JOINT COOPERATION PROGRAMME

Component C3:

Lowland / Peatland subsidence – Future drainability

Document C3.2

PPPs second workshop on *Peatland subsidence and flooding modelling*

Banjarmasin

31 January 2012

Project: 1201430.000

Client: Water Mondiaal
Partners for Water
Royal Netherlands Embassy in Jakarta

Period: January 2011 – March 2013

BMKG

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

PUSAIR

Deltares
Enabling Delta Life

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Enabling Delta Life

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Al Hooijer

JCP second workshop on peatland subsidence and modeling,
30-31 Jan

What is JCP – Joint Cooperation Prgramme?

1.1 General objective of the cooperation

The objective of the cooperation as stated in the Joint Cooperation Agreement is to carry out a long-term knowledge sharing and capacity building program between the four institutes KNMI, BMKG, PusAir and Deltares. Other partners can be added. The ultimate aim is to increase the state of the art of the knowledge base of all the institutes involved and to strengthenthe capacity in Indonesia to plan, develop and manage their water resourcessystems. This is to be achieved in applied hands-on activities where possible: on the job training.

Duration: 2011-2012, with extension to 2015 if value can be shown (Netherlands funding).

Value would be: capacity to jointly define projects that are able to attract independent funding (e.g. WB, ADB, others)

Topical components are:

(B) Integrated Water Resources Management tools.

(C1) Extreme weather / climate change Jakarta

(C2) Hydrological datasets

(C3) Assessing Lowland / Peatland subsidence and future drainability

(D1) Drought Early Warning System for Indonesia

(D2) Flood Earl Warning Systems Jakarta / Bandung

What is JCP – Joint Cooperation Prgramme?

(C3) Assessing Lowland / Peatland subsidence and future drainability

Has been added to JCP at the request of PusAir, to provide them with information and capacity on determining the extent and rate of the likely loss of drainability due to changes in surface elevation (subsidence) and Sea level rise. The result will be a Spatial Model for determining this, as well as projected subsidence/flooding Maps of the area(s) investigated. Results will be disseminated outside PusAir through a Guidelines document and a Master Class. To foster a 'hands on learning' environment, the work is executed in close collaboration with the KFCP project (Kalimantan Forest and Carbon Partnership), an Ausaid-funded REDD demonstration project where Deltares leads several activities related to water management and carbon balance, and where PusAir is developing a DIPA Experimental Research Station (near Mantangai, along the Kapuas river in Central Kalimantan).

What is JCP – Joint Cooperation Prgramme?

(C3) Assessing Lowland / Peatland subsidence and future drainability

C3.1 Investigation of Subsidence in Different Lowland Types
C3.2 Development of a Lowland Digital Elevation Model
C3.3 Modelling of Subsidence for Lowlands
C3.4 Investigations into Sea and River Level rise
C3.5 Modelling of Future Drainage Problems in Lowlands
C3.6 Investigations into Current Drainage Conditions
C3.7 Guidelines for Lowland and Peatland Water Management and Planning
C.3.8 Master Classes on Lowland and Peatland Water Management and Planning
C.3.9 Dissemination of Results

What is peat?

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

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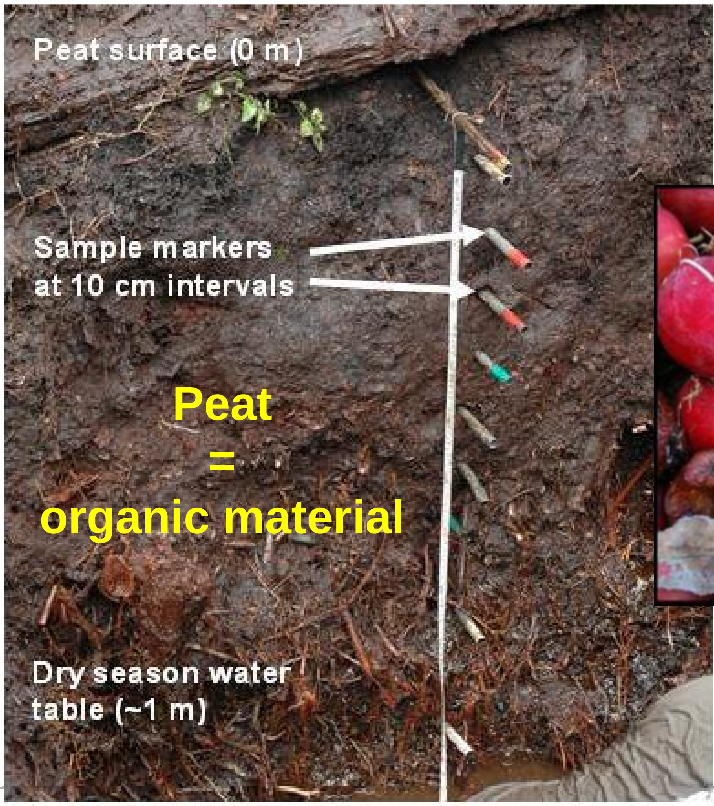
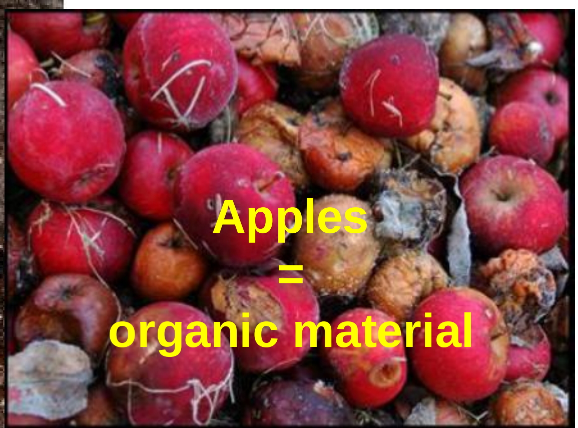
Peat soils consist mostly of water (90%), held together by vegetation remains.





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What are peatlands?

Intact peatswamps (more or less…): vulnerabilities due to fine eco-hydrological balances…

What are peatlands?

Clearing and fires…

What are peatlands?

Effects of peatland clearing and drainage at the local scale:
unit carbon emissions, subsidence

What are peatlands?

Effects of peatland clearing and drainage at the large scale: plantations often not (very) productive, much degraded / burnt forest

(Note that the unplanted but drained area around plantationss is often as large as the planted area.)

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What are peatlands?

In peatlands converted to agriculture, as in degraded peatlands, 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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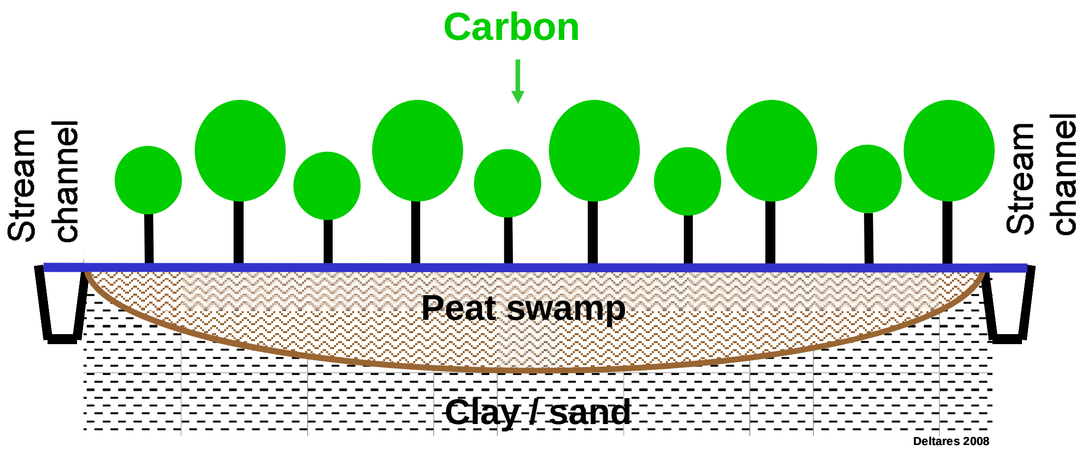
The basics of peatland carbon storage

How do peatlands develop?

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



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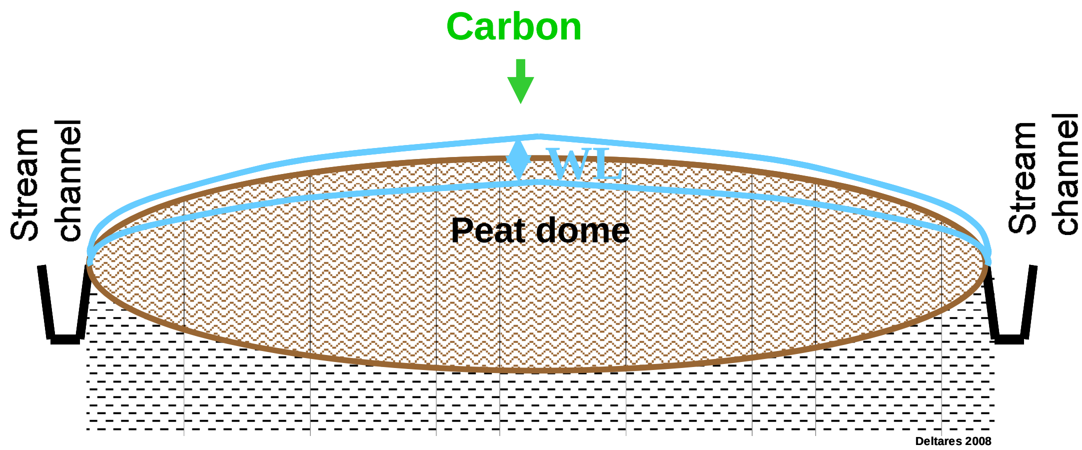
The basics of peatland carbon storage

How do peatlands develop?

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



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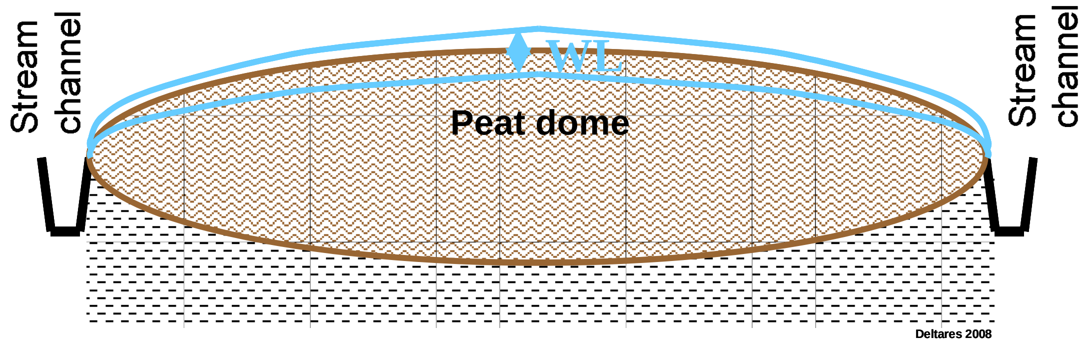
The basics of peatland carbon storage

Why are peatlands different from other lowland areas?

Peat soils consist mostly of water (90%), held together by vegetation remains i.e. mostly carbon (10%)

Peatlands are in some ways more like lakes than land: they are wetlands



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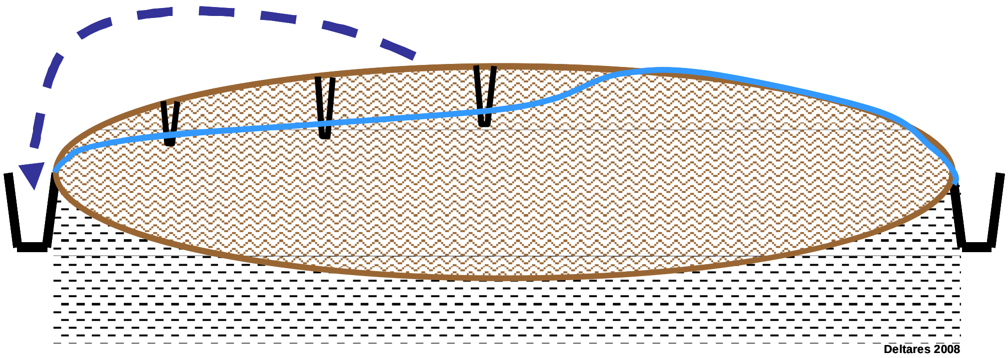
The basics of peatland carbon storage

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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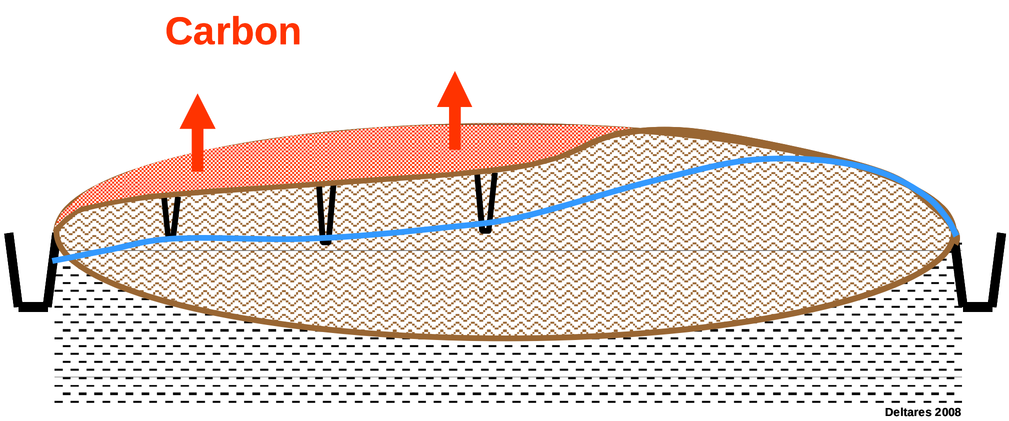
The basics of peatland carbon storage

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

Drainage lowers water table and dries the peat

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



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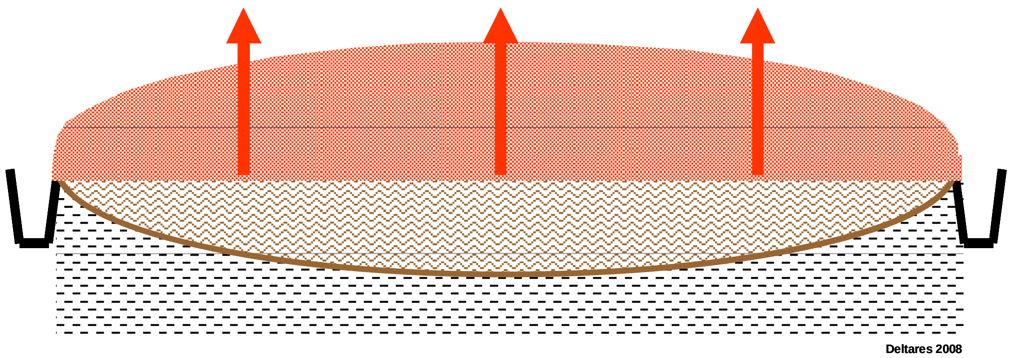
The basics of peatland carbon storage

What is the long-term impact?

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

Without rewetting all peat above drainage limit (River / Sea) will be lost



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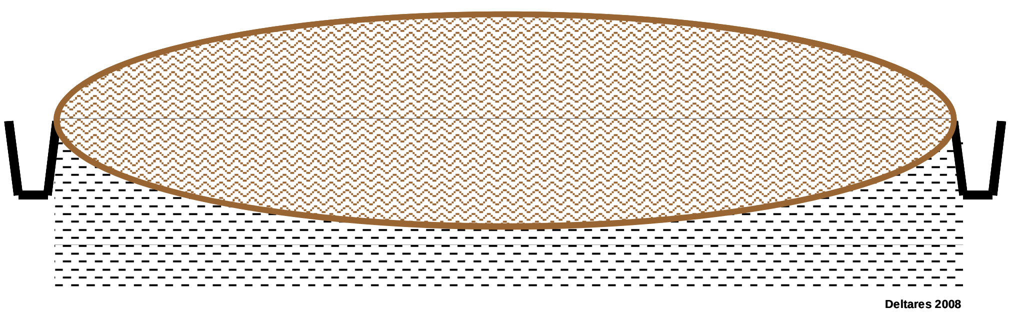
The basics of peatland carbon storage

What are the impacts of peatland drainage?

General environmental impacts:

- **Smoke emissions: local health problems and regional haze**
- **CO_2 emissions (and other greenhouse gases)**
- **Remaining conservation forest progressively drained and lost**



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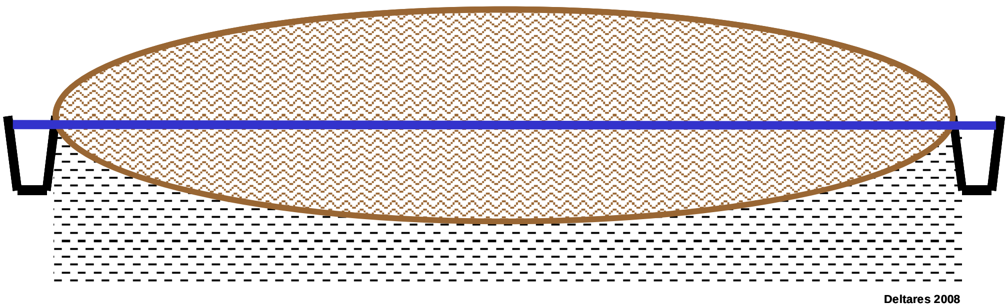
The basics of peatland carbon storage

What are the impacts of peatland drainage?

Impacts directly relevant to peatland agricultural productivity:

- **Peat subsidence increases flooding and reduces drainability: will be less productive / unproductive in future; many drained peatlands already frequently flooded now**
- **Further production loss if peat underlain by 'acid sulphate' soils**
- **Possible downstream production loss and damages if river flood flows increase**



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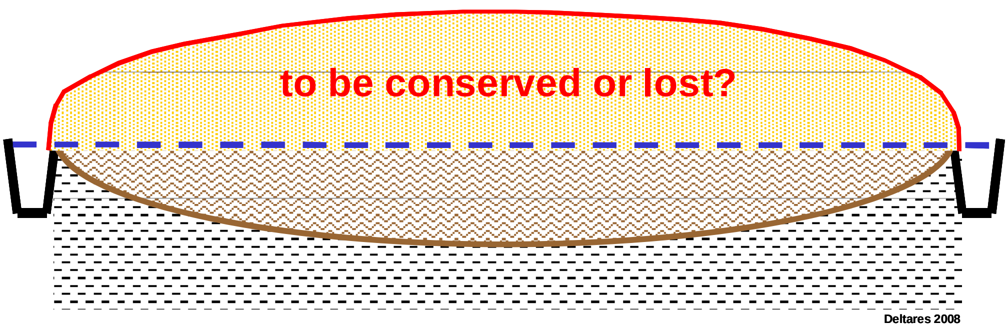
The basics of peatland carbon storage

How can these impacts be stopped or reduced?

Peat loss is assumed to stop when the peat is fully 'rewetted', but it is not clear how soon decomposition ends after the balance between soil carbon, landscape morphology and vegetation has been disturbed. Probably decades, possibly centuries.



