The impact of subsidence: can peatland drainage be sustainable in the long term?

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What is peat?

Peat soils consist mostly of water (>90%),
held together by a little vegetation remains (<10%)

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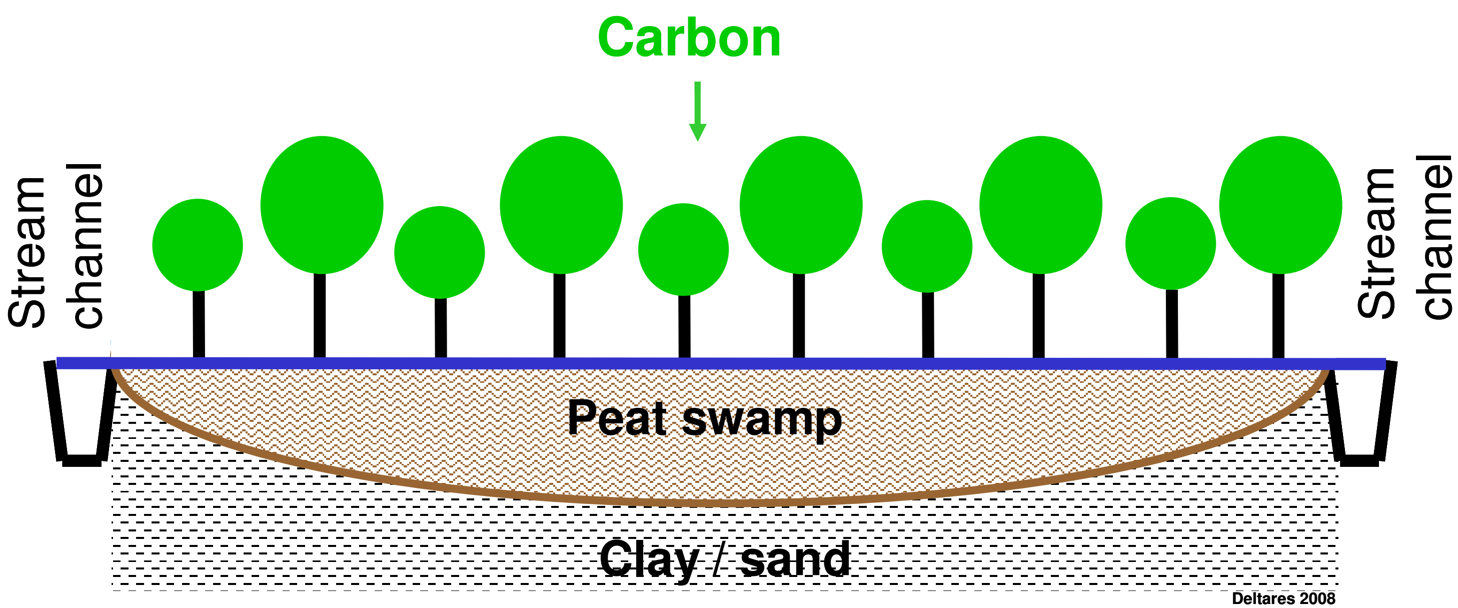
Peatland development and degradation

How do peatlands develop?

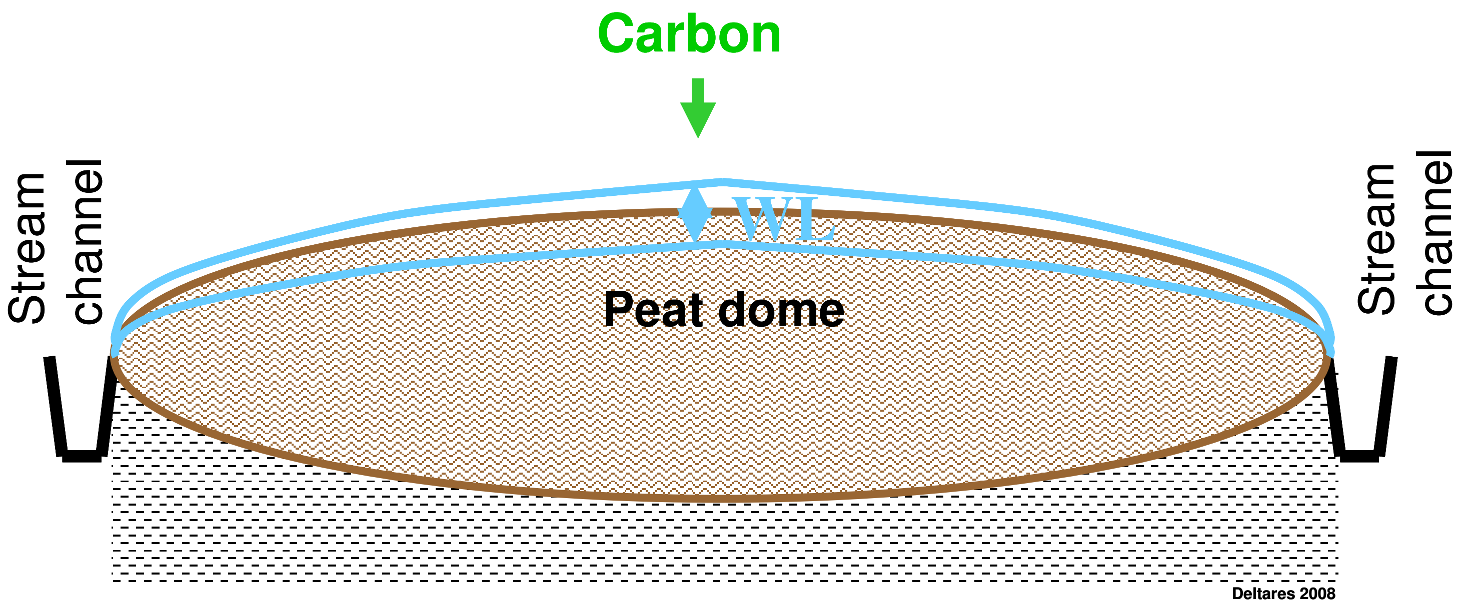
Peatlands develop where dead vegetation (carbon) accumulates over thousands of years, in water-saturated conditions



Peatland development and degradation

How do peatlands develop?

