115	69	23
Carbon loss value (t C ha^{-1})*	114	64	38	13

Degradation of tropical peatlands

Peatland that has been affected by one or more fires → decreasing amount of above-ground fuel potentially available for combustion

Carbon emissions from recurrent fires

Objective

Estimate **peat carbon emissions** from recurrent fires
as a function of fire frequency.

Carbon emissions from recurrent fires

- **Peat carbon emissions:**
  - **A_n**=Total area burnt [ha] per fire frequency n
  - **EF_n**=Emission factor [t C/ha] for fire frequency n

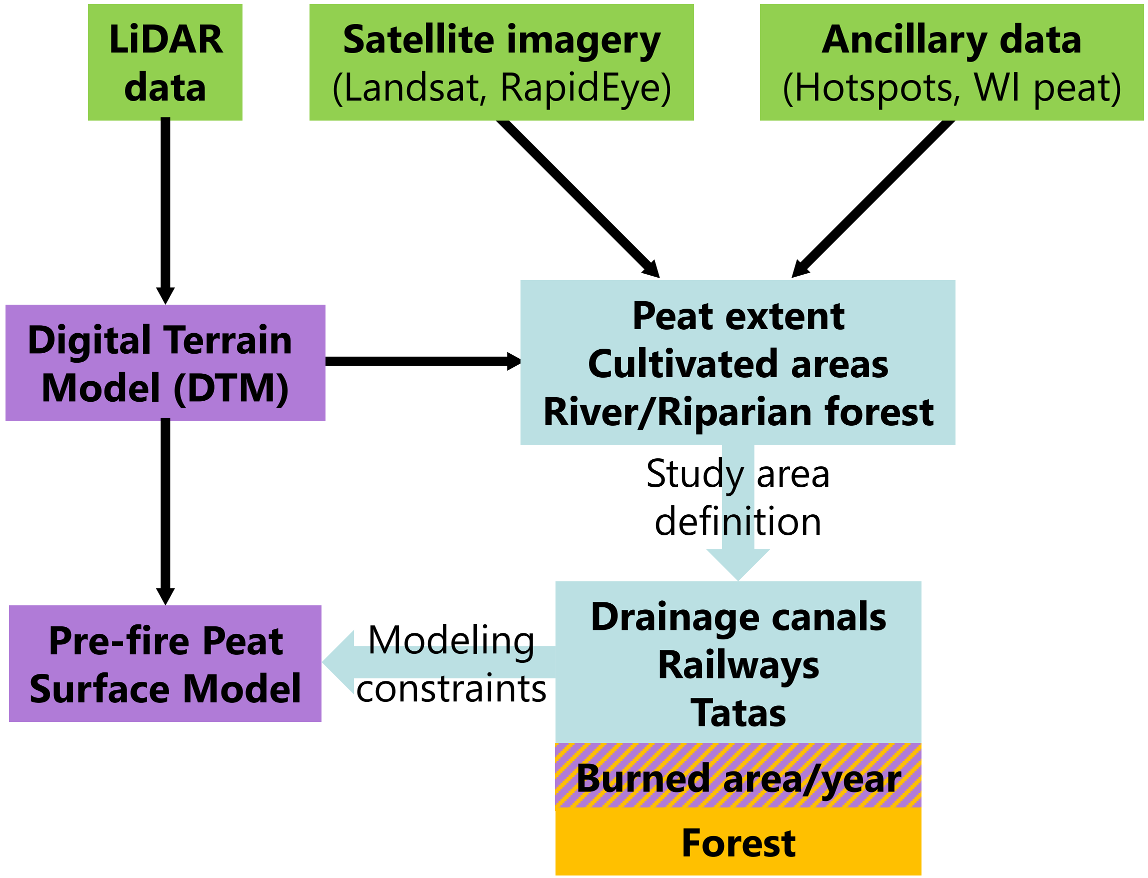
$$EF_n = \boxed{\text{depth of burn [cm]}} * \boxed{\text{peat bulk density } [g/cm^3]} * \boxed{\text{carbon content [\%]}} * \boxed{\text{combustion efficiency}}$$

depth of burn [cm]	peat bulk density [g/cm³]	carbon content [%]	combustion efficiency
35.3 cm *(95% conf. interval: 35.3 ±18.3 cm)* **IPCC, 2014**	**0.121 g/cm^3** *for the first fire* **0.115 g/cm^3** *subsequent*	**55%** **Hooijer *et al.*, 2014**	**1**

IPCC (2014) 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (eds Hiraishi T et al.).

Hooijer A *et al.* (2014) Carbon Emissions from Drained and Degraded Peatland in Indonesia and Emission Factors for MRV of Peatland Greenhouse Gas Emissions –. IAFCP, Jakarta, Indonesia.

Remote sensing data and derivates – Overview



Remote sensing data and derivates – DTM

Airborne LiDAR data – Acquisition and Preprocessing

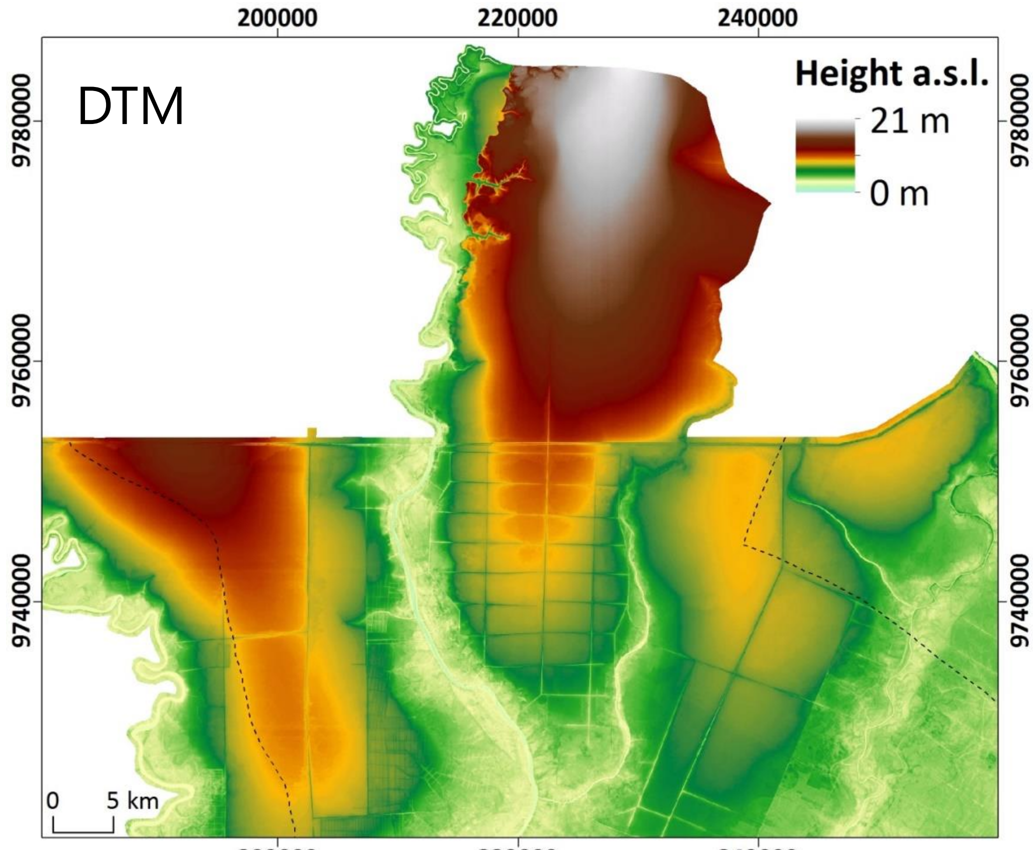
- **Optech Orion M200** airborne laser scanner
  - **Date:** 15.08.-15.10.2011
  - **Area:** ~700,000 ha

Acquisition parameters:	
Laser pulse frequency	100 KHz
Half scan angle	22°
Flying height above ground	800 m
Calculated point density	2.8 pts/m^2

- Hierarchic robust ground and off-ground point filtering (Pfeifer et al., 2001)
- Linear adaptable prediction interpolation (kriging) for DTM generation (5m spatial resolution)
- Accuracy assessment based on 441 differential GPS measurements → 0.12/0.19m RMSE in forested/burned areas

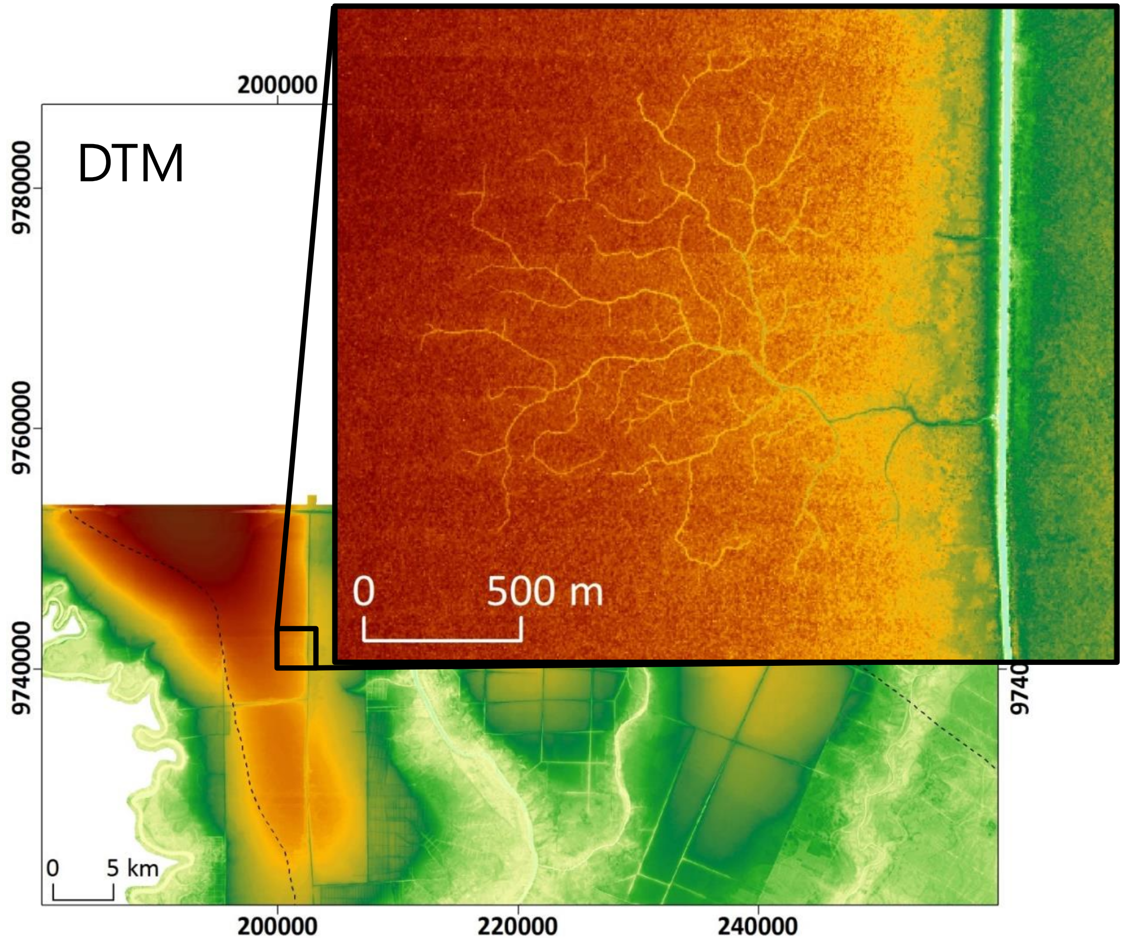
Pfeifer N, Stadler P & Briese C (2001) Derivation of digital terrain models in SCOP++ environment. Proceedings of OEEPE Workshop on Airborne Laserscanning and Interferometric SAR for Detailed Digital Elevation Models.

Remote sensing data and derivates – DTM



Projection: Universal Transverse Mercator (UTM), Zone 50S, Spheroid: WGS1984

Remote sensing data and derivates – DTM



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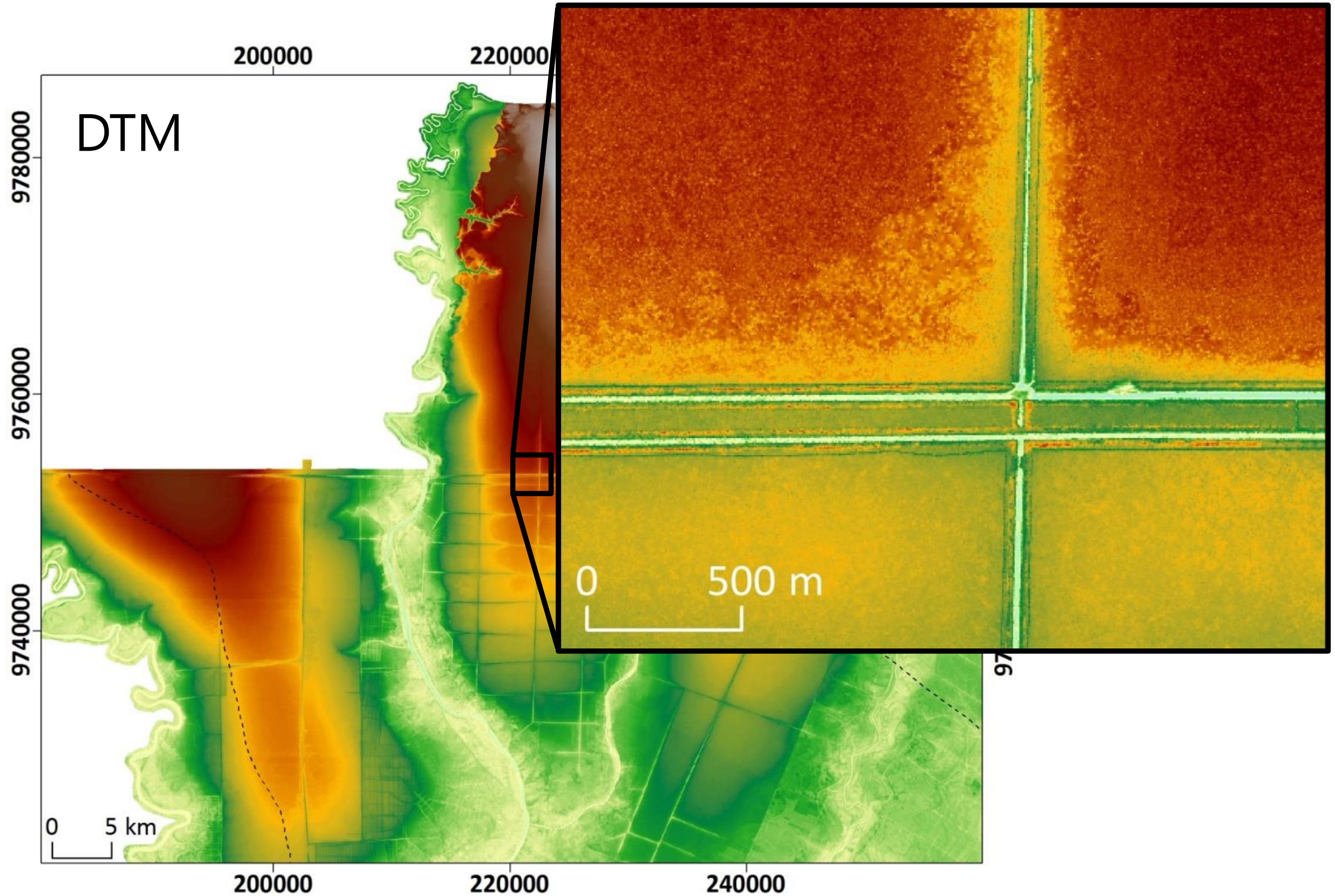
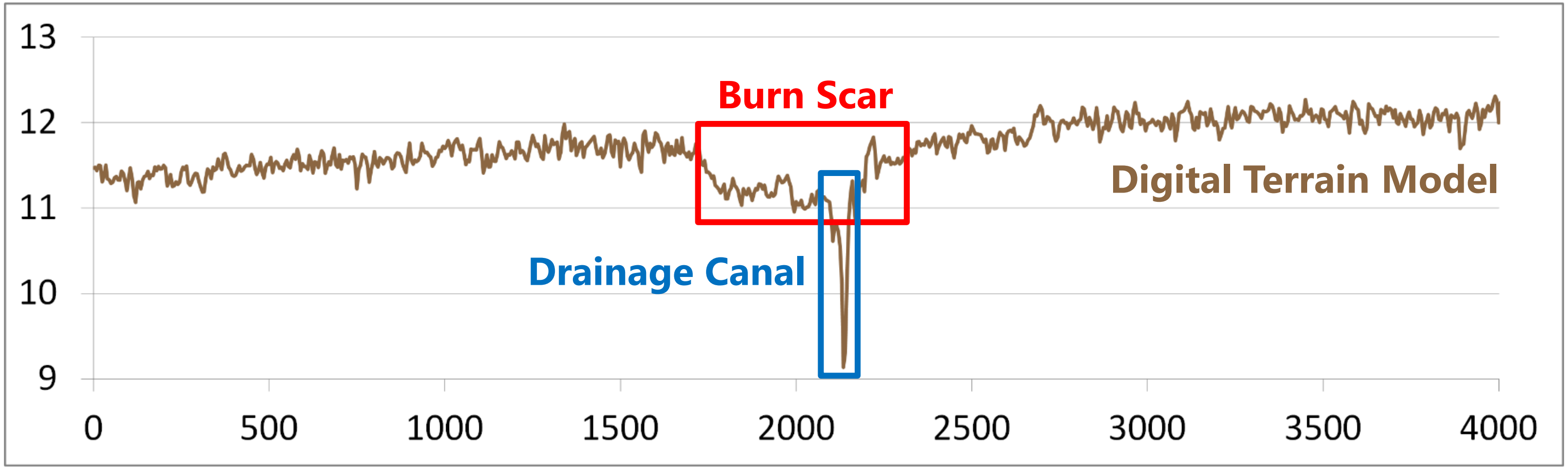
Remote sensing data and derivates – DTM



