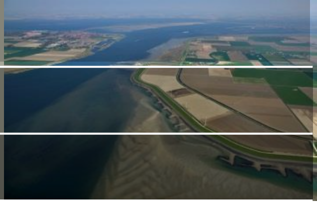
The use of LiDAR data in peatland mapping and management

Deltares 'lowland/peat' team:
Al Hooijer, Ronald Vernimmen, Martijn Visser
Corine ten Velden, Dirk Eilander, Dedi Mulyadi, Angga Yuherdha

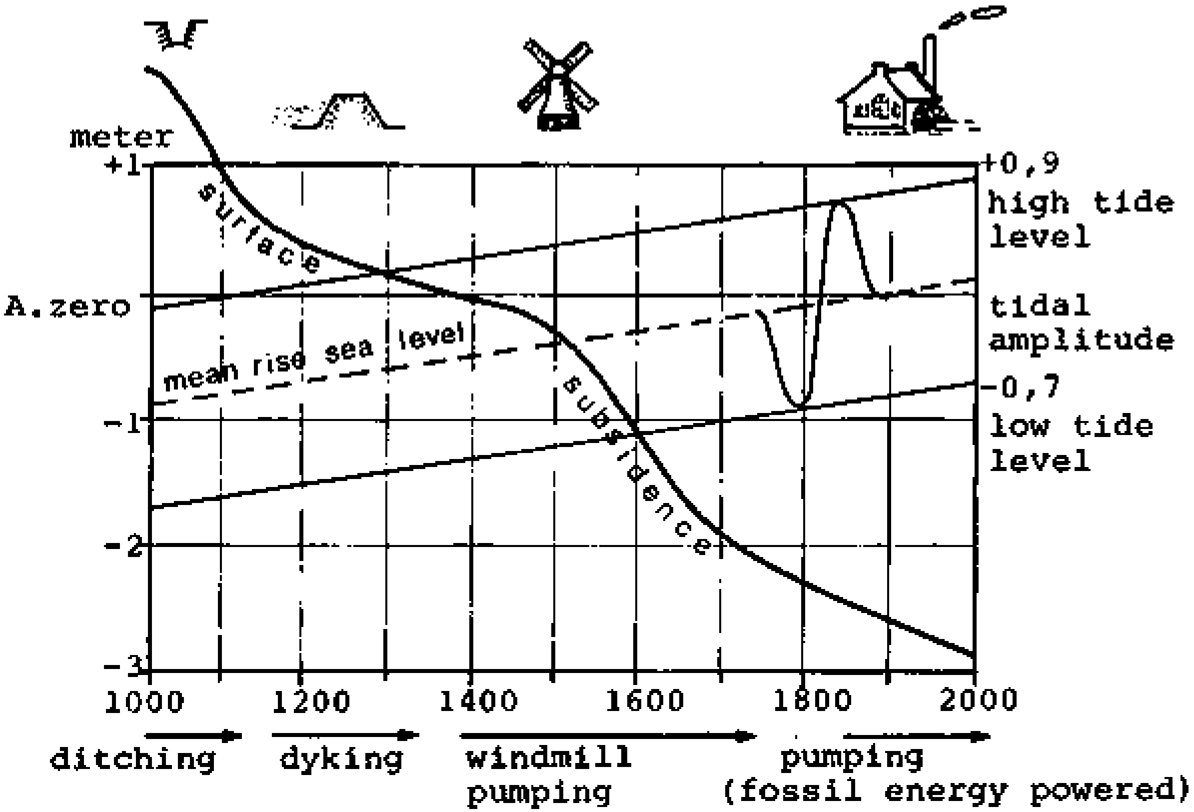
ronald.vernimmen@deltares.nl

Visit of delegation Indonesian Ministry of Environment and Forestry, Wageningen University, 5 April 2016

What is Deltares (Delta Research)



- Deltares is an independent not for profit land and water management research and consultancy institute.
- Founded 1927 to help design Netherlands coastal defence, necessary largely because our peatlands had subsided well below Sea level (!)



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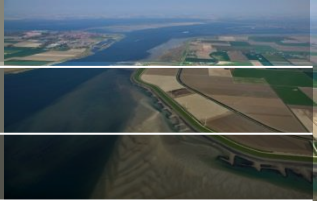
Who am I

<u>Since 1999</u> studying and working in Indonesia.

Graduated in 2001 from Vrije Universiteit Amsterdam, **<u>MSc. Environmental Sciences</u>**

<u>Started PhD</u> at Vrije Universiteit Amsterdam, Earth and Life Sciences department **<u>in 2001</u>**:
“Hydrology and Biogeochemistry of heath forests (hutan kerangas) of contrasting stature in Central Kalimantan, Indonesia”

<u>In 2007</u> started at Deltares as hydrologist, working mainly on projects related to the hydrology and water management of peatlands in Indonesia:
<u>Tasks:</u> *setup hydrological monitoring networks and databases; hydrological analysis, processing and analysis of RS imagery, spatial modelling, LiDAR processing, training and supervision of local staff*



Topics

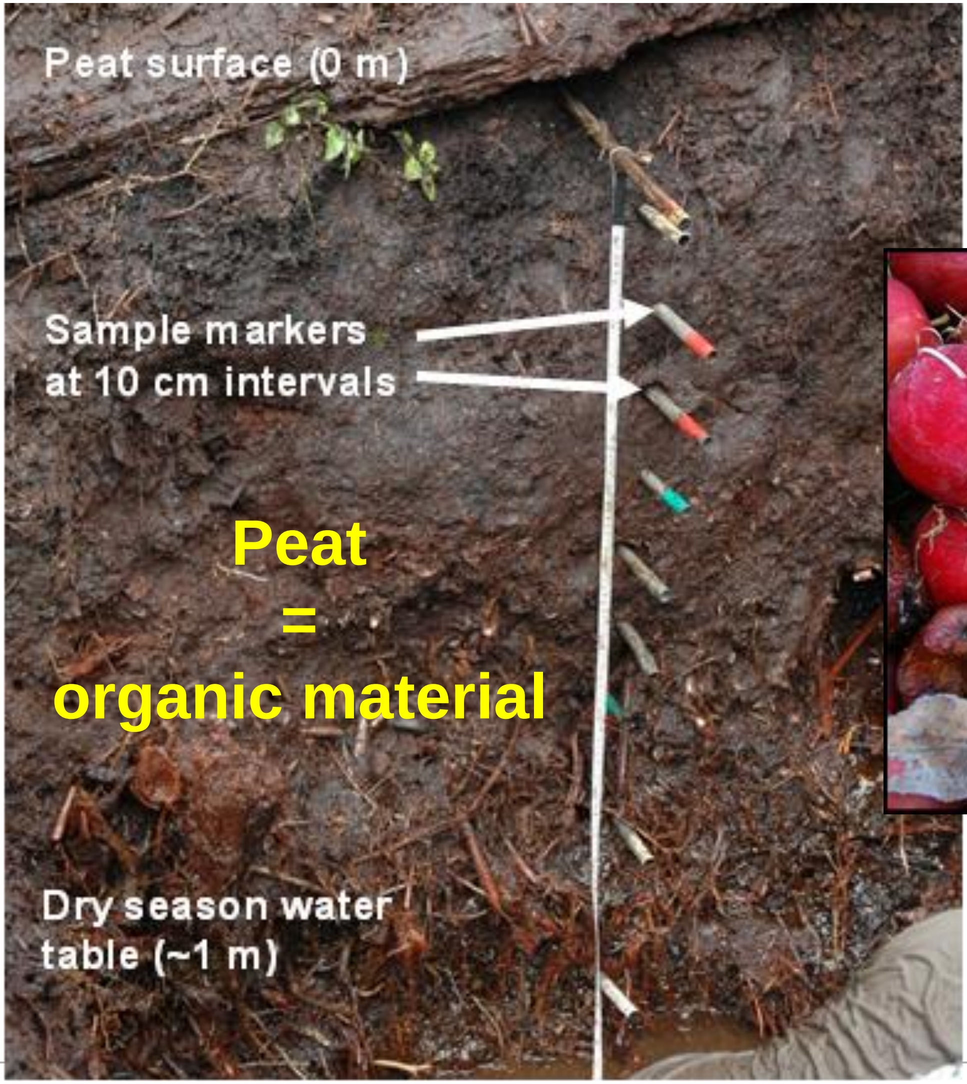
- Background
- Method for creating elevation models from ‘strip’ LiDAR data (not full coverage)
- Creating peat dome thickness models from elevation models
- Limitations of peat thickness mapping using elevation models
- Other applications of LiDAR data in support of improved peatland management
  - *Flood risk*
  - *Historical subsidence*
  - *Forest canopy heigth and degradation*
  - *Water levels in canals*

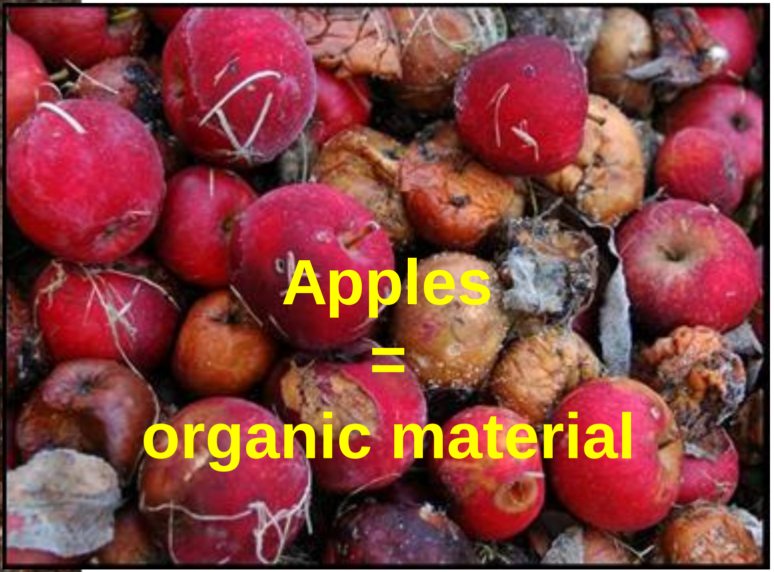
What is peat?

Peat soils consist mostly of water (90%), held together by vegetation remains (mostly carbon).

What is peat?