Peat accumulation continues as long as water tables are near the soil surface: 'carbon sink'



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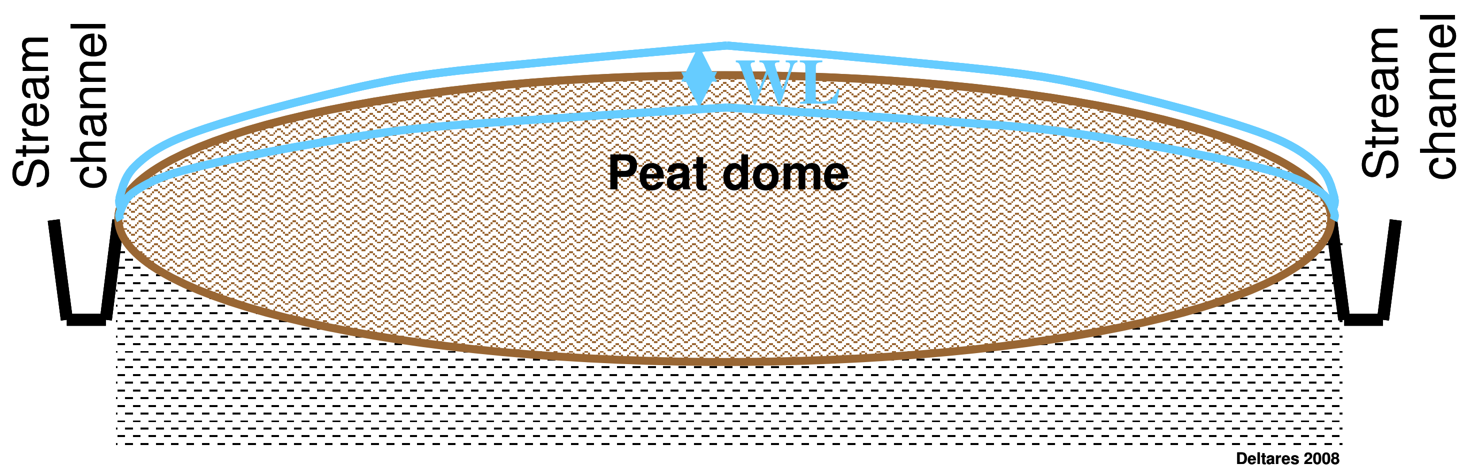
Peatland development and degradation

How do peatlands develop?

The water remains stored as long as natural vegetation and hydrology remains in place, with water levels near the surface



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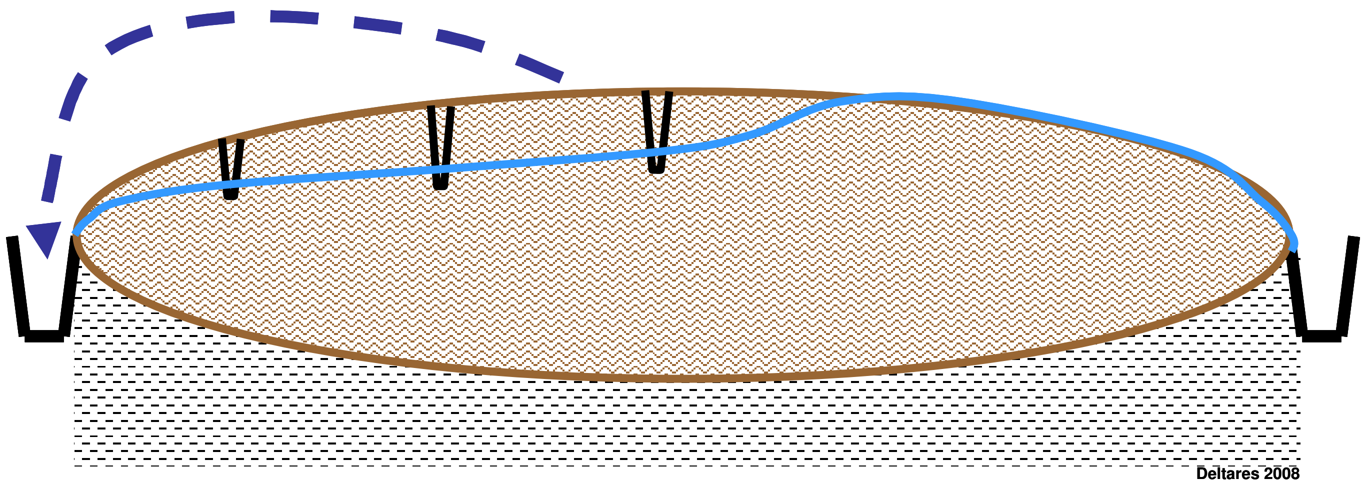
Peatland development and degradation

Why does peatland drainage lead to subsidence, flooding, fire and CO_2 emissions?

Drainage lowers water table and dries the peat



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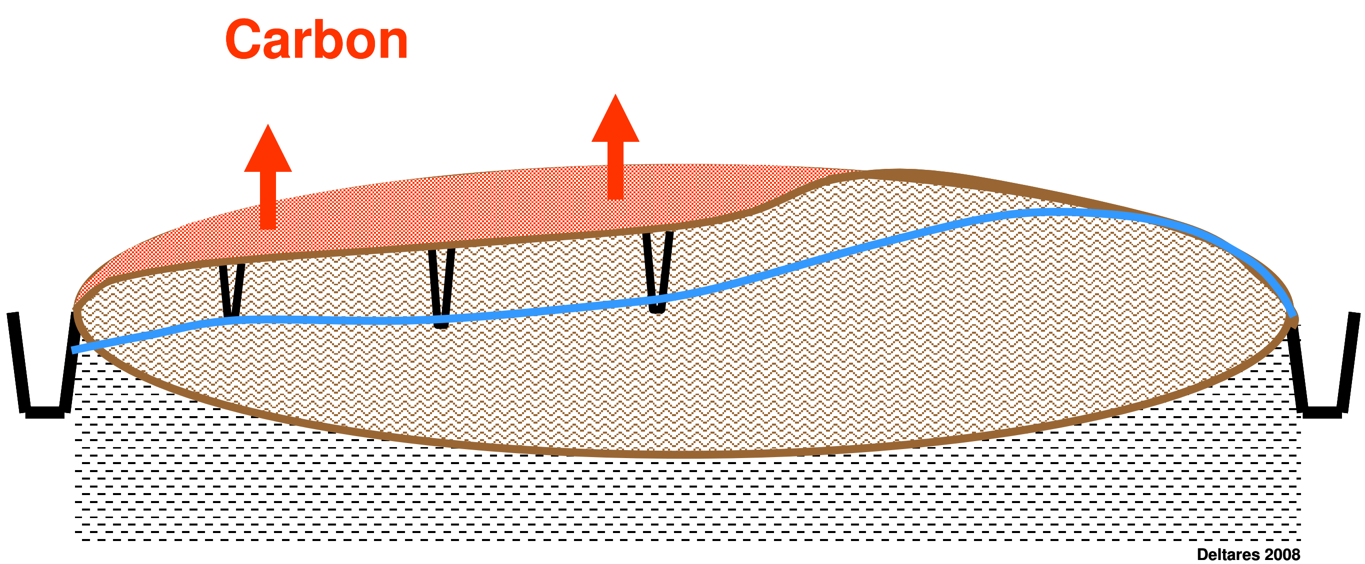
Peatland development and degradation