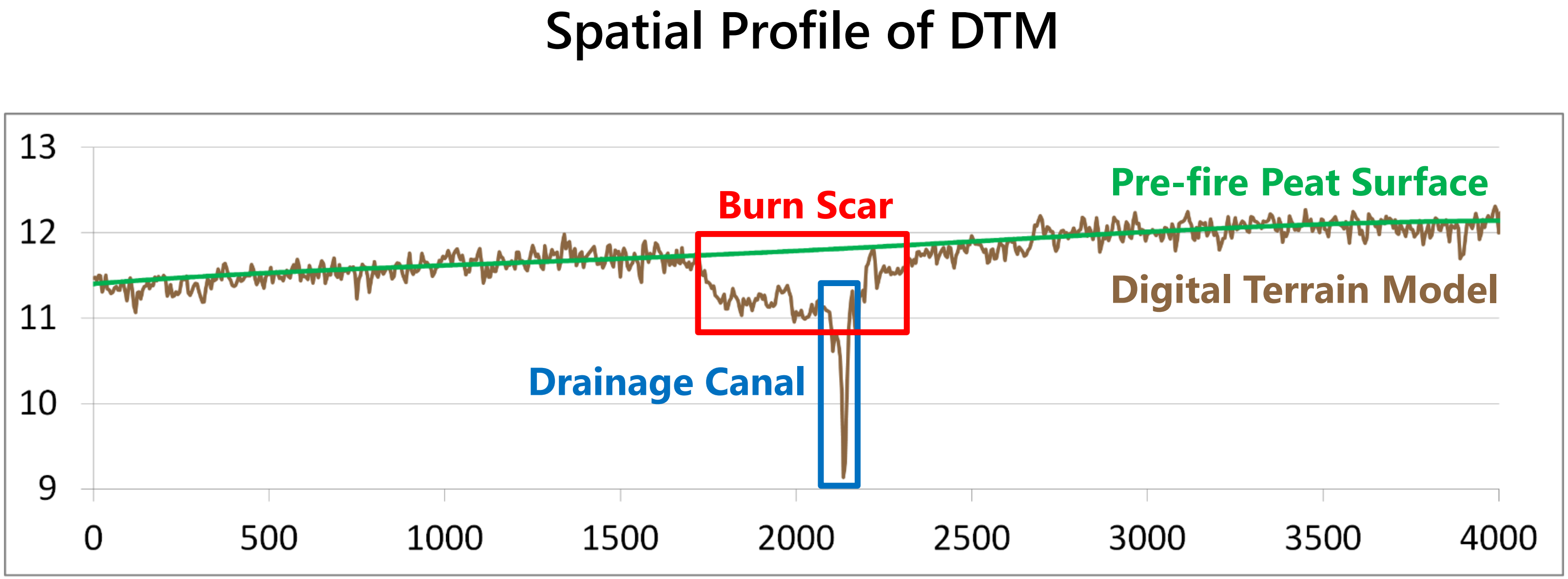
Projection: Universal Transverse Mercator (UTM), Zone 50S, Spheroid: WGS1984

Remote sensing data and derivates – Pre-fire Peat Surface Model

Spatial Profile of DTM

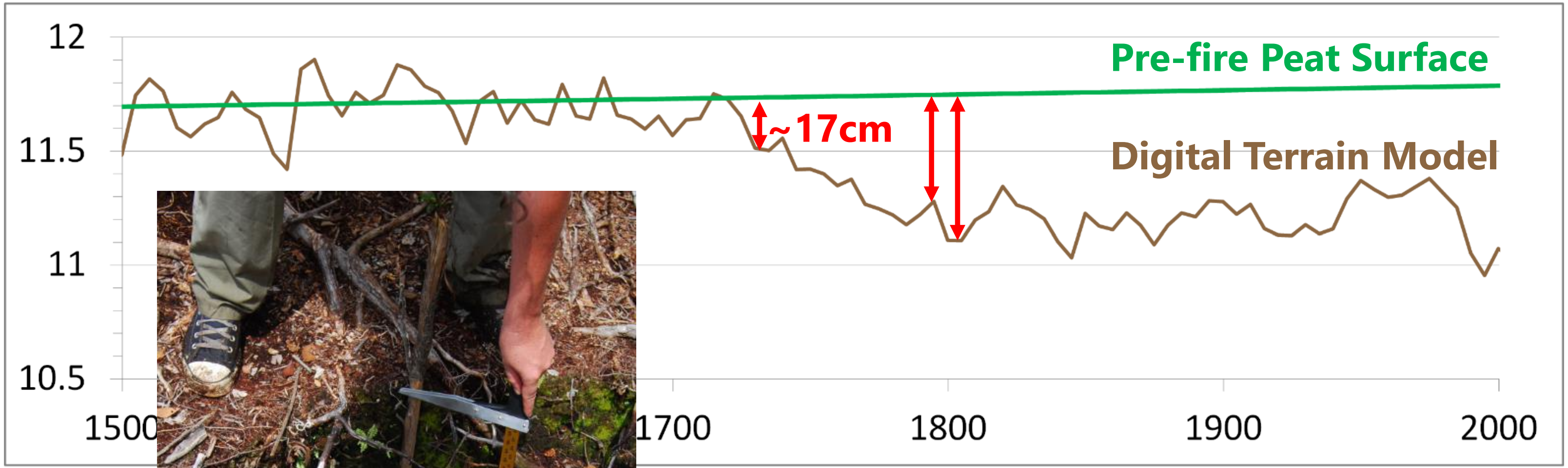


Remote sensing data and derivates – Pre-fire Peat Surface Model

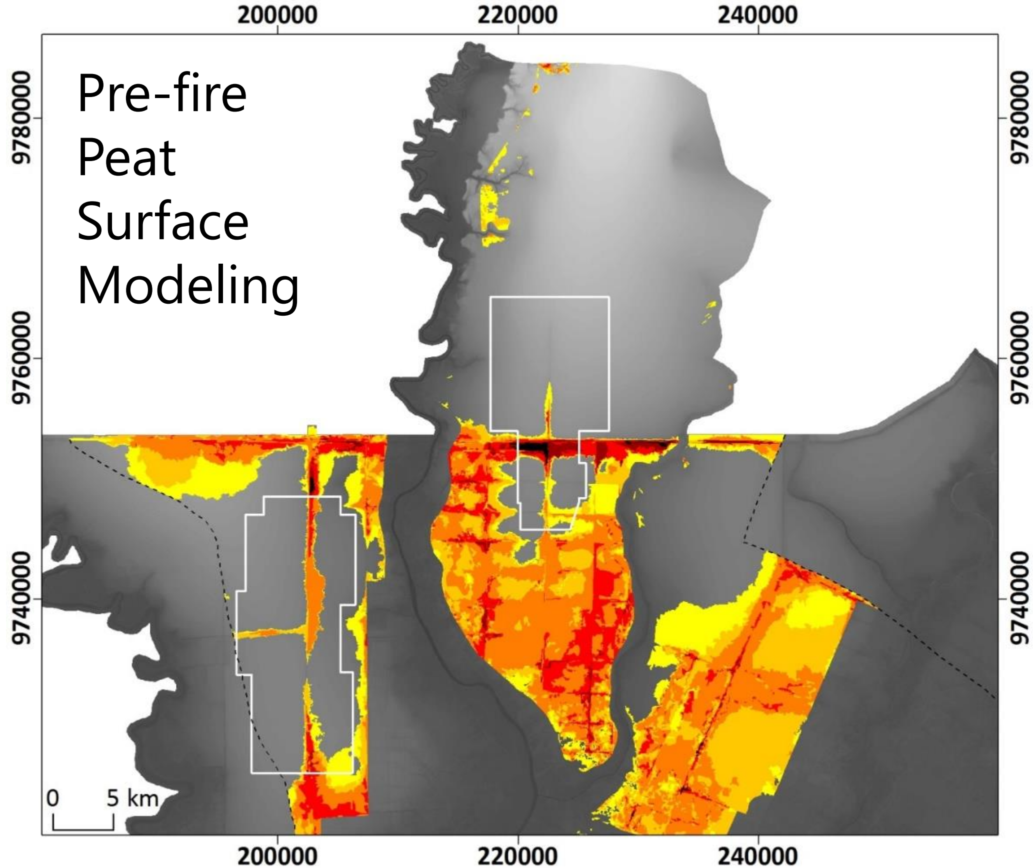


- Bézier approximation for spatial interpolation of pre-fire elevation

Remote sensing data and derivates – Pre-fire Peat Surface Model

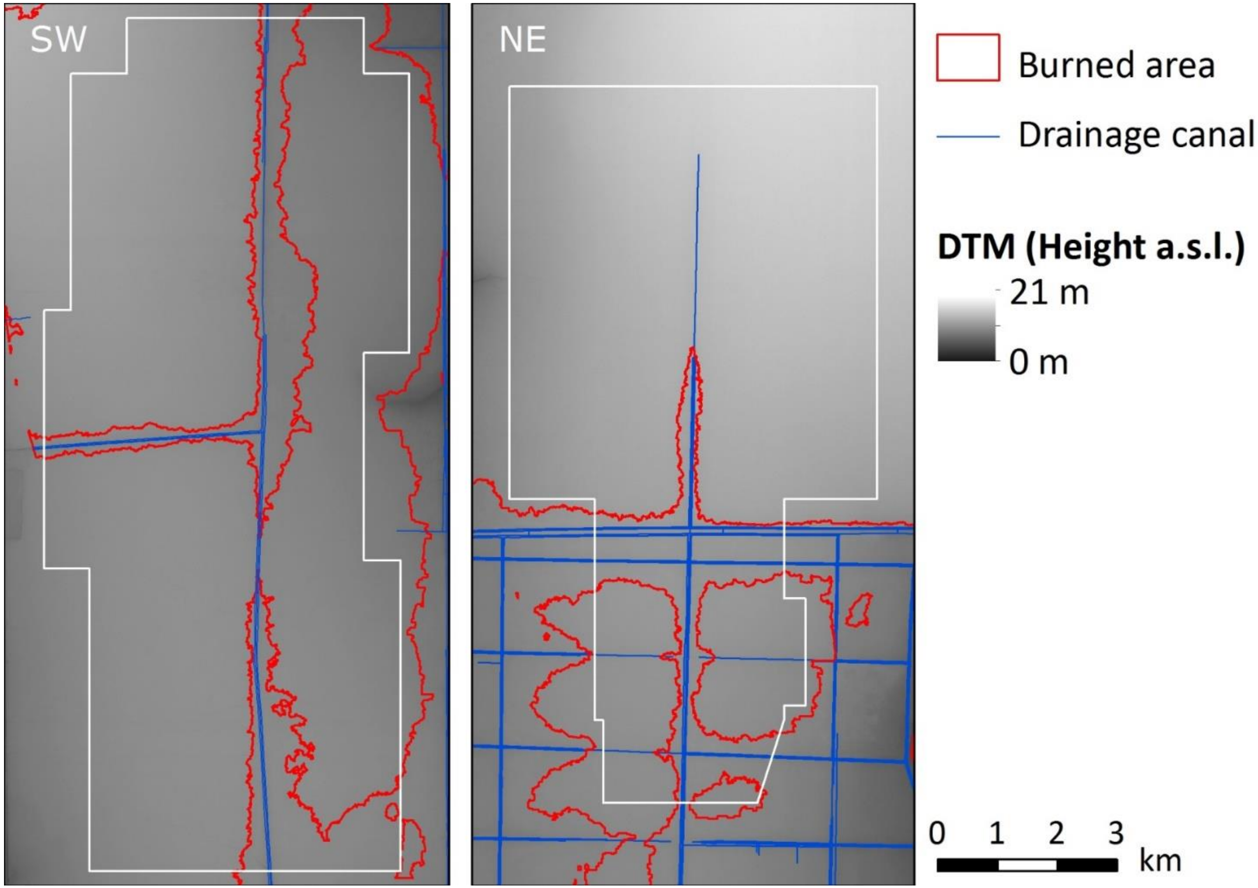


Remote sensing data and derivates – Pre-fire Peat Surface Model

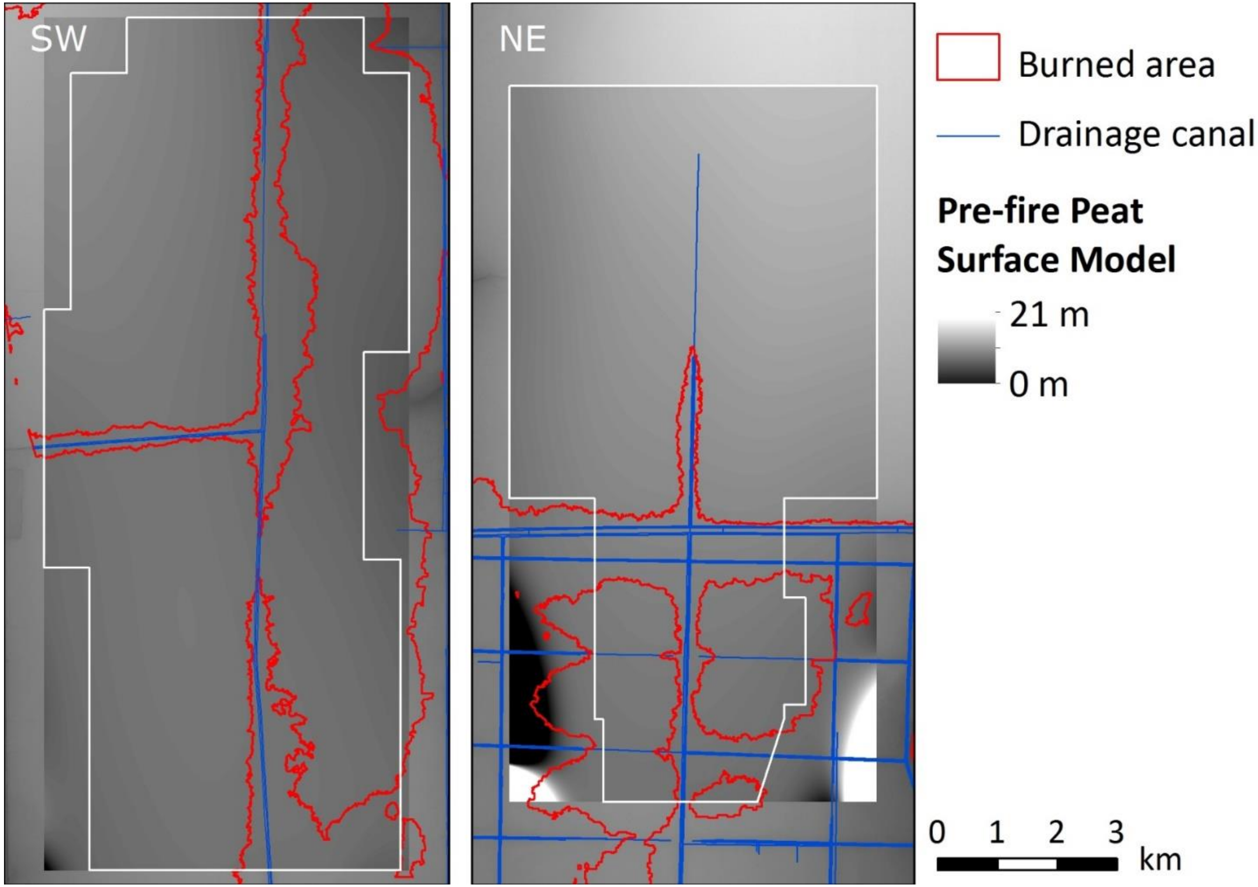


Projection: Universal Transverse Mercator (UTM), Zone 50S, Spheroid: WGS1984

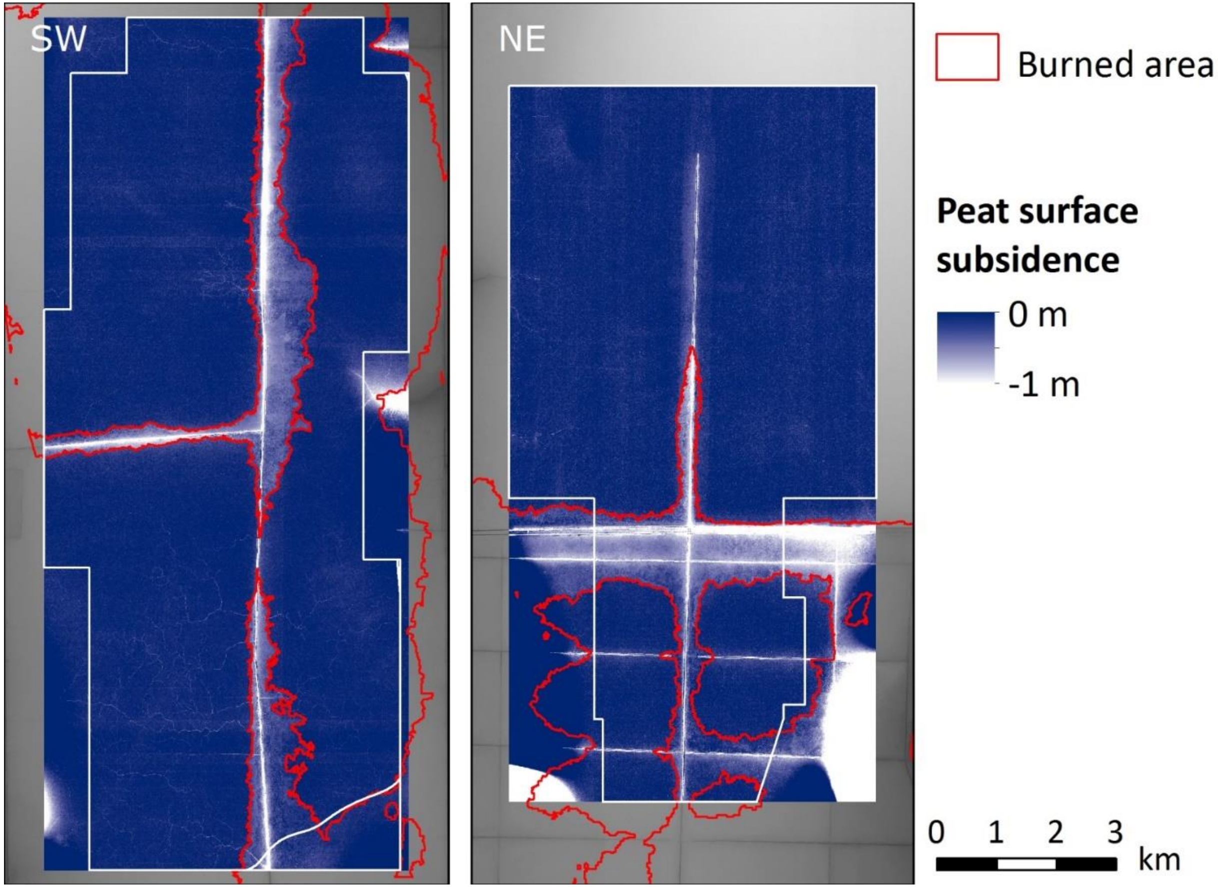
Remote sensing data and derivates – Pre-fire Peat Surface Model



Remote sensing data and derivates – Pre-fire Peat Surface Model



Remote sensing data and derivates – Pre-fire Peat Surface Model



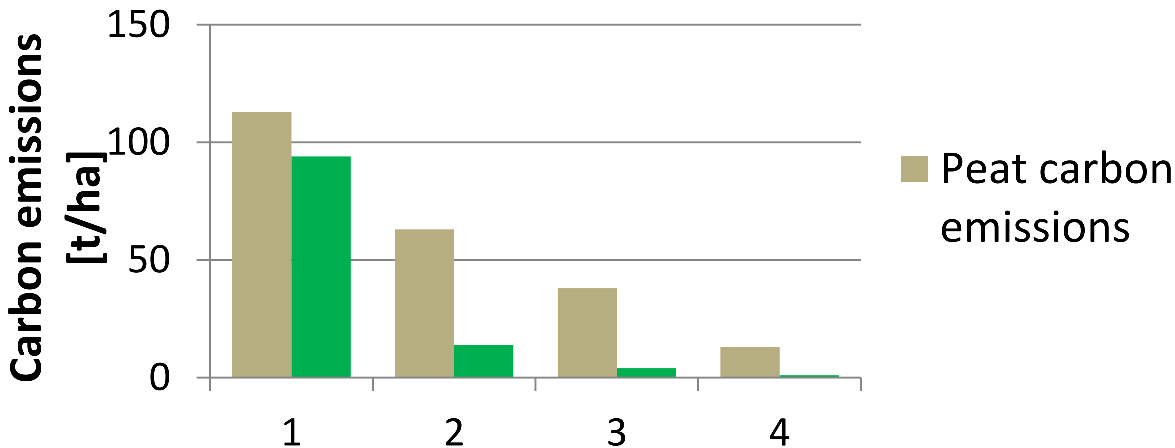
Results & conclusions – Peat carbon emissions

Fire frequency	Depth of burn	EF
1	17 cm	113 t C ha^{-1}
2	10 cm	63 t C ha^{-1}
3	6 cm	38 t C ha^{-1}
≥4	2 cm	13 t C ha^{-1}

→ consistent with field measurements and previous airborne LiDAR measurements (Ballhorn et al., 2009)

Ballhorn U, Siegert F, Mason M & Limin S (2009) Derivation of burn scar depths and estimation of carbon emissions with LIDAR in Indonesian peatlands. *Proc Natl Acad Sci USA* 106:21213–21218.