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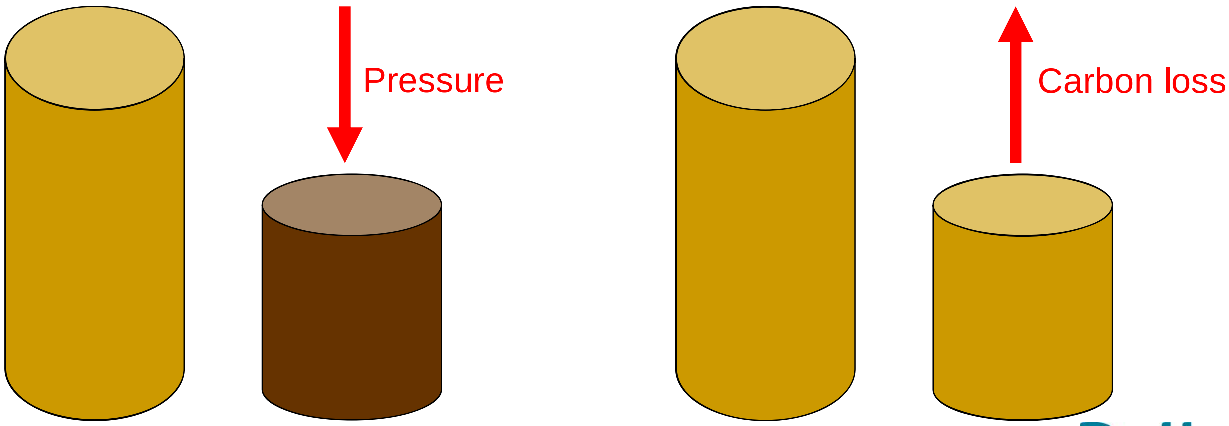
Two main subsidence components

Compaction / consolidation: physical: the peat is compressed, volume reduced, <u>bulk density goes up but mass remains the same.</u>

Compaction		**Oxidation**	
Before	***After***	***Before***	***After***
Height: 10 cm	*Height: 5 cm*	*Height: 10 cm*	*Height: 5 cm*
Weigth: 1 kg	*Weigth: 1 kg*	*Weigth: 1 kg*	*Weigth: 0.5 kg*
BD: 0.1 g/cm³	*BD: 0.2 g/cm³*	*BD: 0.1 g/cm³*	*BD: 0.1 g/cm³*



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Two main subsidence components

There are two groups oif processes that are <u>fundamentally different</u>

Compaction and consolidation are **physical**: the peat is compressed, volume reduced, <u>bulk density goes up but mass remains the same.</u>

Oxidation is **biological / chemical**: the peat is decomposed by organisms, volume is reduced, <u>bulk density remains the same but mass is lost.</u>

WE NOTICE THEY ARE OFTEN CONFUSED

IF STANDARD SOIL-ENGINEERING EQUATIONS ARE USED TO EXPLAIN SUBSIDENCE IN PEATLANDS, THE RESULTS WILL MEANINGLESS AND INACCURATE.

APPLYING STANDARD EQUATIONS TO PEAT SUBSIDENCE IGNORES THE LOSS OF PEAT MATTER, AND THEFORE THE CO2 EMISSION

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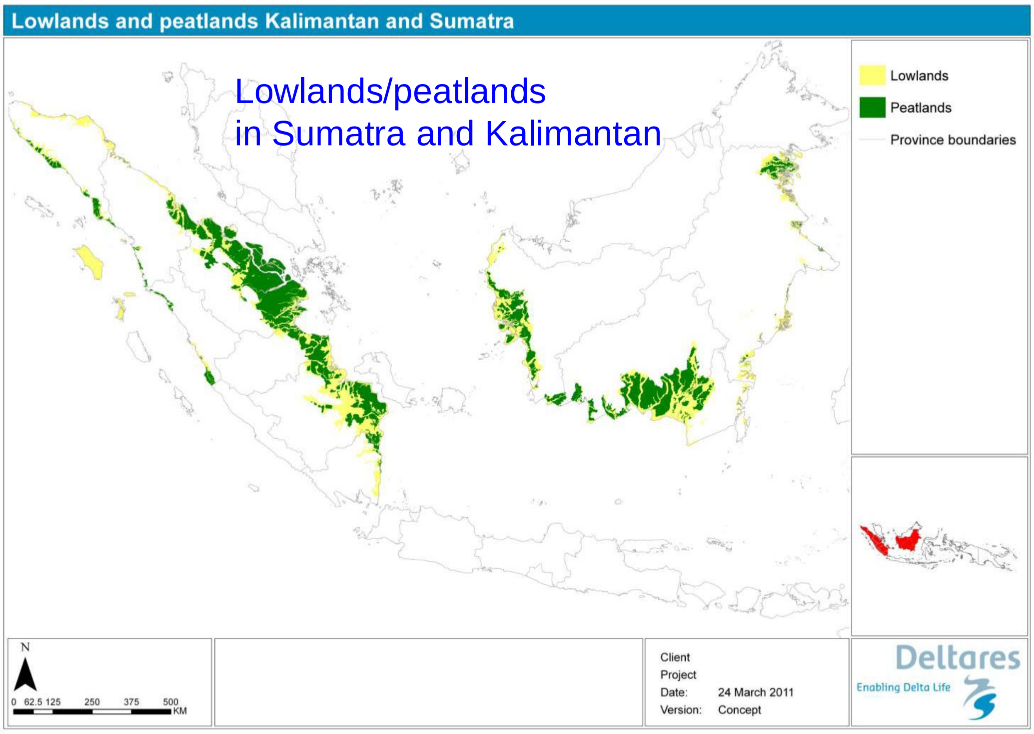
Peatland extent & condition

Indonesia has about 21 Million hectare of peatland

- **12 % of the land area**
- **Over 60% of the lowland area (of ~35 Mha, depending of definition)**



Many policy makers are not much aware of the extent or location of peatlands, which complicates planning and management.

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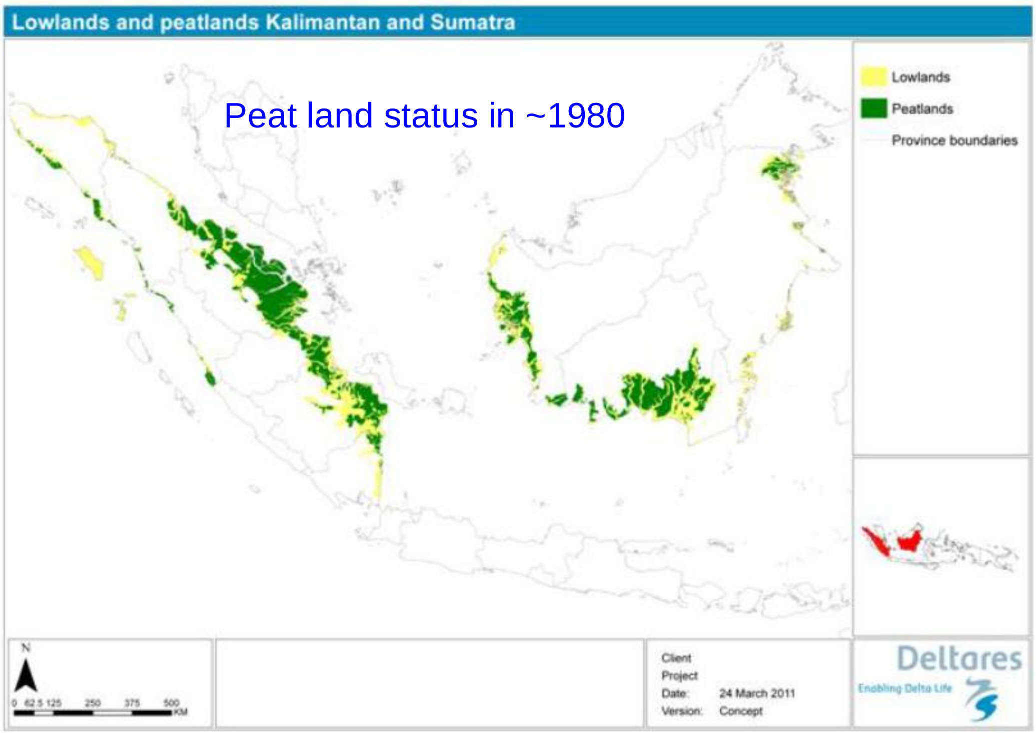
Peatland extent & condition

Indonesia has about 21 Million hectare of peatland:

- **Nearly all of this was largely intact in 1980, only 30 years ago, and even in 1995…**



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Peatland extent & condition

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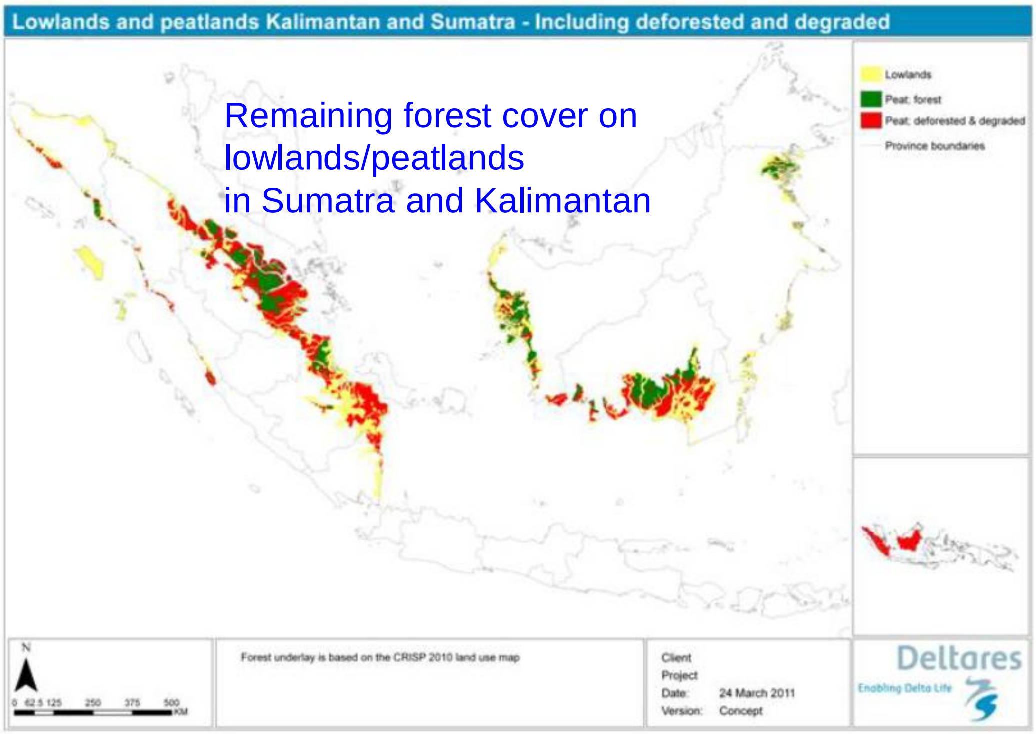

Most peatland forest has been lost, in the last 20 years…

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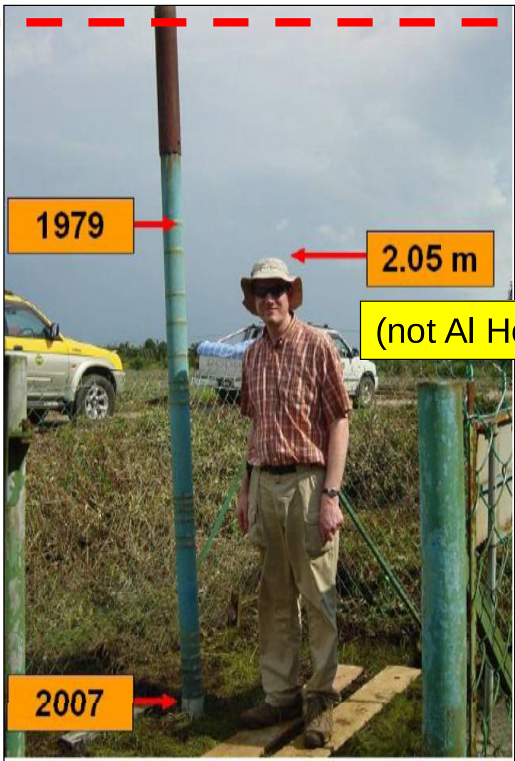
International examples

Johor, Malaysia

Surface before drainage?

(subsidence pole placed after drainage)



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International examples

Johor, Malaysia

J.H.M. Wösten et al. / Geoderma 78 (1997) 25–36

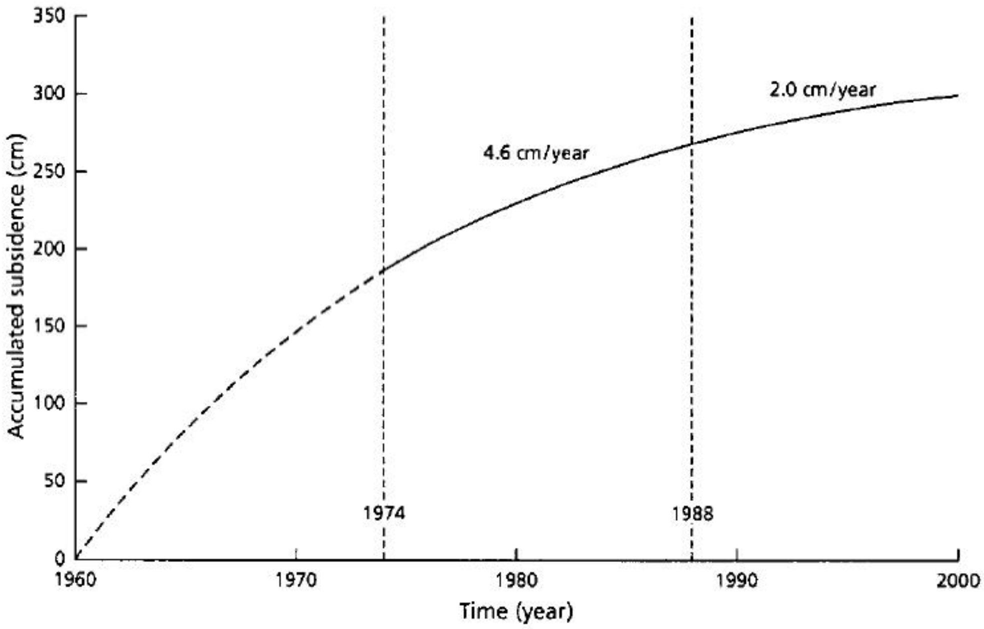

Fig. 3. Average subsidence versus time relationship for the project area as a whole.

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International examples

Johor, Malaysia

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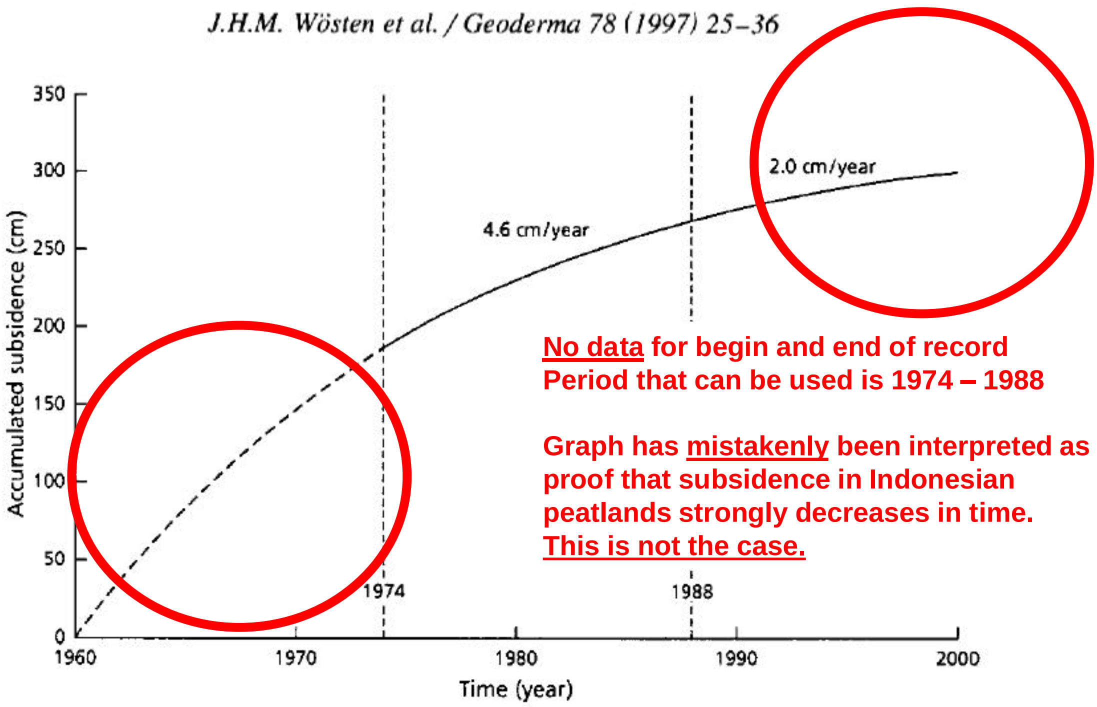

Fig. 3. Average subsidence versus time relationship for the project area as a whole.

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Long-term projections

In tropical peatlands like in Indonesia or Everglades, where subsidence is mostly caused by oxidation, there is
<u>very little soil compaction</u> after first 5 years following drainage, and therefore
<u>no or very little ‘soil ripening’, and therefore a</u>

<u>constant subsidence rate for many decades, until the area becomes undrainable</u>

Long-term projections

<u>constant subsidence rate for many decades, until the area becomes undrainable</u>

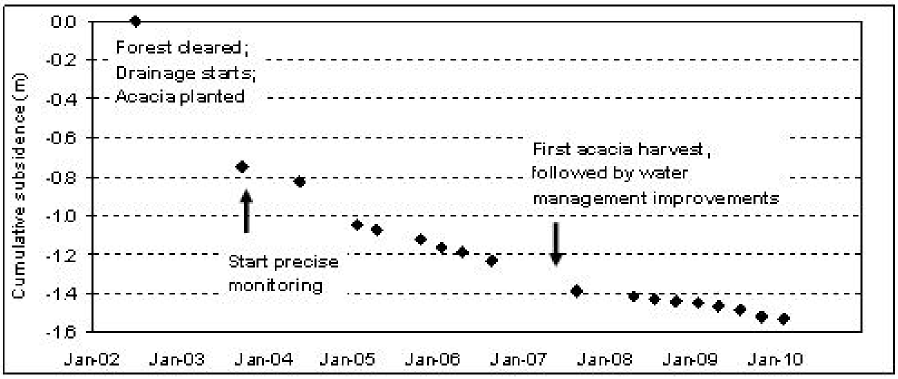
<u>1 m subsidence in first year after drainage</u>

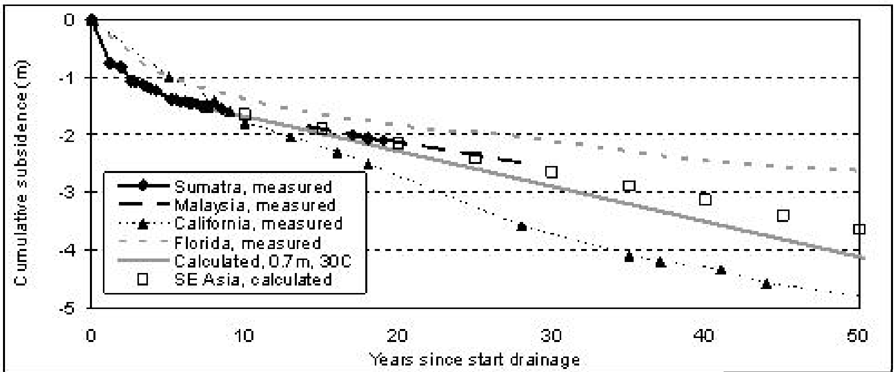
<u>1.5 m subsidence in 5 years</u>

<u>2.5 m subsidence in 25 years</u>

<u>3.5 m subsidence in 50 years</u>

<u>6 m in 100 years?</u>



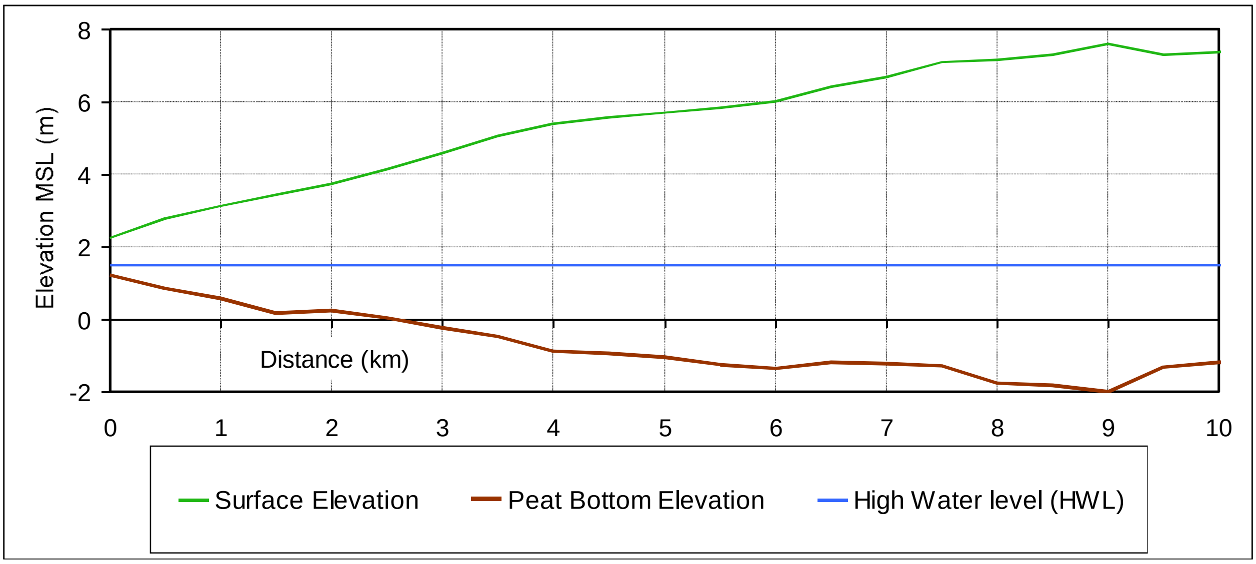


Hooijer et al. 2011

Long-term projections

The average cross section for Indonesia was constructed (16 cross sections)

Very similar to Sarawak; difference largely due to difference in cross section length and number.