Why does peatland drainage lead to subsidence, flooding, fire and CO_2 emissions?

Dry peat will burn easily, but also decomposes ('rotting') without fires: 'carbon source'



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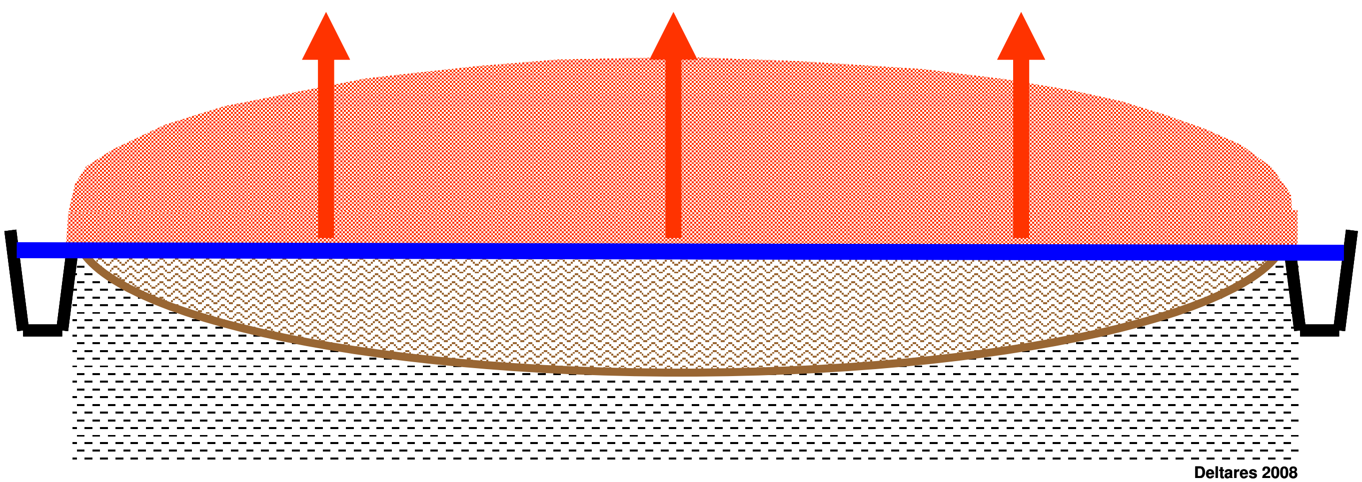
Peatland development and degradation

What is the long-term impact?

Peat loss can be quick (fires) or slow (oxidation)

When drained, all peat above drainage limit (River / Sea) will inevitably be lost



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Peatland development and degradation

In peatlands converted to agriculture, conditions have changed radically compared to natural conditions:

1. **From very wet to dry, through drainage**
2. **From dense vegetation cover to open, leading to high soil temperature**
3. **From low nutrients to high nutrients, through vegetation**
4. **From stable soil to disturbed soil**

Each of these effects causes peat oxidation.
Carbon loss from drained peatlands is therefore inevitable.

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International examples of peatland subsidence

In nearly all countries where it has been attempted, peatland drainage has resulted in subsidence-related problems. Good examples are:

- **Netherlands**
- **UK**
- **USA**
- **Others…**

Some of these examples will be illustrated here.

The lesson that has been learnt by these countries is that drainage of (deep) peatlands should be avoided, as it is uneconomic in the longer term and causes a number of environmental problems.

Indeed, Indonesia and Malaysia are now the only countries still attempting large-scale developent of new agriculture on peatland. Other countries are now attempting to undo some of the damage that peatland drainage has done there – with great difficulty, often limited success and at enormous cost. Over 25 billion dollar for the US Everglades swamps alone!