Like fruit or vegetables, peat is lost when exposed to air





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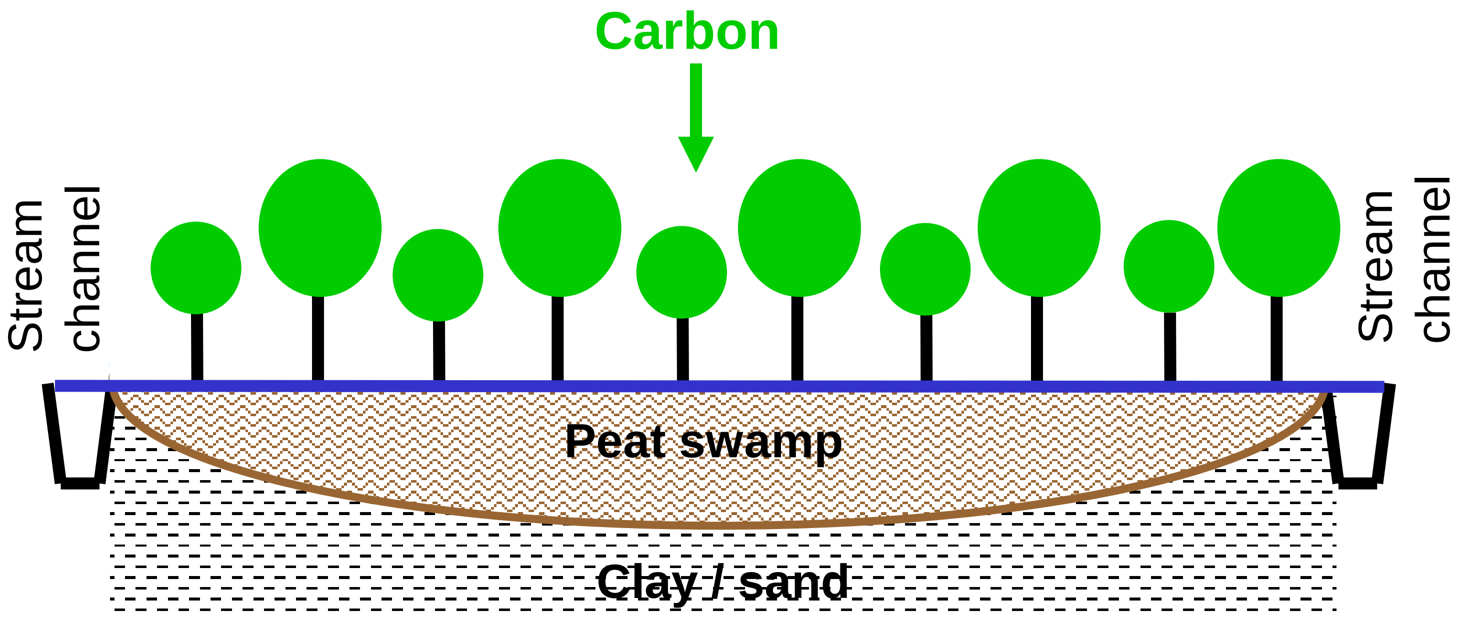
Peatland drainage inevitably causes carbon loss and subsidence



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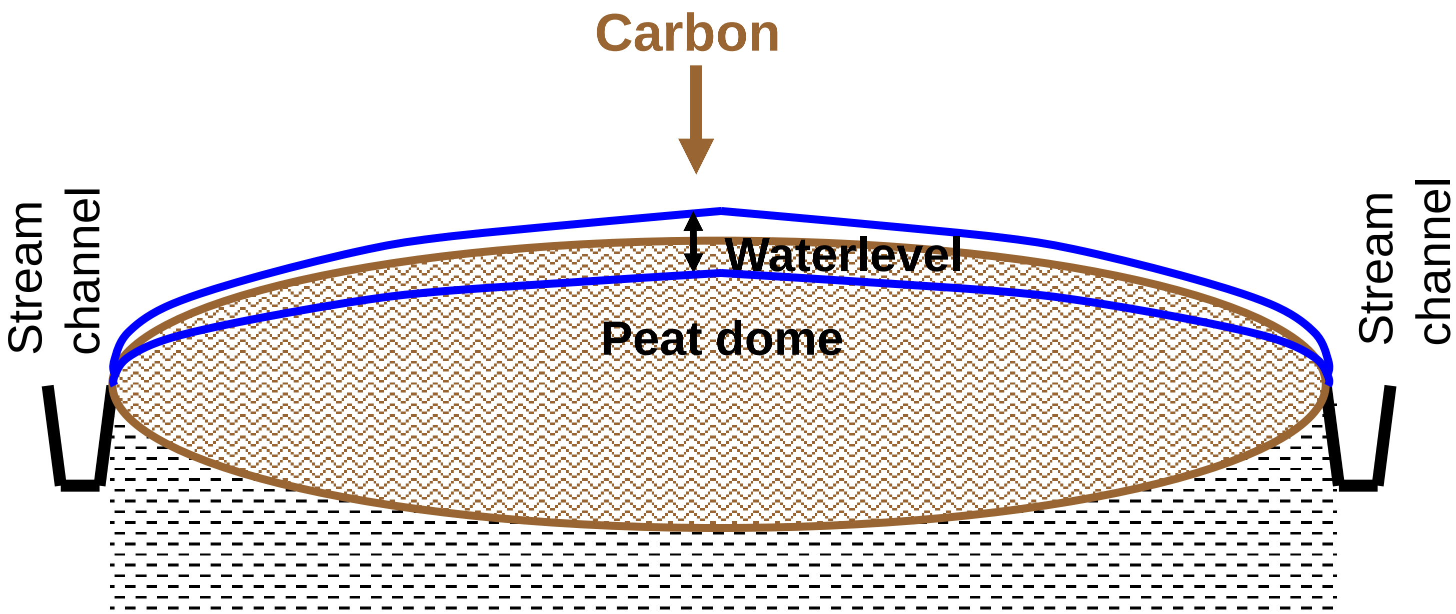
Peatland drainage inevitably causes carbon loss and subsidence



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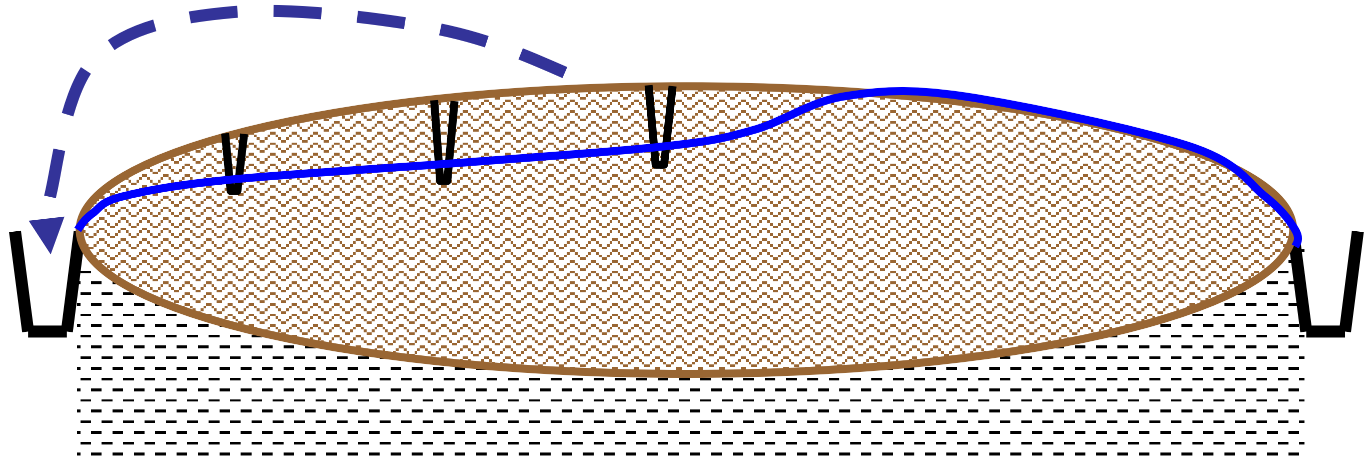
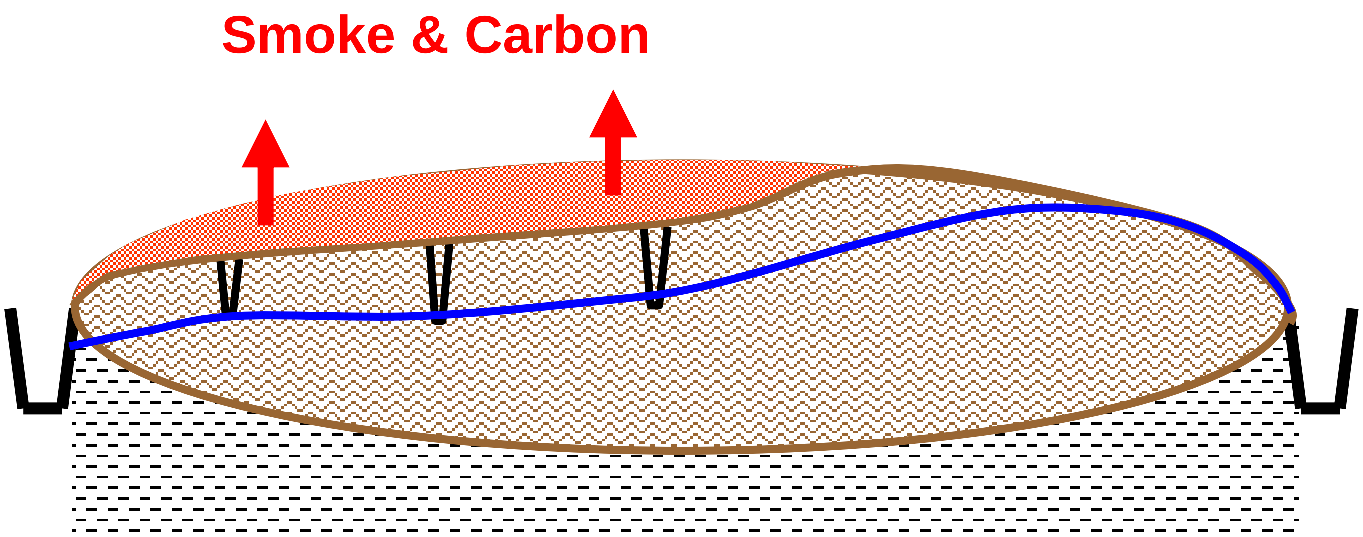
Peatland drainage inevitably causes carbon loss and subsidence



Peatland drainage inevitably causes carbon loss and subsidence



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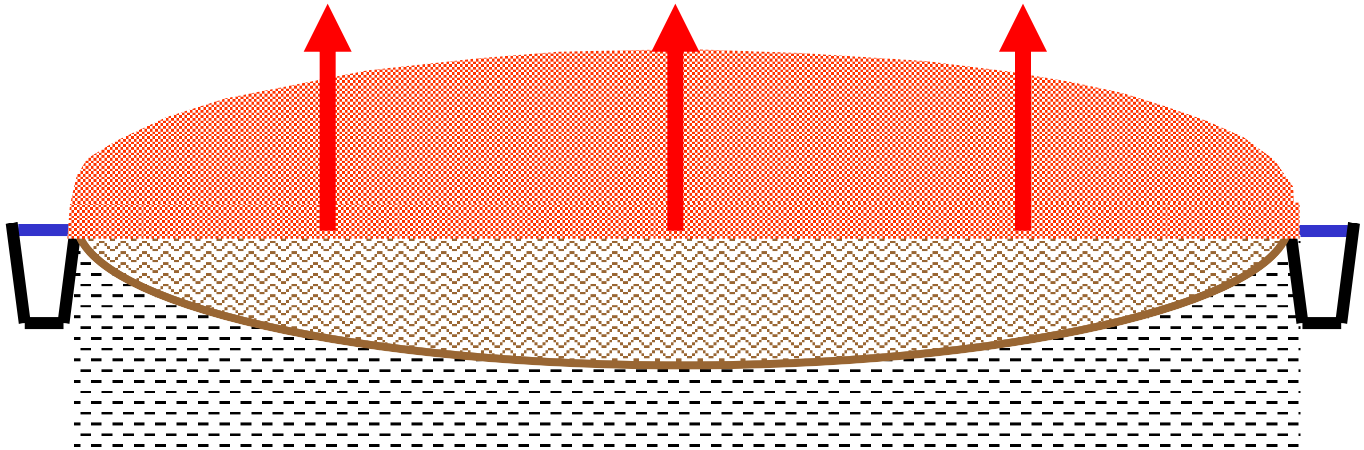
Peatland drainage inevitably causes carbon loss and subsidence



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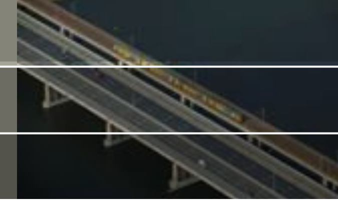


Background - summary

Peat consists of 90% water and 10% organic material that is mostly carbon.

After drainage, peat will decompose, and often burn, causing carbon emissions to the atmosphere, as well as land subsidence that results in flooding.

Peatlands are therefore not really ‘land’ in the normal sense, but should be managed as wetlands with high water levels and limited disturbance to keep the carbon stored and the surface above flood levels.