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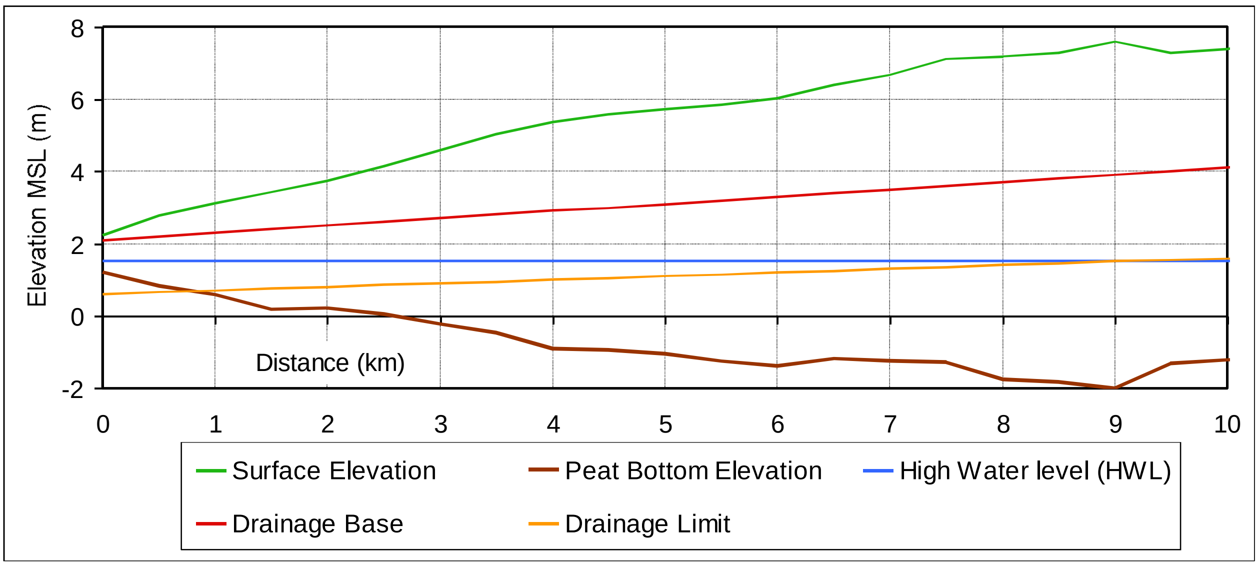
Long-term projections

The average cross section for Indonesia was constructed (16 cross sections)

With drainage base & limit added



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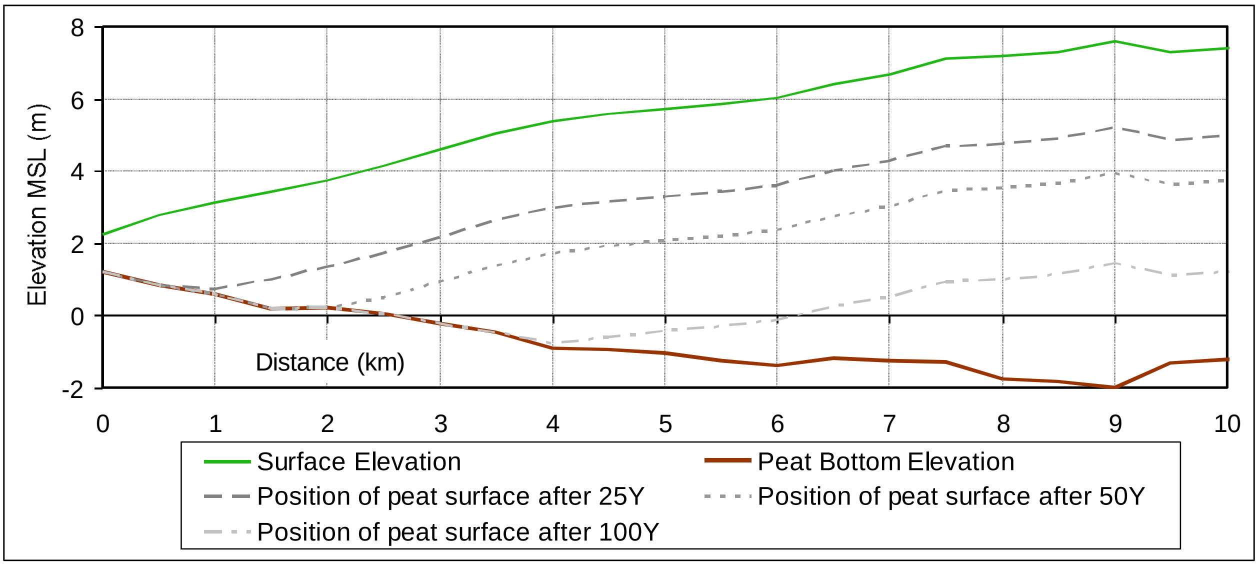
Long-term projections

The average cross section for Indonesia was constructed (16 cross sections)

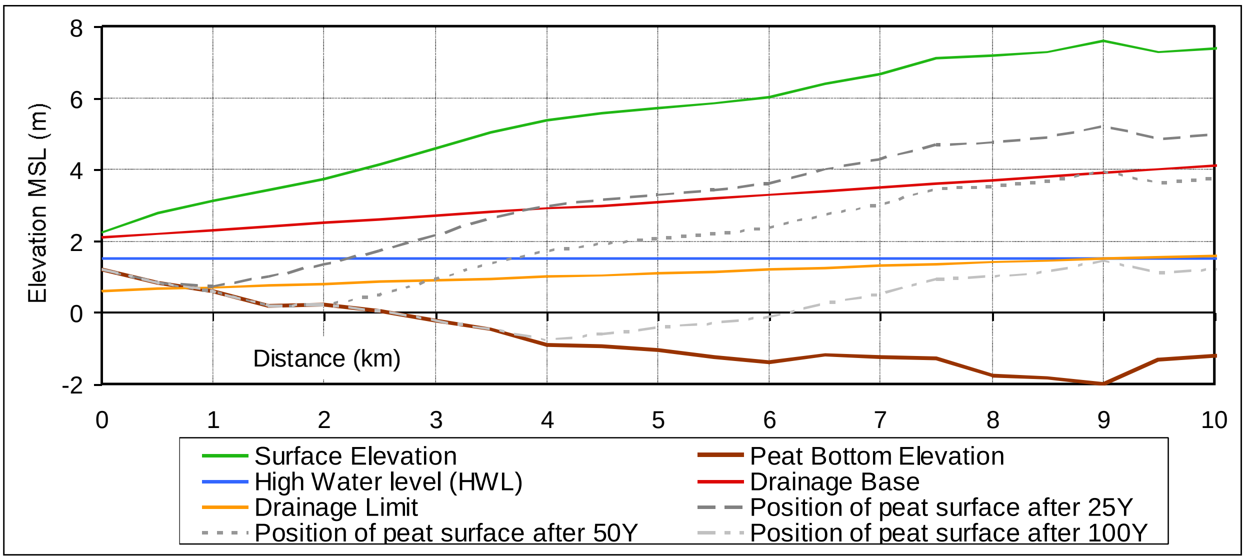
With surface levels after 25, 50 and 100 years drainage added (<u>excluding fires</u>)



Long-term projections

The average cross section for Indonesia was constructed (16 cross sections)

With drainage base & limit + surface levels after 25, 50 and 100 years drainage added



Long-term 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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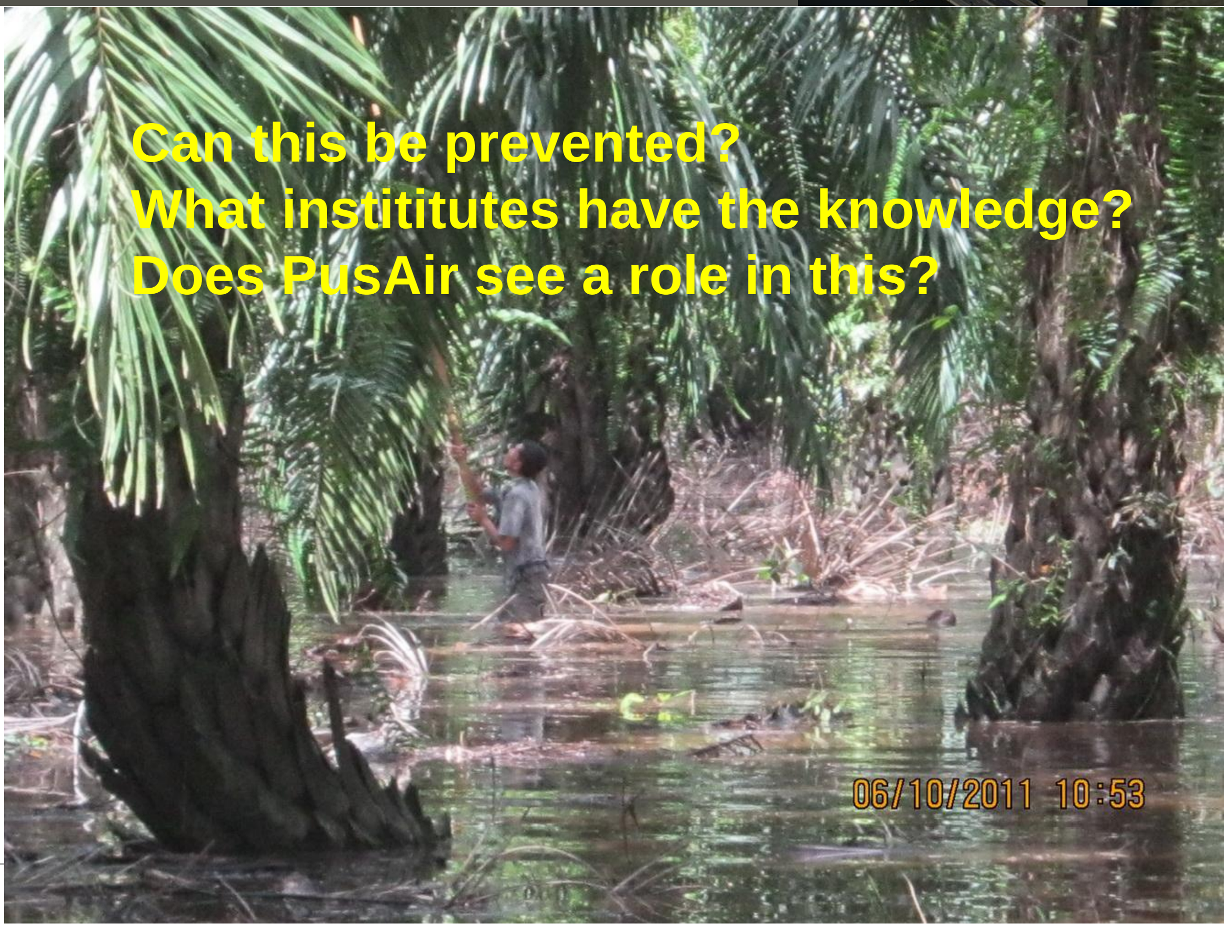
Long-term projections



Long-term projections

Of the 21 Mha peatland in Indonesia, more than 10 Mha may be flooded and improductive if drained, and nearly all would become less drainable and less productive.

This is probably the largest and most impacted subsidence area in the world.

It is one of the biggest problems that Indonesia has:

- Insecure ‘food security’ if planned in peatlands
- Loss of export crops (oil palm, pulp & paper)
- Poverty of local population
- Environmental degradation (fires, health, water quality, fisheries etc)
- Carbon emissions

At present, little policy/media attention and little good research taking place. Those who favour peatland deforestation and drainage produce ‘studies’ that show this is not a problem, based on very little knowledge and information.

JCP offers PusAir and others a change to generate capacity to take part in this important national debate.

We must now plan how this will be done in practice: this activity is about more than workshops but aims to produce simething (model, maps, guidelines, Master Classes by PusAir for others in Indonesia).

Questions?

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Examples of international experience in peatland subsidence & research

Recent findings in Indonesia

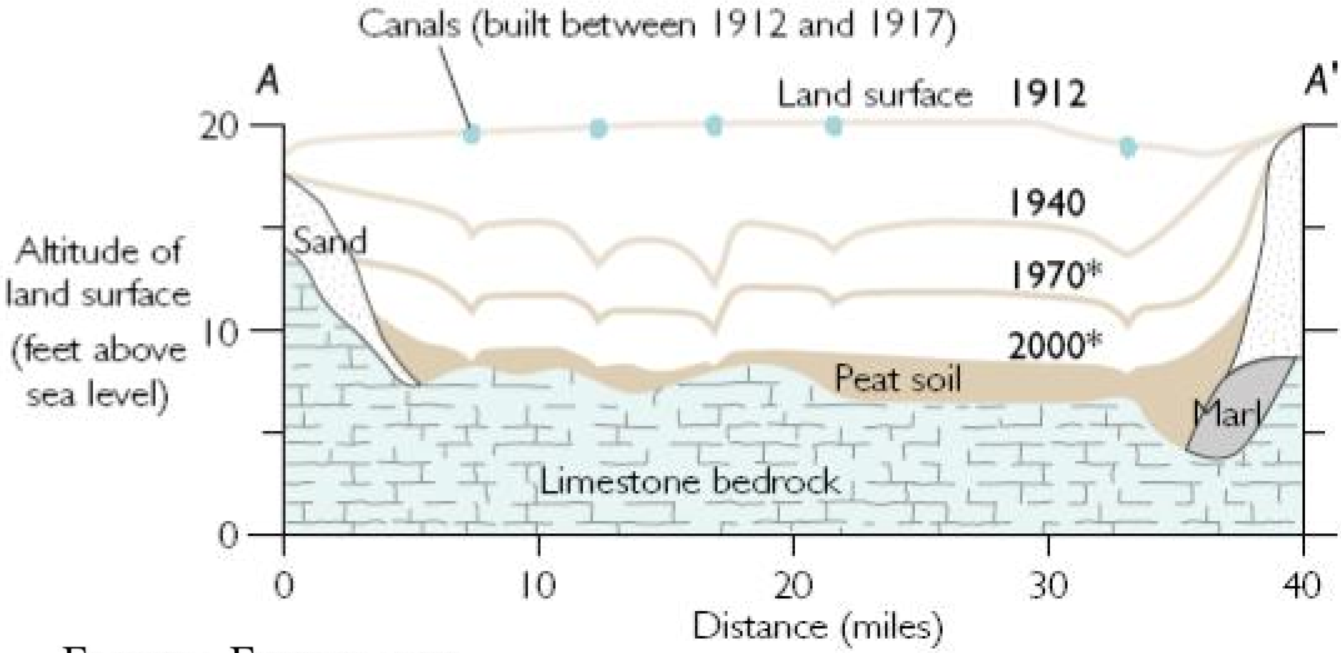
Al Hooijer
JCP second workshop on peatland subsidence and modeling,
30-31 January

International examples

Everglades, Florida, USA

International examples

Everglades, Florida, USA



FLORIDA EVERGLADES

Subsidence threatens agriculture and complicates ecosystem restoration

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

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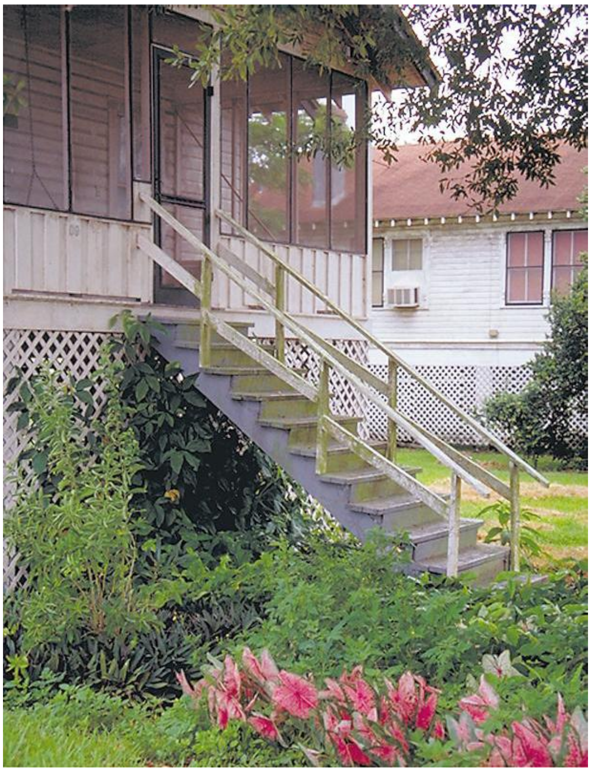
International examples

Everglades, Florida, USA



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Everglades, Florida, USA

3m subsidence over 100 years; slows down only when water depths reduced, accelerates when new pumps installed

Geological Society of America
Reviews in Engineering Geology, Volume VI
1984

Organic soil subsidence

John C. Stephens, Consulting Geohydrologist
(Formerly Agricultural Administrator, USDA, ARS)
1111 N.E. 2nd Street
Ft. Lauderdale, Florida 33301

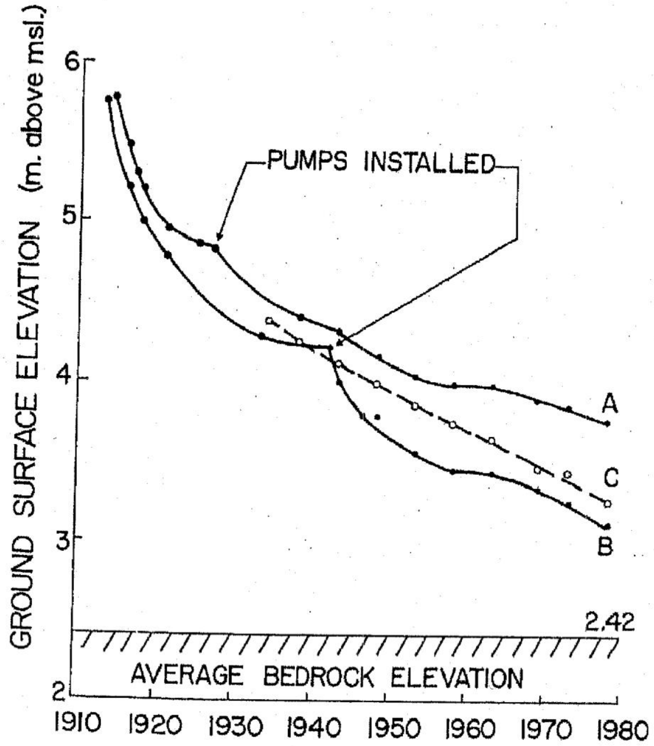

Figure 3. Sequence of observed subsidence of organic soils in the Florida Everglades after initial drainage, circa 1912.