Results & conslusions – Total carbon emissions



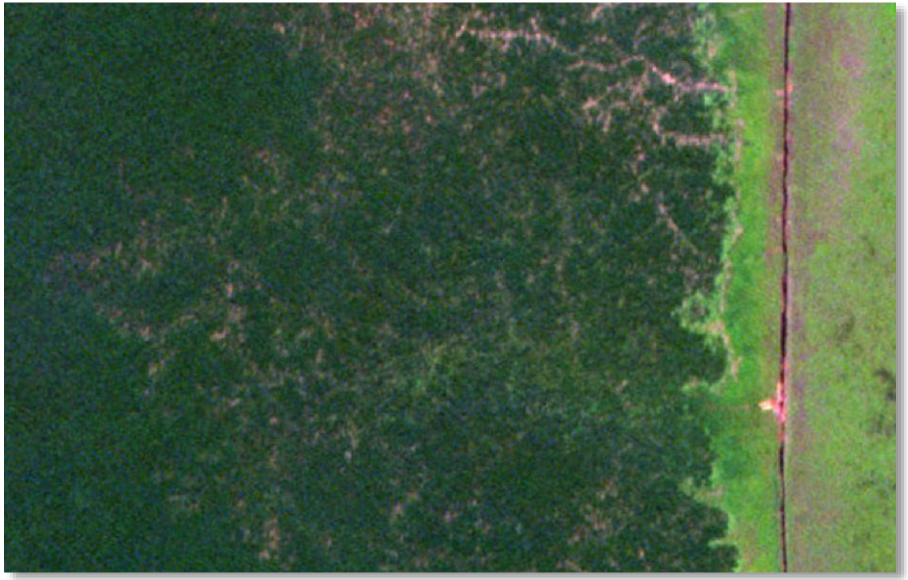
Fire frequency	**EF (total)**	*% aboveground carbon emissions*	*% peat carbon emissions*
1	207 t C ha^{-1}	*45%*	*55%*
2	77 t C ha^{-1}	*19%*	*81%*
3	42 t C ha^{-1}	*10%*	*90%*
≥4	14 t C ha^{-1}	*7%*	*93%*

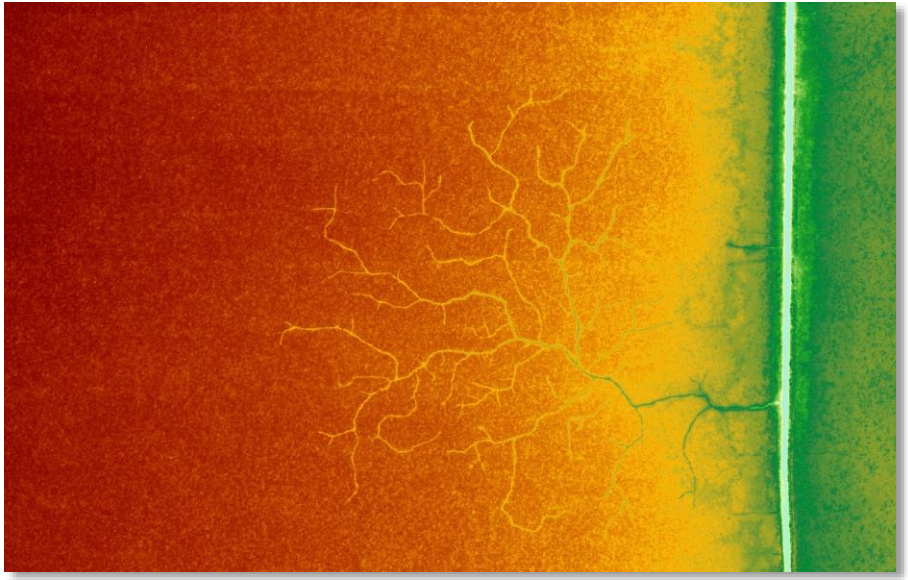
Planning of peatland rehabilitation by remote sensing

- Most land uses on peatlands require drainage
- Drainage of peat leads to GHG emissions due to bacterial decomposition and increase fire risk
- Peatland rehabilitation reduces emissions