UK: Fenlands

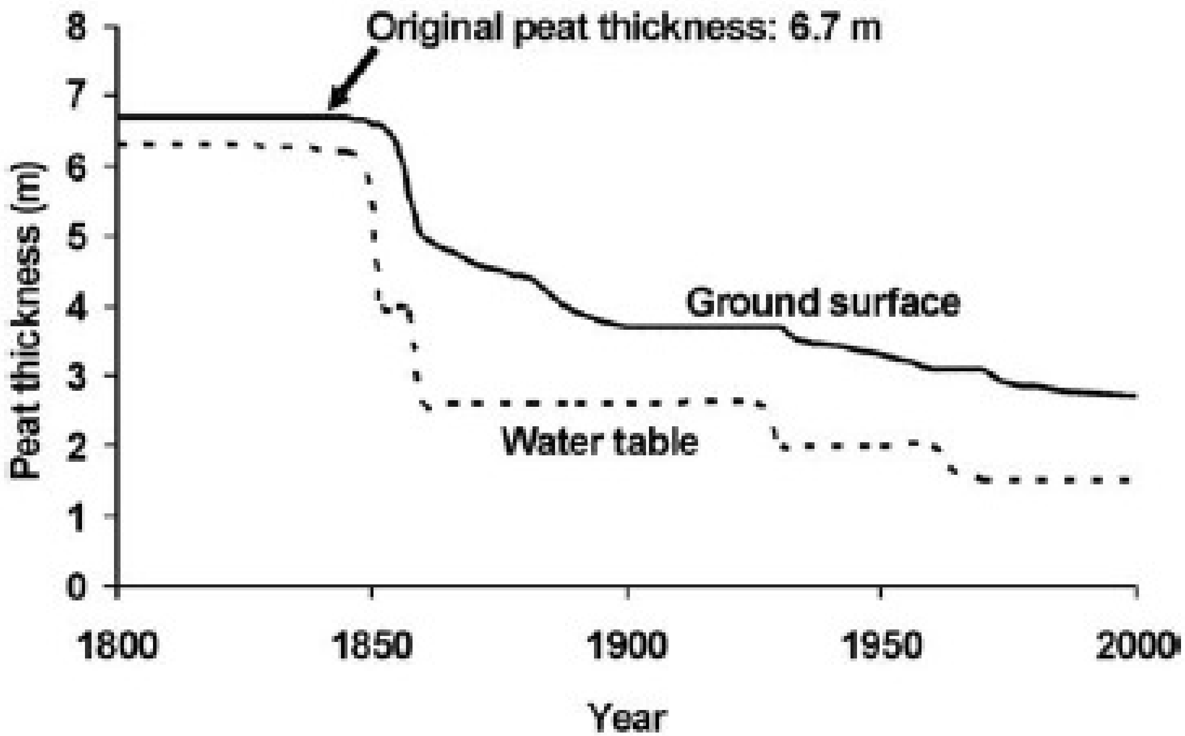

Fig. 1. Stages of peat subsidence after drainage of a peatland at Holme Fen, Cambridgeshire, UK, modified after Hutchinson (1980).

Geoderma 154 (2010) 181–187

Subsidence and degradation of agricultural peatlands in the Fenlands of Norfolk, UK

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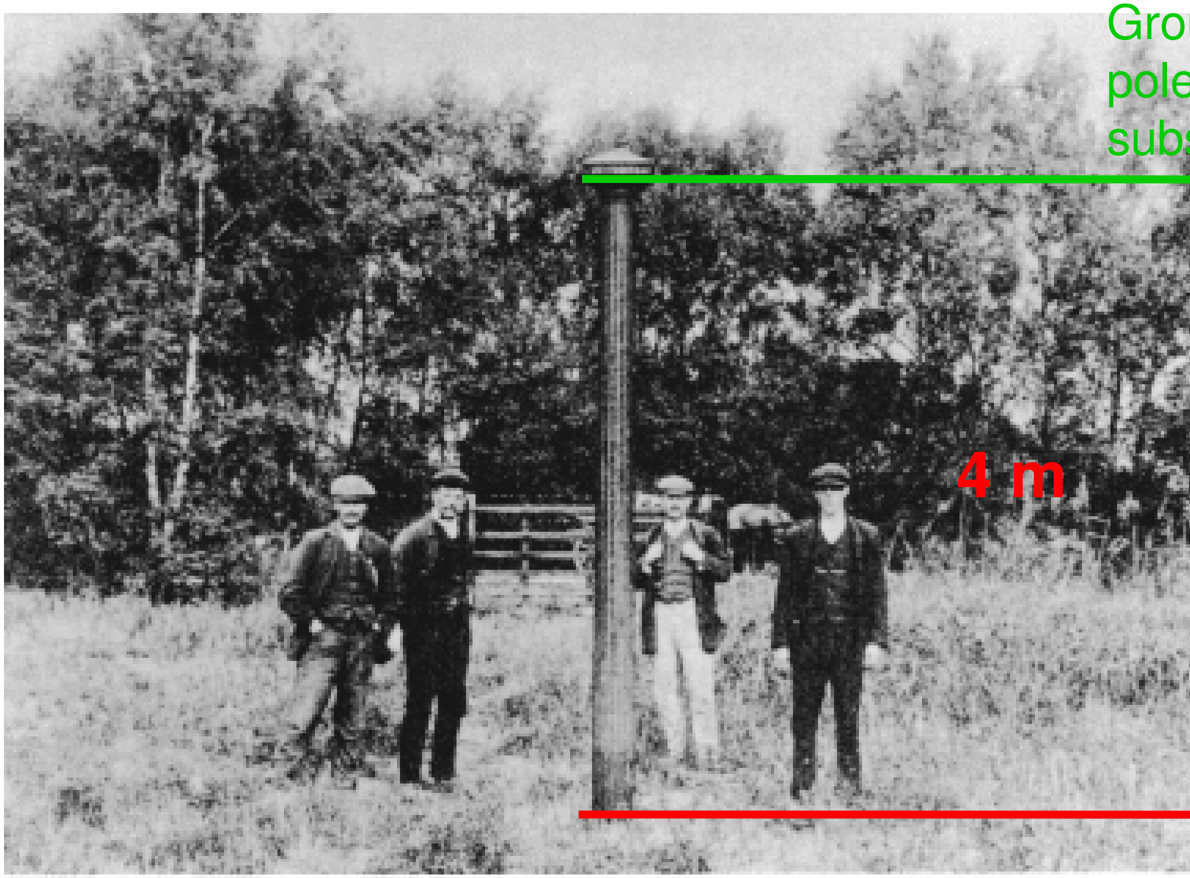
UK: Fenlands

Ground surface when pole was built (well AFTER subsidence started)



4 m

1913

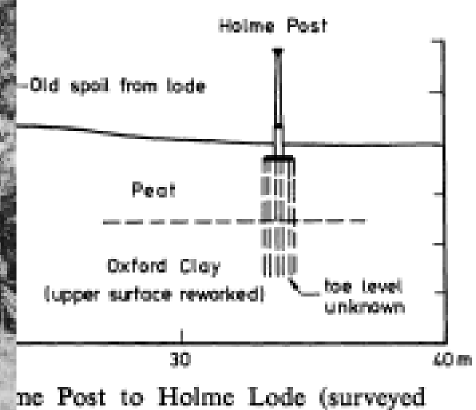


PLATE 4. Holme Post (protruding c. 3·0 m). Photograph taken not later than 1913, and probably between 1910 and 1913, looking NW (with acknowledgments to Cooper Square Publishers, N.Y.).