International examples

Everglades, Florida, USA

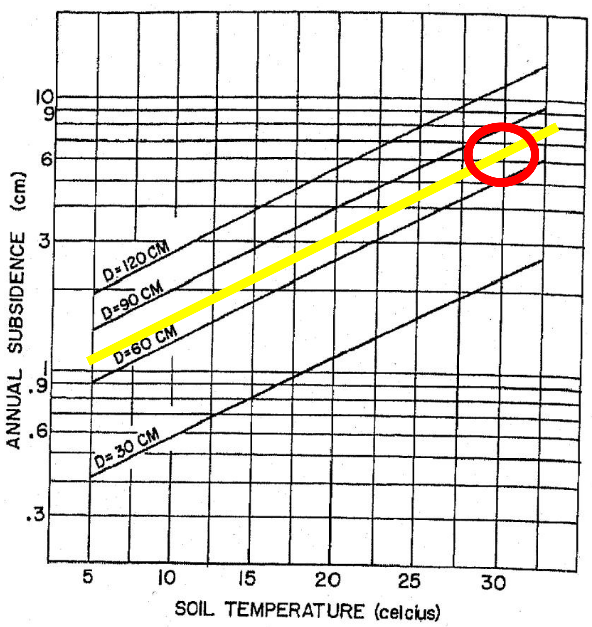

Figure 5. Annual subsidence of organic soils at various water-table depths and soil temperatures.

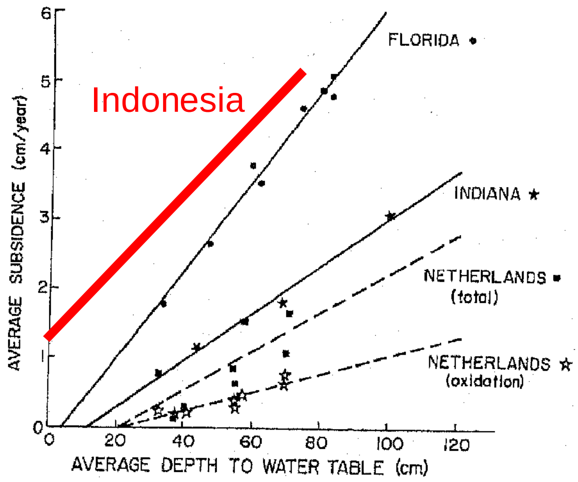

Figure 4. Comparative subsidence rates of organic soils in Indiana and the Florida Everglades versus water-table depth. Organic soil data for western Netherlands superimposed from Schothorst, 1977. The two lines shown for the Netherlands show total subsidence and subsidence attributable to biological 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.

Oxidation component temperature dependent: highest in tropics

International examples

Everglades, Florida, USA

Constant subsidence; does not slow down

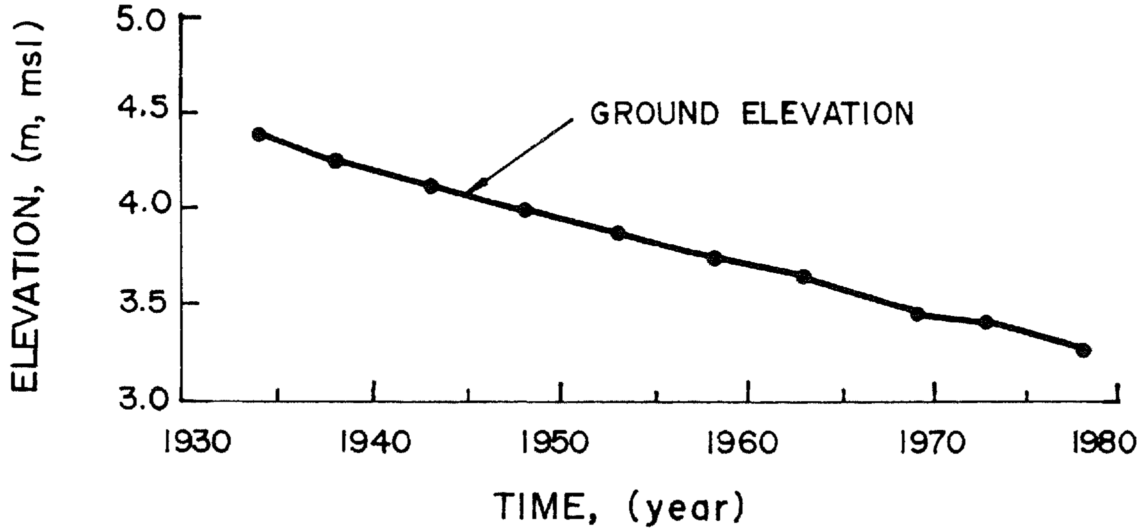

Figure 2. Subsidence of East Line at the Agricultural Research and Education Center (AREC).

IMPACT OF SUBSIDENCE ON WATER MANAGEMENT IN EVERGLADES AGRICULTURAL AREA.
S. F. SHIH (U.S.A.)

International examples

Venice Lagoon, Italy

Peatlands: Evolution and Records of Environmental and Climate Changes
I.P. Martini, A. Martínez Cortizas, W. Chesworth, Editors

Chapter 23

Peatland subsidence in the Venice watershed

M. Camporese, G. Gambolati, M. Putti and P. Teatini

International examples

Venice Lagoon, Italy

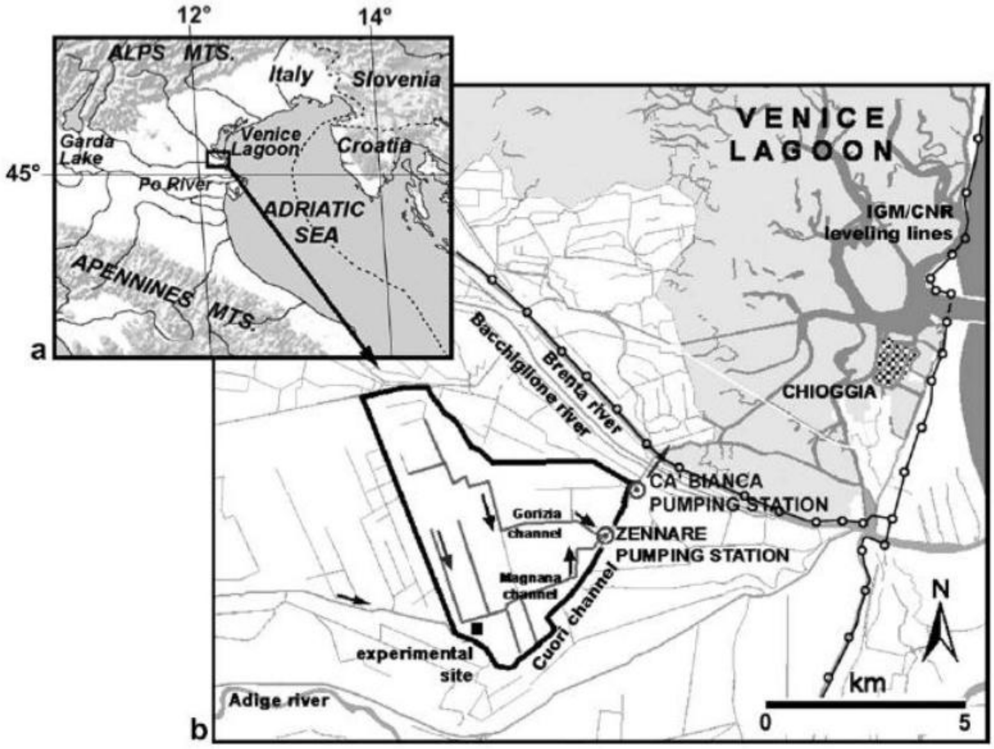

Figure 23.1. Maps of the study area. (a) Map of the northeastern Italy. (b) Map of the Zennare Basin in the southern catchment of the Venice Lagoon. The major watercourses and the leveling lines used to measure land subsidence since 2000 are shown (after Gambolati et al., in press).

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International examples

Venice Lagoon, Italy

Figure 23.4. Evidence of the anthropogenic land subsidence in the reclaimed area. (a) A bridge has been turned into a useless structure: the left drainpipe helps convey the water of the channel originally flowing through the protruding infrastructure. (b) An old masonry culvert presently above the water level and substituted by two lower concrete drainpipes, the higher of which already unusable. The approximate position of the ditch section in the original configuration is sketched. (c) The protrusion of a sluice wall above the bed of an old disappeared channel. (d) An old bridge hanging over the canal bank that settled by 1.5 m.

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International examples

Venice Lagoon, Italy

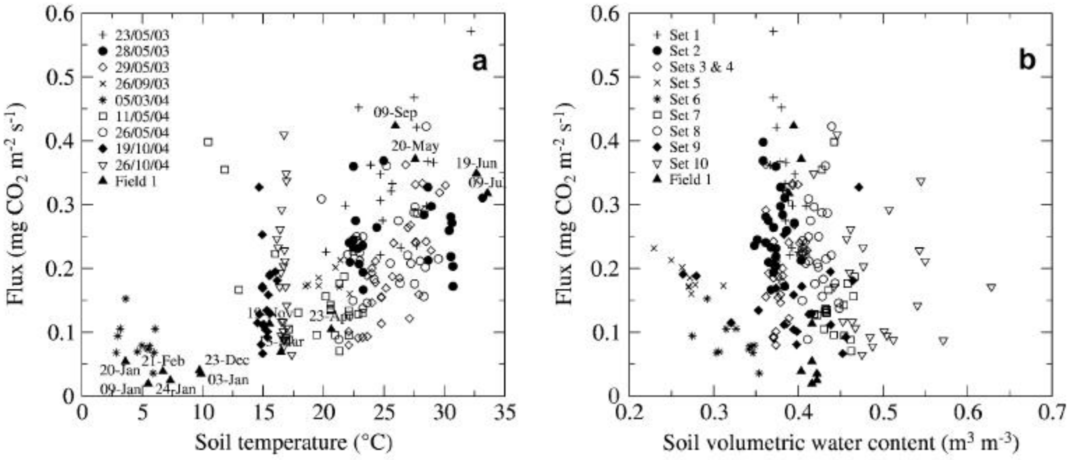

Figure 23.16. CO_2 flux versus (a) soil temperature and (b) water content measured in the Zennare Basin.

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International examples

England

Fenlands

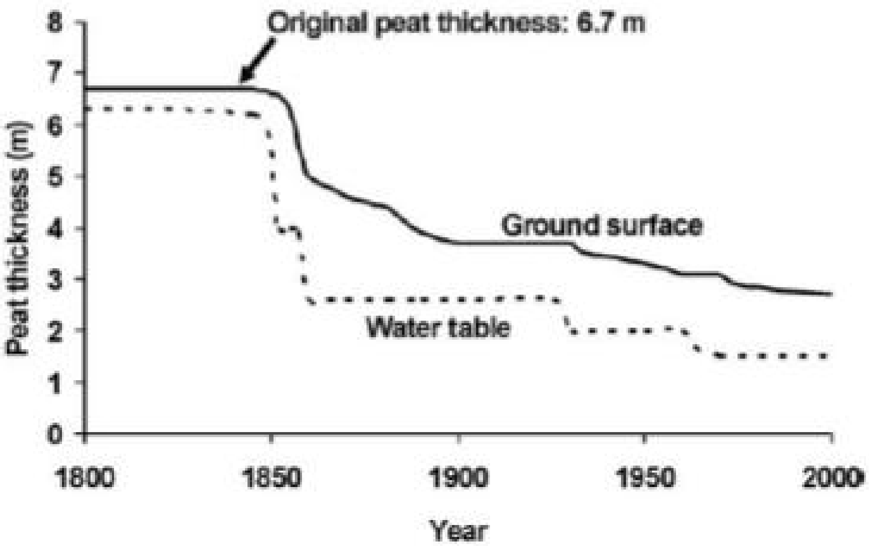


Fig. 1. Stages of peat subsidence after drainage of a peatland at Holme Fen, Cambridgeshire, UK, modified after Hutchinson (1980).

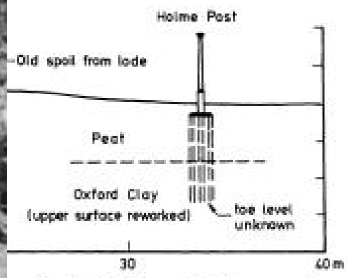
Geoderma 154 (2010) 181–187

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

Q. Dawson [a], C. Kechavarzi [b,*], P.B. Leeds-Harrison [b], R.G.O. Burton [b]

Deltares

England Fenlands



ne Post to Holme Lode (surveyed

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.).

England

Fenlands

PLATE 3. The various Whittlesey Mere Pumping Stations. Photograph taken Feb. 1963 from the Engine Drain, looking E. The twin buildings to the left, adjoining the chimney, housed the original and the second pumping plants; the central building housed the 1924 diesel plant; the latest station is lower down to the right.

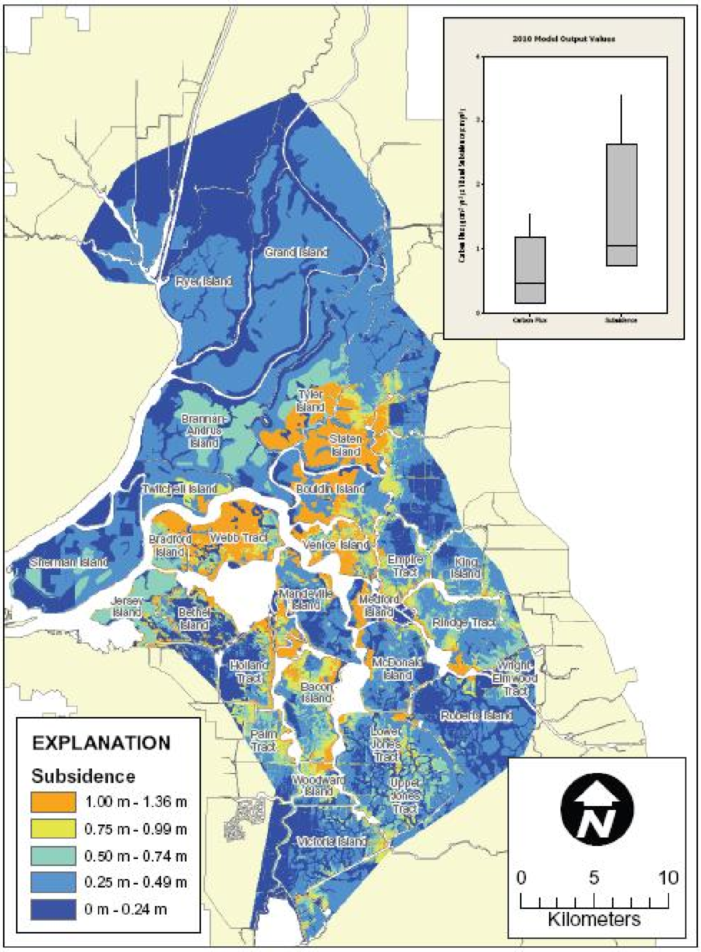
Journal of Ecology (1980), **68**, 229–249

THE RECORD OF PEAT WASTAGE IN THE EAST ANGLIAN FENLANDS AT HOLME POST, 1848–1978 A.D.

J. N. HUTCHINSON

International examples

Sacramento Delta, California, USA



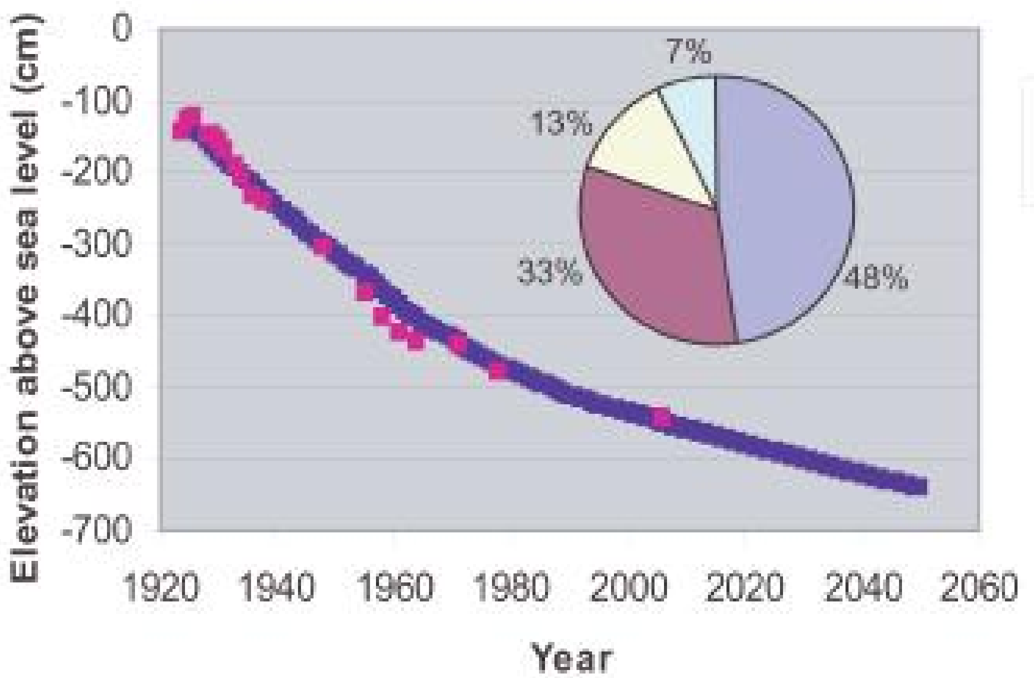
Historic, Recent, and Future Subsidence, Sacramento-San Joaquin Delta, California, USA

Steven J. Deverel[1] and David A. Leighton

Deltares

International examples

Sacramento Delta, California, USA

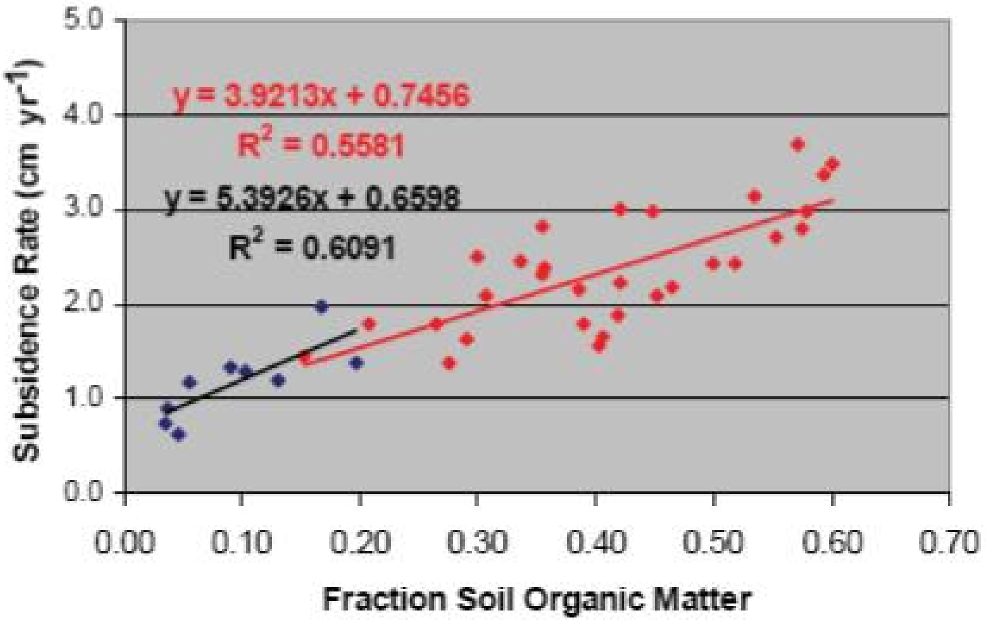


Historic, Recent, and Future Subsidence, Sacramento-San Joaquin Delta, California, USA

Steven J. Deverel[1] and David A. Leighton

Deltares

Sacramento Delta, California, USA



Historic, Recent, and Future Subsidence, Sacramento-San Joaquin Delta, California, USA

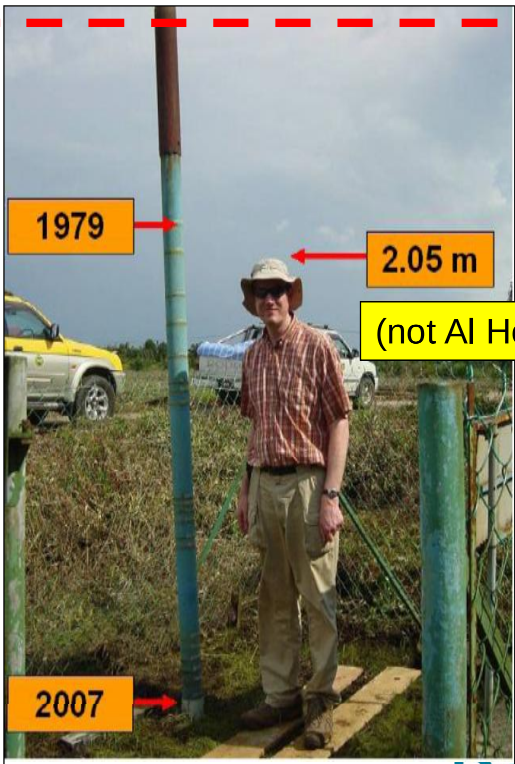
Steven J. Deverel[1] and David A. Leighton

International examples

Johor, Malaysia

Surface before drainage?