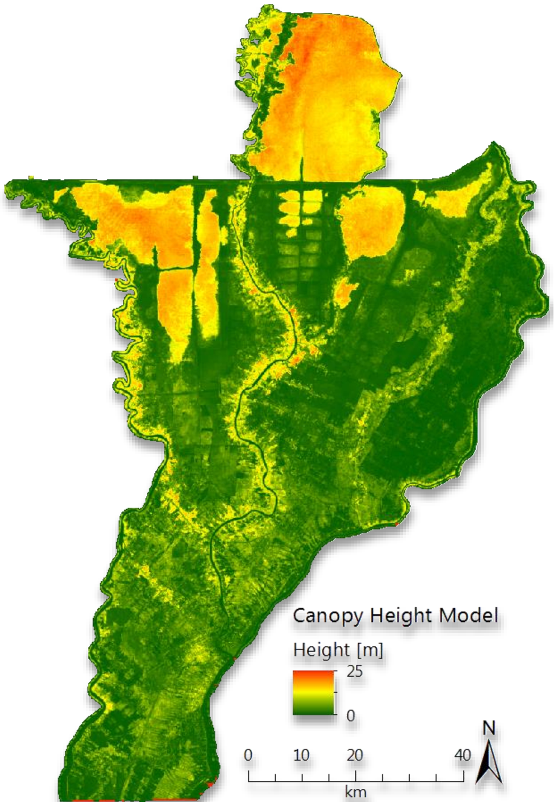


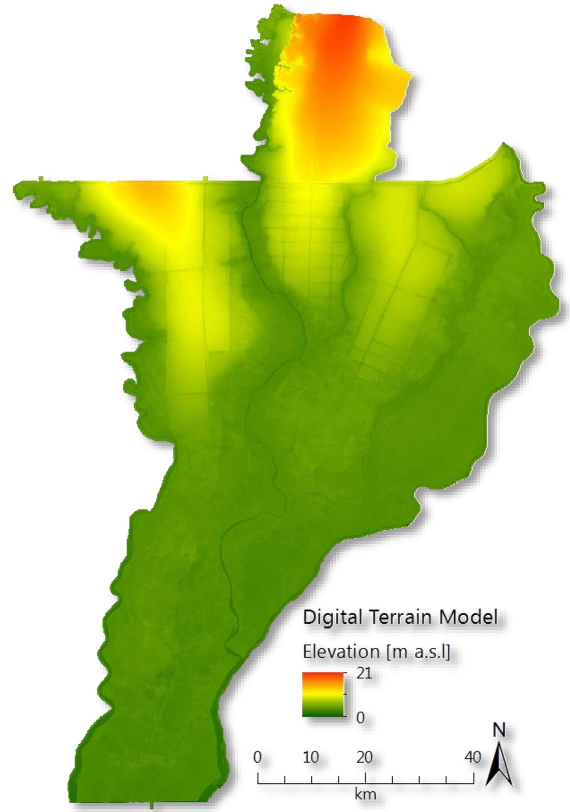
Peat drainage by logging operations



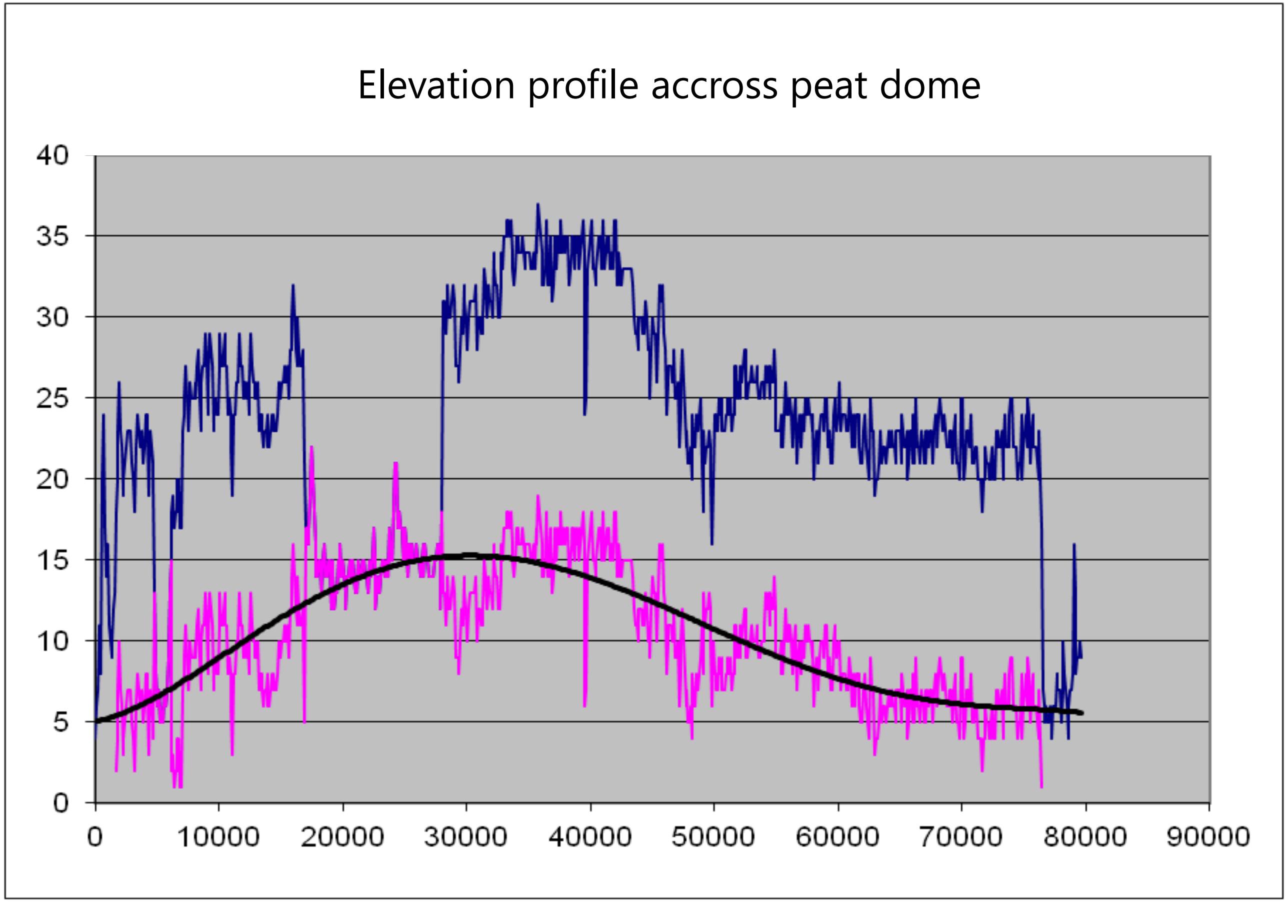


Mapping peat topography

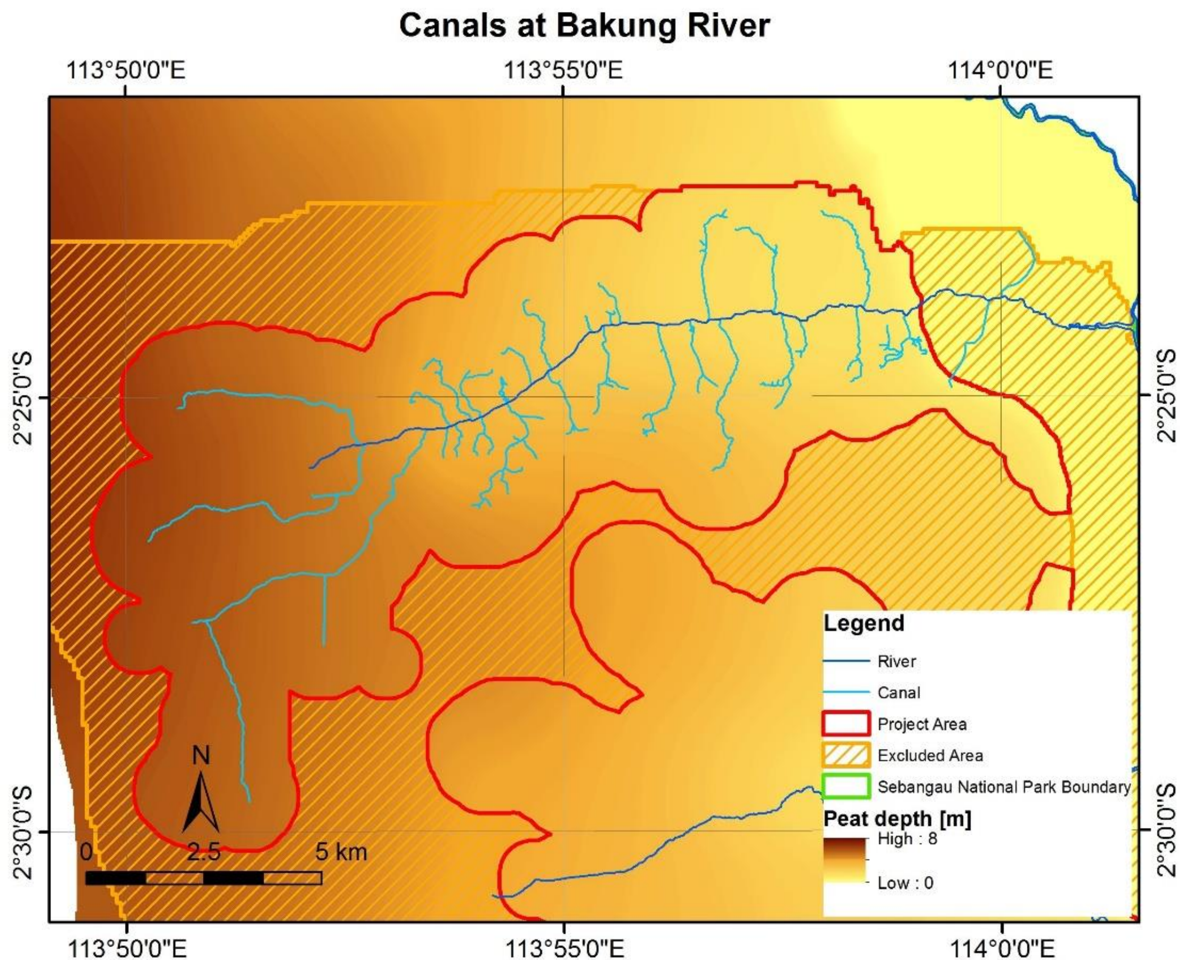




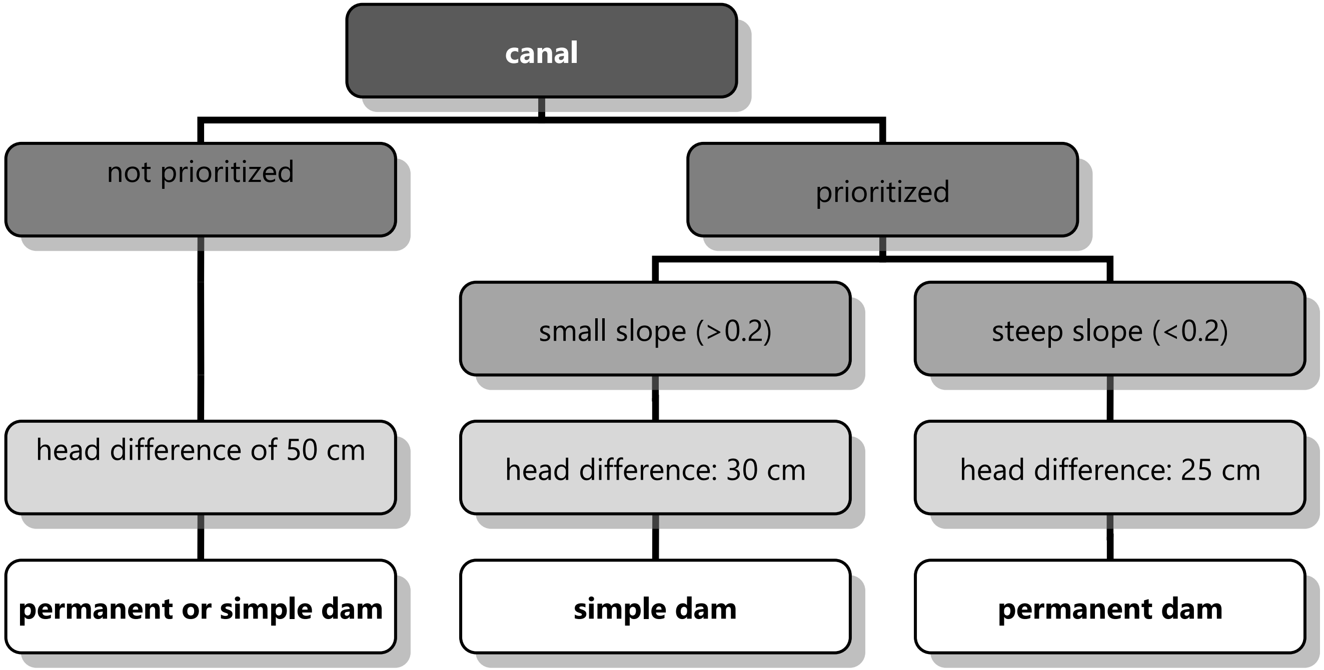
Mapping peat topography



Mapping of drainage canals

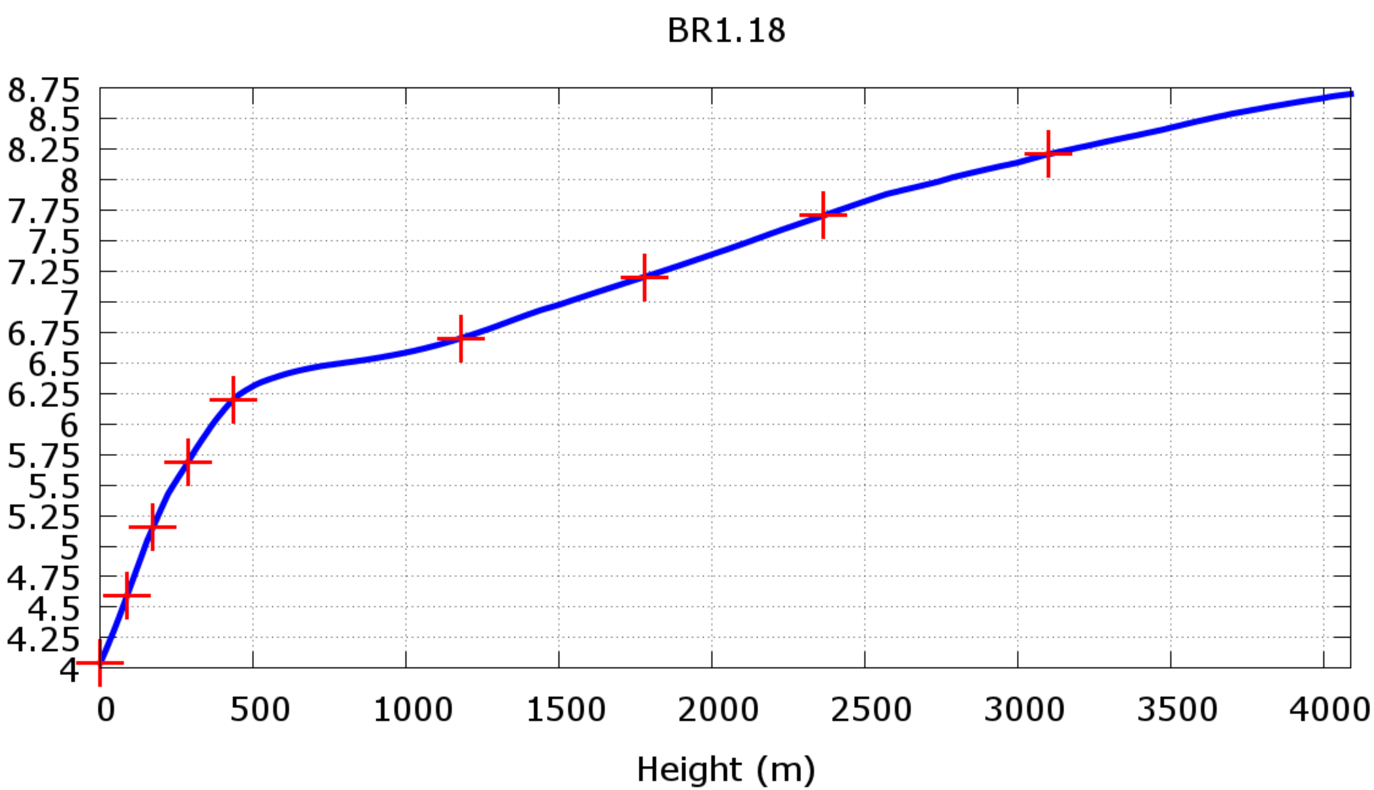


Planning of dam locations

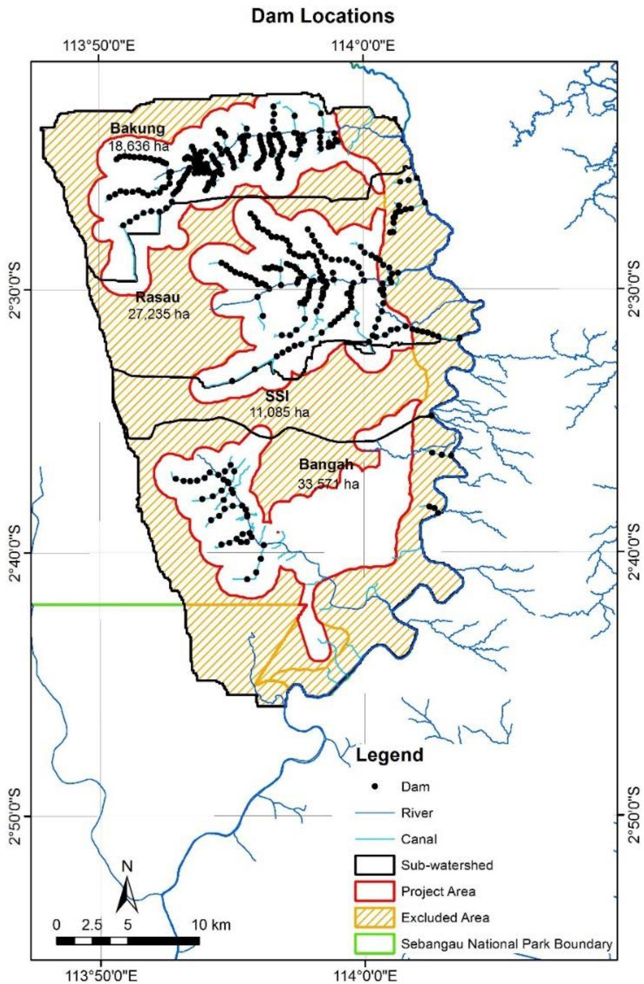


Development of dam technical design

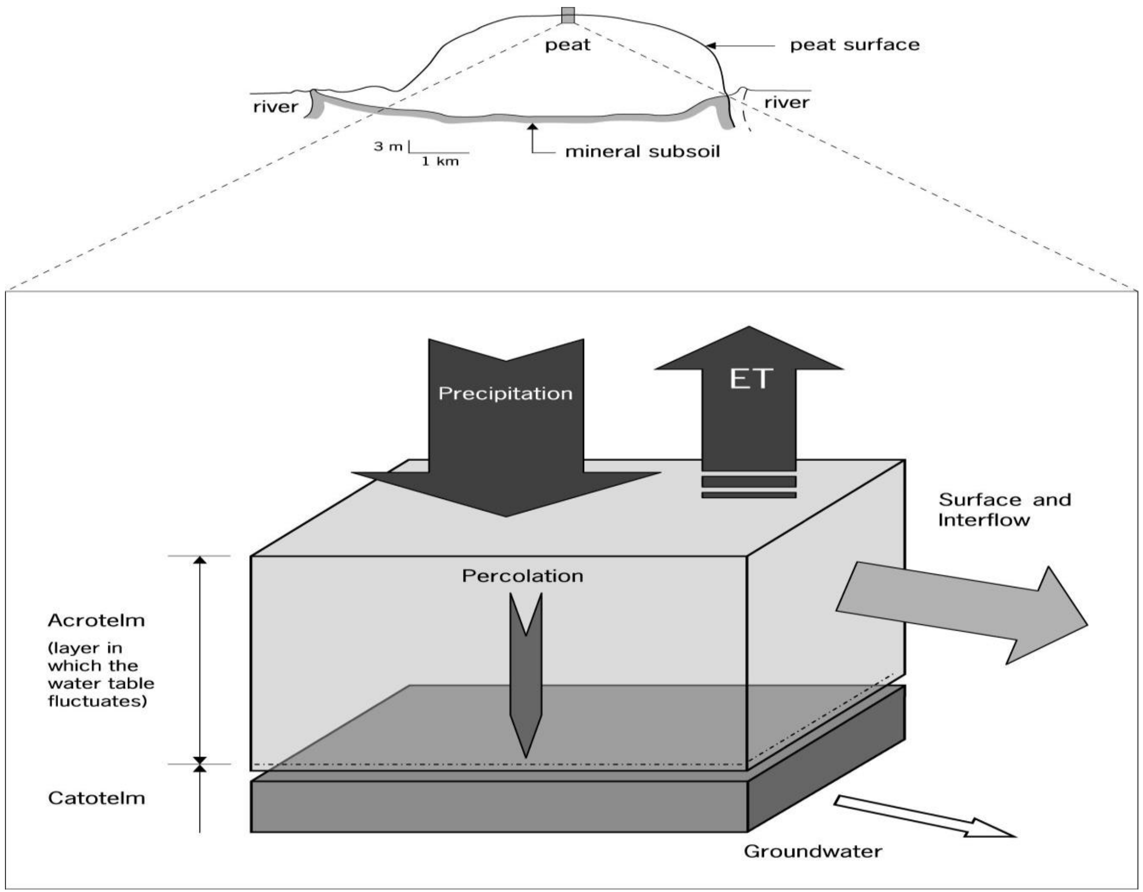
Planning of dam locations



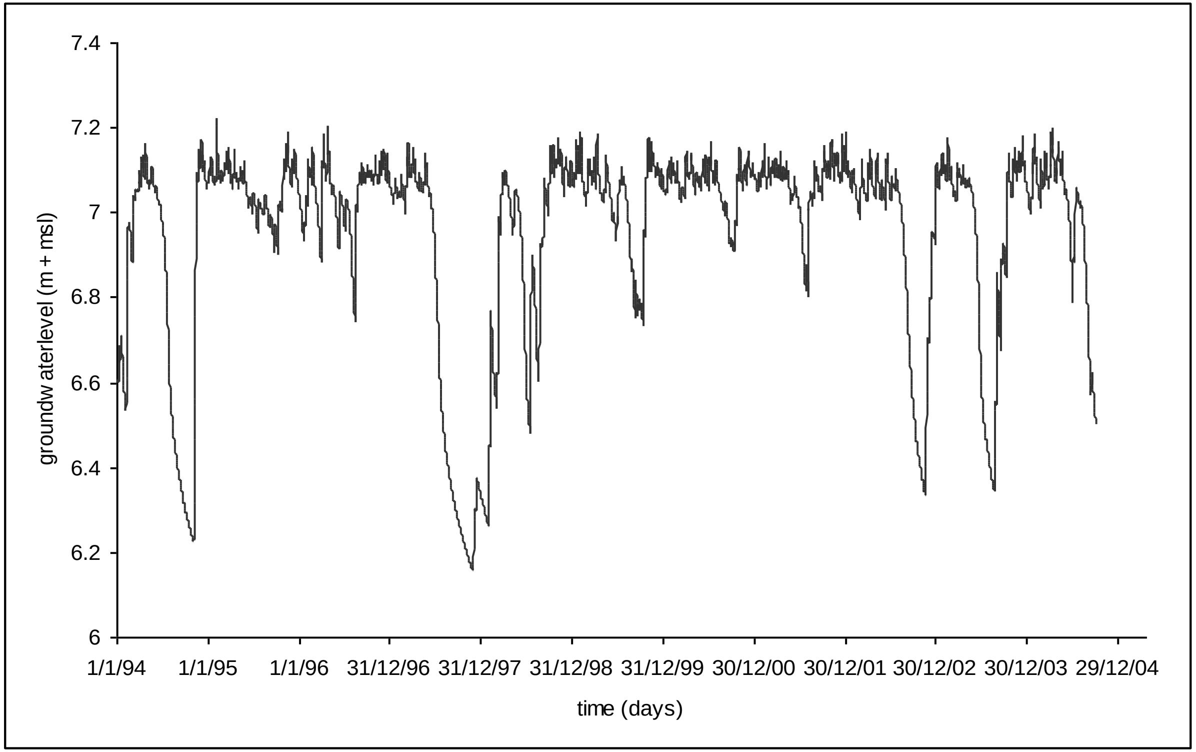
Dam locations



Water balance



Calculated water table fluctuations



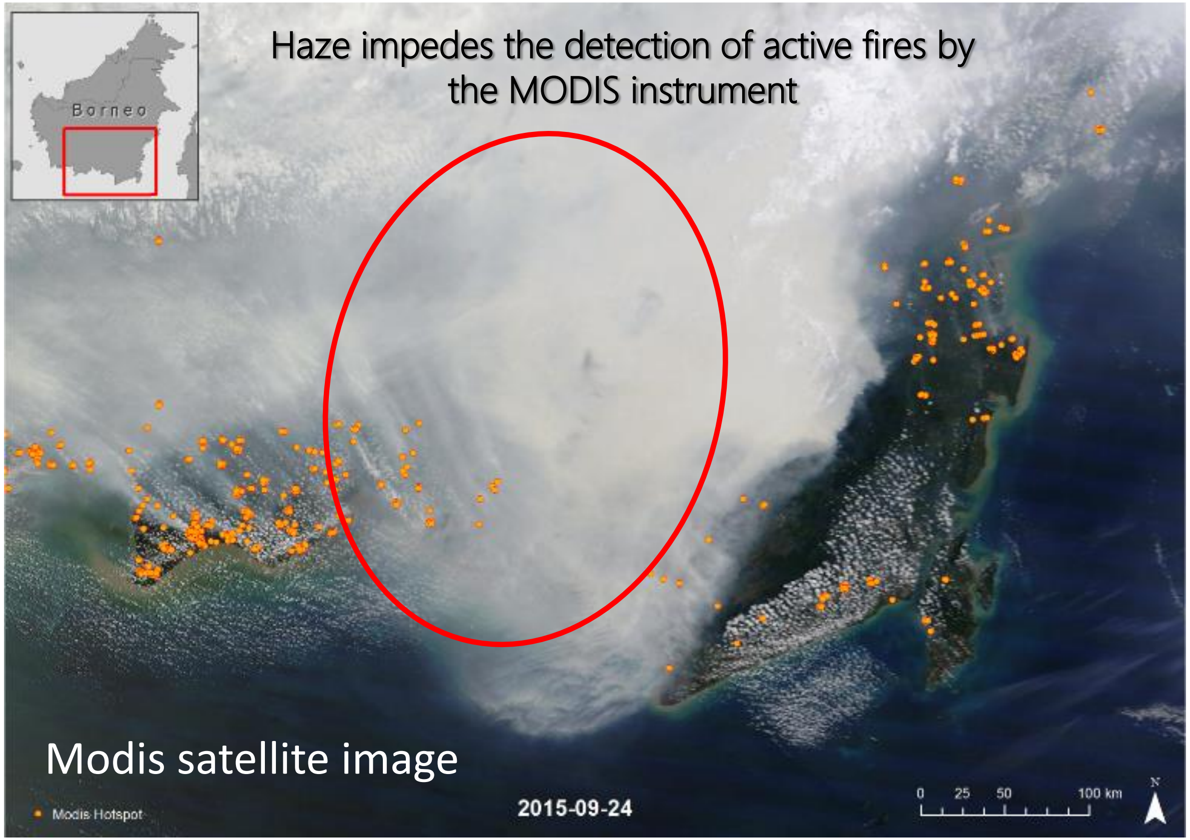
A new satellite system for Near real time monitoring of fires

	MODIS	**FireBird/TET**
Fire detection Mode	Monospectral	Bispectral
Fire detection bands	MWIR: 4.0 µm (2x) LWIR: 10.8-11.3 µm	MWIR: 3.4-4.2 µm LWIR: 8.5-9.3 µm
Saturation temperature	331 K resp. 500 K 340 K (A), 400 K (T)	>1500K due to adaptive gain control
Pixel resolution	1,000 m x 1,000 m	160 m x 160 m
Revisit time (day and night images)	0.5 day	3 days

Benefits of FireBird/TET

- Better detection through smoke and haze
- Higher sensitivity of low energy fires
- 6x higher spatial resolution

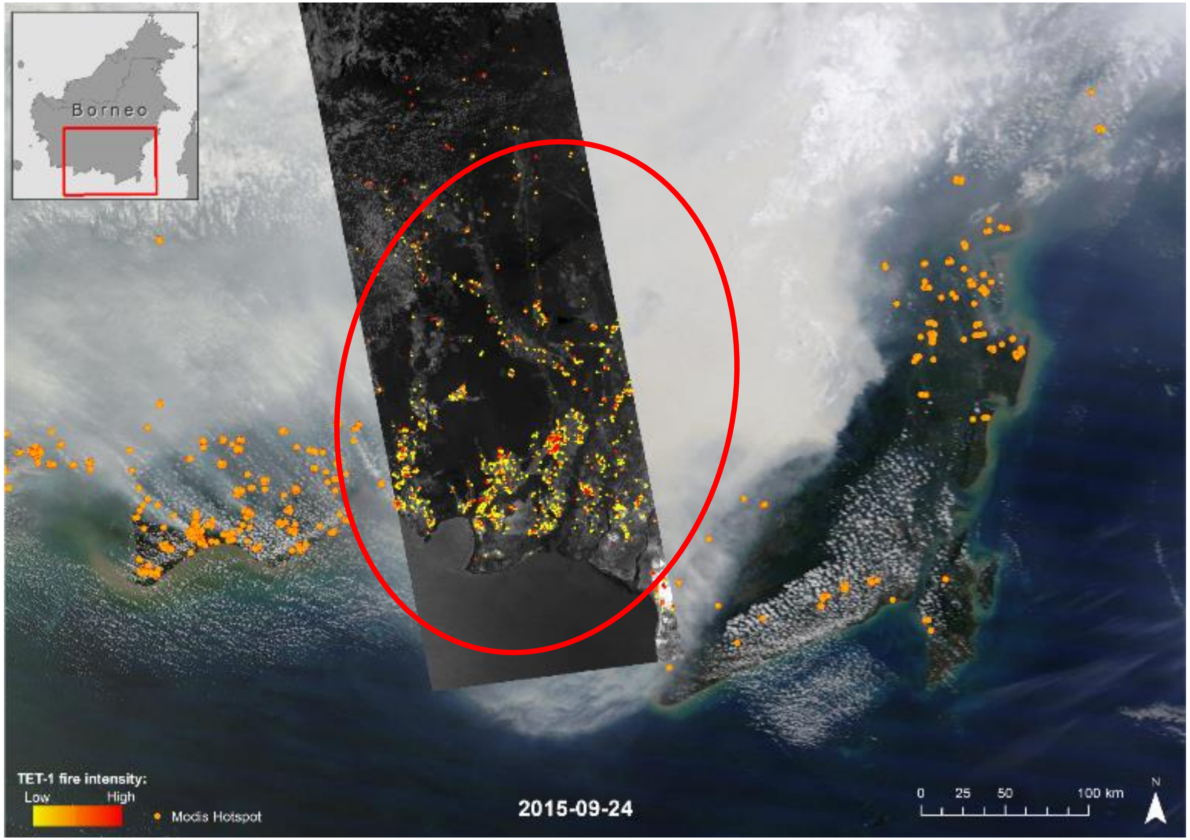
Improved fire detection capability by TET



Peat fires burn at low temperatures and release thick clouds of smoke due to incomplete combustion

© OuTrop

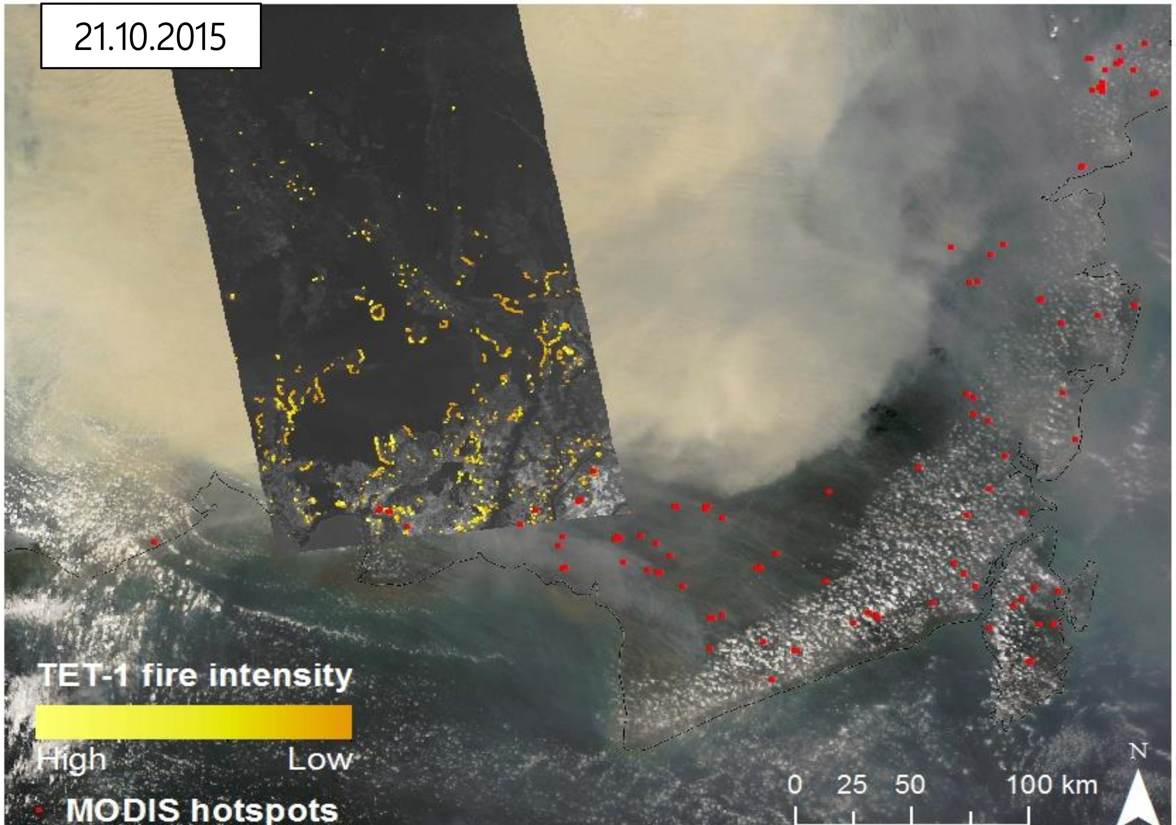
Improved fire detection capability by TET



TET image acquired the same day - Massive active fires seen through the haze!