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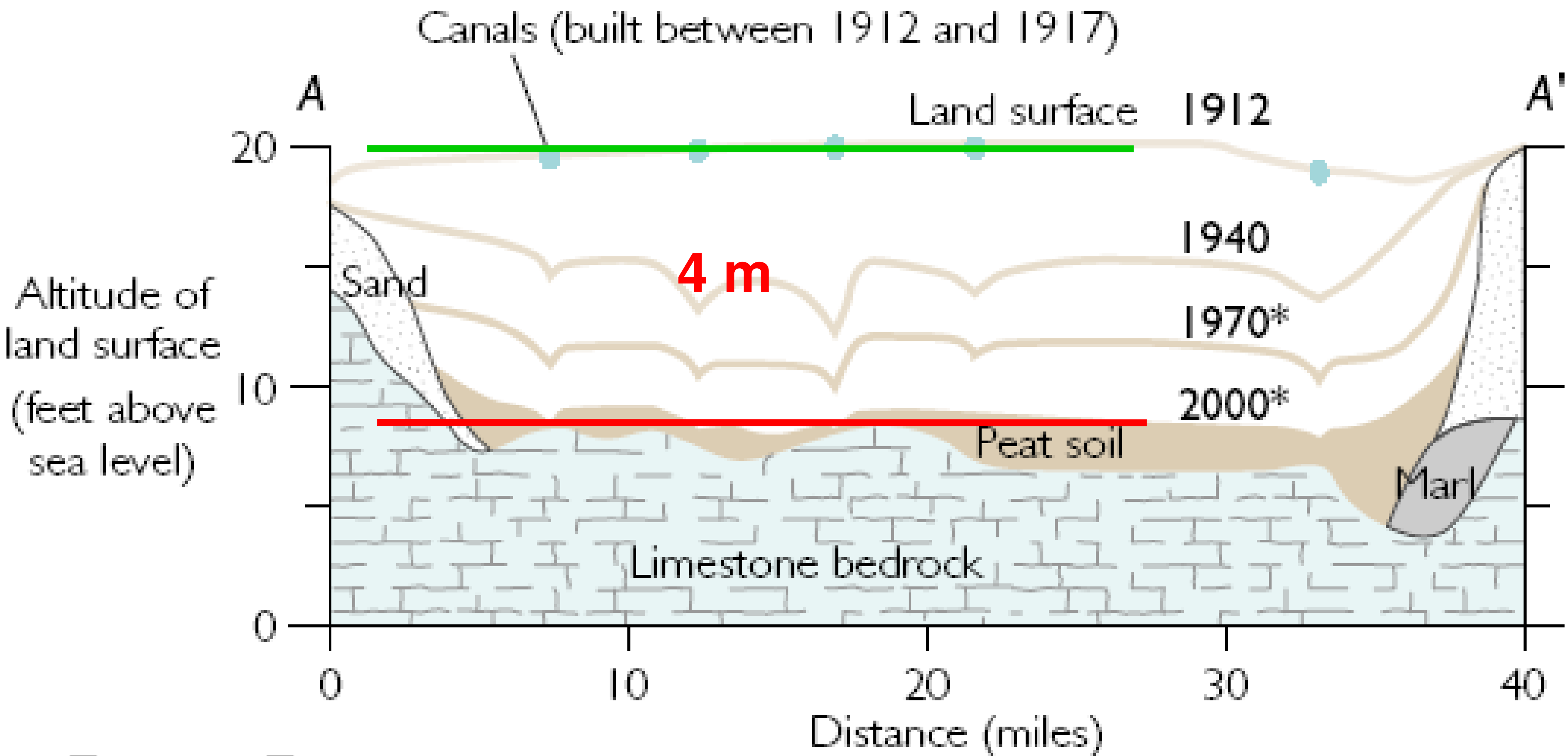
USA, Florida: Everglades swamps



FLORIDA EVERGLADES

Subsidence threatens agriculture and complicates ecosystem restoration

S.E. Ingebritsen
U.S. Geological Survey, Menlo Park, California

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USA, California: Sacramento Delta

Now 3 to 8 m below Sea (and canal) level…

USA, California: Sacramento Delta

Being below Sea level means flooding, even in USA…

es

What international science tells us about SE Asia

Peat oxidation temperature dependent: <u>subsidence far higher in tropics</u>

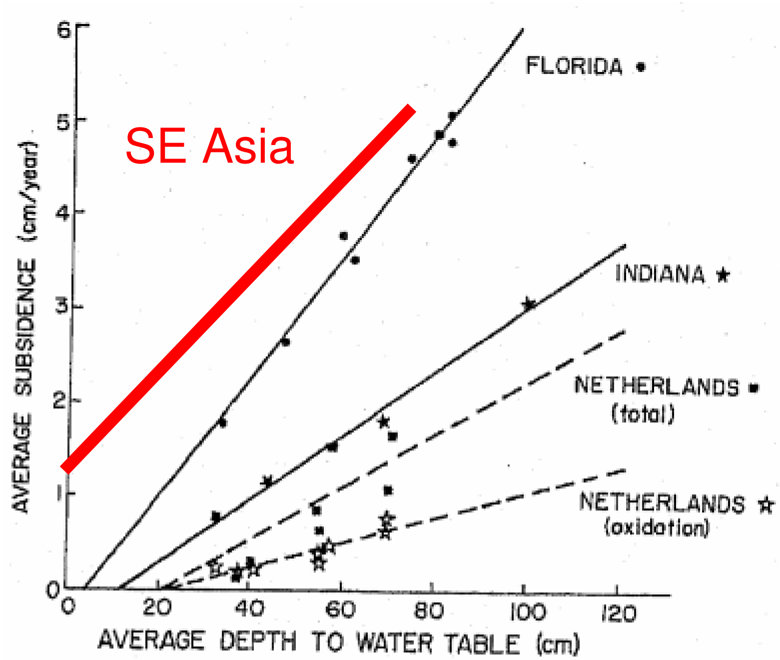

Figure 4. Comparative subsidence rates of organic soils in Indiana and the Florida Everglades versus water-table depth. Organic soil data for western Netherlands superimposed from Schothorst, 1977. The two lines shown for the Netherlands show total subsidence and subsidence attributable to biological oxidation. The linear regression equations are (a) Florida: Y = 0.0643X – 0.259; (b) Indiana: Y = 0.0344X – 0.429; (c) Netherlands (total subsidence): Y = 0.0281X – 0.581; (d) Netherlands (oxidative subsidence): Y = 0.0134X – 0.291; where Y is the predicted subsidence in cm per year, and X is the average depth to water table in cm.