(subsidence pole placed after drainage)



International examples

Johor, Malaysia

J.H.M. Wösten et al. / Geoderma 78 (1997) 25–36

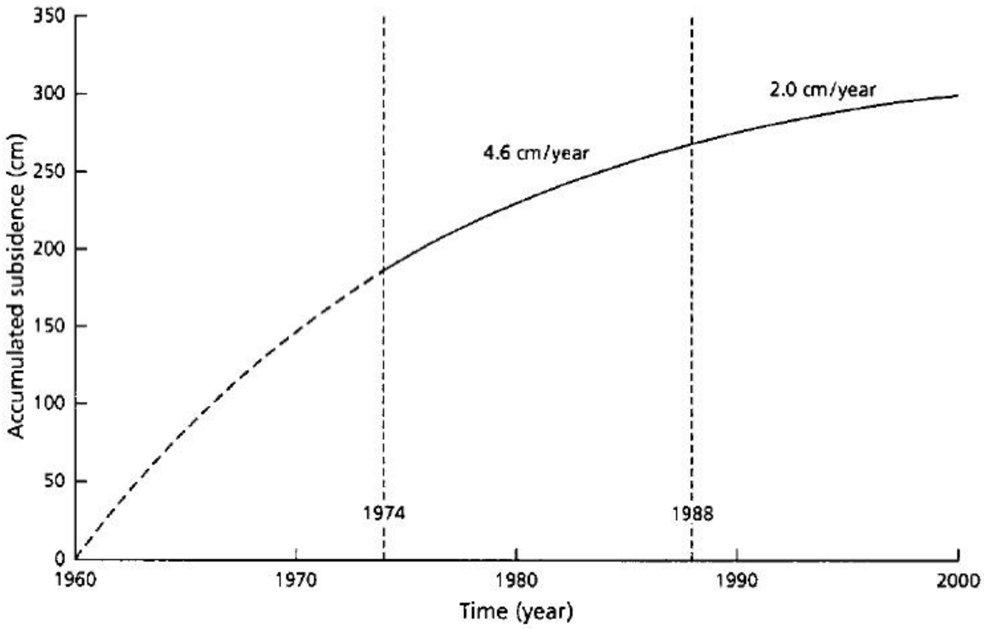


Fig. 3. Average subsidence versus time relationship for the project area as a whole.

International examples

Johor, Malaysia

J.H.M. Wösten et al. / Geoderma 78 (1997) 25–36

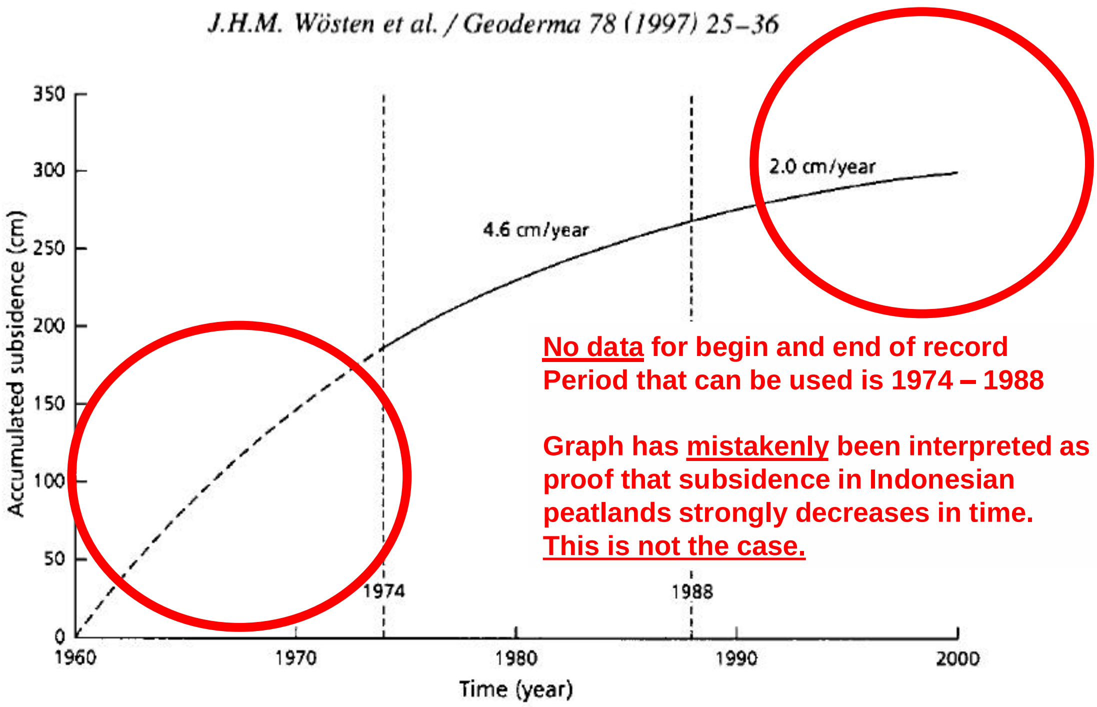


Fig. 3. Average subsidence versus time relationship for the project area as a whole.

Long-term projections

In tropical peatlands like in Indonesia or Everglades, where subsidence is mostly caused by oxidation, there is
very little soil compaction after first 5 years following drainage, and therefore
no or very little ‘soil ripening’, and therefore a

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

Recent studies in Indonesia: Jambi Oil Palm Plantations

Recent studies in Indonesia: Jambi Oil Palm Plantations

Recent studies in Indonesia: Jambi Oil Palm Plantations

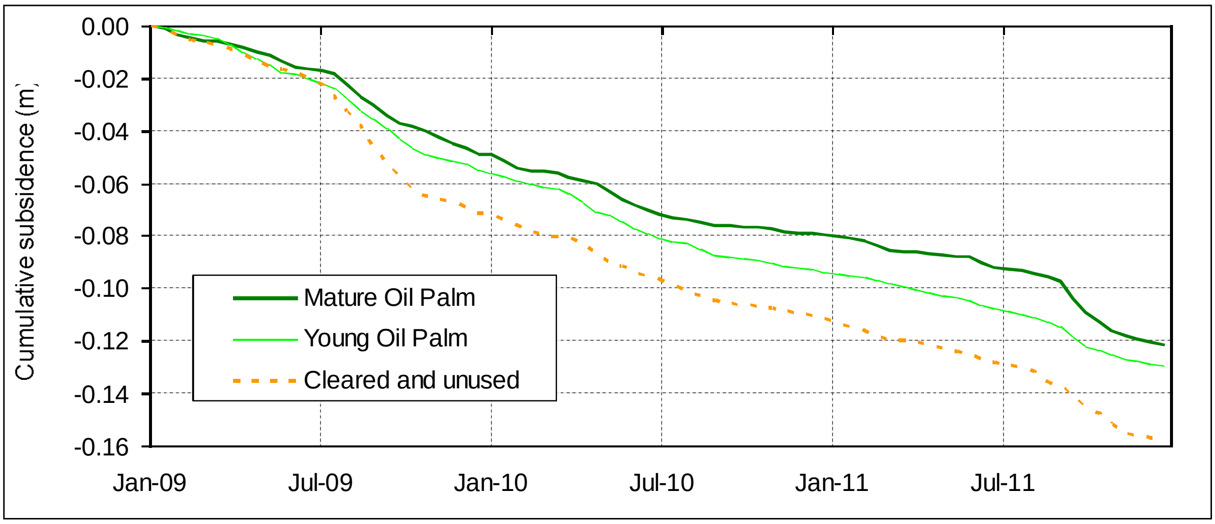
In

	Mature oil palm	Young oil palm	Cleared and unused	All
Number of monitoring locations	42	29	14	85
Years since drainage	15–20	4–7	4–7	4–20
Average peat thickness (m)	7.6	7.4	9.3	7.8
Average water table depth over 3 years (m)	-0.64	-0.44	-0.51	-0.53
Avg water table depth 2009 and 2011 (m)*	-0.66	-0.46	-0.53	-0.56
Avg water table depth 2010 (m)	-0.56	-0.40	-0.47	-0.48
Avg. subsidence over 3 years (cm/y)	4.1	4.3	5.3	4.4
Avg. subsidence 2009 and 2011 (cm/y)*	4.5	4.6	5.9	4.8
Avg. subsidence 2009 and 2011 (cm/y)*	8.0	9.5	11.4	3.5
Minimum monthly subsidence (cm/28 days)	0.02	0.07	0.09	0.06
Minimum monthly subsidence (cm/28 days)	1.31	0.87	1.45	1.01

** Rainfall and water depths in 2009 and 2011 are close to long-term averages.*

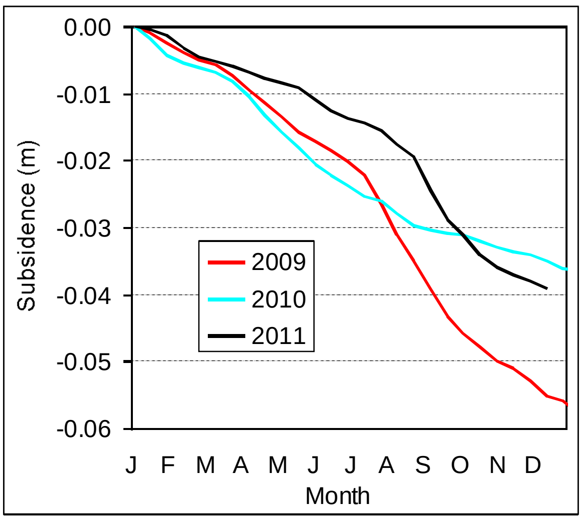
Recent studies in Indonesia: Jambi Oil Palm Plantations

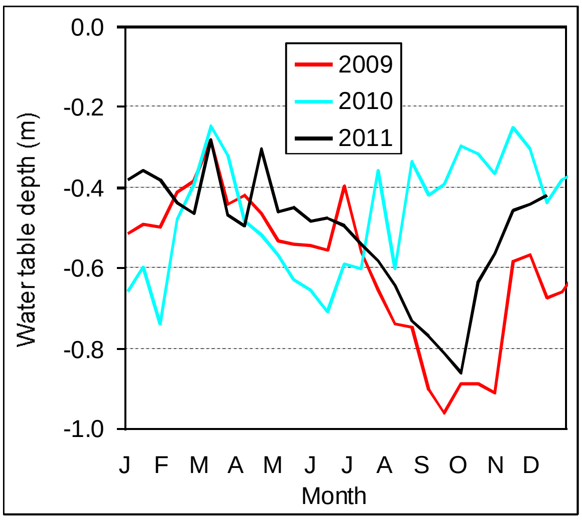
In



Recent studies in Indonesia: Jambi Oil Palm Plantations

In

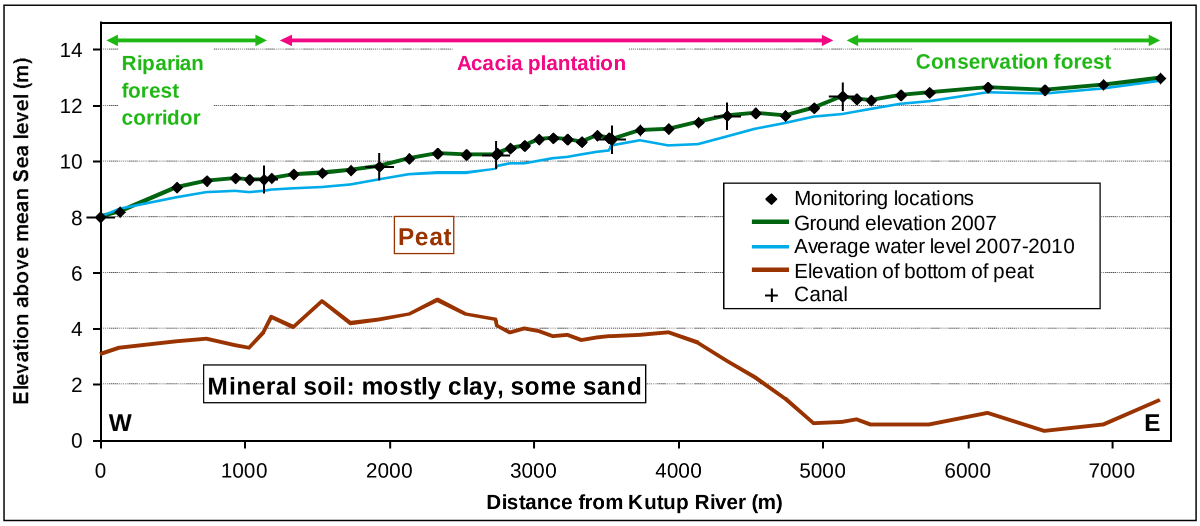




Deltares

Recent studies in Indonesia: Jambi Oil Palm Plantations

Recent studies in Indonesia: Kampar Peninsula *Acacia* Plantations

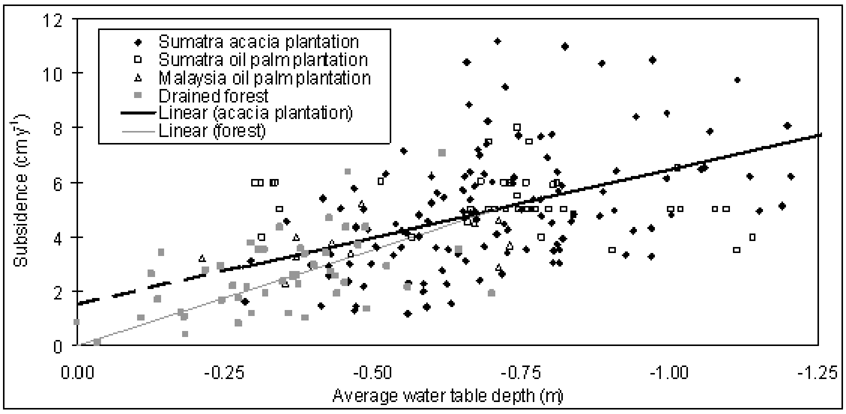


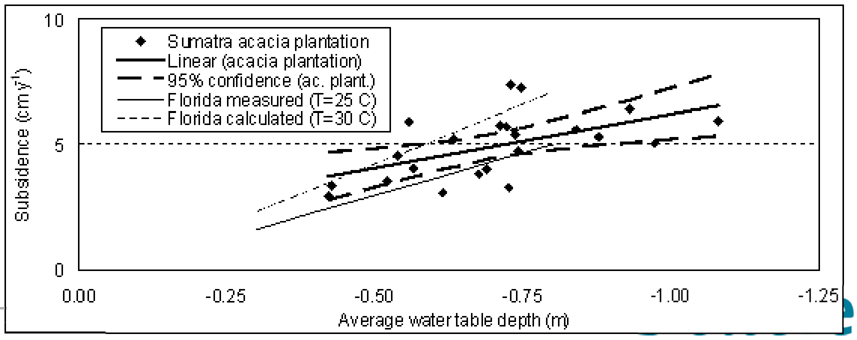
Measurements of water depth and subsidence rate 2007-2010 at 176 (after quality screening) monitoring locations accross peat domes in Riau.

Recent studies in Indonesia:
Kampar Peninsula *Acacia* Plantations

Latest subsidence – water depth relation: S = 1.5 + 4.98*WD

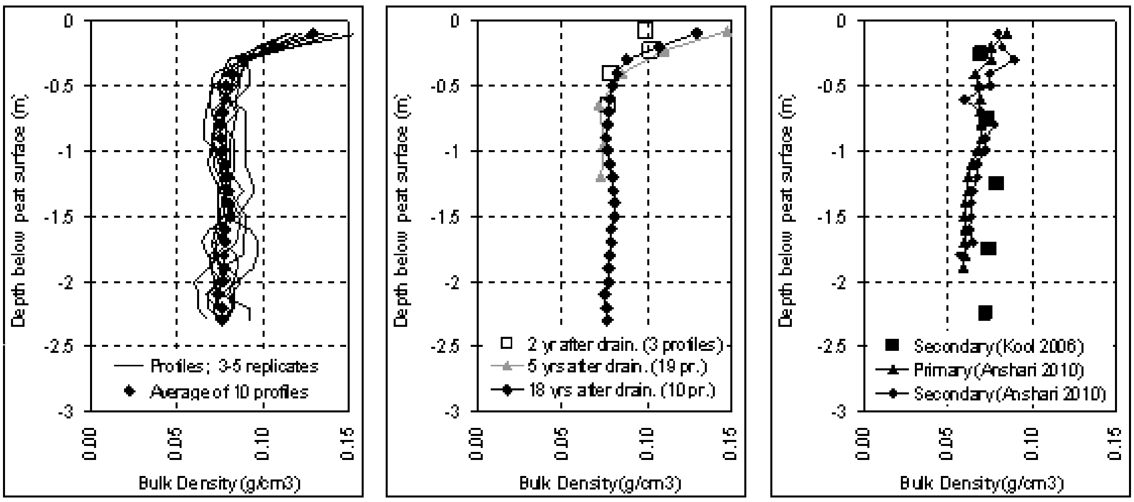
there is definitely a relation with water depth, BUT soil temperature also very important!