The TET sensor detects many more active fires due to it's higher sensitivity

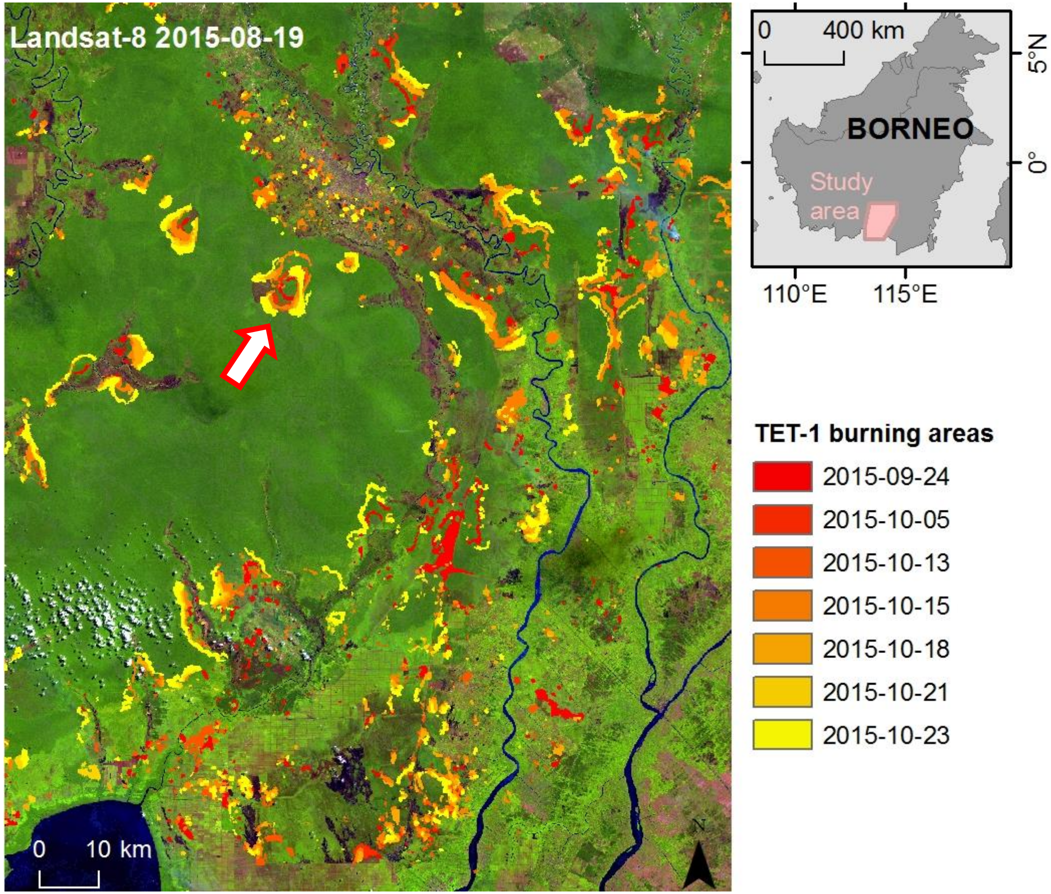
Detection of active fires using TET



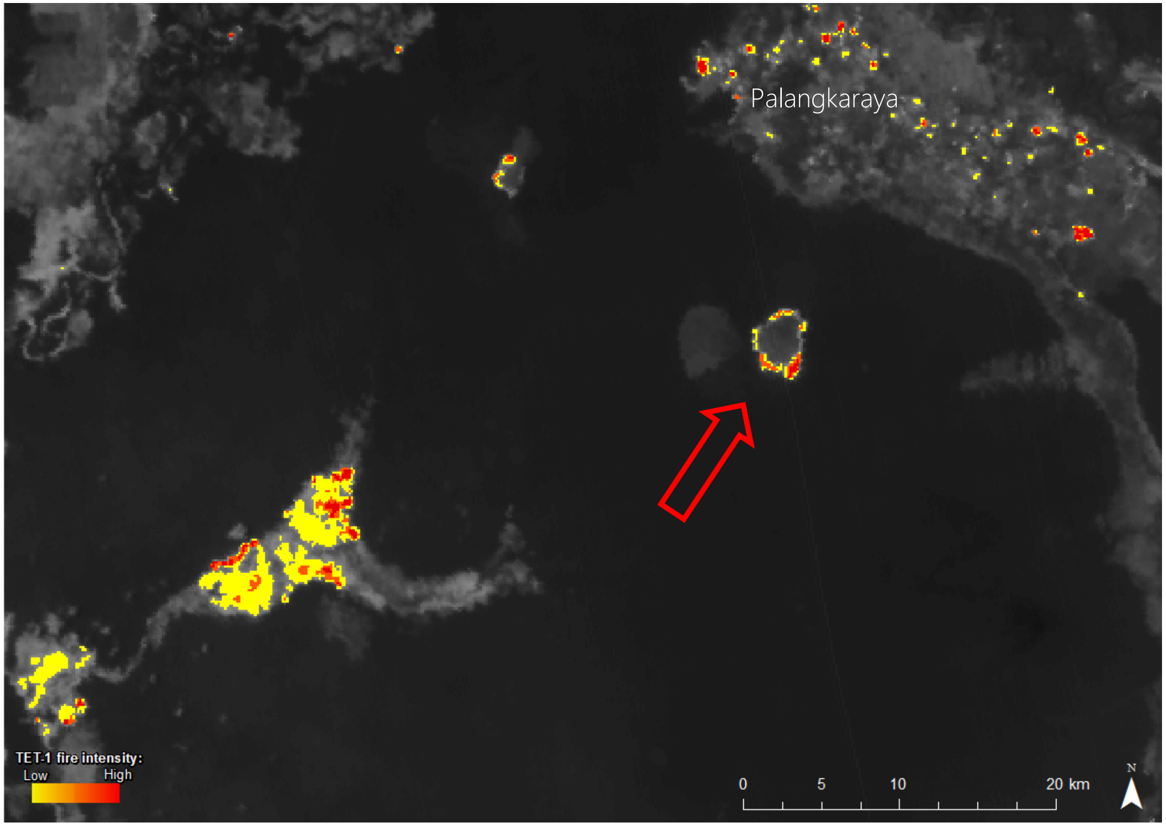
– MODIS under-detecting low intensity fire fronts