Everglades, USA (Stephens et al. 1984)

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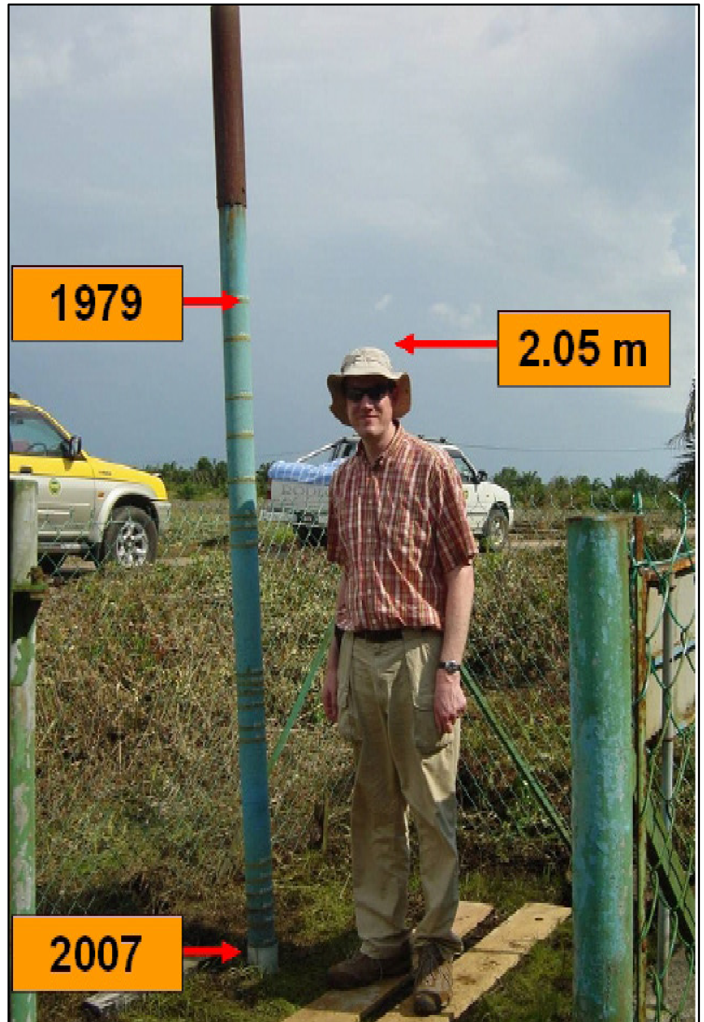
The oldest experience in SE Asia: Johor, Malaysia

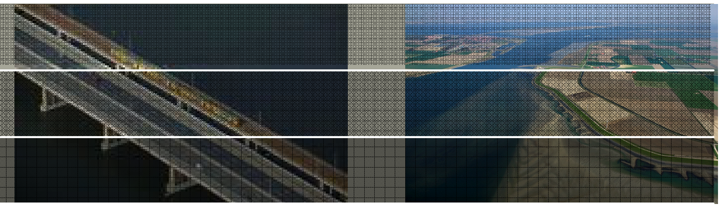
Surface before drainage?

(subsidence pole placed well after drainage)

The first industrial oil palm plantations on peat, developed early 1960s

Now we see 3 to 4 metres ofsubsidence within 50 years





Subsidence rates from all known published field studies in SE Asia

In plantations, more than 5 years after drainage, on peat >3m:

(Stephens et al. 1984 (extrapolation from Everglades): up to 8 cm/y in tropical peat)

Andriesse, 1988 (Southeast Asia measurements; FAO): up to 6 cm/y

Wosten et al., 1997 (Johor): 4.6 cm/y after 14-28 years

DID Sarawak, 2001: 5 cm/y

Mohammed et al., 2008 (Sarawak): 4.3 cm/y after 15 years under best management

Hooijer et al. 2012 (Riau, Jambi): ~5 cm/y

Conclusion: subsidence in deep drained tropical peatlands is always 4–6 cm/y.

This is regardless of management regime, as oxidation is controlled by high temperature, soil disturbance and fertilizer – not only by water table depth.

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Long-term subsidence projections

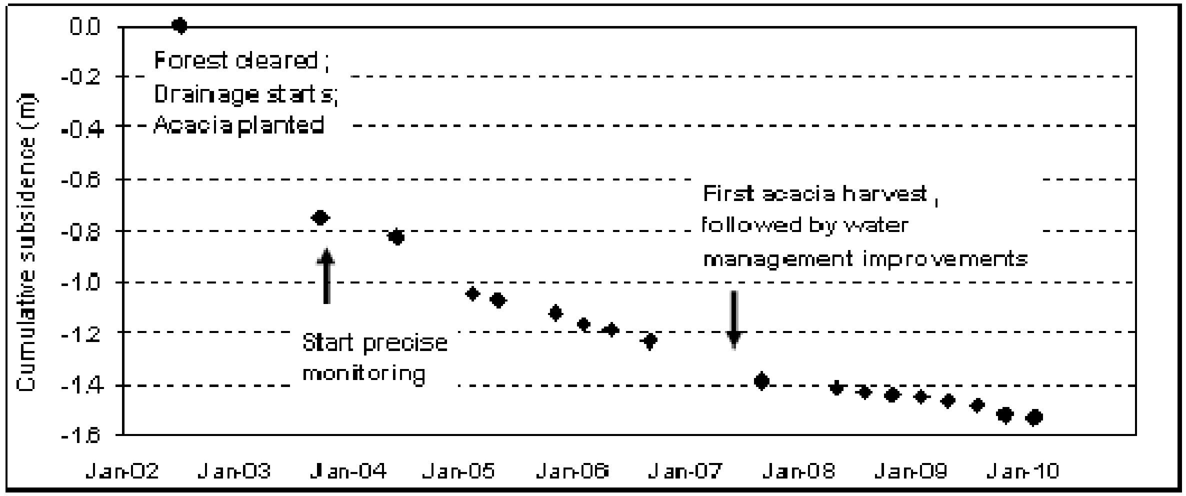
constant subsidence rate for many decades, until the area becomes undrainable