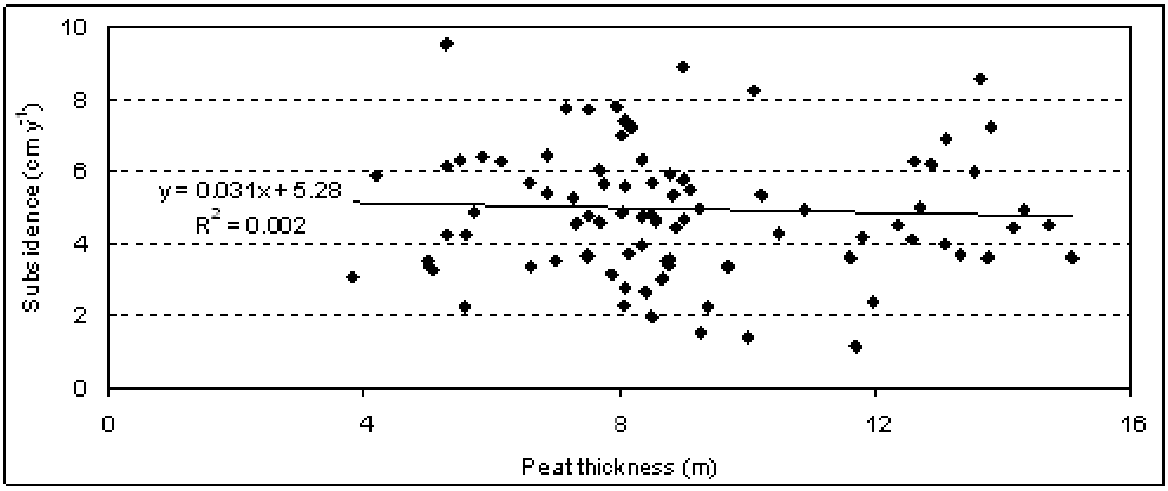
Recent studies in Indonesia:
Kampar Peninsula *Acacia* Plantations

… bulk density proviles show that compaction in unsaturated zone is minimal …



Recent studies in Indonesia: Kampar Peninsula *Acacia* Plantations

…and consolidation in the saturated zone appears to be absent…



… so <u>oxidation explains most (90% or more) of subsidence after 5 years or more</u>.

Recent studies in Indonesia: Jambi Oil Palm Plantations

To be added in coming months:

- **relation between subsidence and soil temperature**
- **relation between subsidence and soil moisture content**
- **further analyses of oxidation / compaction percentages using bulk density and ash content profiles**
- **analysis of decomposition depths / horizons from peat characteristics (wood content etc)**
- **linking subsidence over 3-year monitoring period to long-term rainfall regime**

Recent studies in Indonesia: KFCP forest / degraded

Deltares

Long-term projections

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

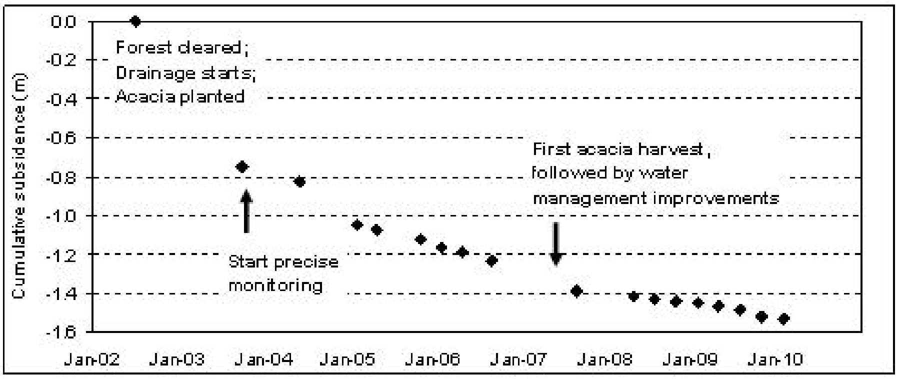
1 m subsidence in first year after drainage

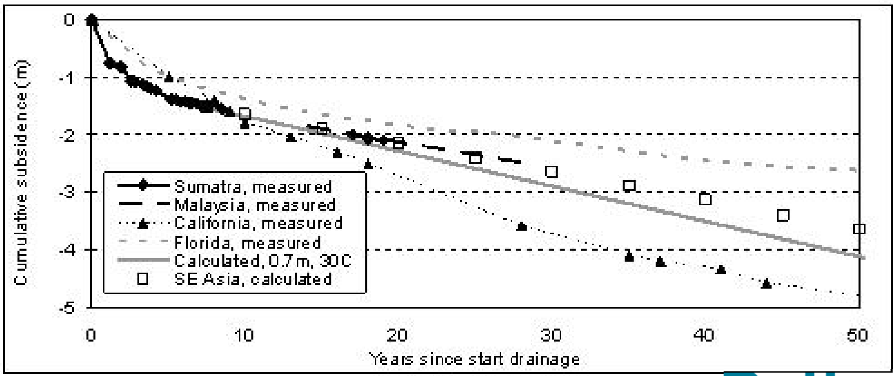
1.5 m subsidence in 5 years

2.5 m subsidence in 25 years

3.5 m subsidence in 50 years

6 m in 100 years?





Hooijer et al. 2011

Deltares

Long-term projections

Of the 21 Mha peatland in Indonesia, more than 10 Mha may be flooded and improductive if drained, and nearly all would become less drainable and less productive.

This is probably the largest and most impacted subsidence area in the world.

It is one of the biggest problems that Indonesia has:

- Insecure 'food security' if planned in peatlands
- Loss of export crops (oil palm, pulp & paper)
- Poverty of local population
- Environmental degradation (fires, health, water quality, fisheries etc)
- Carbon emissions

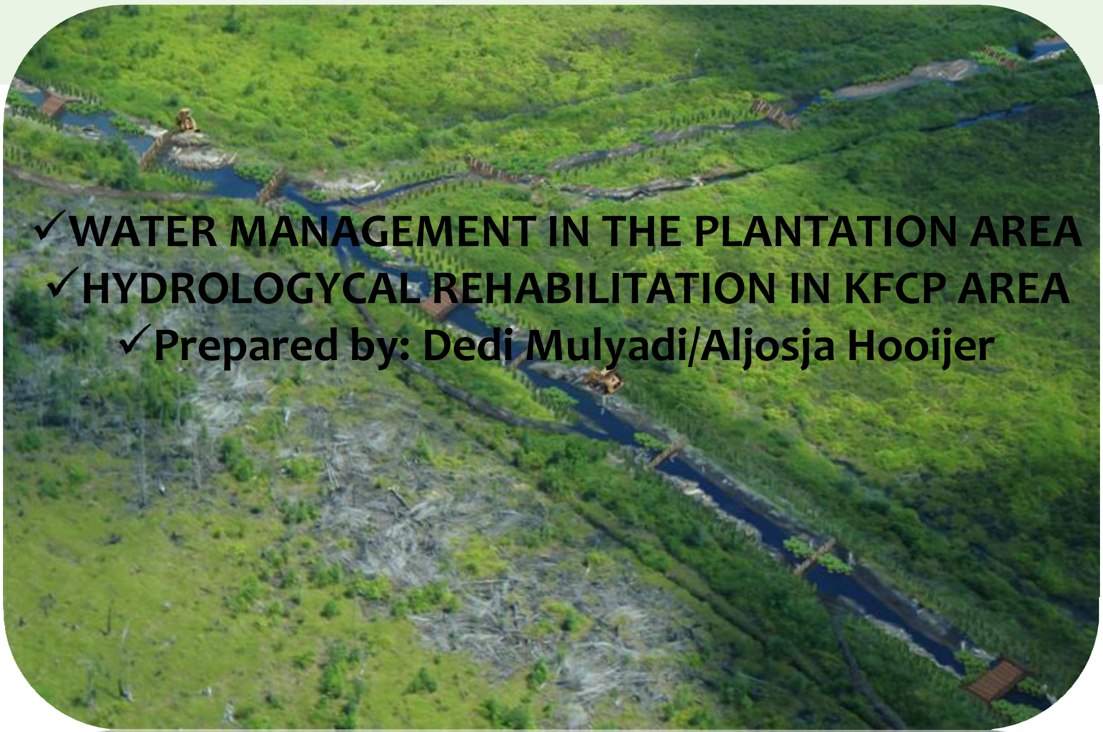
At present, little policy/media attention and little good research taking place. Those who favour peatland deforestation and drainage produce 'studies' that show this is not a problem, based on very little knowledge and information.

JCP offers PusAir and others a change to generate capacity to take part in this important national debate.

We must now plan how this will be done in practice: this activity is about more than workshops but aims to produce simething (model, maps, guidelines, Master Classes by PusAir for others in Indonesia).

Questions?

DESIGN AND PLANNING OF CANALS BLOCKING IN PLANTATION AND IN KFCP AREA



- ✓WATER MANAGEMENT IN THE PLANTATION AREA
- ✓HYDROLOGYCAL REHABILITATION IN KFCP AREA
- ✓Prepared by: Dedi Mulyadi/Aljosja Hooijer

FIRST:
WATER MANAGEMENT IN THE PLANTATION AREA

THE OBJECTIVE OF WATER MANAGEMENT IN PLANTATION

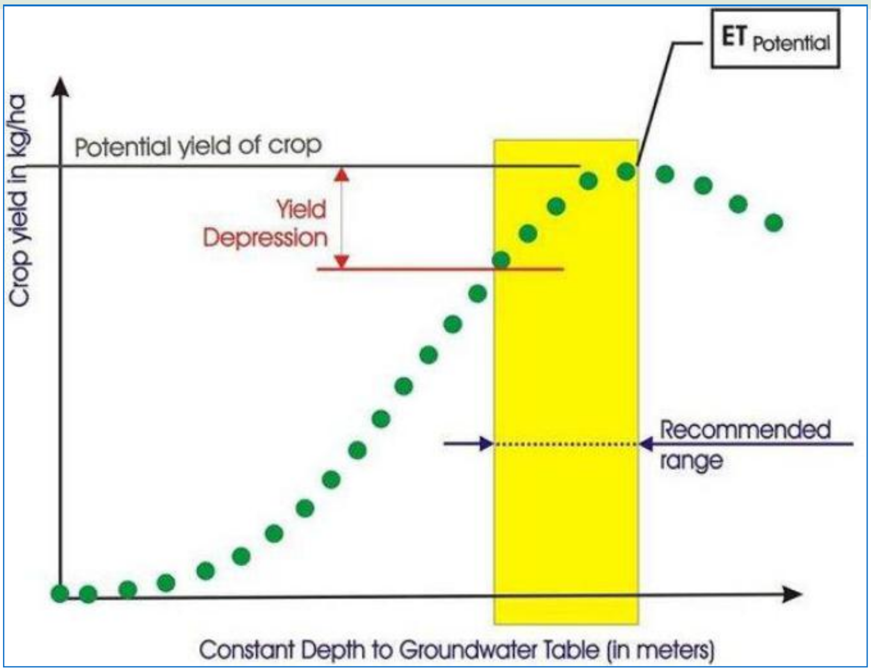
Why water management is needed on the plantation in peat lands?

1. Water management in peat lands plantation constructed by compacted peat dams, intended to establish zoning on ground water level, each zone at 50-80 cm below the peat surface, in order to promote growth of acacia and get maximum crop yields.
2. In addition, zoning is also required for the smooth transportation in the canal, especially during the dry season, with the principle to keeping water for each water zone. Transport canal is required in plantations for wood logging, planting, maintenance, fertilizing, etc.
3. Reduce subsidence rate by controlling the water level in the canal that will affect to the water table in peat lands.
4. Principles of water management in plantations is to maintain water levels during the dry season and remove excess water during rainy season. So that the dams on the boundary zones should be able to function as a controller of water, then the design of dams must be equipped with a controller such as spillways and bypasses.
5. Water zoning formed by compacted peat dams in areas that have a similar elevation, where the compacted peat dams serve as the boundary zone. Zoning area of water will greatly depend on the topography or gradients of peat lands. More steep peat lands, more narrow distribution of its zoning areas, and more the number of zones.

Thus a water management system in plantation has to perform several functions. Specifically, it should:

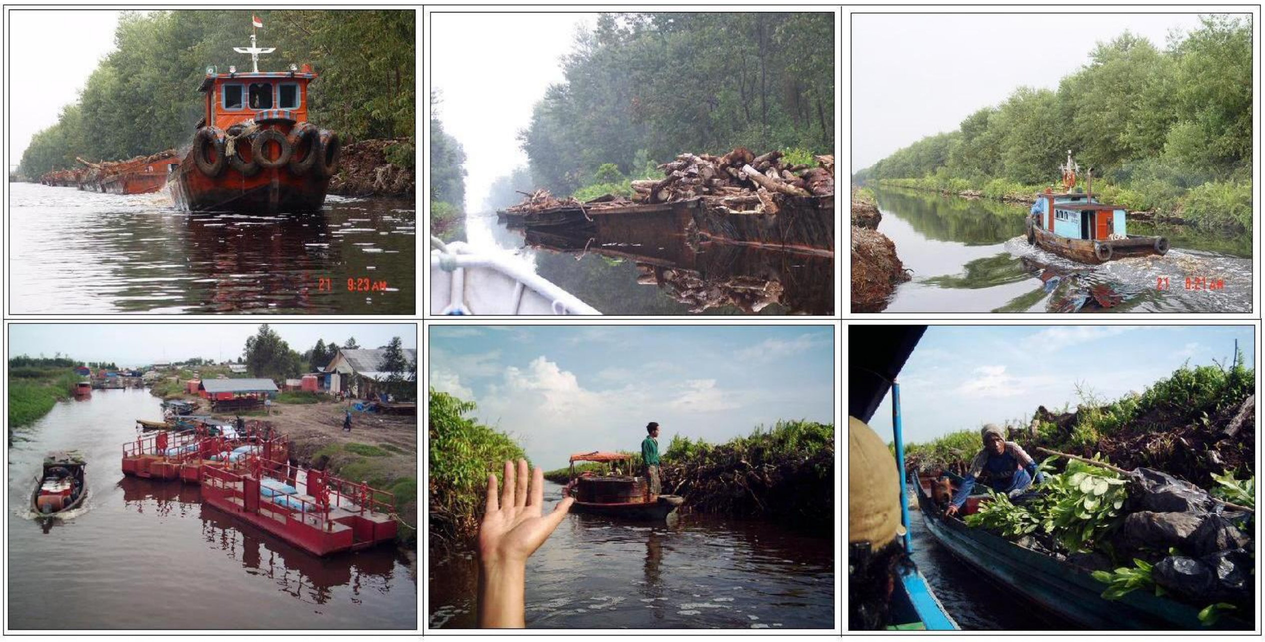
- Control (maintain) the water level at sufficient levels to meet transport requirements,
- Control (maintain) the water level at sufficient levels to meet tree crop water requirements.

RELATIONSHIP BETWEEN WATER TABLE AND CROPS YIELD



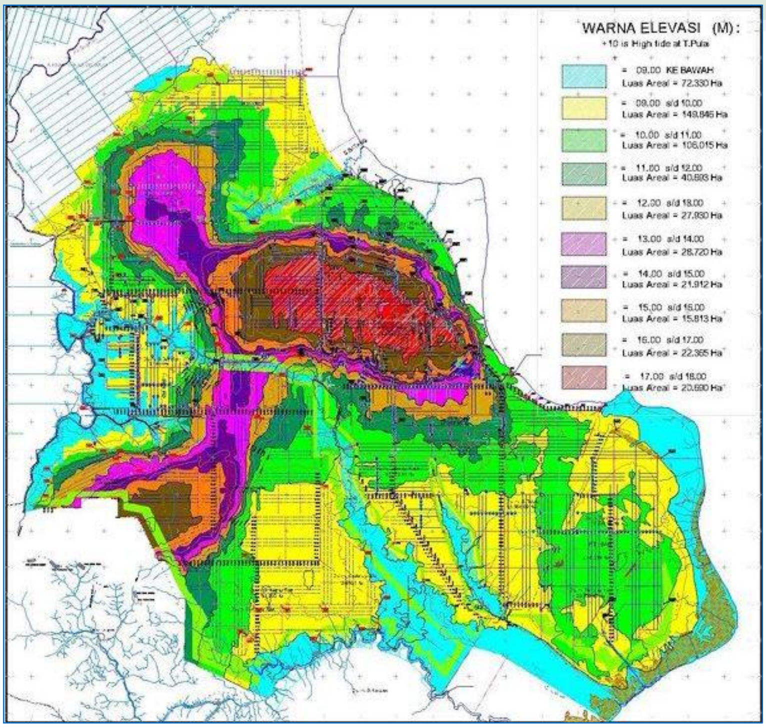
sources: Research and Development of APP, relationship between water table and crop yields, water table is one very important thing to be managed in the plantation industry to get maximum crop yields.

WATER ZONING SYSTEM WITH CANALS BLOCKING FOR TRANSPORTATION ACTIVITIES



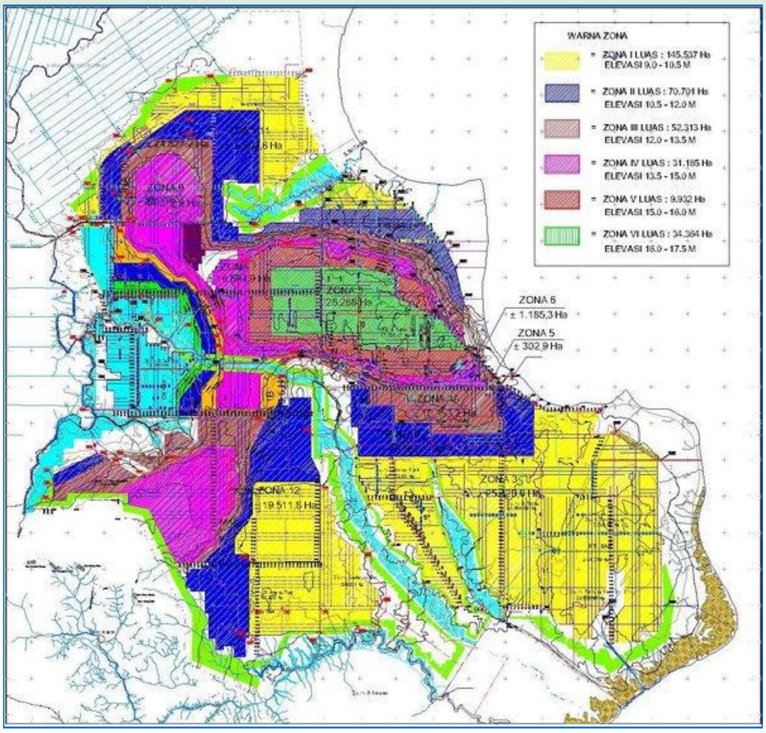
Transportation activities in the plantation by using the canals including transport of logging, fuel, seeds, etc.. This can be done with water zoning.

CONTOUR MAP FOR WATER ZONING



contour maps which colored every one meter interval as the main data to make the water zoning.

WATER ZONING SYSTEM WITH CANALS BLOCKING IN THE PLANTATION



zoning map, each zone boundary is limited by dams with water control structures.

COMPACTED PEAT DAM AS BOUNDARIES OF WATER ZONING

NOTE: dam width in plantations is about 6 – 10 metres and with a crest at the level at the surrounding peat. They are robust, but still require some maintenance.
In rehabilitation schemes, this will be upscaled to 10 to 20 metres to make them even stronger and maintenance-free. Crests will be 1m above the surrounding peat.