– MODIS active fire detection inhibited by thick smoke and haze

First estimate of damage extent



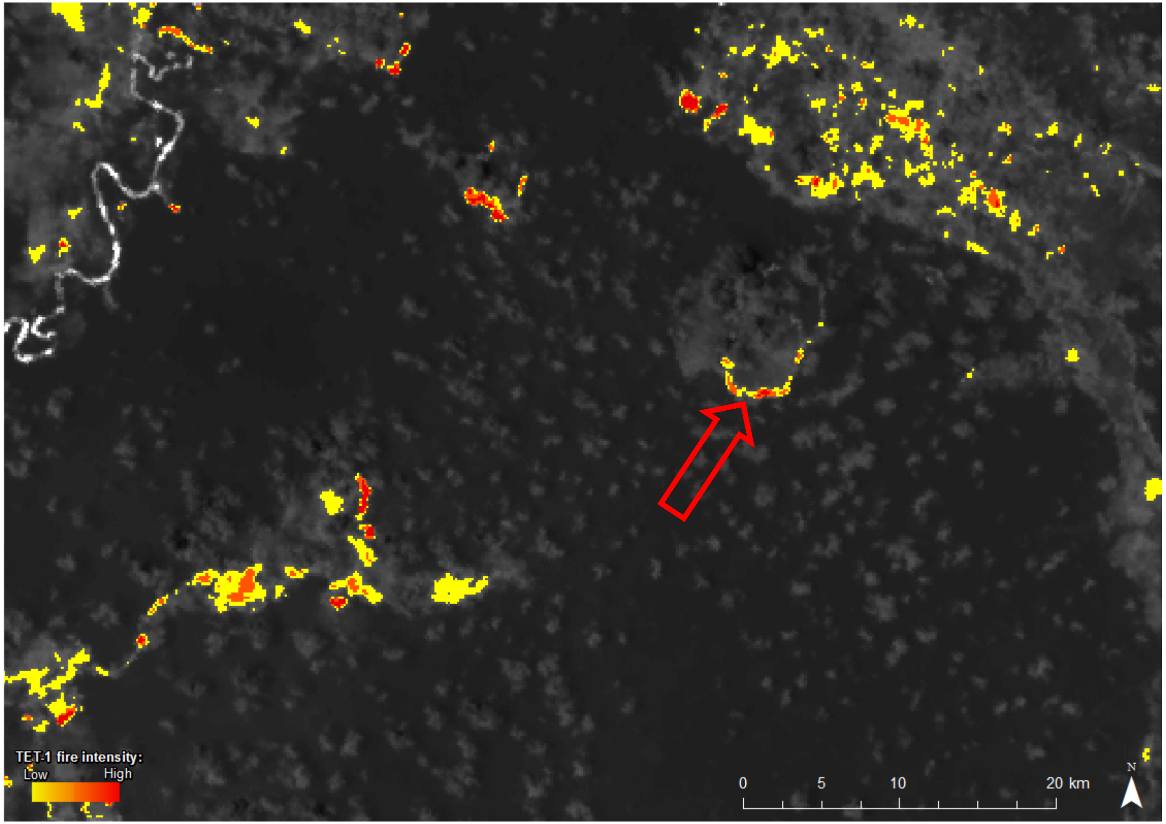
Spread of fire in Sebangau NP



TET 24/09/2015

~ 10 days

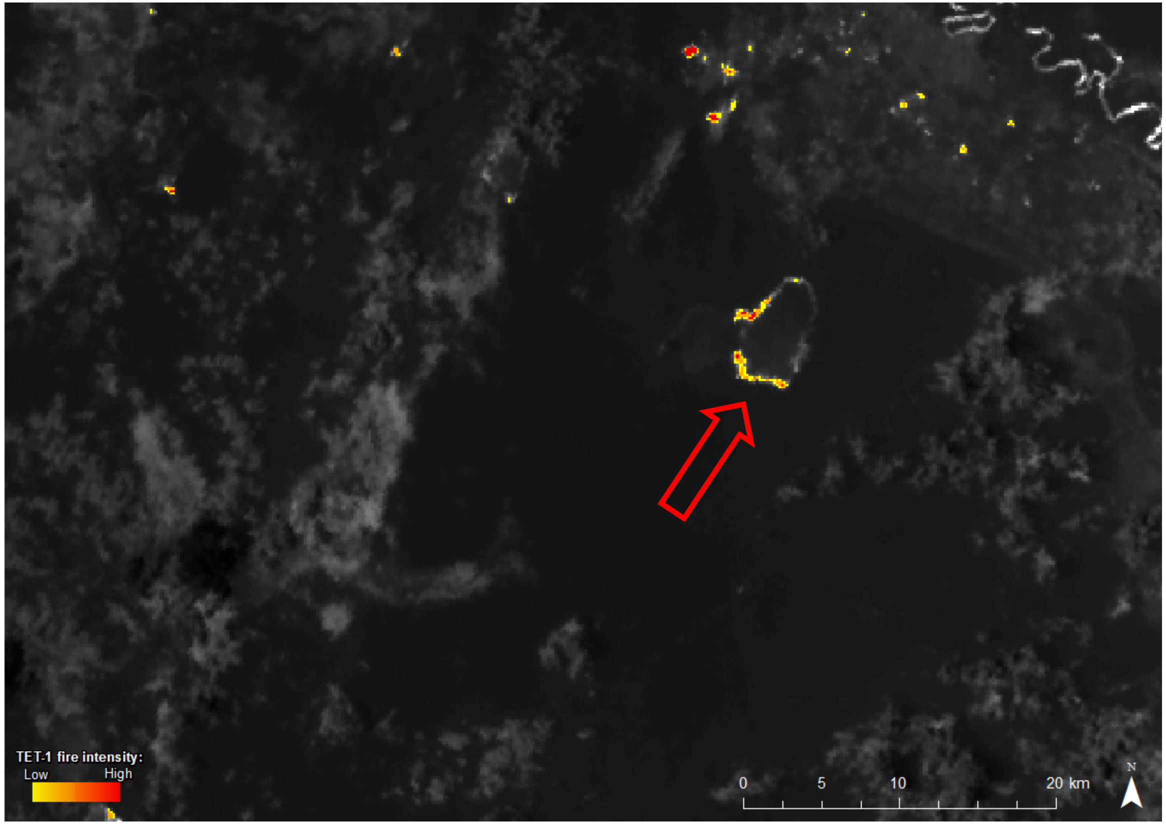
Spread of fire in Sebangau NP



TET 5/10/2015

~ 21 days

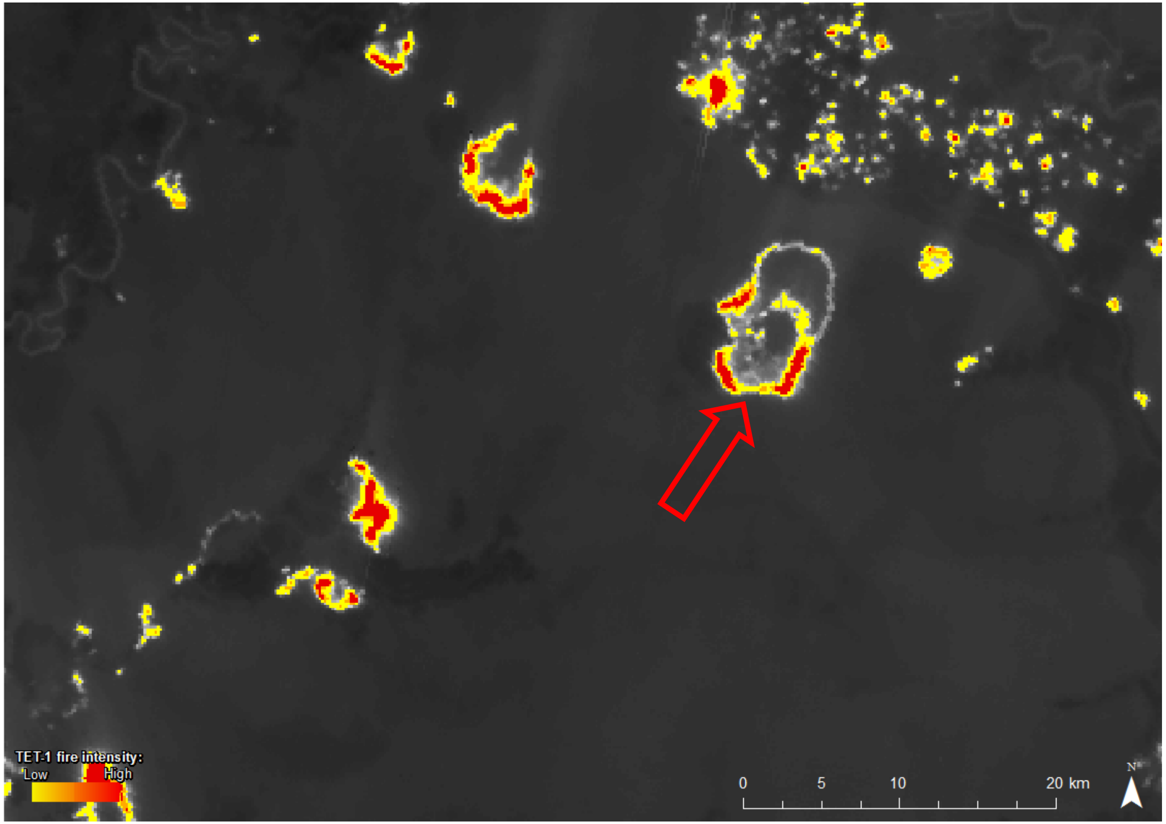
Spread of fire in Sebangau NP



TET 13/10/2015

~ 29 days

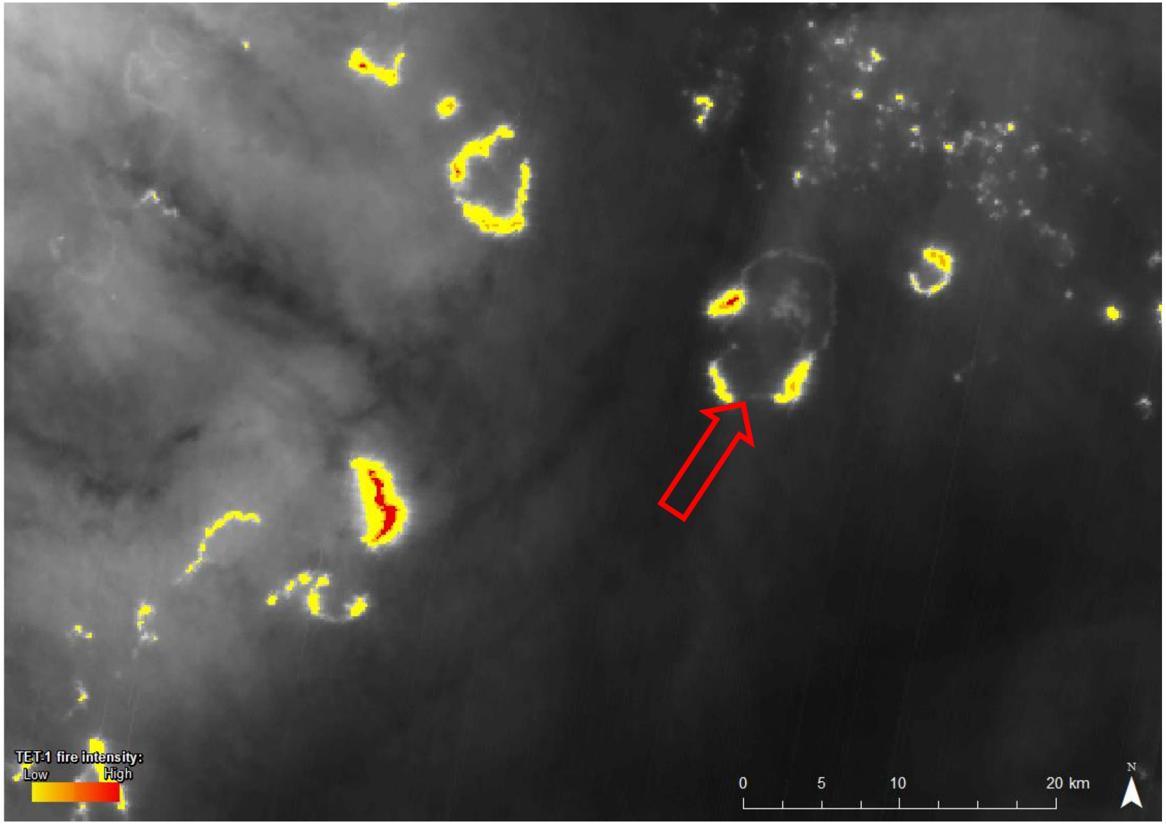
Spread of fire in Sebangau NP



TET 15/10/2015

~ 31 days

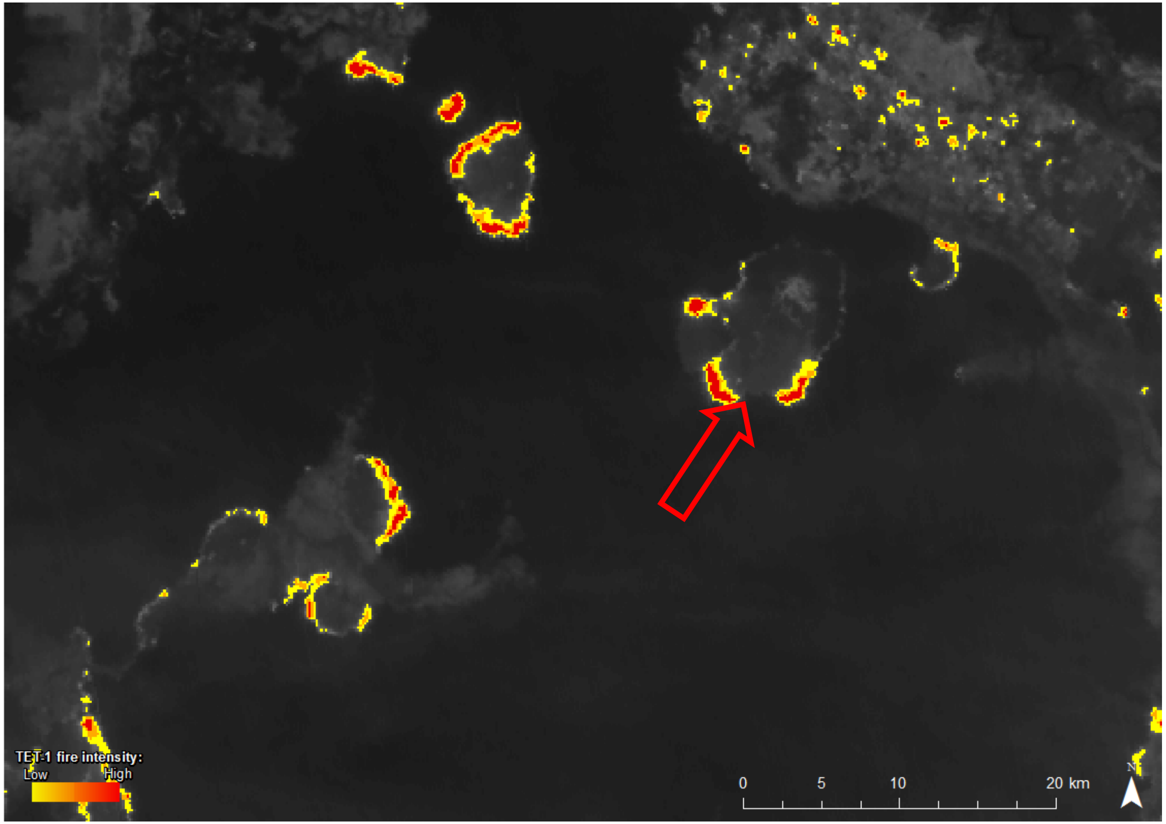
Spread of fire in Sebangau NP



TET 18/10/2015

~ 34 days

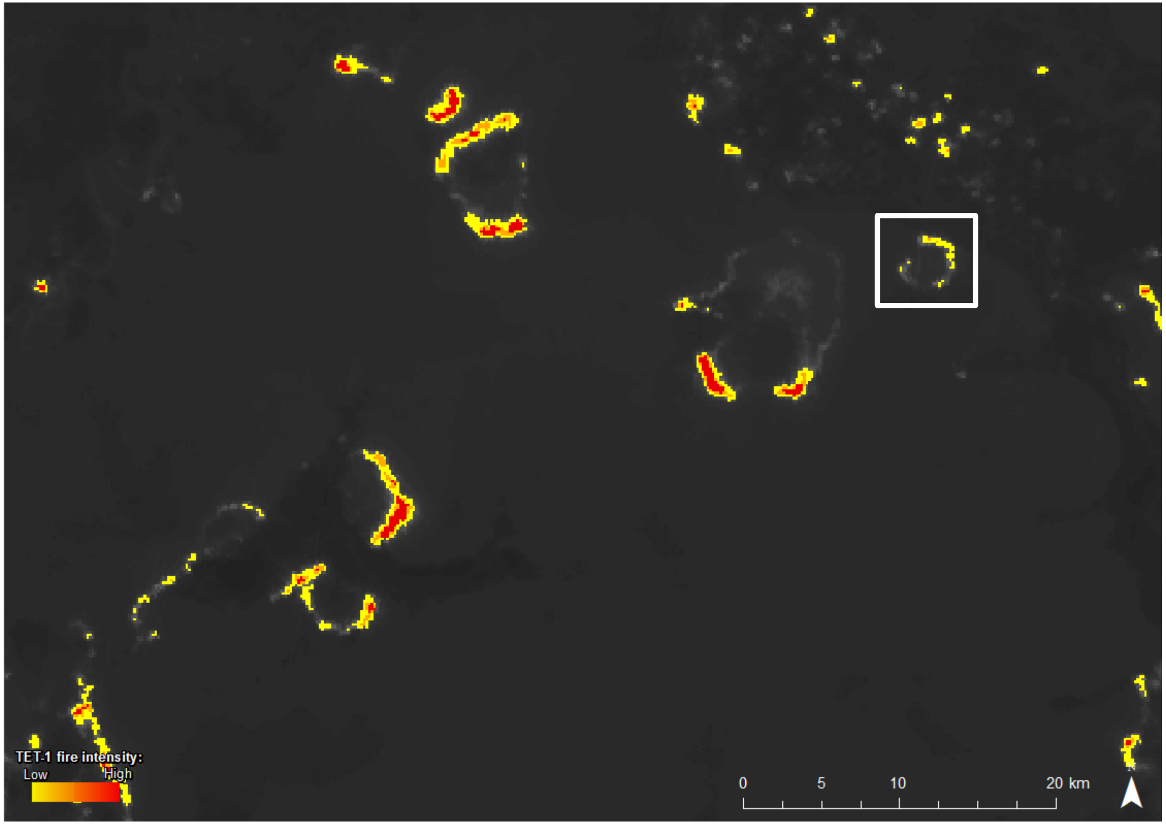
Spread of fire in Sebangau NP



TET 21/10/2015

~ 37 days

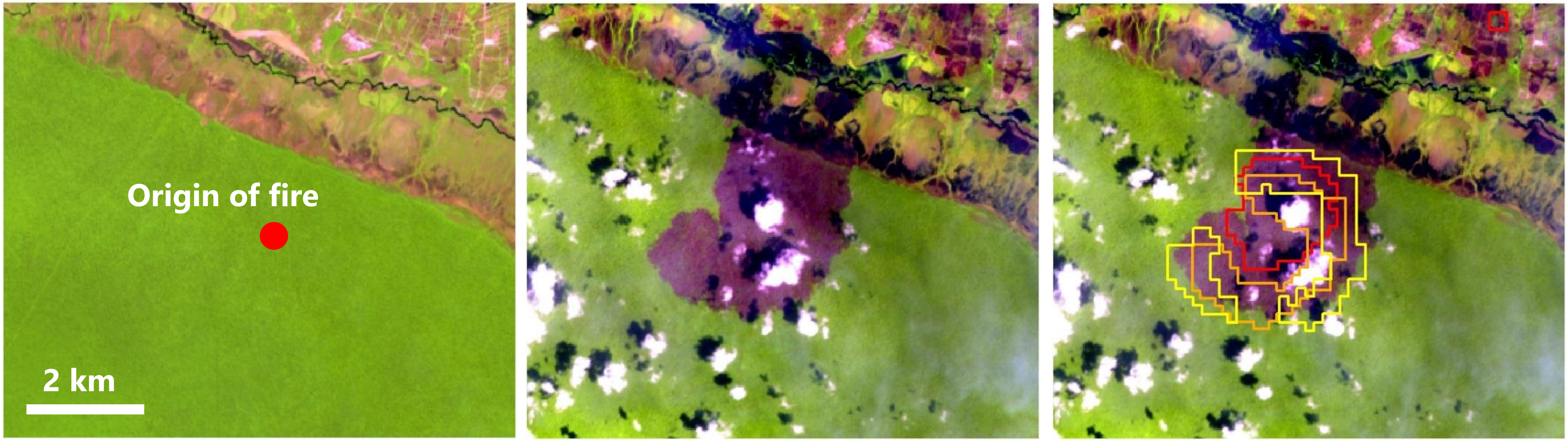
Spread of fire in Sebangau NP



TET 23/10/2015

~ 39 days

Field data collection by UAV



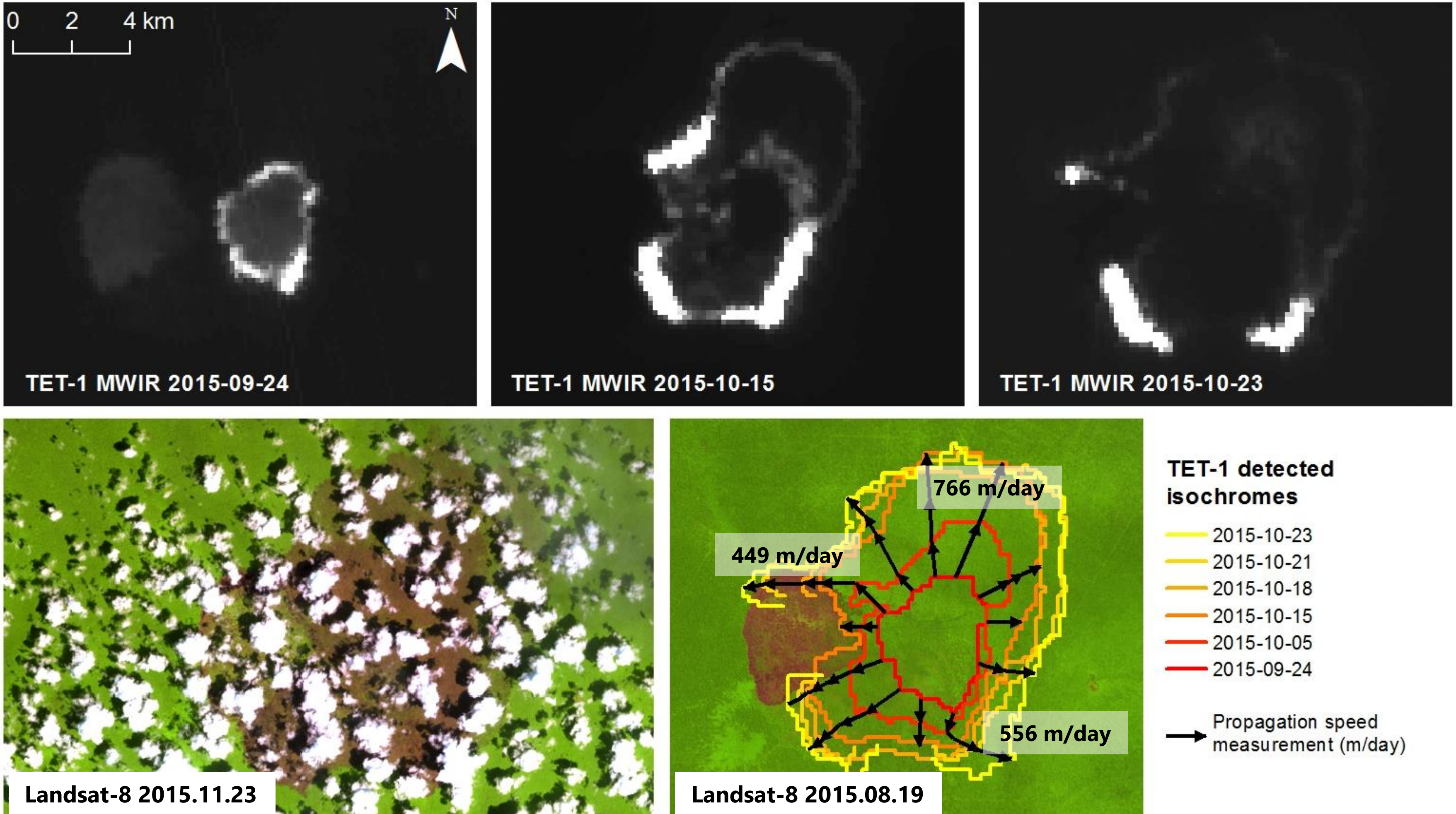
Landsat-8 2015.08.19

Landsat-8 2015.11.23

TET-1
2015.10.15
2015.10.18
2015.10.23

Field data collection by UAV

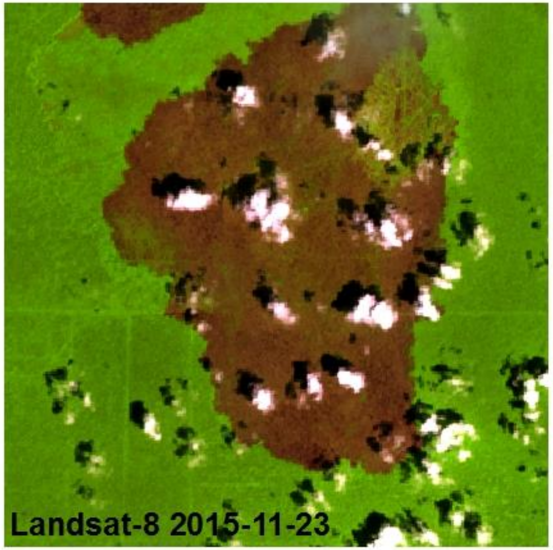
Fire ring propagation

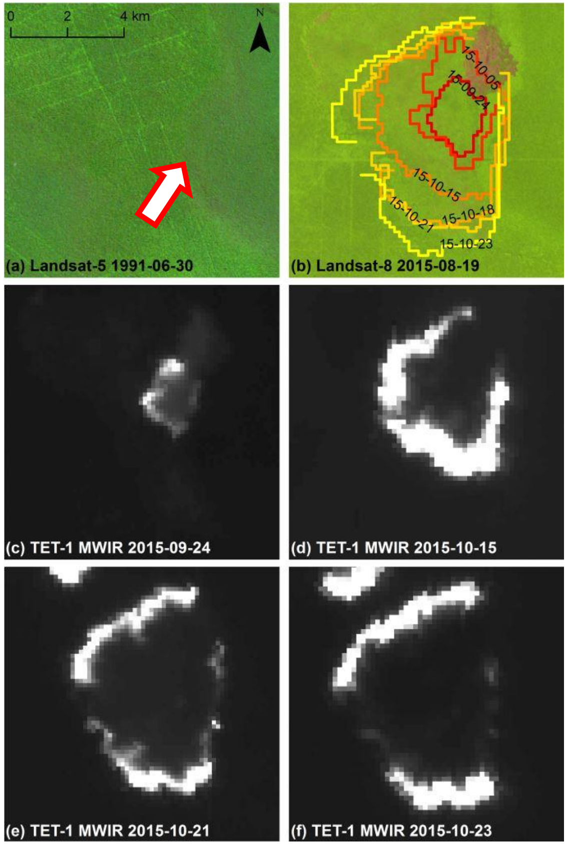


Propagation speed & vegetation type

Before

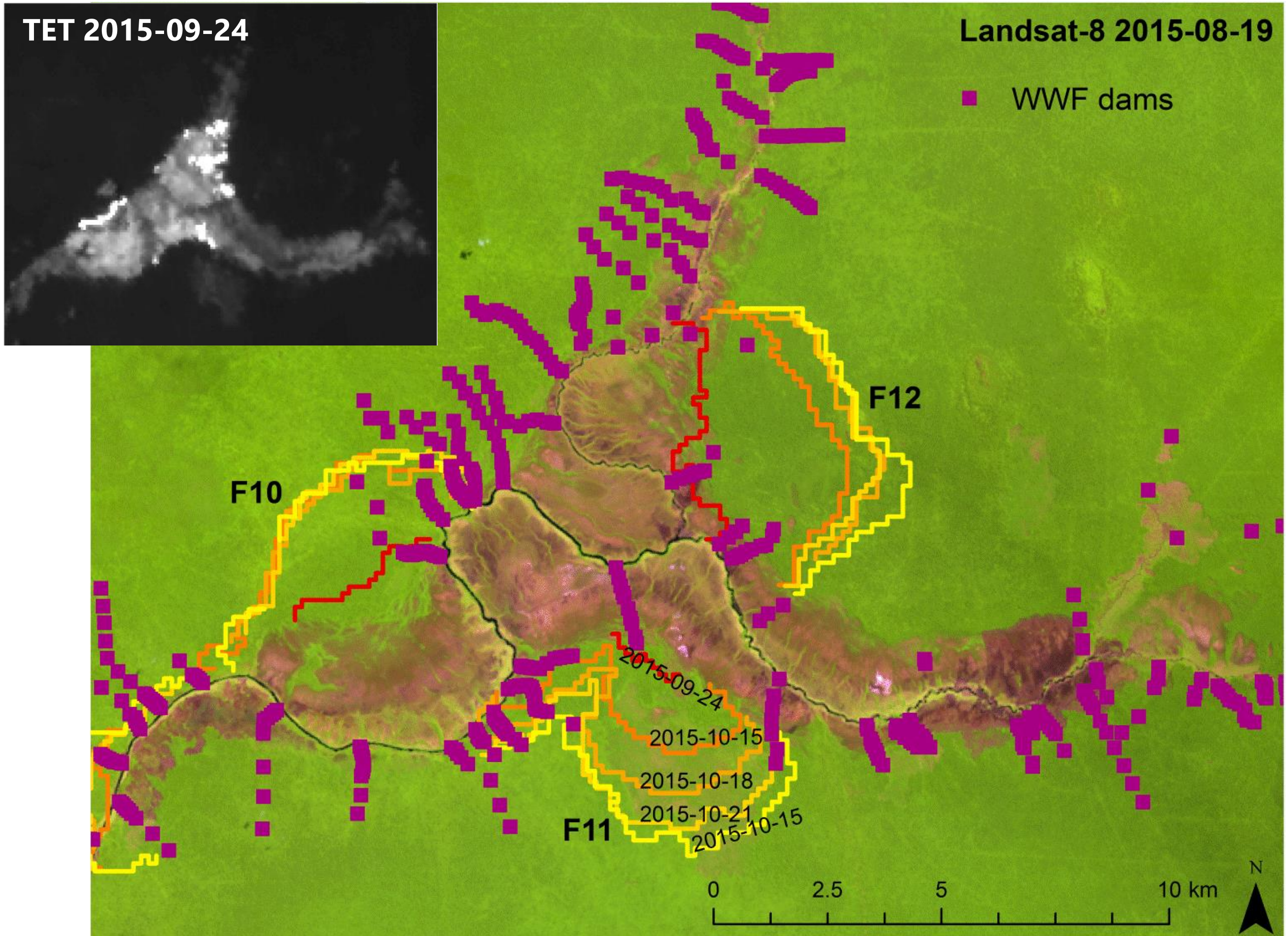
After





Ground type	Propagation speed (m/day)				
	N	Average	S.D.	Minimum	Maximum
peat+sand (depth unknown)	14	97.63	87.62	20.50	361.00
peat 0-1 m	30	134.94	131.90	4.62	490.00
peat 1-2 m	77	161.53	172.53	4.09	978.50
peat > 2m	202	187.01	237.82	5.21	1903.50