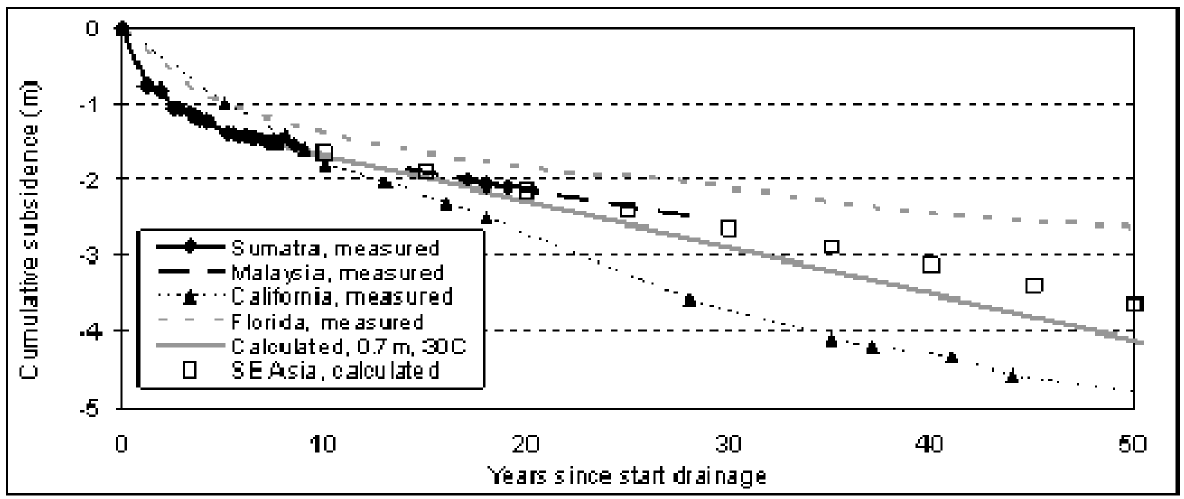
1 m subsidence in first year after drainage

1.5 m subsidence in 5 years

2.5 m subsidence in 25 years

>5 m in 100 years?





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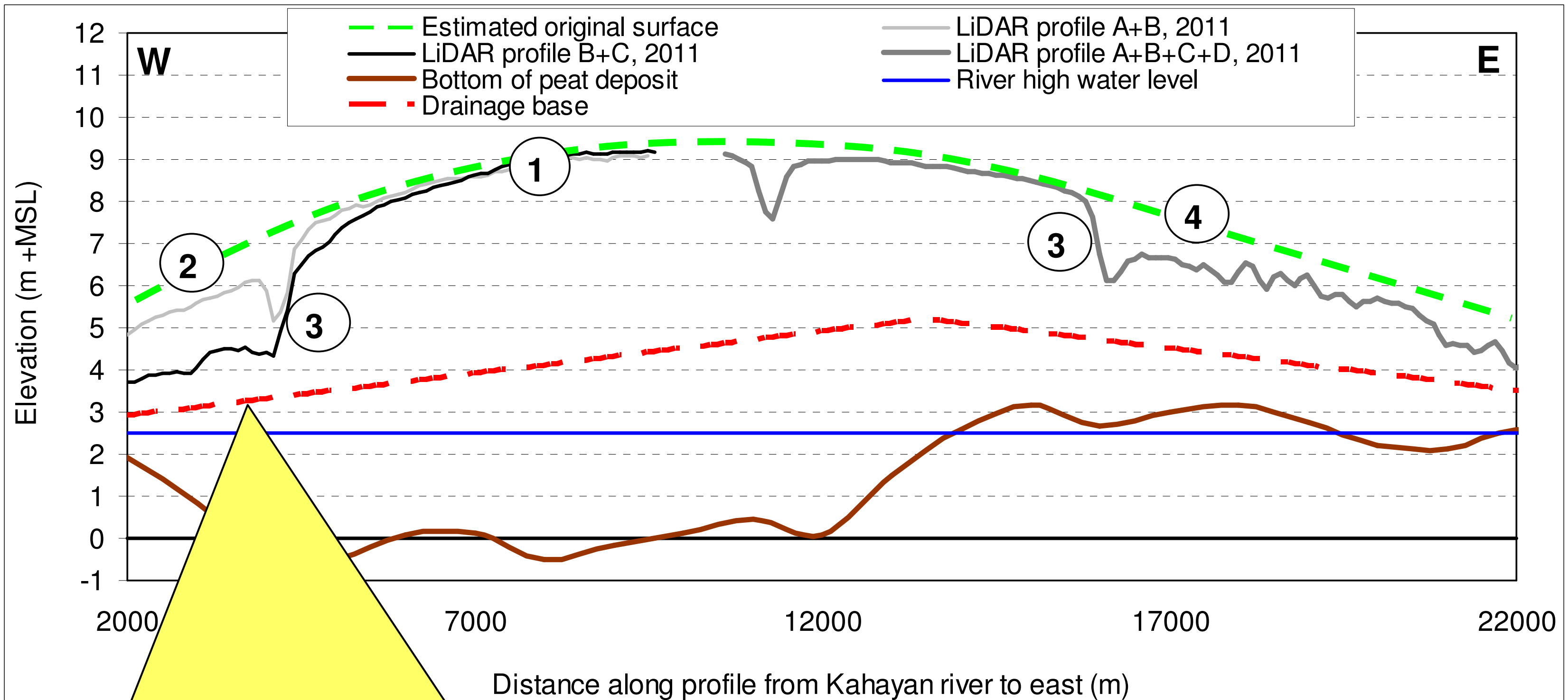
Long-term subsidence & drainability projections

We see the effect of subsidence on the landscape, wherever good elevation date are available (usually they are not!).

LIDAR cross section in Central Kalimantan, EMRP Blok B:



Oil palm plantation in Central Kalimantan: already well underway to becoming undrainable, 5-15 years after drainage…

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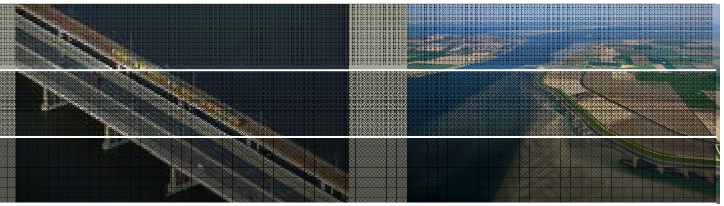
Long-term drainability projections

Long-term drainability projections



Resulting statistics are indicative, and maybe surprising, but need further work, with more data and with Indonesian experts, in the Joint Cooperation Programme?