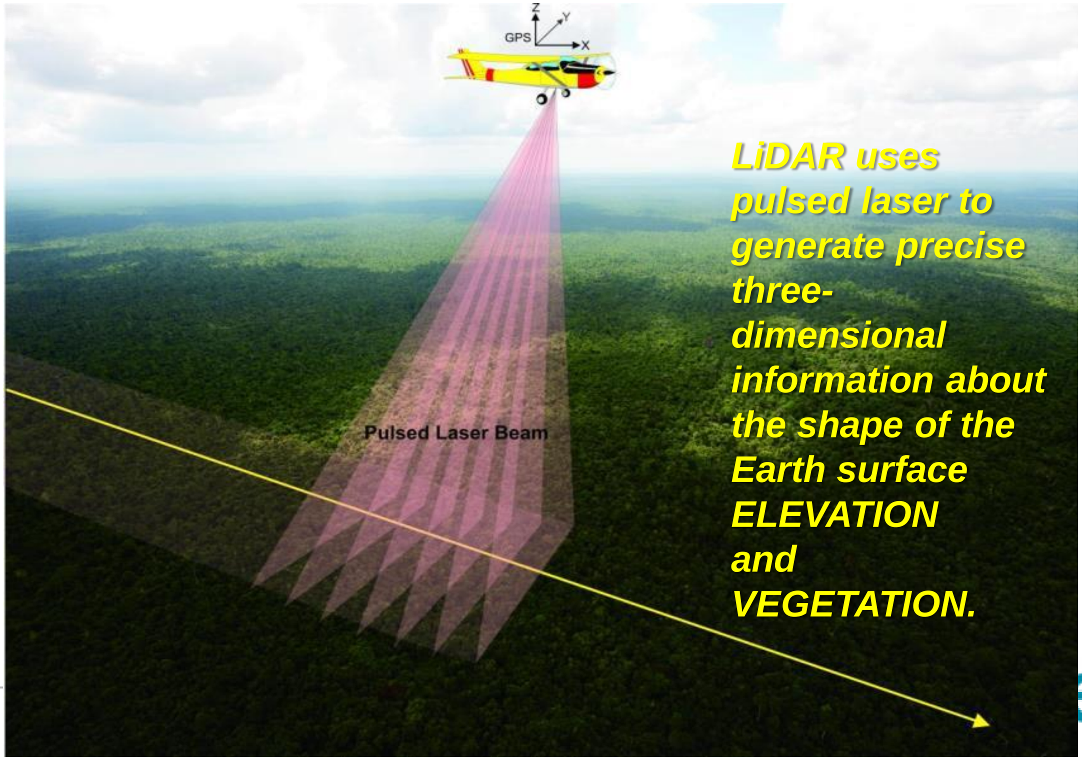
Better data is needed for better management. Elevation models can be used to produce peat thickness maps as well as flood risk models.

Such maps are needed to determine what activities are possible on peatland, as deep peat is known to be unsuitable for many uses. With better maps, better spatial planning and zoning is possible that minimizes carbon emissions, fire risk and flood risk.

New approach to cover large areas at reduced cost

<u>Airborne LiDAR is the most accurate and fastest method for establishing land surface elevation models</u>, especially in vegetated and built-up areas where other methods such as satellite radar (i.e. SRTM) are not suitable. It is widely applied globally. However it is a costly technique.

To be able to cover large areas at greatly reduced cost, Deltares has developed an approach that does not require data to be collected full coverage but yield good results with coverage of approximately 10-15% of the area of interest.



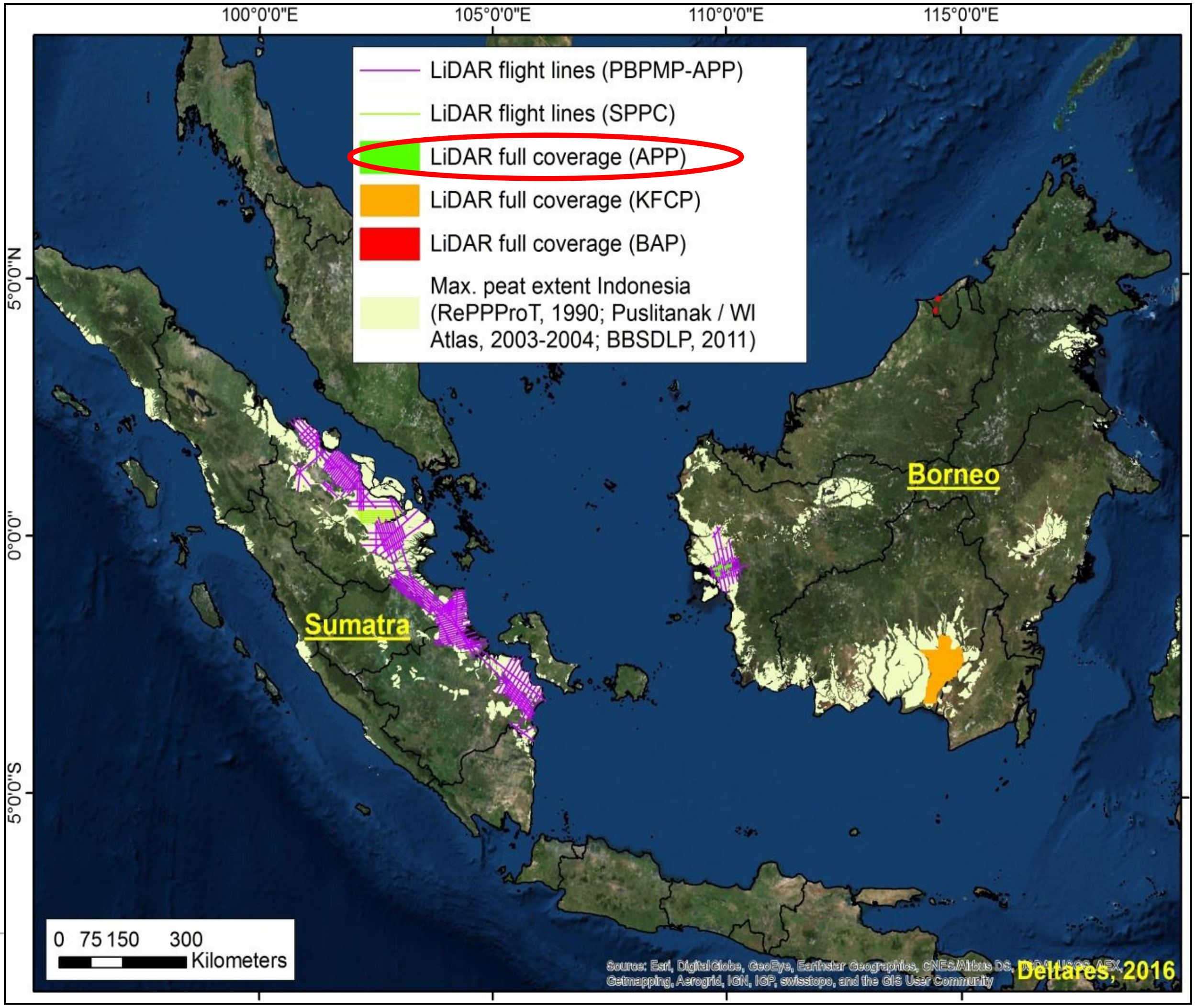
Development and application in Indonesia

Deltares and partners have produced LiDAR based elevation and peat dome thickness models in several projects in Kalimantan and Sumatra starting in 2007, for increasingly large areas and with increasing accuracy.

Overview map of all LiDAR data applied by Deltares in projects in Sumatra and Borneo (Indonesia and Brunei).

Projects using LiDAR are:

- ***2010-14: KFCP; Central Kalimantan; Ausaid funded.***
- ***2013-15: SPPC; SE Asia; with WI and UGM; NORAD funded.***
- ***2014-15: BAP; Brunei; with WI; Shell funded.***
- ***2014-15: PBPMP; Indonesia; APP funded.***



Determining the peat extent to be mapped

The LiDAR based approach can be used to determine the extent of peat domes from elevation models, from the shape of the landscape or from estimated peat thickness. In Indonesia, we find it to be suitable for mapping peat that is over 2 or 3 metres in depth.

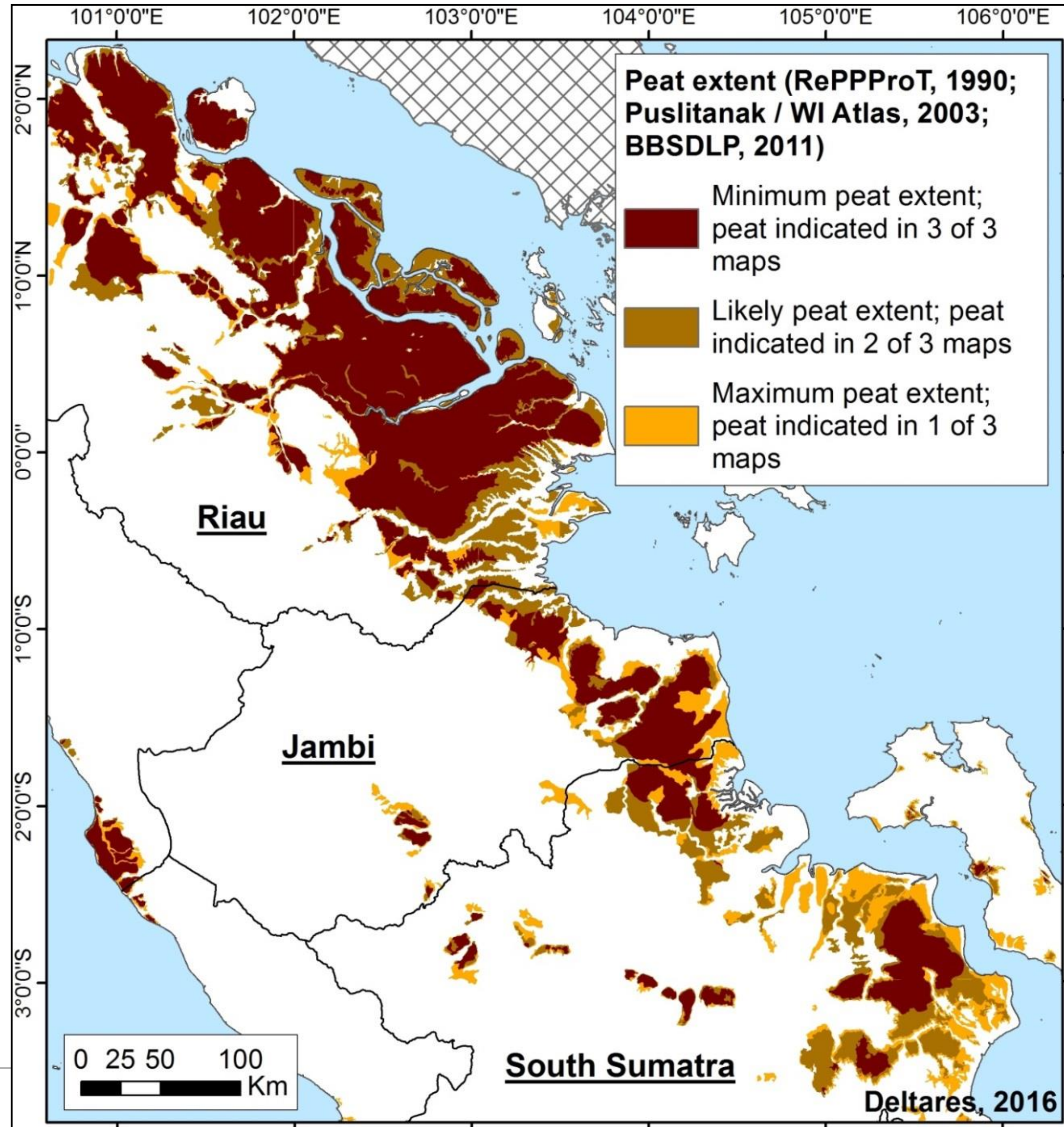
However, it is less suitable for mapping the full extent of peatland because there are areas of shallow peat that can not be distinguished from LiDAR images.