Potential beneficial effects from peatland rehabilitation



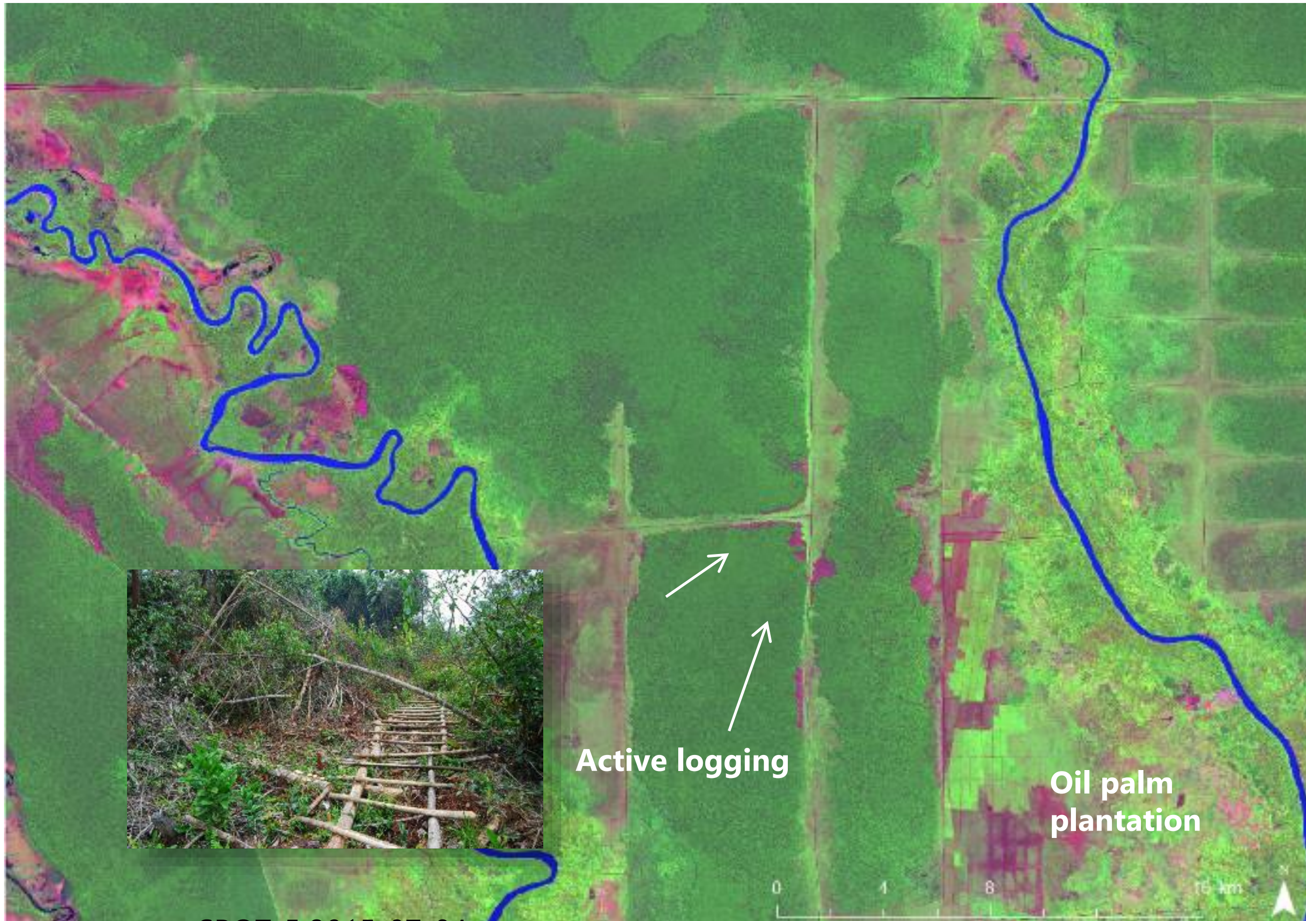
Fire F10 had **lowest average fire propagation speed** (88 m/day)

East and west boundaries of the F10 and F11 fires **correspond to dam locations**