	Sarawak	Kalimantan + Sumatra	**Sarawak + Kalimantan + Sumatra**
Number of cross sections available	27	16	**43**
Average length of cross sections, from river (km)	7.0	12.2	**9.0**
Average peat depth (m)			
Average peat depth (m)	6.2	7.5	**6.7**
Percentage peat depth > 3m	81%	88%	**83%**
Position of peat surface			
Position above MSL, 1 km from river (m)	3.8	3.1	**3.6**
Position above MSL, 5 km from river (m)	5.9	5.7	**5.8**
Position of peat bottom			
Percentage peat bottom below MSL	60	68	**63**
% peat bottom below MSL + Sea Level Rise[a]	67	75	**70**
% peat bottom below High Water Level[b]	83	94	**87**
% peat bottom below Drainage Base[c]	92	97	**94**
Trend in start of drainage problems (peat surface below Drainage Base)			
after 25 years	46	48	**46**
after 50 years	70	68	**69**
after 100 years	83	89	**85**
Trend in end of gravity drainage (peat surface below Mean Sea Level)			
after 25 years	12	12	**12**
after 50 years	32	27	**30**
after 100 years	52	52	**52**

[a] *A value of 0.5 has been assumed for Sea Level Rise over 100 years (IPCC, 2007)*

[b] *High Water Level: High Tide Level near the Sea, and Flood level along inland rivers*

[c] *The Drainage Base was defined by adding a conveyance gradient of 0.2 m/km to HWL for River dominated water levels, and to MSL for Sea dominated water levels.*

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Long-term drainability projections

Of the 25 Mha peatland in SE Asia, 15–20 Mha may be flooded and improductive within decades. The region may in fact be losing up to 10% of its actual usable land area, in the long term.

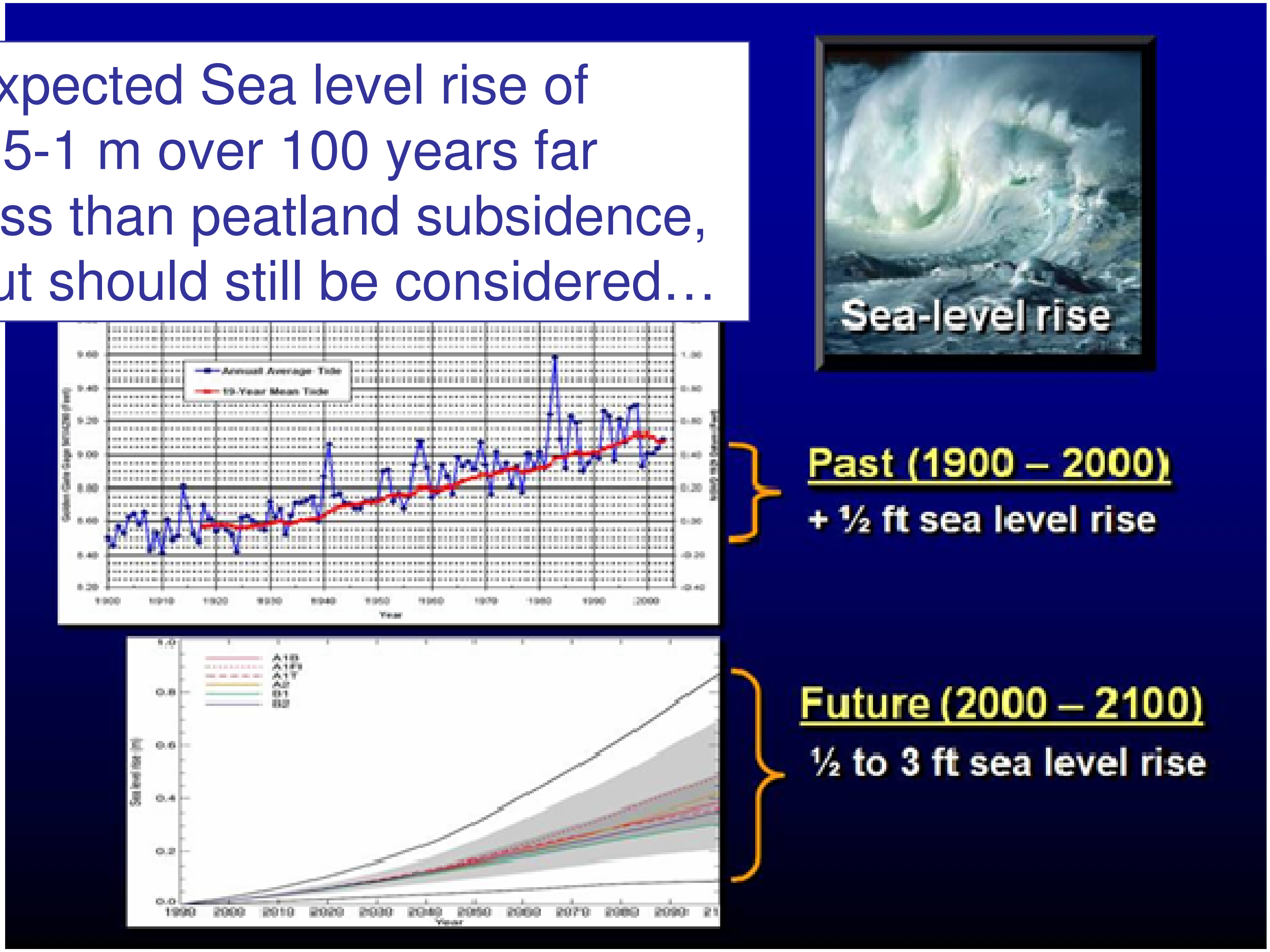
This is by far the largest and most impacted subsidence area in the world (Netherlands: 1.5 Mha subsided; other areas < 1 Mha).

Peatland subsidence due to drainage may well become one of the biggest economic problems in SE Asia:

- **Insecure 'food security' if agriculture expansion planned in peatlands?**
- **Loss of export crops (oil palm, pulp & paper)?**
- **Increased poverty of local population?**
- **Further increased carbon emissions?**

And then there is climate change and Sea level rise…

Expected Sea level rise of 0.5-1 m over 100 years far less than peatland subsidence, but should still be considered…



We are in the process of building projection models…

Prototype example for Rajang Delta, Sarawak

Data gaps for this area: not accurate but realistic

Movie?

Questions?