WATER CONTROL STRUCTURES FOR MAINTAIN WATER LEVEL

water control structures in peat land in APRIL area was originally formed by several narrow and shallow canals with 10 m spacing. Over time, canal bottom eroded by water and make deeper. Then the canal made wider and the bottom of canals coated with geomembran to prevent scour by water.

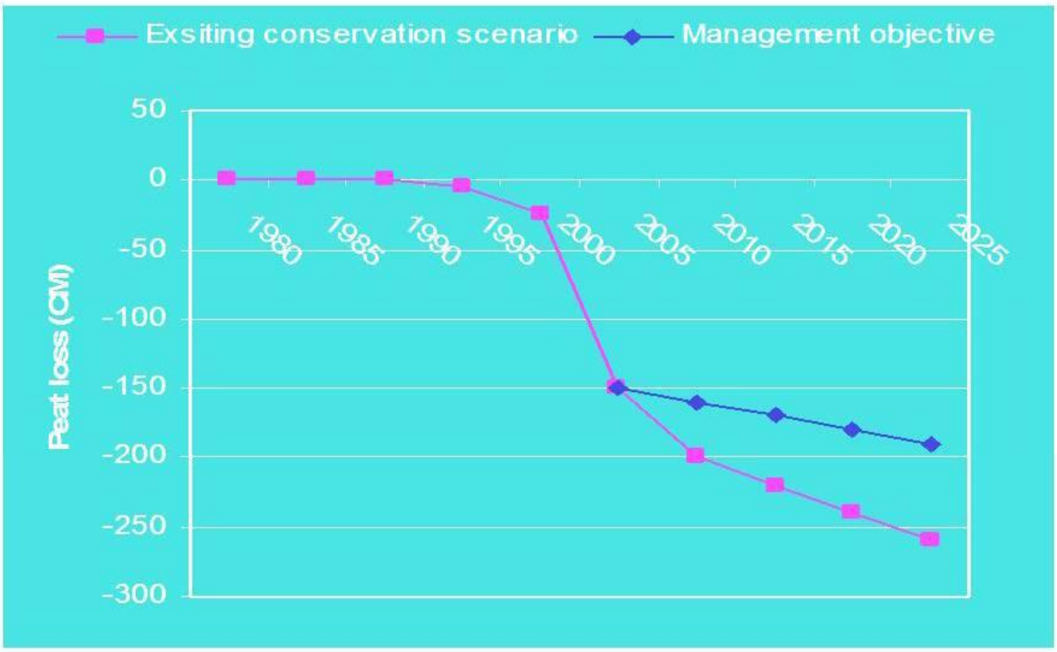
WATER CONTROL STRUCTURES FOR MAINTAIN WATER LEVEL

water structures in the APP area built by an open metal box painted with anti corrosion. in front of the building is equipped by wood slabs that serves as water controller and opened during the rainy season.

SUBSIDENCE IN PLANTATION AREA


picture above shows there has been subsidence, mostly by fire in 1997.

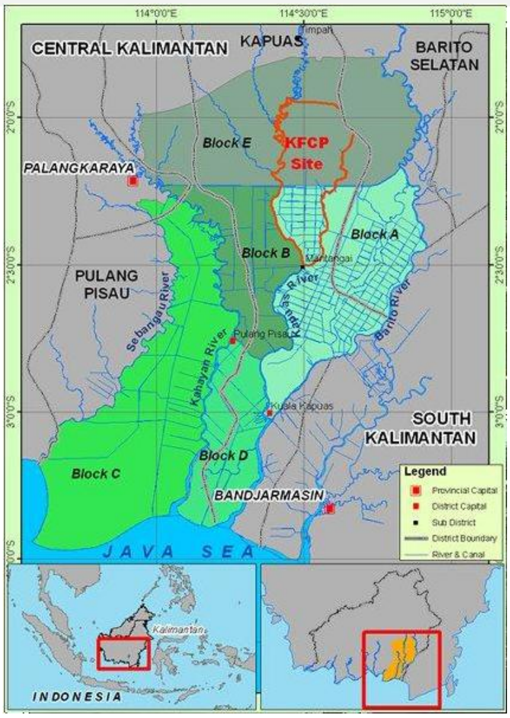
SUBSIDENCE IN PLANTATION AREA



sources: Research and Development of APP, chart above shows the subsidence of peat in the plantation area. With water management, the subsidence rate can be reduced to blue line.

SECOND:
HYDROLOGICAL REHABILITATION IN KFCP AREA

KFCP area covering 120,000 Ha is bounded by two rivers, Kapuas River in the west and Mantangai River in the east. Within the area more than 300km of canals were dug in 1996-97, which has left the area divided into 47 compartments most of which are roughly 5km by 2km in size.



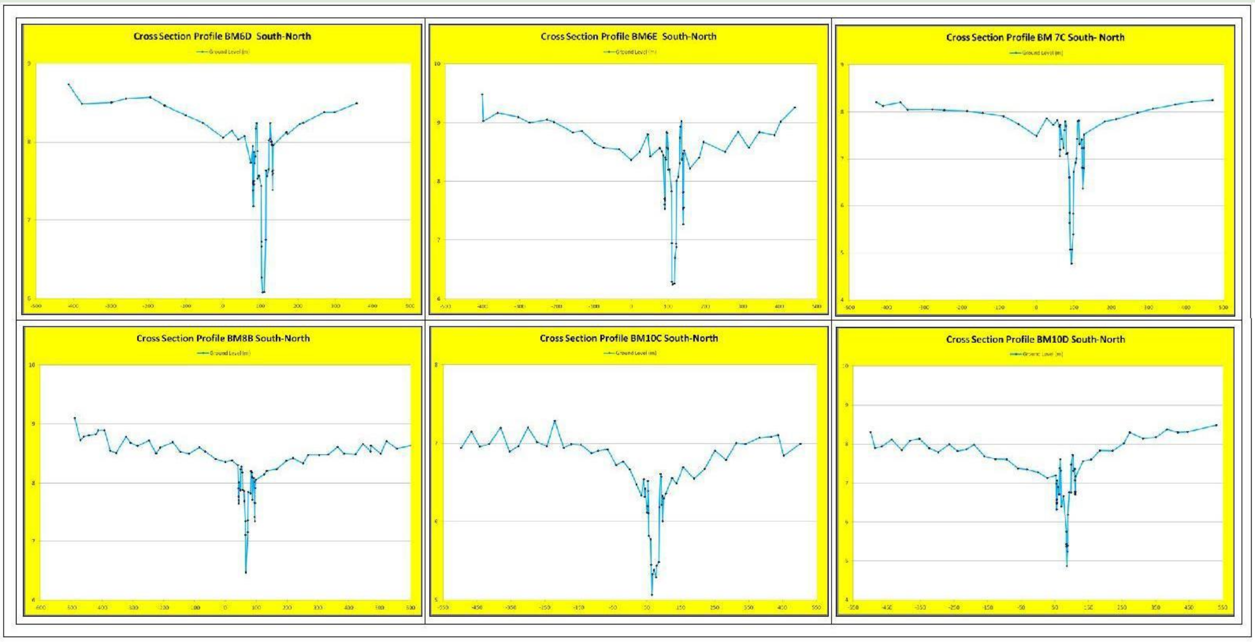
THE OBJECTIVE OF HYDROLOGICAL REHABILITATION

Why is necessary to hydrology rehabilitation in KFCP Area?

1. **The highest impact of drainage canals has occurred within a few hundred meters from each canals and has resulted in subsidence of the oxidation (and possibly fire) is the greatest closer to the canal. This pattern of subsidence has resulted in the formation of "mini peat domes" within each compartment.**
2. **Canals blocking will push up the upstream canal water-levels, which in turn will help to keep groundwater-levels high and so reduce drying out of the peat, reducing fire risk.**
3. **blocking of canals will improve soil moisture conditions for forest re-growth and replanting**
4. **The system of canal blocking will have an important positive long-term impact, on reducing future GHG emissions. The difference in emissions between the situation after canals blocking and the current situation without canal blocking will define the overall emissions reduction.**

The objective of hydrological rehabilitation is to raise water levels as high as possible in order to (a) reduce peat oxidation, (b) reduce fire risk and (c) improve soil moisture conditions for forest re-growth and replanting. This can best be achieved through the blocking of canals that can also limit access to the area.

CROSS SECTION CANALS IN DEEP PEAT



picture above shows subsidence has occurred around the canal until a few hundred meters of each canal due to drainage

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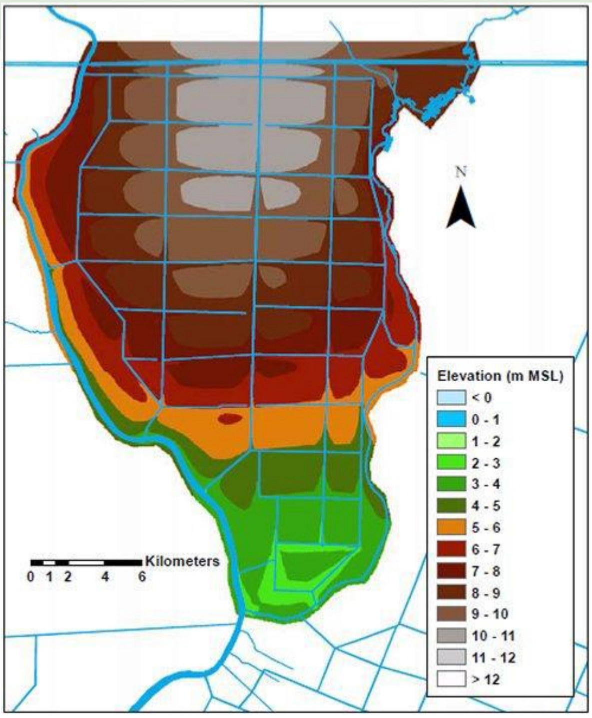
ELEVATION MAP OF KFCP AREA



map above shows there has been subsidence that began around the canals, and form a small peat dome.

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A BRIEF OUTLINE OF THE KFCP APPROACH TO HYDROLOGICAL REHABILITATION

The method requires 4 components:

1. **Compacted peat dams, which are the robust 'hard blocks', using excavators.**
2. **Partial canal-infilling, with peat from 'berms' on canal side.**
3. **Larger numbers of palissades and other light constructions using traditional techniques. This is mostly to keep the partial infilling material in place in 'debris blocks'.**
4. **Revegetating canals, not just canal sides, starting with compacted peat dams and debris blocks.**

Each of these components is essential for succesful canal blocking. <u>Only</u> Component 1 and some of Component 2 requires excavators. Compenents 3 and 4, and some of Component 2, require manual labour from local communities. Most KFCP project time and budget for rehabilitation will go to Components 3 and 4, i.e. to local communities.

THE KFCP APPROACH TO HYDROLOGICAL REHABILITATION

KFCP approach to hydrological rehabilitation, consist of: compacted peat dams, palisades, partial canal infilling, and revegetating canals.

WHY THE KFCP WATER MANAGEMENT AND PEAT EXPERT TEAM FINDS THAT EXCAVATORS ARE NEEDED TO CONTRIBUTE TO CANAL BLOCKING

In brief:

1. **Field evaluations in the EMRP Master Plan project, by a large team of engineers and peat experts (from Mott McDonald, Deltares and Witteveen & Bos) have shown that the dams built to raise water levels in small-scale projects (especially in Bloks A, C and E) have not worked as they are too few, not strong enough, not high enough and are therefore destroyed very quickly.**
2. **Engineering expertise and peat science dictate that only a large number of compacted peat dams, that can only be built with excavators, can raise water levels in the long term.**
3. **This system of compacted peat dams have been well proven in many plantations in peatlands: it is standard technology there. Also, it is very cost-effective.**

In this presentation, we will demonstrate these three points. We conclude that the use of excavators offers the only chance for KFCP, or any other project, to demonstrate that canal blocking can be A) robust, B) effective in reducing carbon emissions and C) cost-effective.

FIELD EVALUATIONS OF THE CONDITION OF THE EXISTING BOX DAMS IN THE KFCP AREA

- The following photos are from one area, along the first canal that KFCP aims to block in the Demonstration Phase, but they are representative for all dams build to date for peatland rehabilitation in Kalteng.
- The EMRP Master Plan expert team already concluded in 2008 that the longest period a box dam filled with sand bags would last is 5 years (we find this is usually less than 2 years), and that box dams filled with peat will only last 1 or 2 years without constant rebuilding.

BOX DAM 01 on the CANAL SPU-7 NORTH

February 2009	June 2010	March 2011

- Box dam 01 is located on the canal SPU-7 North, 50 m SPI-1 , built in 2007 by the CKPP project.
- The dam was partly destroyed in 3 years, fully in 4 years.

BOX DAM 02 on the CANAL SPU-7 NORTH

August 2010	October 2010	February 2011

- Box dam 02 is located on the canal SPU-7 North, 900 m SPI-1, built by the CKPP project in August 2010.
- The dam was partly destroyed within 3 months, fully in 6 months.

BOX DAM 03 on the CANAL SPU-7 NORTH

July 2010	October 2010	March 2011

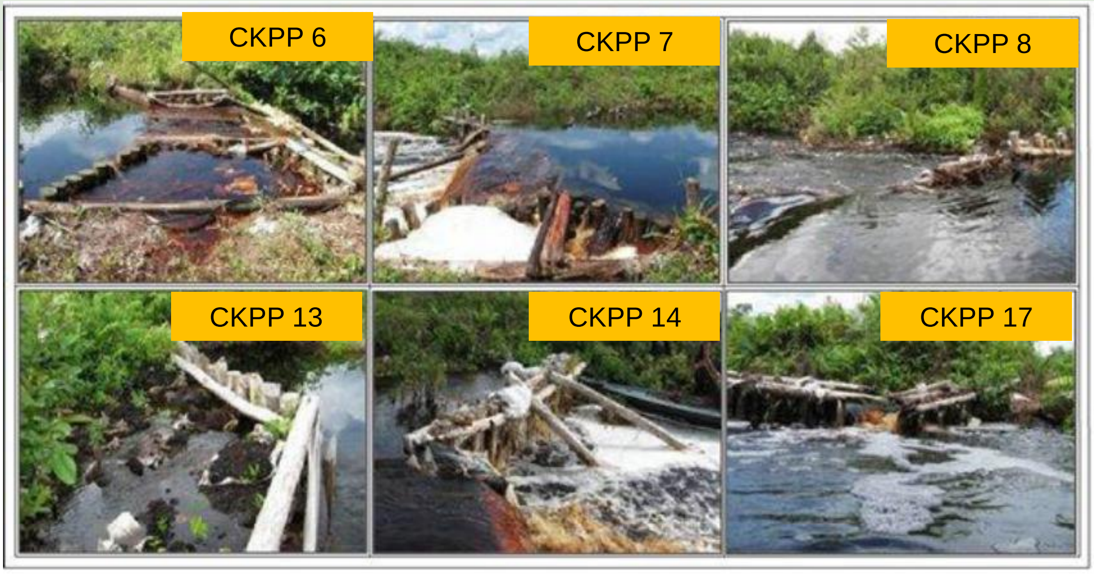
- Box dam 03 is located on the canal SPU-7 North, 1 km from SPI-1, built by the CKPP project in 2008.
- The dam was destoyed within one or 2 years.

Overview of dams built by CKPP in 2007 (-2010)
Status of new dams directly after building

Wooden box dams, filled with sand bags, small numbers so large head differences, very low crests, little understanding of engineering and peat science.

The cost of individual dams was estimated at above $10,000

Overview of dams built by CKPP in 2007 (-2010)
Status of dams in 2009-2010



Most dams have been destroyed completely within a year. Others were bypassed, so part of the dam still stands but water levels were not raised.

Note that we have similar photo series of destroyed dams for other box dam types, e.g. peat-filled ones in Blok C.

As CKPP was a Pilot Project, lessons should have been learnt: this small-scale approach to canal blocking can not work. Professional approach is needed.

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Summary evaluation of dams built up to 2010 for peat rehabilitation, all using wooden box-dam type designs

The reason such box dams have not worked, are:

- Box dams can only be built with manual labour: this is very slow, expensive and inefficient, so only small numbers of dams can be built (CKPP: <20 in Block A/E). This causes a number of problems:
  - Loss of any dam means loss of the effect of the whole system.
  - Dams are too far apart, so water level differences are too great: water levels are not brough up much and water pressure on dams is too great.
- Dam crests are too low, so water flows over them which erodes the dams. SOLUTION: dam crests must be high, water should never flow over them.
- Box dams are narrow (<6m) and will inevitably have water flow/leakage through and around them: the dams will inevitably erode. SOLUTION: dams must be wider and made of more compact material.
- Wood is not a strong building material: it decomposes. SOLUTION: stronger material needed.
- Sand bags are an usuitable filling material, as they are weak and too heavy: the dam sinks into the peat, lowering the crest. SOLUTION: use peat as a building material, as it has the same weight as the surrounding peat.
- Peat that is not sufficiently compacted (which is impossible without excavators) is an unsuitable filling material: it is far too weak. SOLUTION: only use compacted peat, which is much stronger and has no leakage.

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Summary evaluation of dams built up to 2010 for peat rehabilitation, all using wooden box-dam type designs

EMRP Master Plan evaluation (2009 report): "box dams can last 5 years at the very most when filled with sand bags, only 2 years when filled with peat: using sandbags results in somewhat stronger dams (uncompacted) peat, but not much. All box dams will need continuous maintenance."

KFCP evaluation with much more field data: even box dams filled with sand bags will be destroyed within a year.

Conclusion of both projects (and other evaluations, by professionals and donors): wooden box dams can never work at the large scale and in the long term, an alternative approach is needed.

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THE KFCP APPROACH, BASED ON INDONESIAN AND INTERNATIONAL ENGINEERING AND PEAT EXPERTISE

Experts in EMPR Master Plan (2008: MottMcDonald, Deltares, Witteveen and Bos) and KFCP have designed this approach:

- The objective of the Hydrological Rehabilitation is to bring up water levels along the canal to as high as possible to A) reduce carbon emissions as much as possible and B) ensure most water flow is over land so it does not destroy the dams.
- This can only be achieved by constructing a canal blocking system of many blocks, so head differences are less than 0.4m (target 0.2m): hundreds of structures are needed.
- As structures will block canal, maintenance will be impossible: dams must be very strong and last many years.
- Dams can only be that strong if they are made of compacted material and water never flows over them: their crests must be above the surrounding peat surface.
- For structural integrity, dam designs should aim at smaller head difference to avoid seepage endangering the structure, but this will require a much greater number of dams to effectively raise canal water-levels.

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THE KFCP APPROACH, BASED ON INDONESIAN AND INTERNATIONAL ENGINEERING AND PEAT EXPERTISE

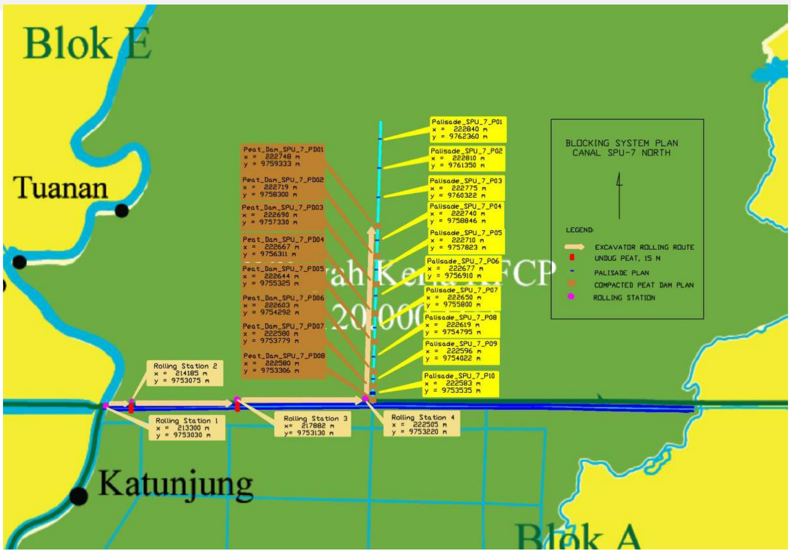
CONCLUSION: part of the work <u>must</u> be done by excavators, because that is the only way to:

- construct strong compacted peat dams in
- large enough enough numbers,
- relatively quickly and
- very cost effective.