To plan the area over which airborne LiDAR data should be collected for mapping of peat domes, we first determine minimum, likely and maximum peat extent from three existing maps.

Determining the peat extent to be mapped

Minimum, likely and maximum peat extent in East Sumatra (Riau + Jambi + South Sumatra) as determined from three existing maps (RePPProT 1990; Puslitanak / Wetlands International Peat Atlas 2003/04; BBSDLP 2011).

Note that while the maximum peat extent map overreports in some areas, it underreports in other areas that have so far never been mapped as being peat, by any source. Both overreported and underreported areas may be identified visually from Landsat images.



Method for creating a surface elevation model from LiDAR strip data

Over the period of April to May 2015, LiDAR data were collected covering the coastal peatlands of East Sumatra along a total of ~9,600 km of flight lines at 5 to 10 km intervals.

The LiDAR data were referenced to Mean Sea Level (MSL) through linking the LiDAR data to 6 national second order vertical control benchmarks distributed throughout the survey area; referencing was verified against actual Sea levels as occurring in the LiDAR data.

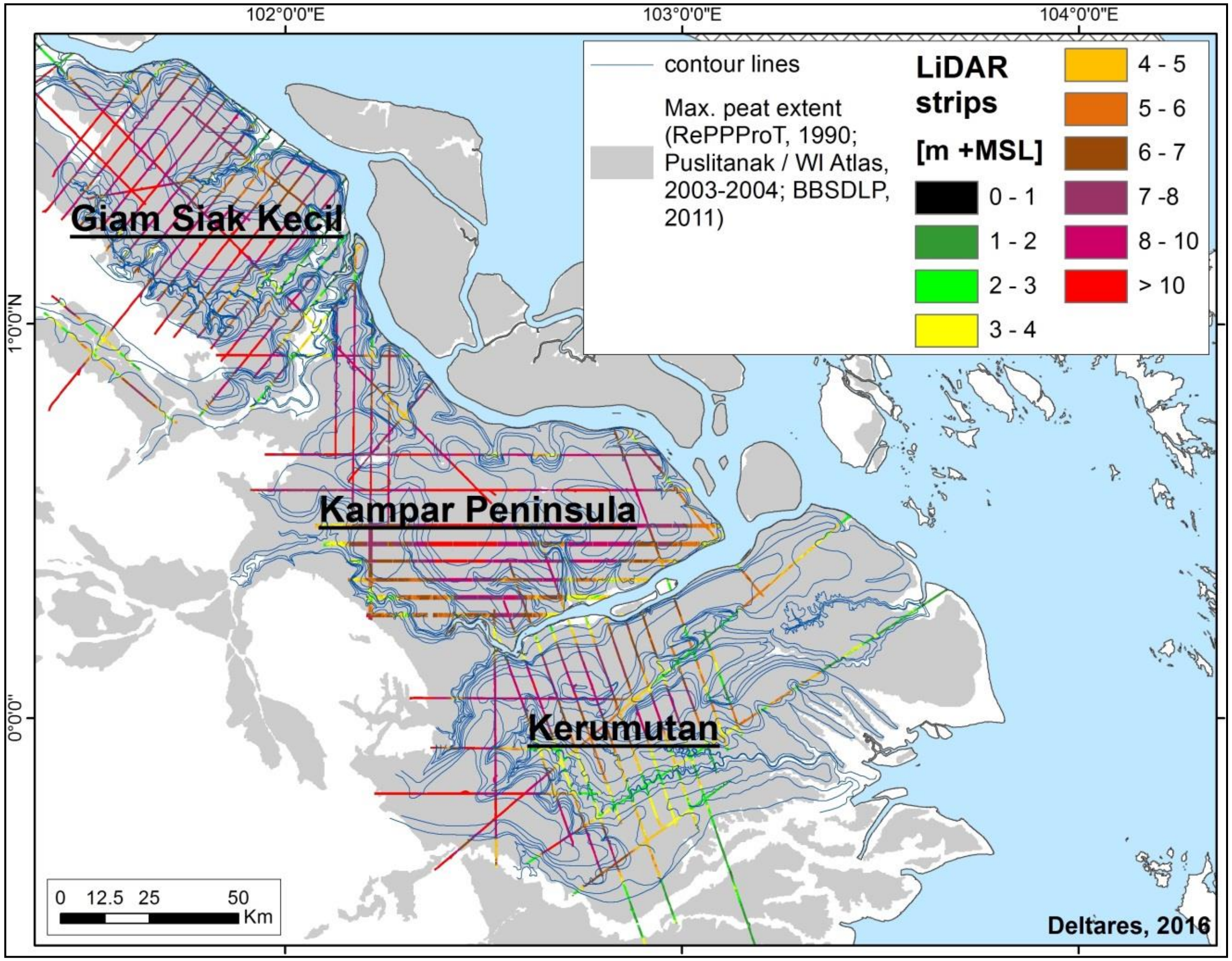
Vegetation signal was filtered out, yielding ‘strips’ of LiDAR data points representing surface elevation only;

Contour lines at 1 m intervals were manually drawn between ‘data strips’, aided visually with Landsat composite images in the background to take into account location of rivers and general landscape morphology, to improve accuracy of the resulting surface elevation model that was created through inverse distance interpolation between strip data and contour lines.

Method for creating a surface elevation model

LiDAR STRIPS and manual contour lines for the major peat dome landscapes along the Riau coastline (Giam Siak Kecil, Kampar Peninsula and Kerumutan).

Contour lines are drawn manually by geographers, interpreting landscape patterns from the position of coastline, rivers and other morphological features.



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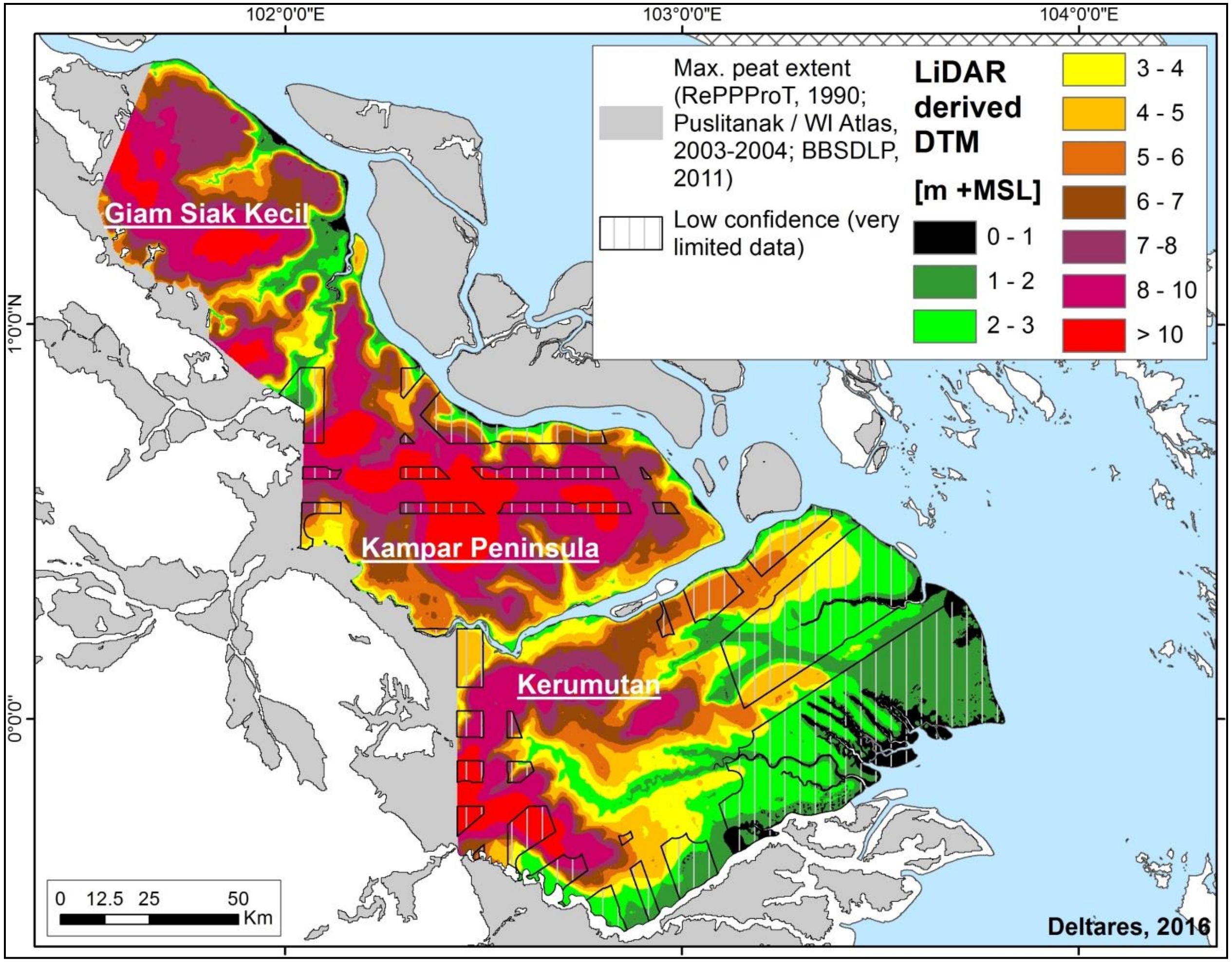
Method for creating a surface elevation model

LiDAR based surface elevation model for the major peat dome landscapes along the Riau coastline (Giam Siak Kecil, Kampar Peninsula and Kerumutan).