F12 fire occurred on thin peat layer overlying sand

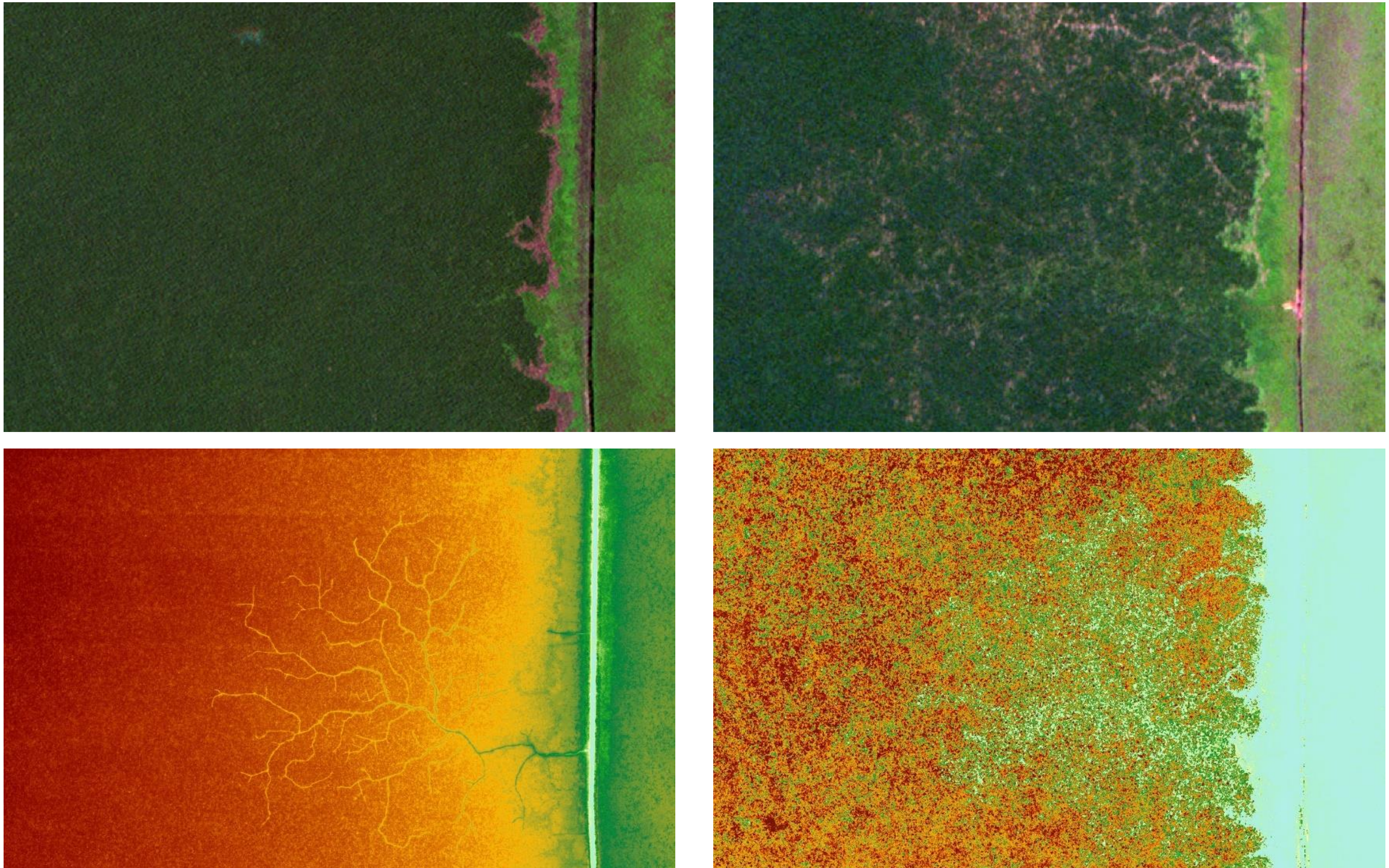
- Reduced dampening effect

Logging and fire propagation



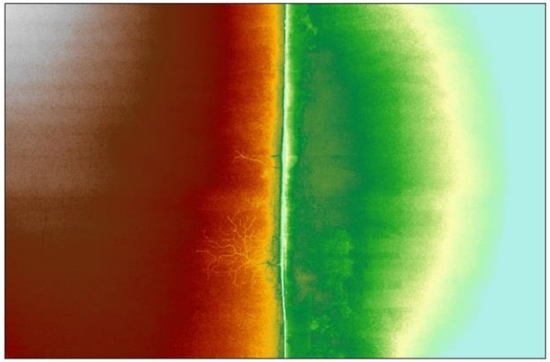
SPOT-5 2015-07-04

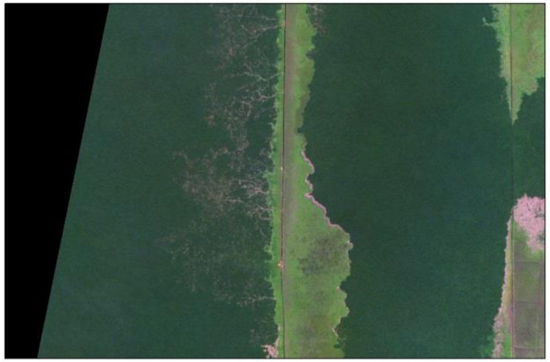
Logging and fire propagation



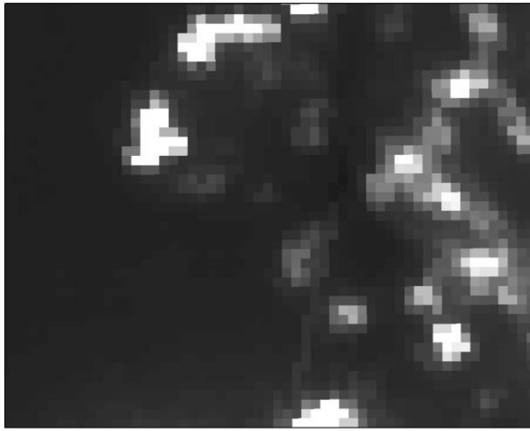
SPOT-5 2015-07-04

Logging and fire propagation

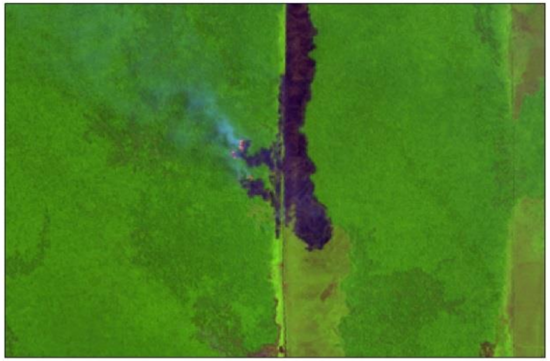




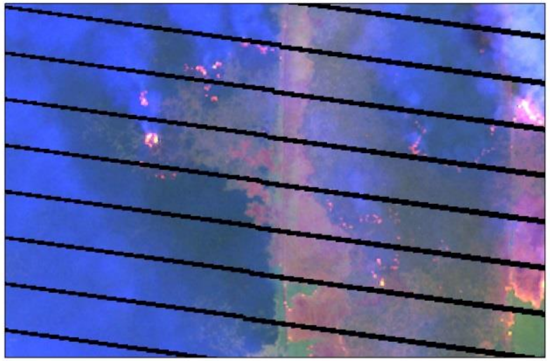
RapidEye 2012.07.29



TET-1 2015.10.15



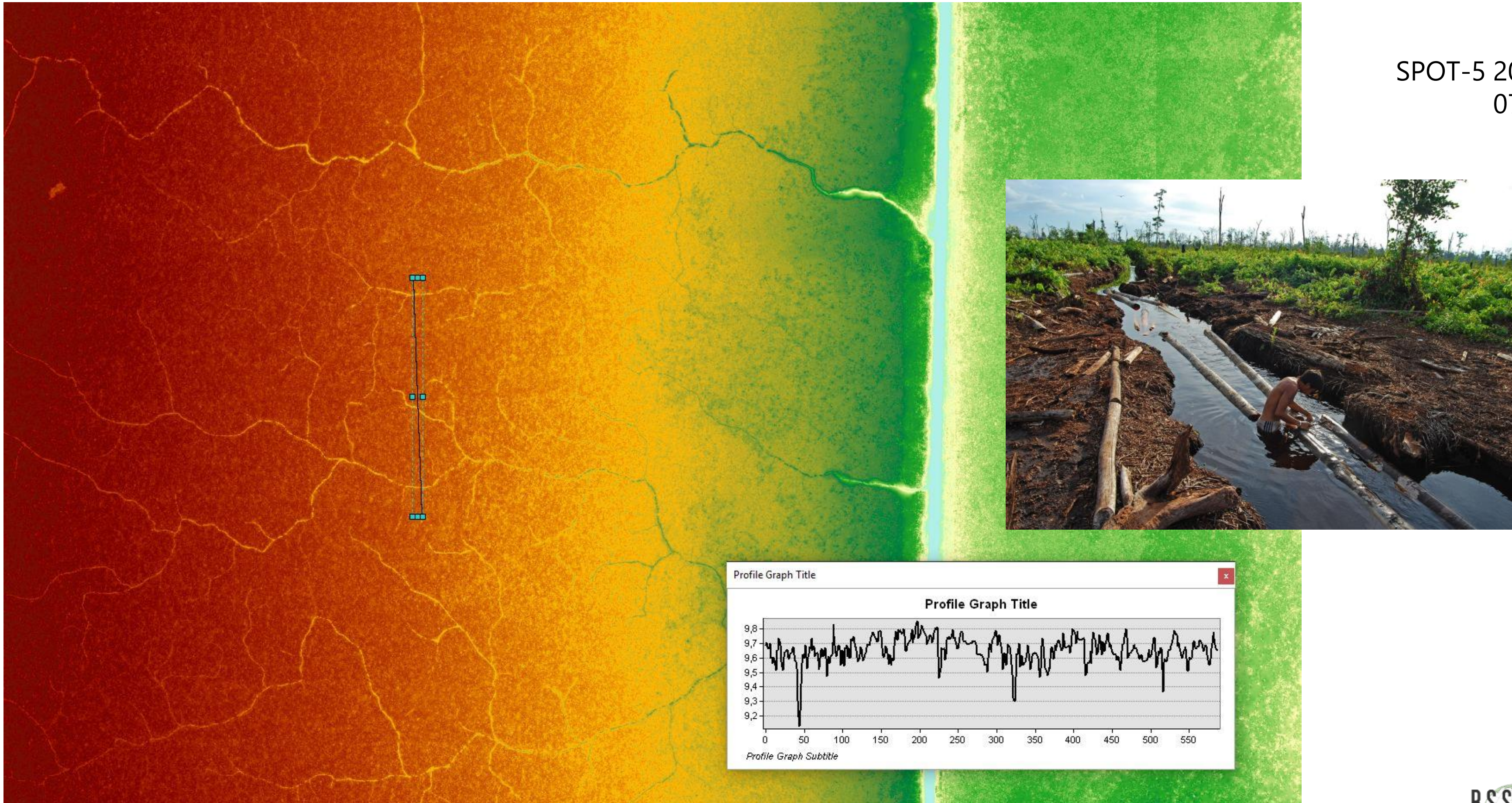
Landsat-8 2015.08.19



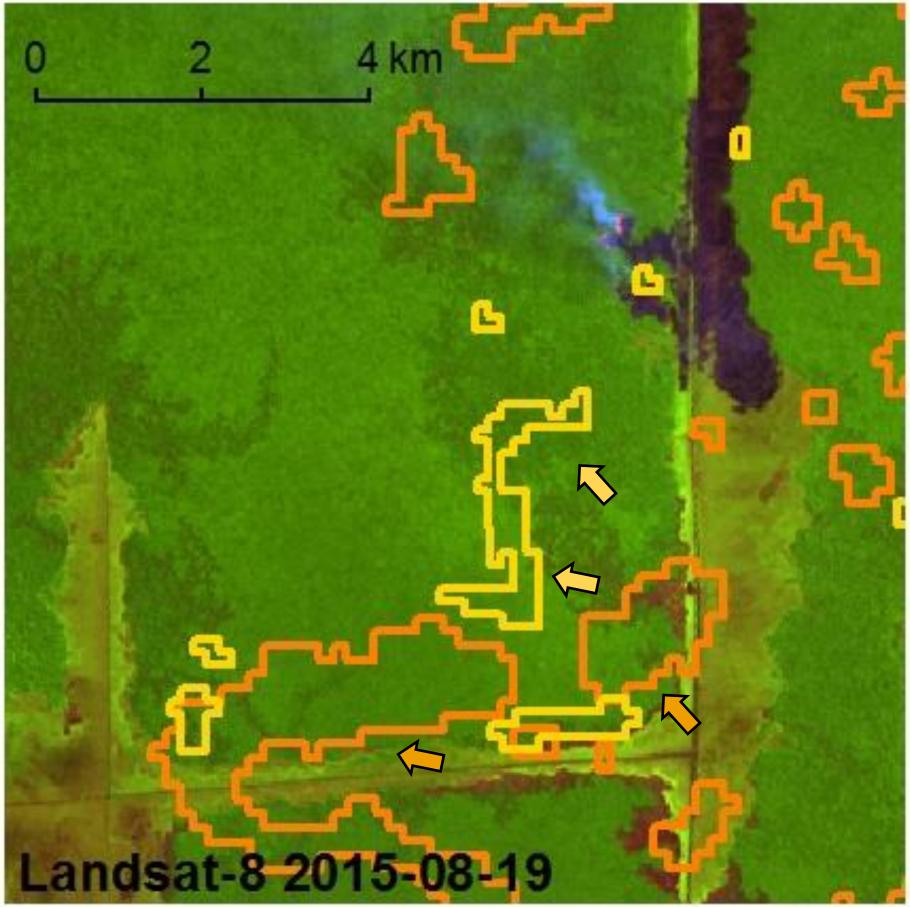
Landsat-7 2015.10.14

Logging and fire propagation

SPOT-5 2015-07-04

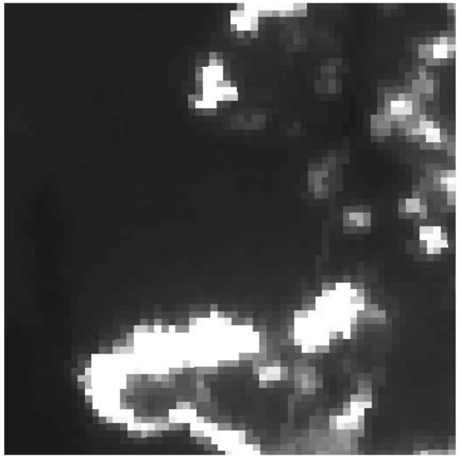


Spread of fire in Ex MRP area

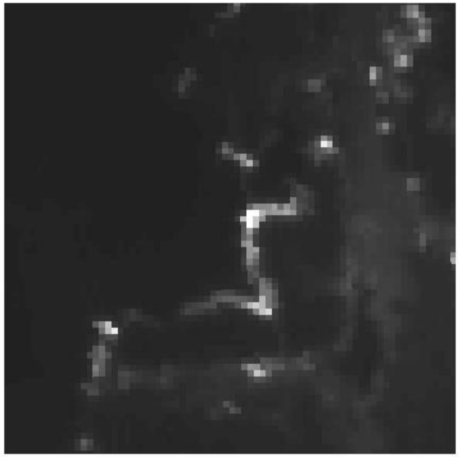


TET-1: 2015.10.15 2015.10.21

TET-1 time series

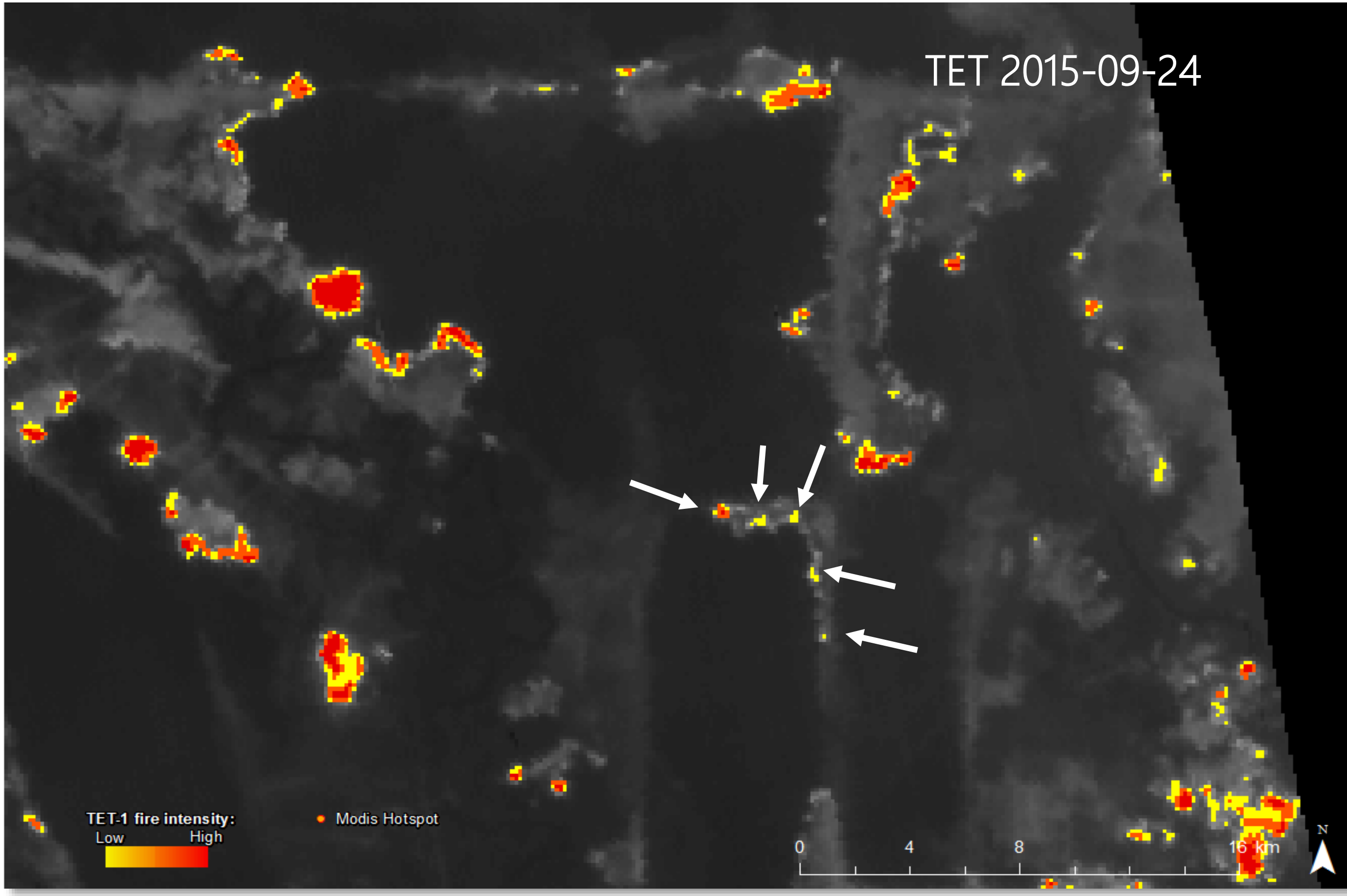


2015.10.15



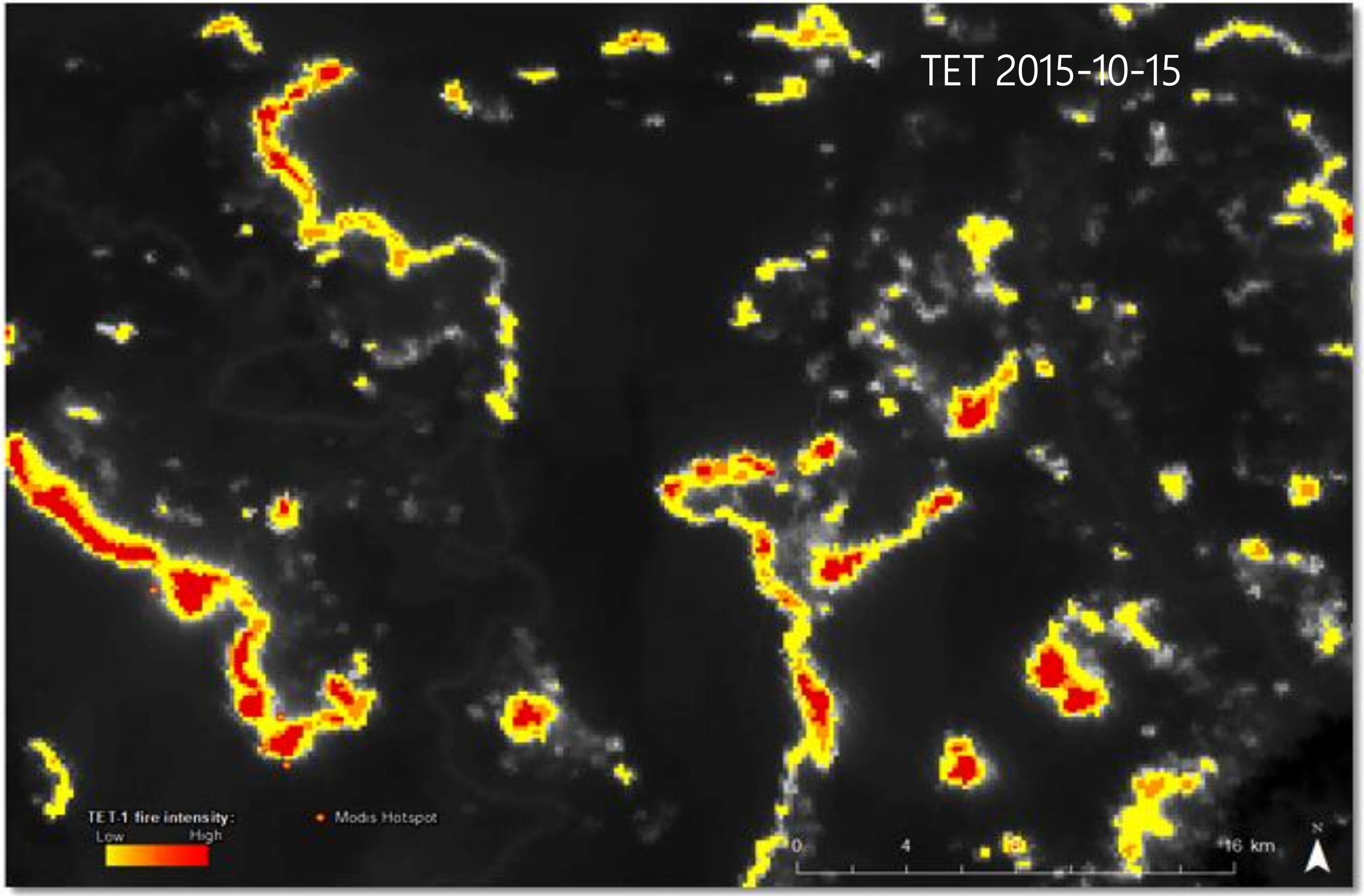
2015.10.21

Spread of fire in Ex MRP area



Several sources of ignition…

Spread of fire in Ex MRP area

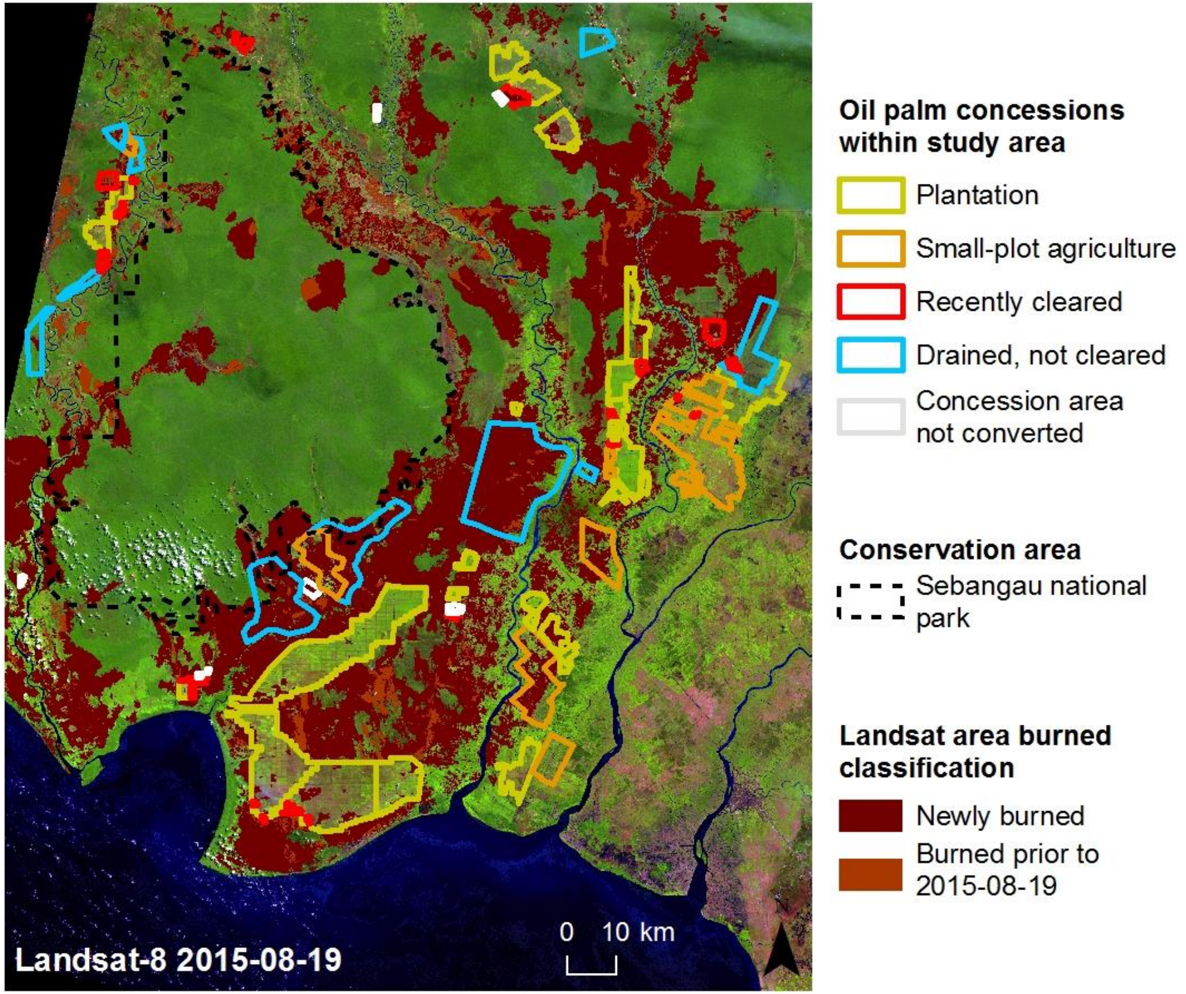


Three weeks later:

… lead into one large fire line fronts

Measured propagation speeds were in excess of **500 m/day**

First estimate of damage extent



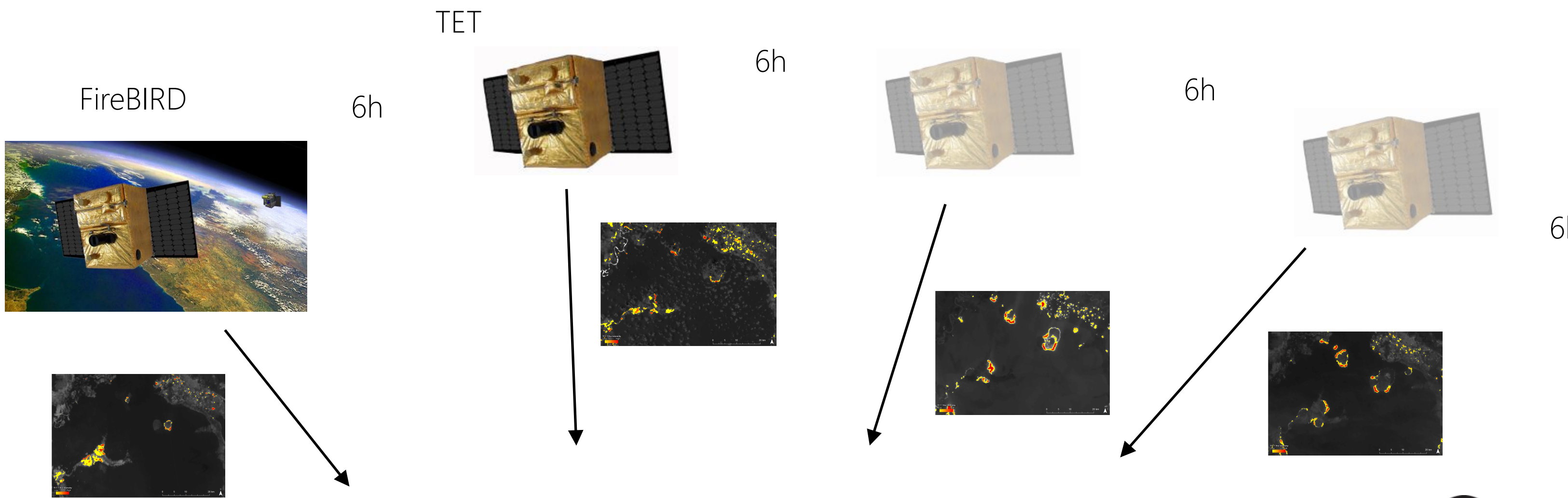
Fire monitoring

- TET-1 detects **twice** as many active fires as MODIS hotspots
- High spatial resolution allows more accurate delineation of burning areas
- Enables measurement of fire behavior (size & speed of fire fronts)
- Better identification of low energy peat fires (sensor sensitivity 0-1000 MW, bispectral method)
- Improved estimates of fire emissions (FRP)

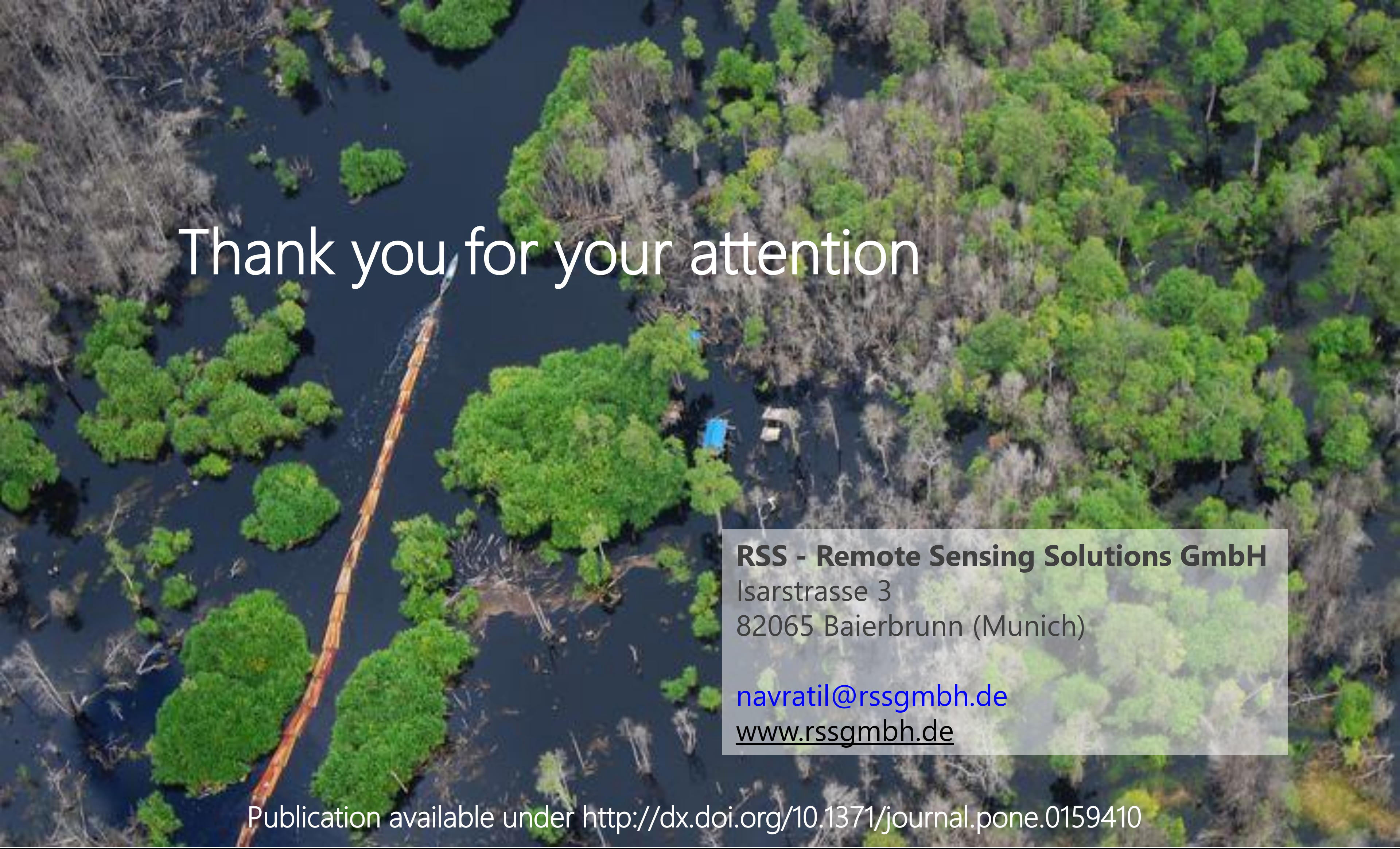
Near real time monitoring by Firebird constellation

- Early detection of fire: midday and afternoon
- Early detection of fires while still small
- Enable quick firefighting response
- Improved fire control management
- Law enforcement: identify origin of fire

Near real time monitoring by Firebird constellation



Improve fire control management capabilities



Thank you for your attention

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