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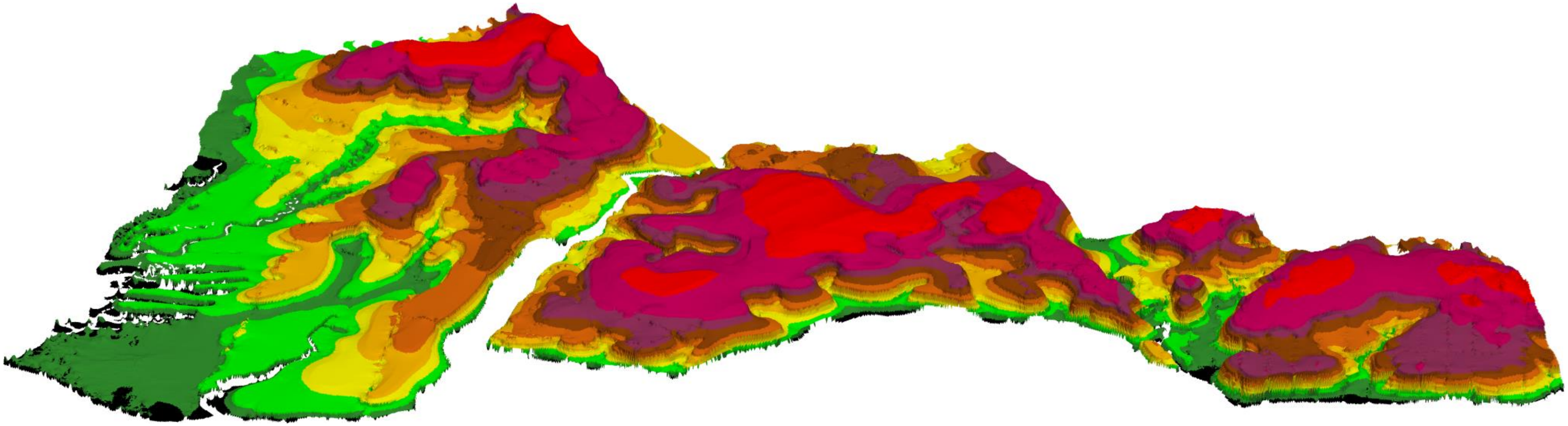
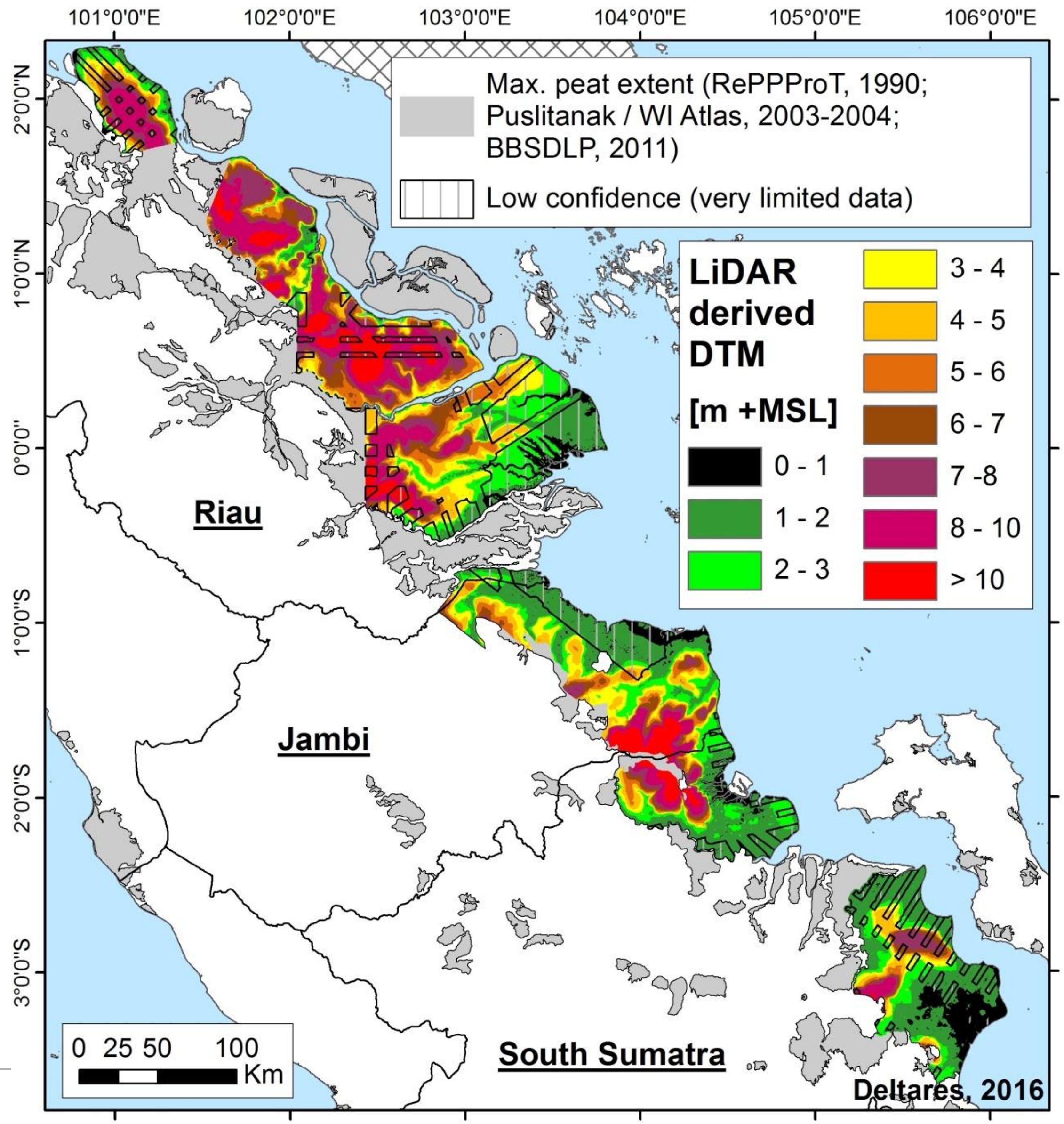
Method for creating a surface elevation model

3D version of the Kerumutan, Kampar Peninsula and Giam Siak Kecil peat domes along the Riau coastline.



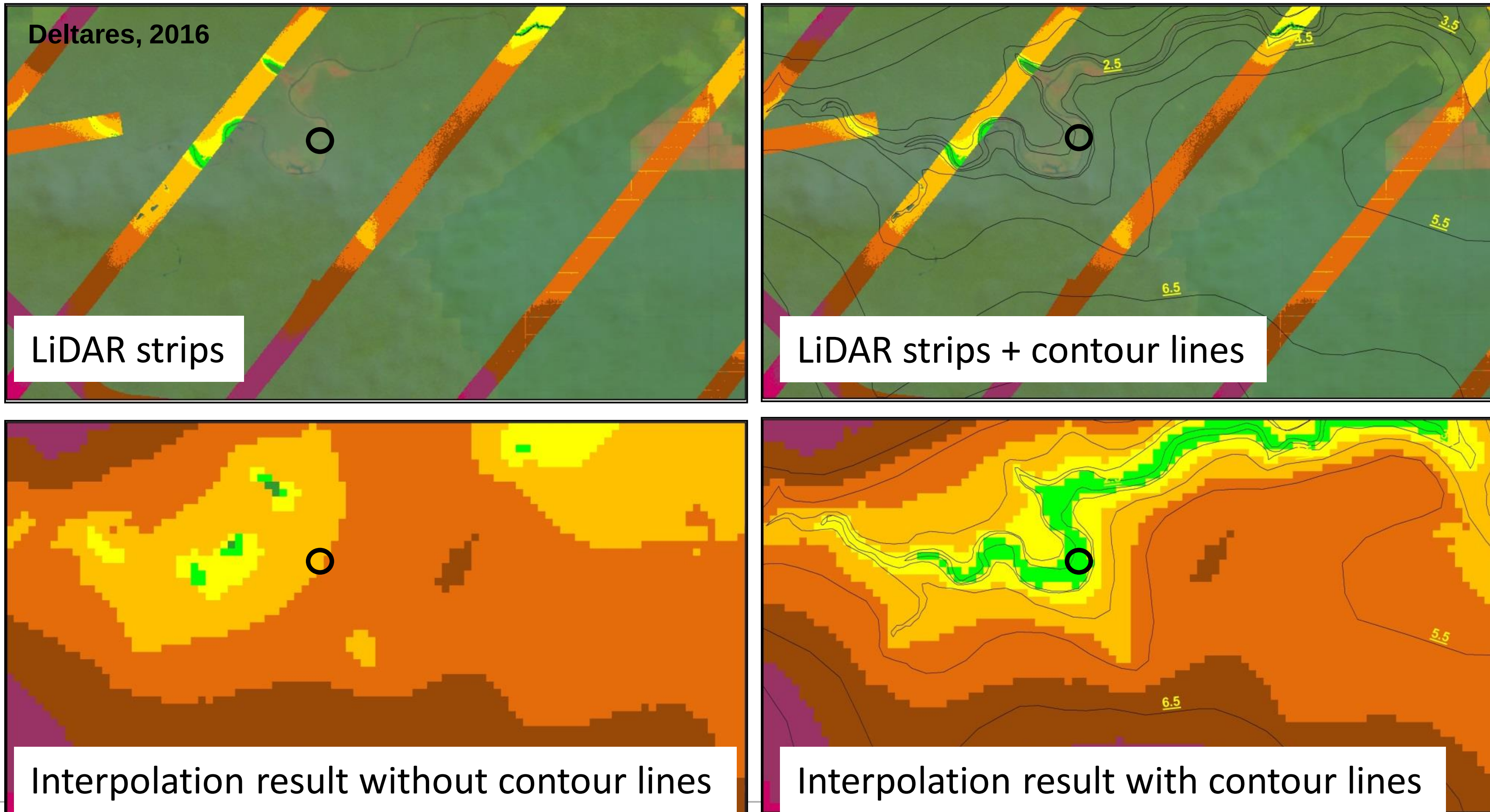
Method for creating a surface elevation model

LiDAR based surface elevation model for East Sumatra (Riau + Jambi + South Sumatra).



Method for creating a surface elevation model

Example of the effect of manually adding contour lines before interpolating LiDAR elevation information, as compared to the result without contour lines. The top figures show a Landsat image in the background.

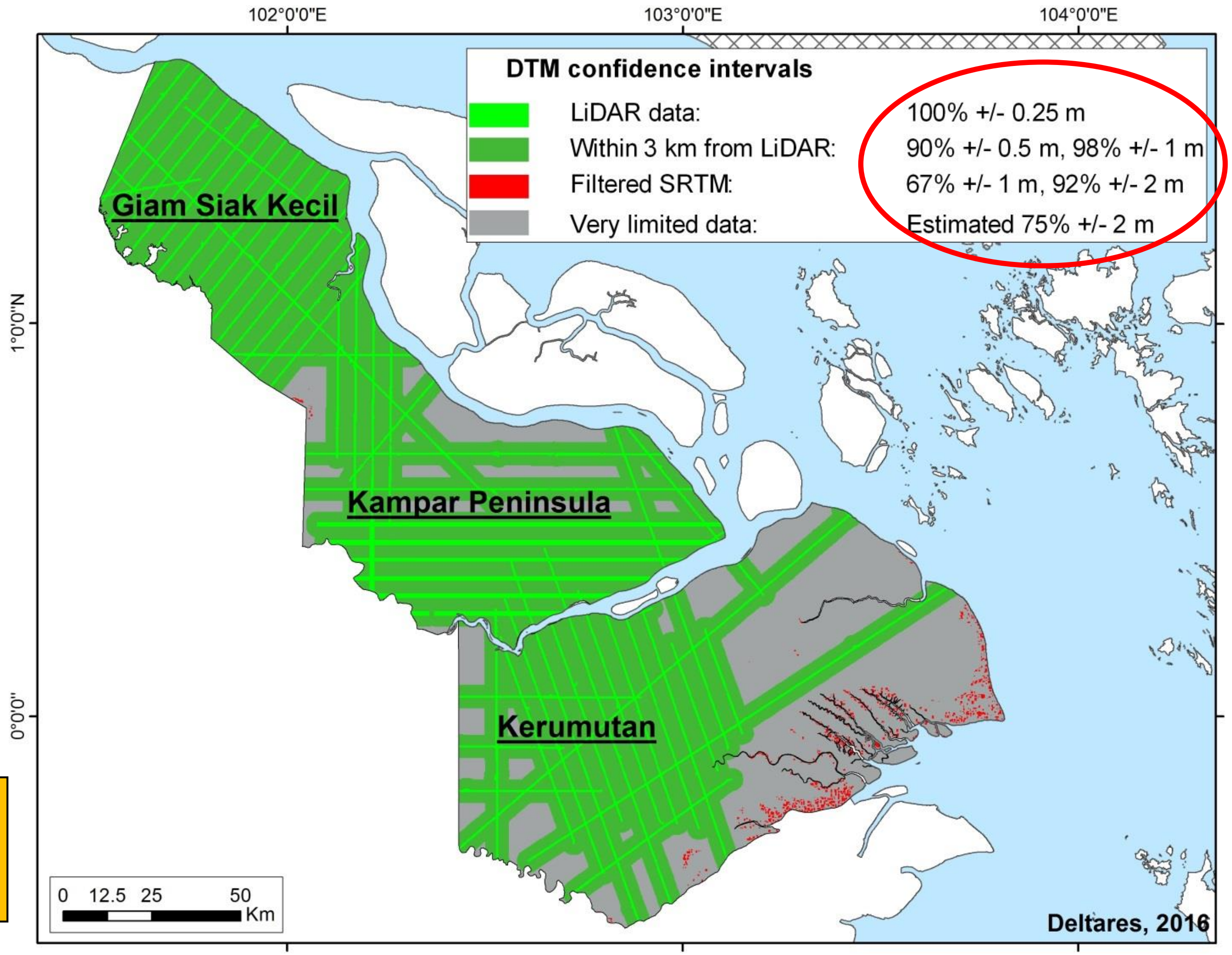


Accuracy of surface elevation model

Estimated accuracy levels of the LiDAR based elevation model for the major peat dome landscapes along the Riau coastline (Giam Siak Kecil, Kampar Peninsula and Kerumutan).

Accuracy levels based on previous study where the method was first tested (Central Kalimantan).

<u>To be revised in April 2016</u>



Results are considered accurate enough for most applications, but <u>full coverage data</u> will be needed for <u>detailed water management design purposes</u> in some complex area.

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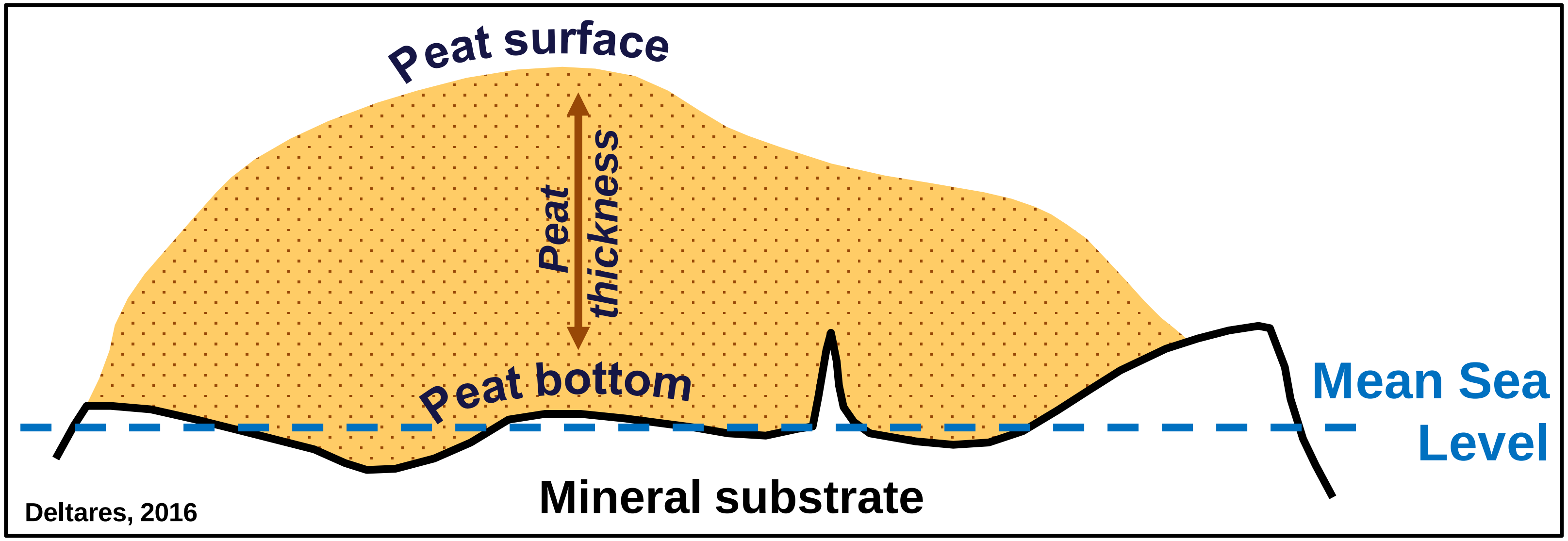
Using the surface elevation model to create a peat thickness model for peat domes

Coastal peatlands in SE Asia started development some 5,000 years ago in areas swamped by river water after Sea levels rose. The bottom of most peatland is therefore still near Mean Sea Level (MSL) today.

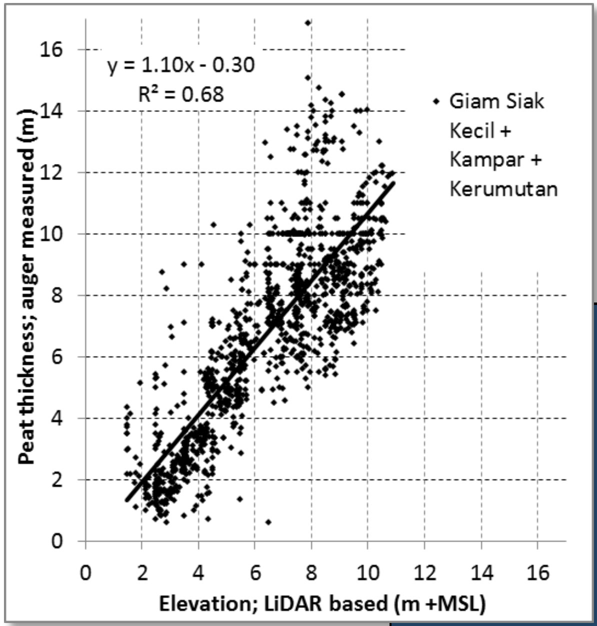


Schematic profile through a coastal peat dome, showing how the peat bottom is usually around Mean Sea Level.

Using the surface elevation model to create a peat thickness model for peat domes

LEFT: Graph of LiDAR based surface elevation vs peat thickness (as measured in the field using augers) in the major peat dome landscapes along the Riau coastline (Giam Siak Kecil, Kampar Peninsula and Kerumutan).

RIGHT: Statistics for the same data.



To be updated in April 2016 (ongoing field surveys)

Landscape	STATISTICS OVER FIELD MEASUREMENTS															
		Elevation			Peat Thickness							Peat Bottom				
	# field measurements	Average	Standard deviation	Median	Average	Standard deviation	Median	% > 3 m	% > 5 m	within +/- 1 m from model (with peat bottom at 0 m +MSL)	within +/- 2 m from model (with peat bottom at 0 m +MSL)	Average	Standard deviation	Median	% < 0 m +MSL	% < 'MEDIAN' m +MSL	% < 2 m +MSL
Giam Siak Kecil	337	7.6	1.5	7.5	7.9	2.2	8.1	95	92	33	61	-0.4	2.0	-0.6	59	50	86
Kampar	570	7.3	2.0	7.7	8.1	2.7	8.3	97	88	48	76	-0.8	1.9	-0.5	60	50	96
Kerumutan	358	3.8	1.3	3.5	3.4	1.9	2.9	46	14	61	91	0.4	1.3	0.7	21	50	98
GSK + Kam + Ker	1265	6.4	2.4	6.9	6.7	3.2	7.1	82	68	48	76	-0.3	1.8	0.0	49	50	94

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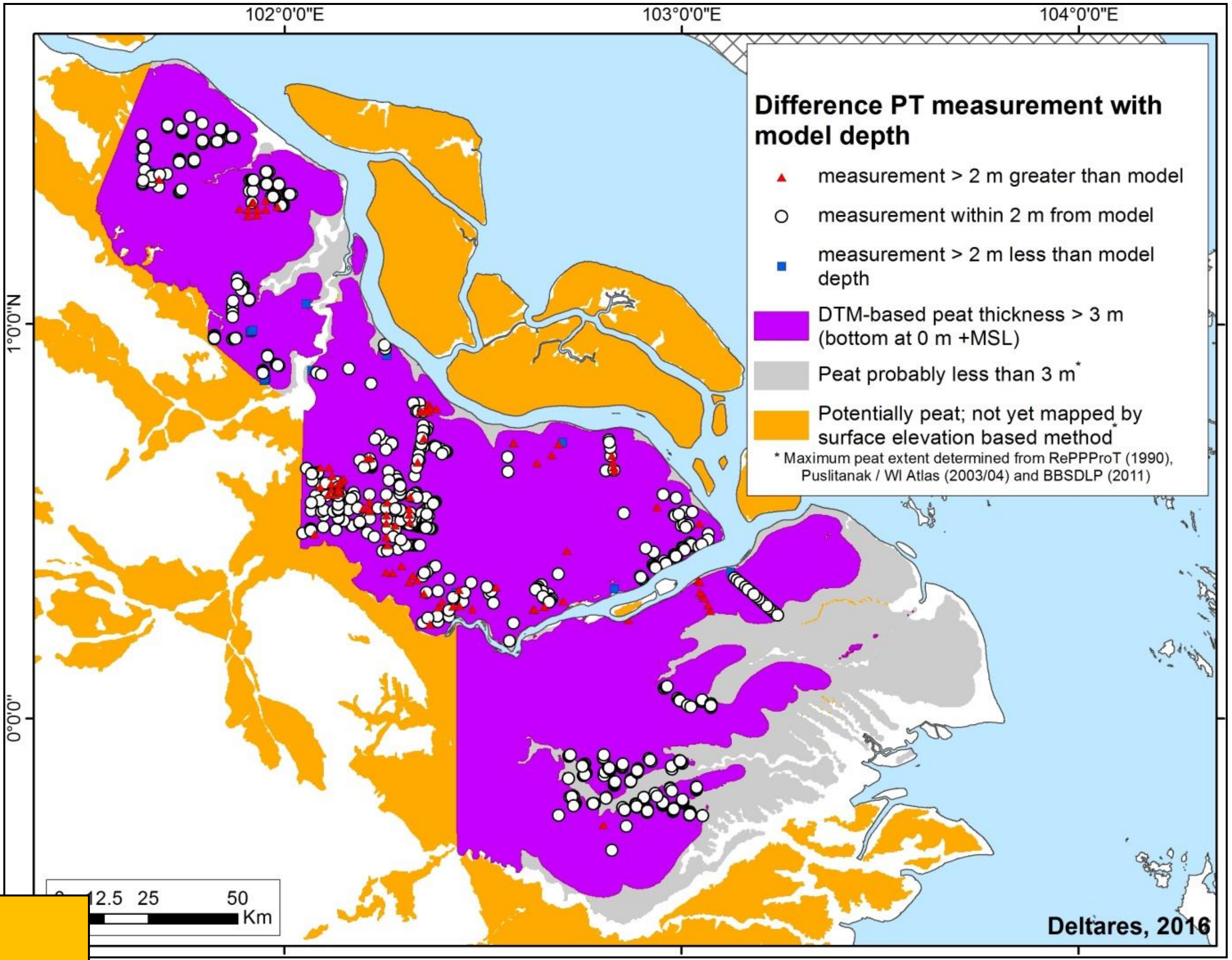
Using the surface elevation model to create a peat thickness model for peat domes

Peat thickness map for peat deeper than 3 m, for the major peat dome landscapes along the Riau coastline (Giam Siak Kecil, Kampar Peninsula and Kerumutan), as determined from LiDAR data by assuming the peat bottom is at 0 m + MSL. Also indicated is whether field (auger) peat thickness measurements yield values that are more than 2 m different from this map.



<u>To be updated in April 2016 (ongoing field surveys)</u>

Limitations of peat thickness mapping using elevation models

The determination of peat thickness from LiDAR based elevation models has been shown to work very well in areas where the peat surface is clearly dome-shaped. However, the method does have the following limitations:

1. In some areas, the peat surface is not dome shaped, either naturally or because much peat was already lost after drainage in recent decades. In such areas the peat is often shallow and the relation between peat surface and peat thickness is less clear.

2. In other areas, especially further inland, the bottom of the peat is not near MSL and sometimes not flat, as the peat has developed over a pre-existing landscape that was not a river floodplain or coastal mangrove. In inland areas, too, the peat is often shallower.

3. In such areas as identified under [1] and [2], often areas with shallow peat, peat thickness mapping using LiDAR is not accurate and other methods (especially ground augering) are required.

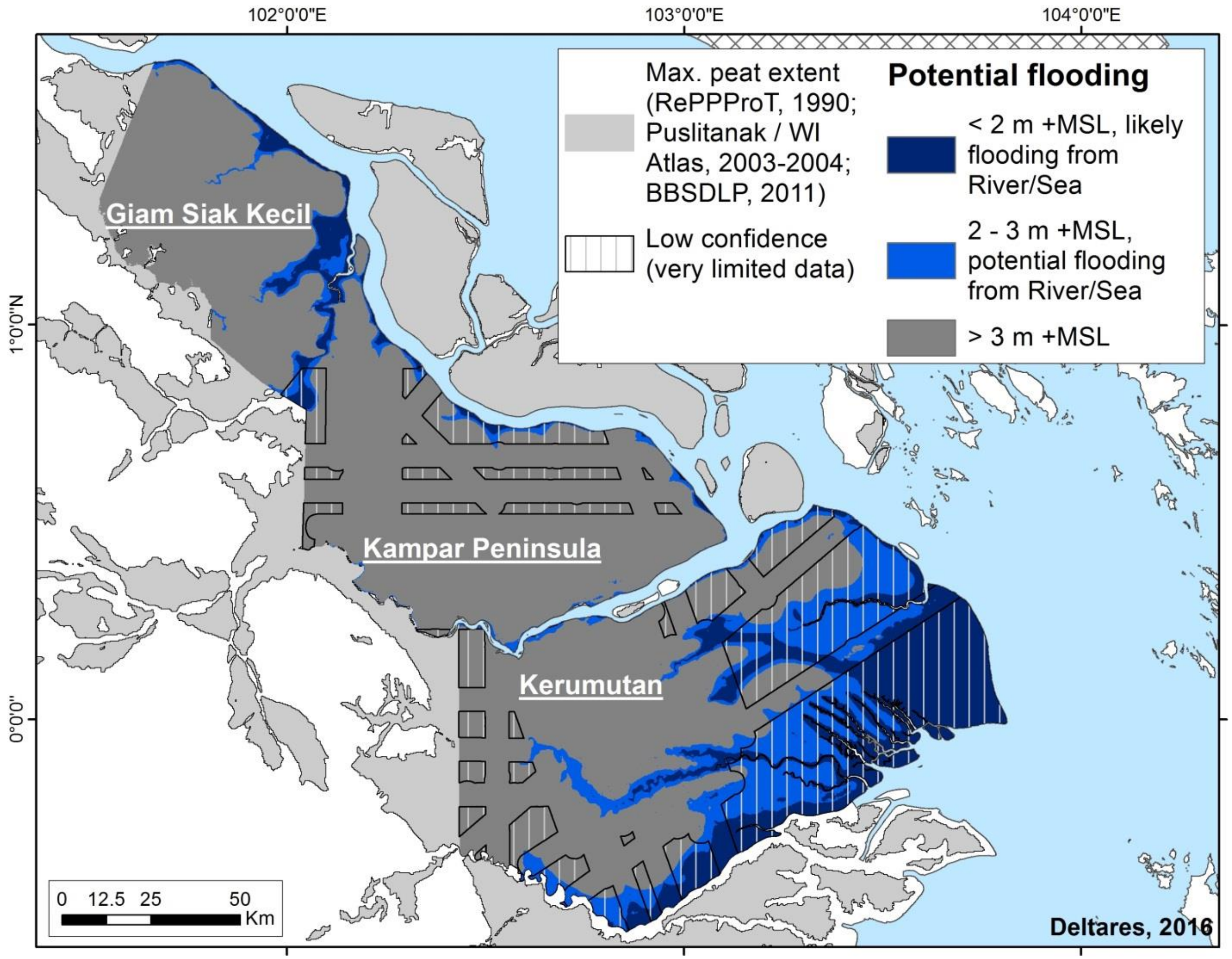
For Sumatra, we estimate this area to be in the order of 20-30% of the total peat area. Therefore, we refer to the LiDAR based method as Coastal Peat Dome Mapping, rather than full Peatland Mapping. We do not think that one single method can suffice to accurately map all peatland, in all landscape settings and under all land uses. The LiDAR based method is therefore a contribution to a set of methods that jointly can be applied to map all peatland, but it can not be the only method to map all peatland.

A further limitation of elevation models derived from ‘strip’ LiDAR (i.e. not full coverage) is that they are meant principally to identify patterns at the larger landscape scale. For applications that require detailed elevation data, such as detailed water management design in plantations with complex morphology due to surface subsidence, additional full coverage LiDAR data may be required.

Other applications of LiDAR data in support of improved peatland management: flood risk

Tentative example of likely and potential flooding extent, assuming that these correspond to areas below 2 m MSL and 2-3 m MSL.

Actual flood levels are more variable in space, and can be higher in some areas. Work towards a refined flood risk map is ongoing.



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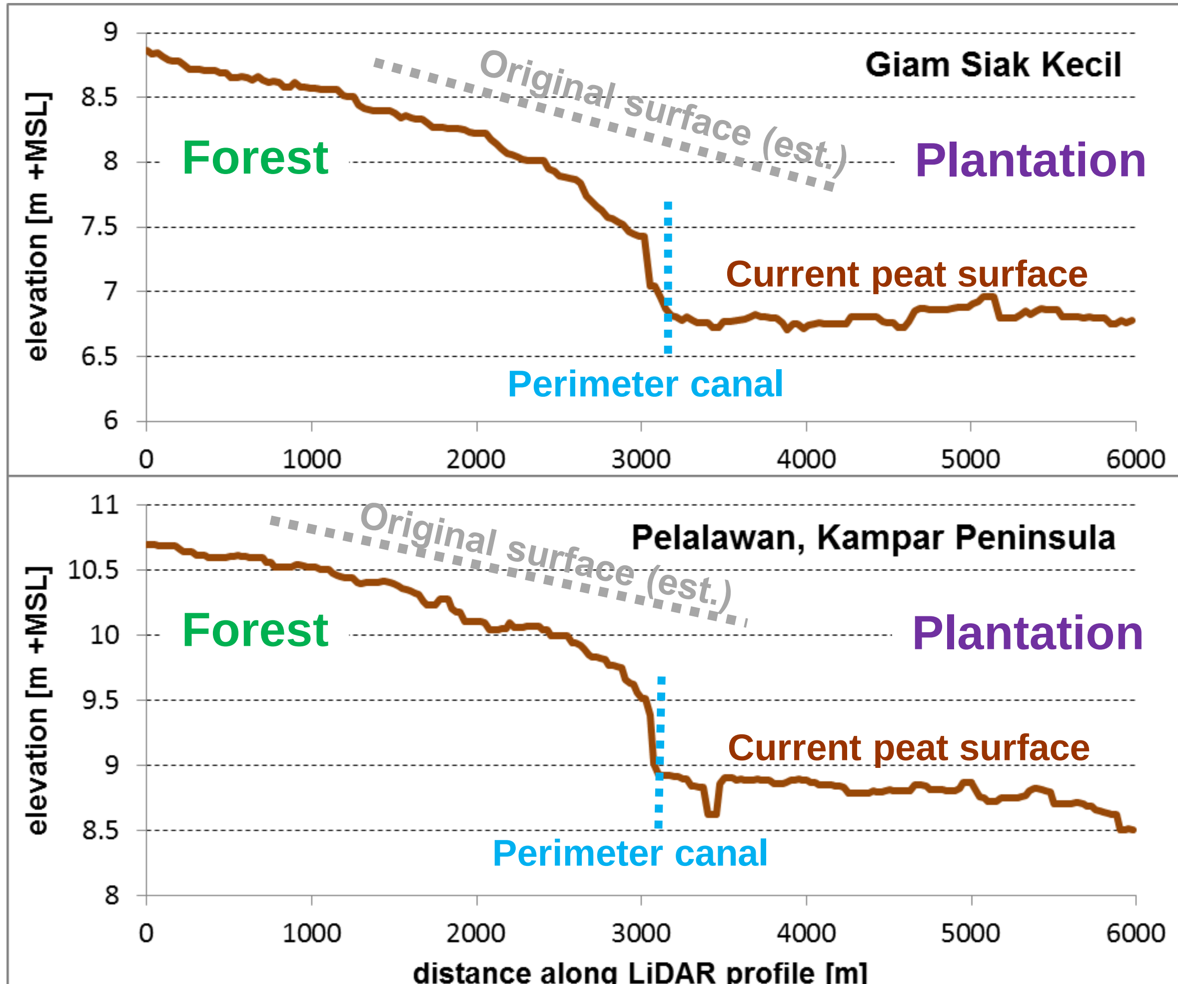
Indonesia: examples of flooding having started

Riau (Dumai, December 2014)

Other applications of LiDAR data in support of improved peatland management: historical subsidence

LiDAR derived peat surface elevation along two transects crossing the perimeter canal between plantations in Riau, Sumatra (developed 10–15 years ago) and remaining forest, on deep peat (~10m).

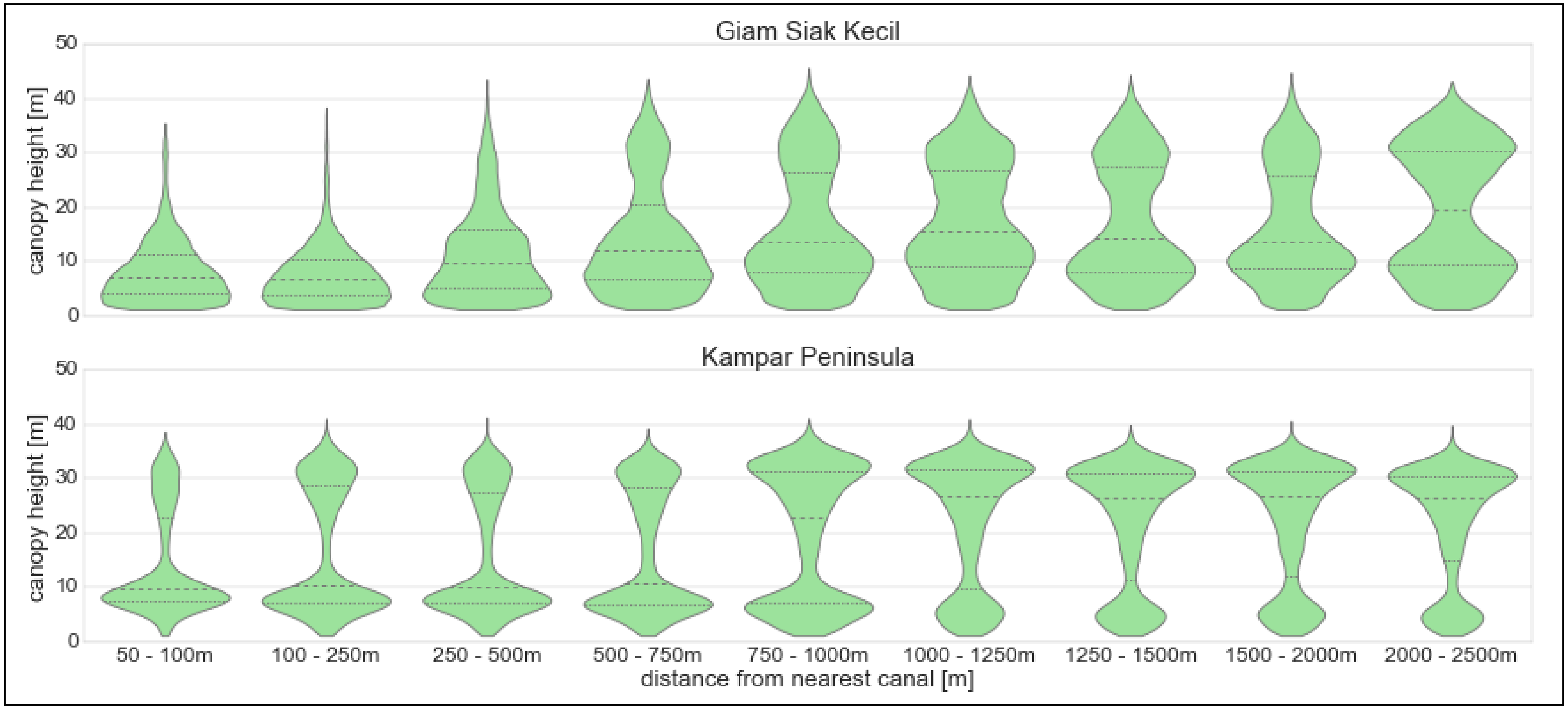
A drop by ~1–1.5 metre is evident in both cases, relative to the estimated original position of the peat surface.



Other applications of LiDAR data in support of improved peatland management: canopy height and degradation

Example of the height distribution in forest canopy as a function of distance to plantation perimeter canal on very deep peat (>10m), as determined from LiDAR data. Historical data and visual inspection of the orthophoto suggest that no logging or fire has occurred along these two transects, indicating that <u>canopy degradation close to the plantation is due to plantation drainage alone</u>.

Edge effect



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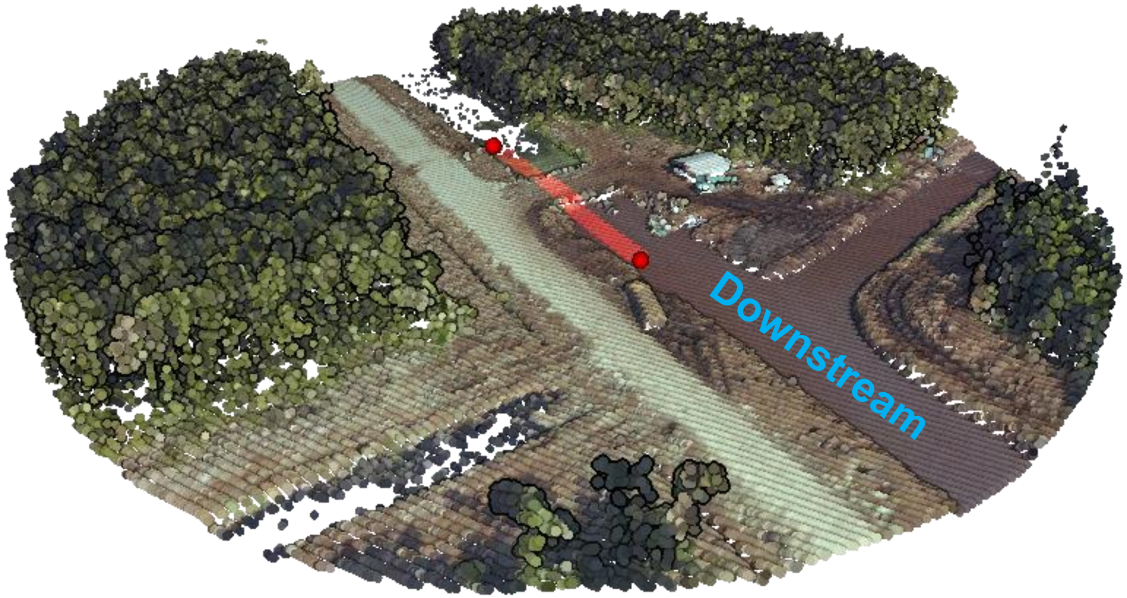
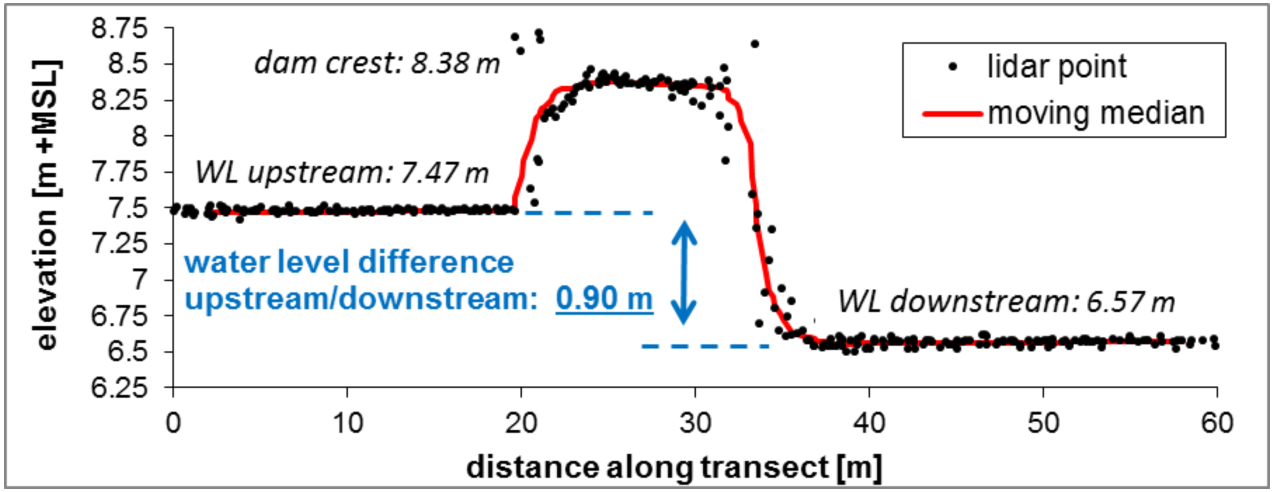
Other applications of LiDAR data in support of improved peatland management: canal water levels

Example of the water levels upstream and downstream of a dam in an Acacia plantation on peat.

TOP: 3D image of location combining LiDAR data and orthophoto.

BOTTOM: Profile over dam, showing a water level difference across the dam of 0.9 m.





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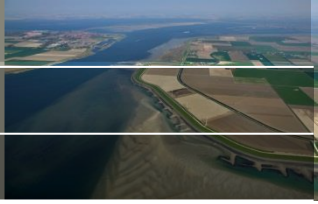
Summary



Deltares, with partners in several projects, is pioneering the use of large-scale but cost-effective LiDAR data collection in coastal lowlands, for spatial planning, management of peatlands and modelling of flood risks.

We are applying new methods in Indonesia that reduce LiDAR cost by almost tenfold (by not flying full coverage) while still yielding elevation models that are accurate enough (90% within 0.5 m) for the purpose of landscape scale assessments of flood risk, peat thickness and related parameters.

Peat thickness mapping applying this data is most accurate in peat domes where peat thickness is over 3 metres; however for the lowest lying areas with shallow peat other ground-based methods will be required for peat mapping.

Apart from information on surface elevation, landscape morphology and peat thickness as determined from surface elevation models, LiDAR data may also be used for measuring and monitoring flood risk, subsidence rates, degradation/growth conditions in forest and plantations, and water levels in canals.

New projects are now being defined that will aim to create elevation models for all coastal peat domes in Sumatra and Kalimantan.

Peat mapping training in Joint Cooperation Program (JCP2)

- Training in the "**LiDAR strip approach method**" to develop peat surface elevation models (24-27 Aug 2015; 33 participants) and from that **MINIMUM peat thickness maps** (3-5 Nov 2015; 24 participants).

- Participants from BIG, BPPT, PusAir, LAPAN, **MoEF**, Bappenas, IPB, UGM, UNPAD, UNDIP, WRI

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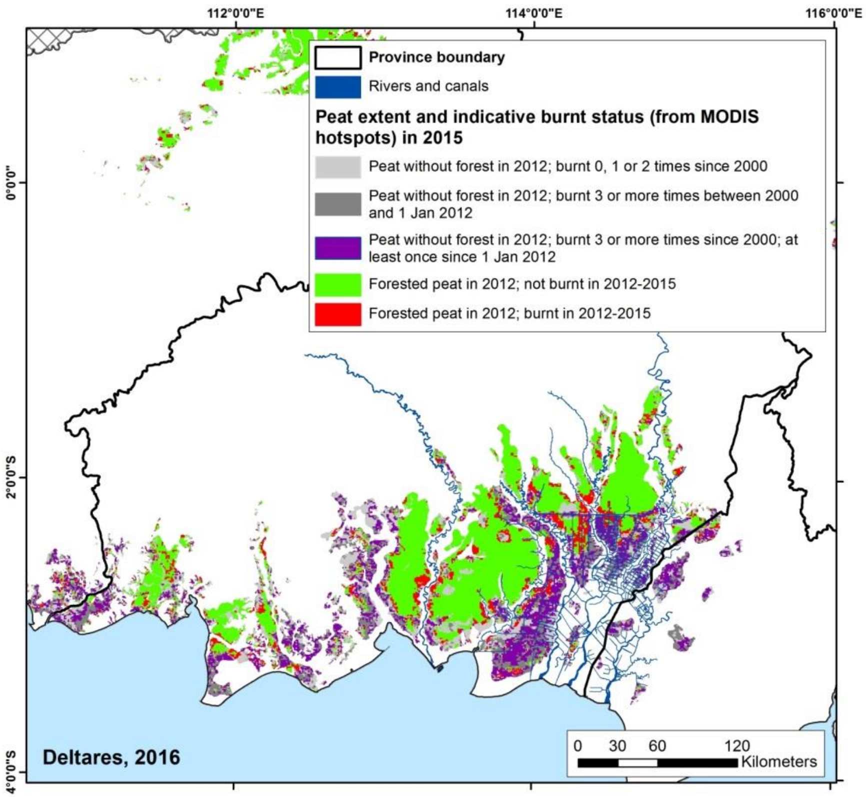
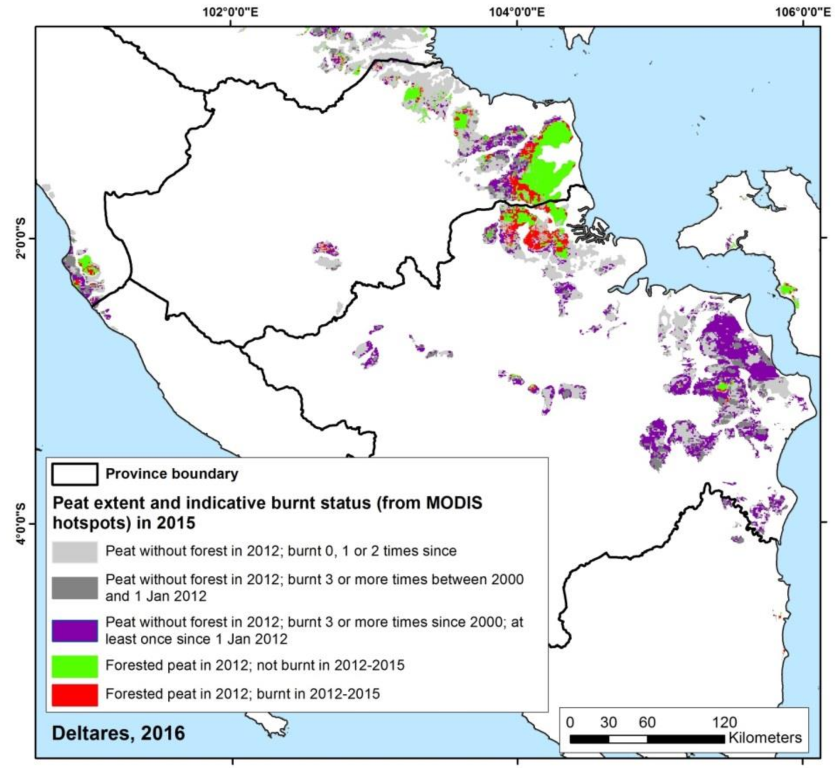
Support BRG (with WRI)

Development of indicative area map for peat restoration based on 4 criteria:

1. peat extent (2 out of 3 sources peat, assume there is peat)
2. 2012 forest / no forest (Margono *et al.*, 2014)
3. (historical) fire occurrence (burnt area, from MODIS hotspots)
4. existence of canals (plantations)





Terima kasih!