The first canal blocking, in SPU_7 alone, aims to demonstrate this concept in Kalteng even though it is well-proven elsewhere.

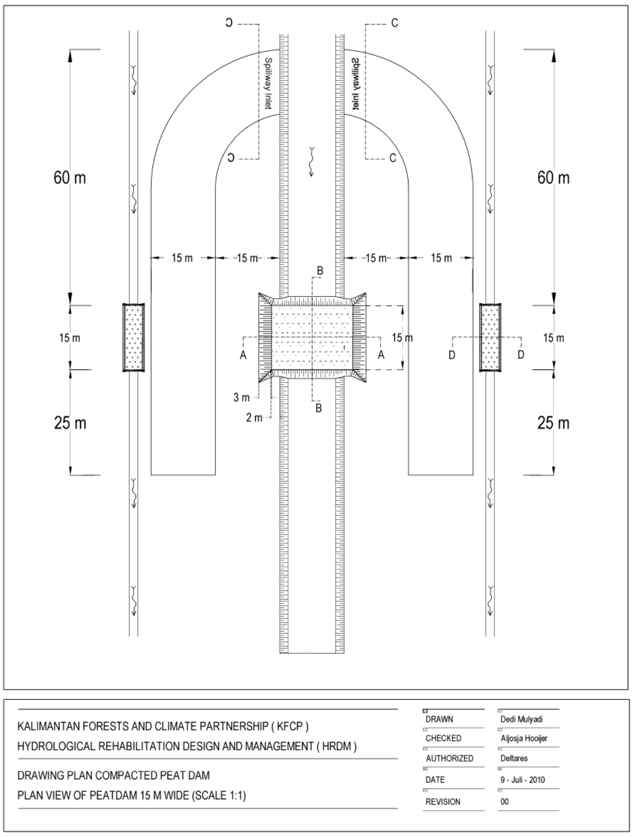
Nevertheless, most of the rehabilitation work in KFCP will still be done by manual labour, from local communities, using traditional techniques.

WORK PLAN FOR CANAL BLOCKING SYSTEM IN BLOCK E



- The canal blocking system will consist of a combination of dams are: compacted peat dams and other ‘soft’ blocking solutions that aim to fill up the canals along much of their length using ‘palisade & canal infilling’ blocks.
- Planned a number of 8 units of compacted peat dams and 10 units of Palisades, and 18 segments canal infilling.

COMPACTED PEAT DAM DESIGN AND MATERIAL CALCULATION

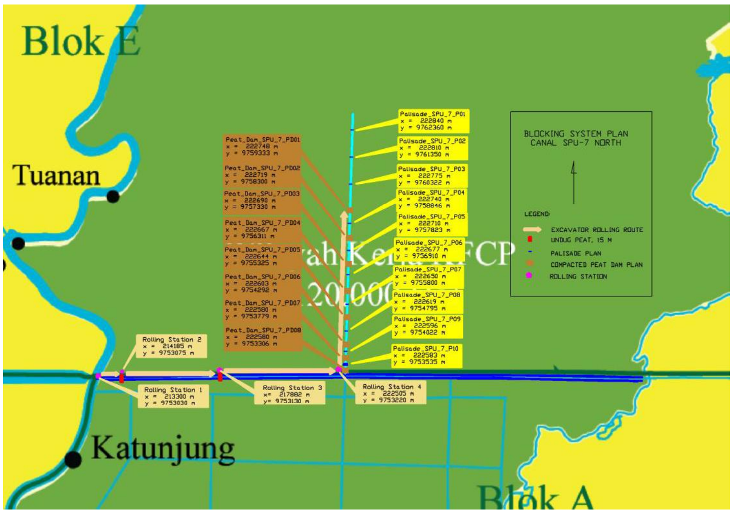


- Sample calculations will be taken on the canal SPU-7 North (Block E),
- Canal dimensions 13x2 m were measured in October 2011,
- The volume of peat are required to make a dam with dimensions of 13 x 15 m as follows:
  - Body dam = 585 m^3
  - Wing dams = 75 m^3
  - Sub Total = 660 m^3.
  - Total material with compaction = 1320 m^3.
- Material from the spillway as follows:
  - Spillway 1 = 750 m^3.
  - Spillway 2 = 750 m^3.
  - Total = 1,500 m^3.

BERM MATERIALS ON THE SPI CANALS

- Peat materials are still available in the SPI canal embankment, the measurement results for only one side of the canal is 4x6x2.5 m, so that the volume per meter run = 12.5 m^3. The length of the embankment measured = 3000 m, the total volume of embankment are available = 37500 m^3, enough to make 25 units compacted peat dams.

ROLLING PATH FOR EXCAVATORS



- Excavators will be rolling on the canal embankment with a maximum width of 6 meters along 15 km. In other words, for block E would be used a maximum area of 0.01% to cross the excavators.

Australia Indonesia Partnership
Kemitraan Australia Indonesia

PHOTOS: BERM MATERIALS WERE AVAILABLE ON THE SPI CANALS

Rolling path of the excavators over the canal embankment that almost burned every year until 2009.

Australia Indonesia Partnership
Kemitraan Australia Indonesia

PHOTOS: PLANNED ROLLING PATH OF THE EXCAVATORS

Rolling path of the excavators over the canal embankment that almost burned every year until 2009.

DIFFICULTIES FACING TO IMPLEMENT THE HYDROLOGICAL REHABILITATION IN THE KFCP AREA:

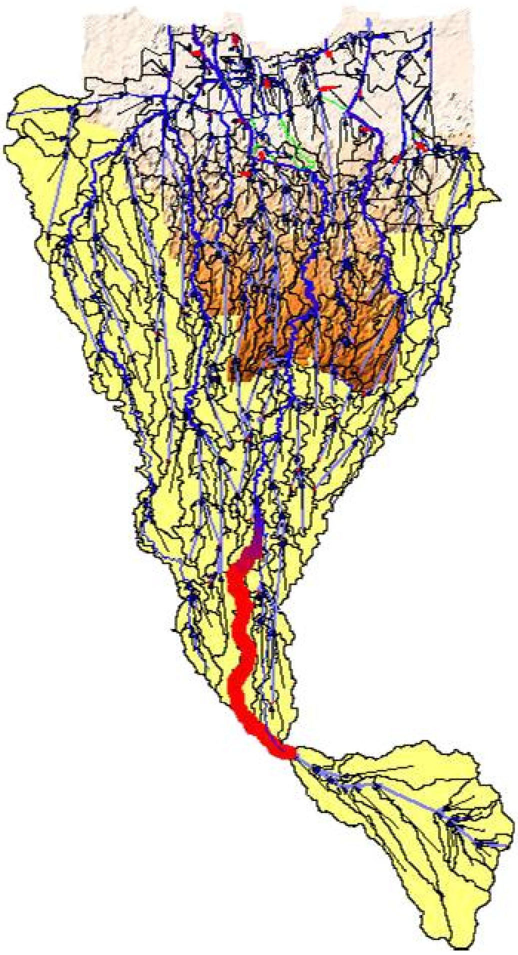
1. This project required by the environmental impact assessment (EIA, replaced by UKL / UPL, has not been legalized by BLH) and also required the village agreements (completed in November 2011).
2. Announcement of the tender phase 1, June 17, 2011 in the "Kalteng Pos“ and “Tabengan” newspapers, not succeeded in attracting a potential contractors.
3. Difficult to get permission for selective cutting of tumih wood from KFCP location. (tumih wood as a building material for palisades). KFCP still trying to get permission.
4. Limited berms material in the canal SPU-7 North for partial canals infilling and compacted peat dams, mostly have been lost by fire.

conclusion: from the point 1-3, KFCP not ready with this project, for point 4, can be solved technically in the field.

THANKS

hopefully useful

Australia Indonesia Partnership
Kemitraan Australia Indonesia



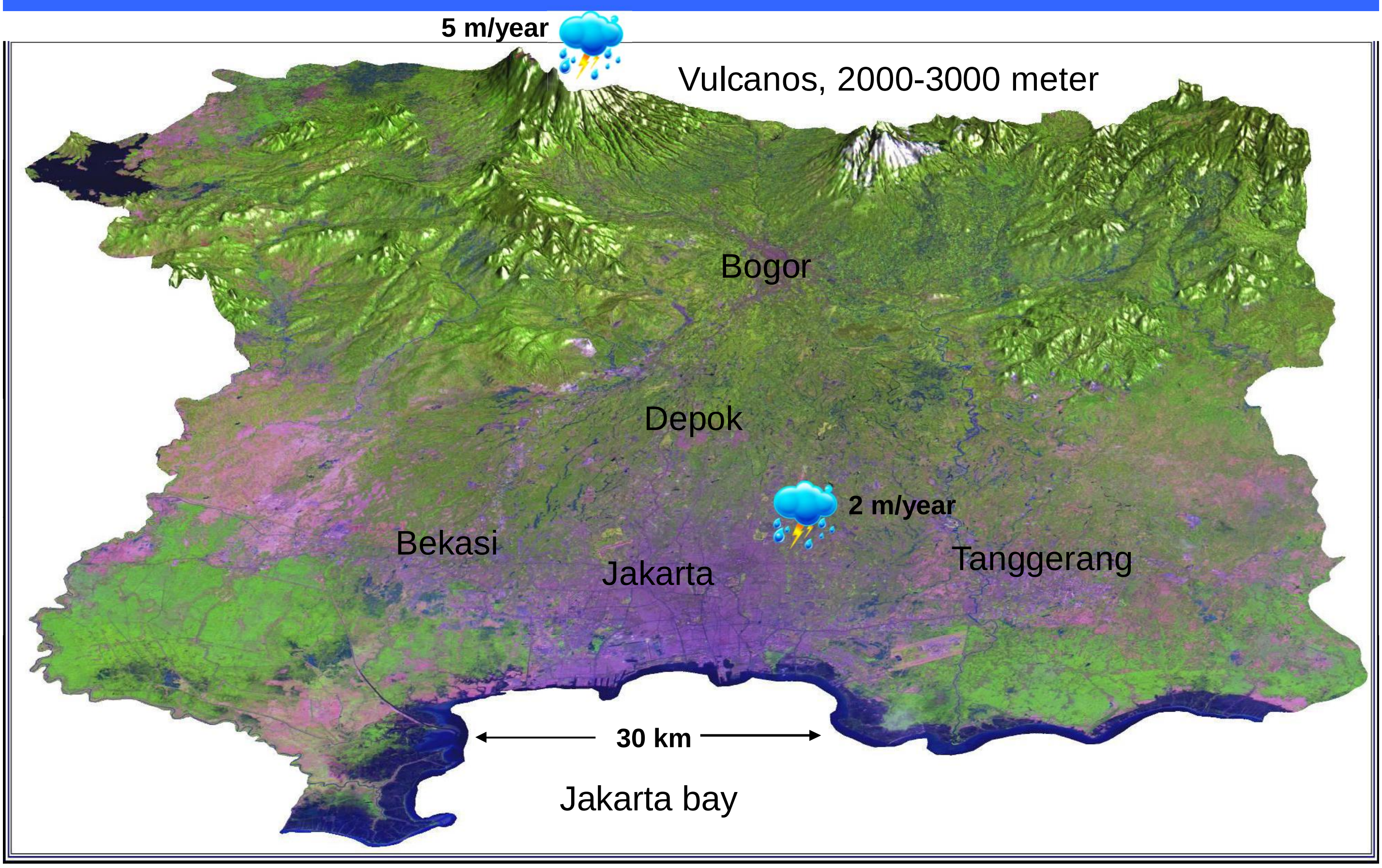
JCDS selection for JPC training in Banjarmasin

Jakarta Coastal Defence Strategy (JCDS) study

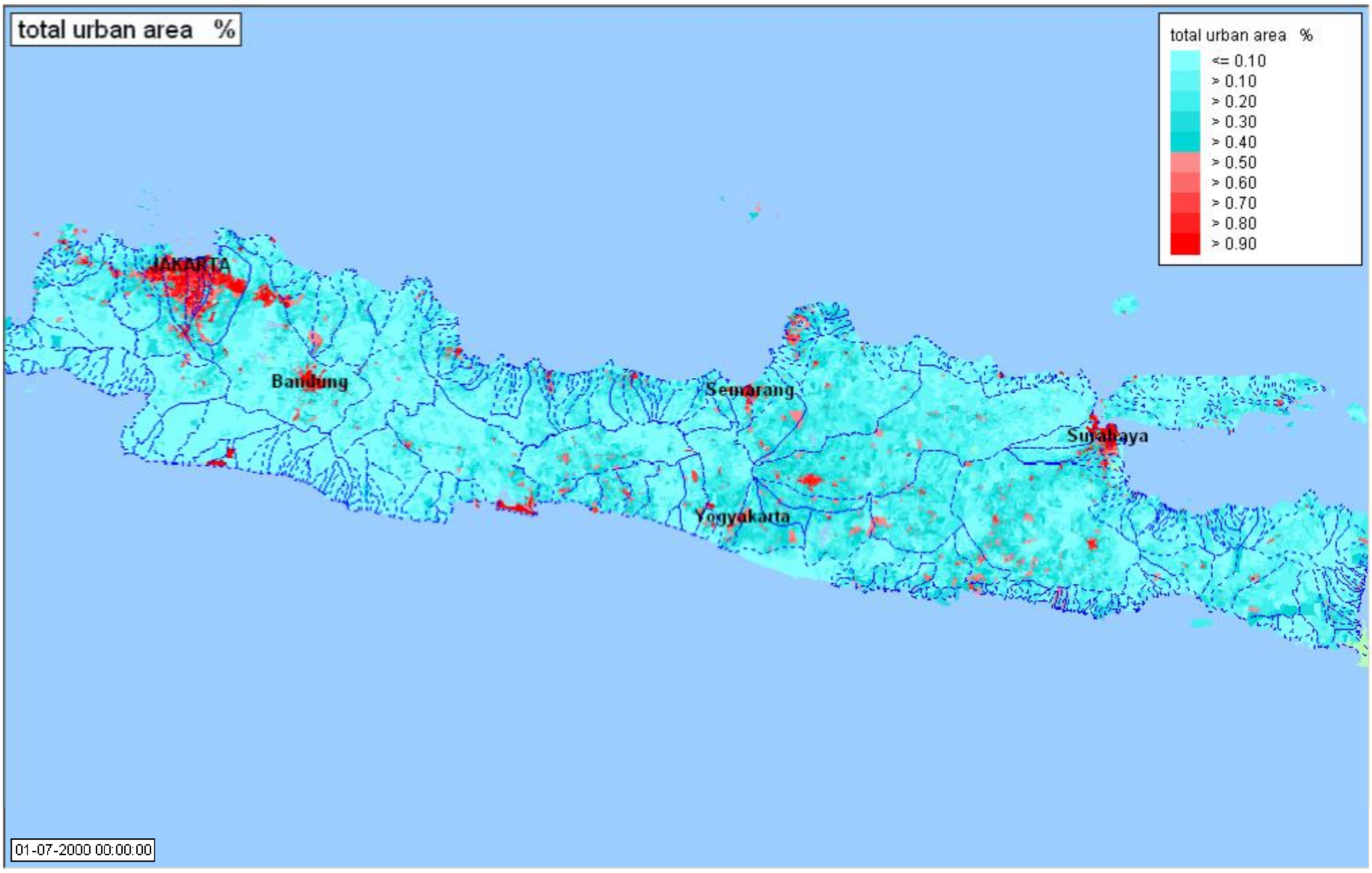
JanJaap Brinkman, Deltares

Integrated GOI-GON Delta approach

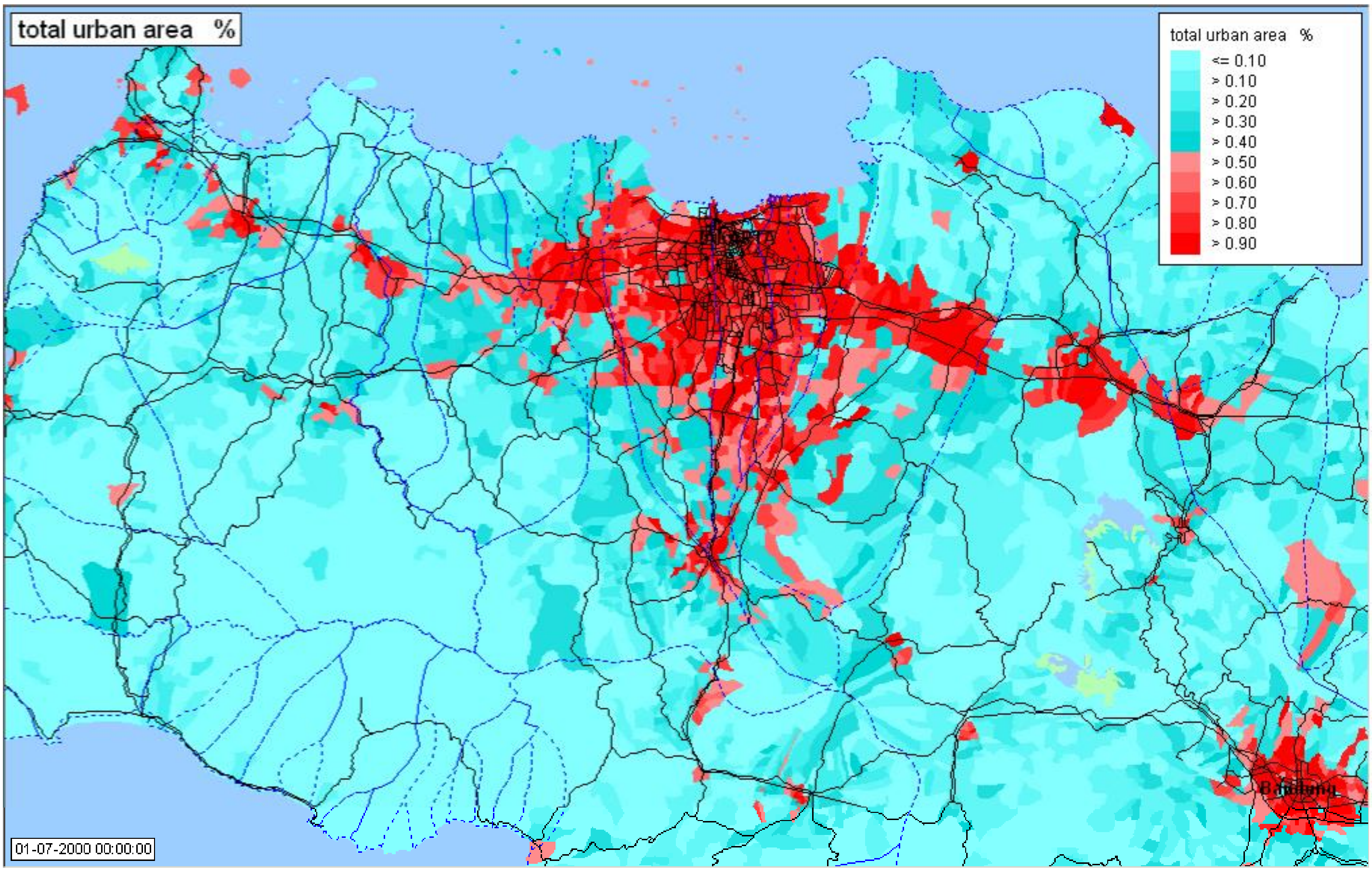
Greater Jakarta, 1992

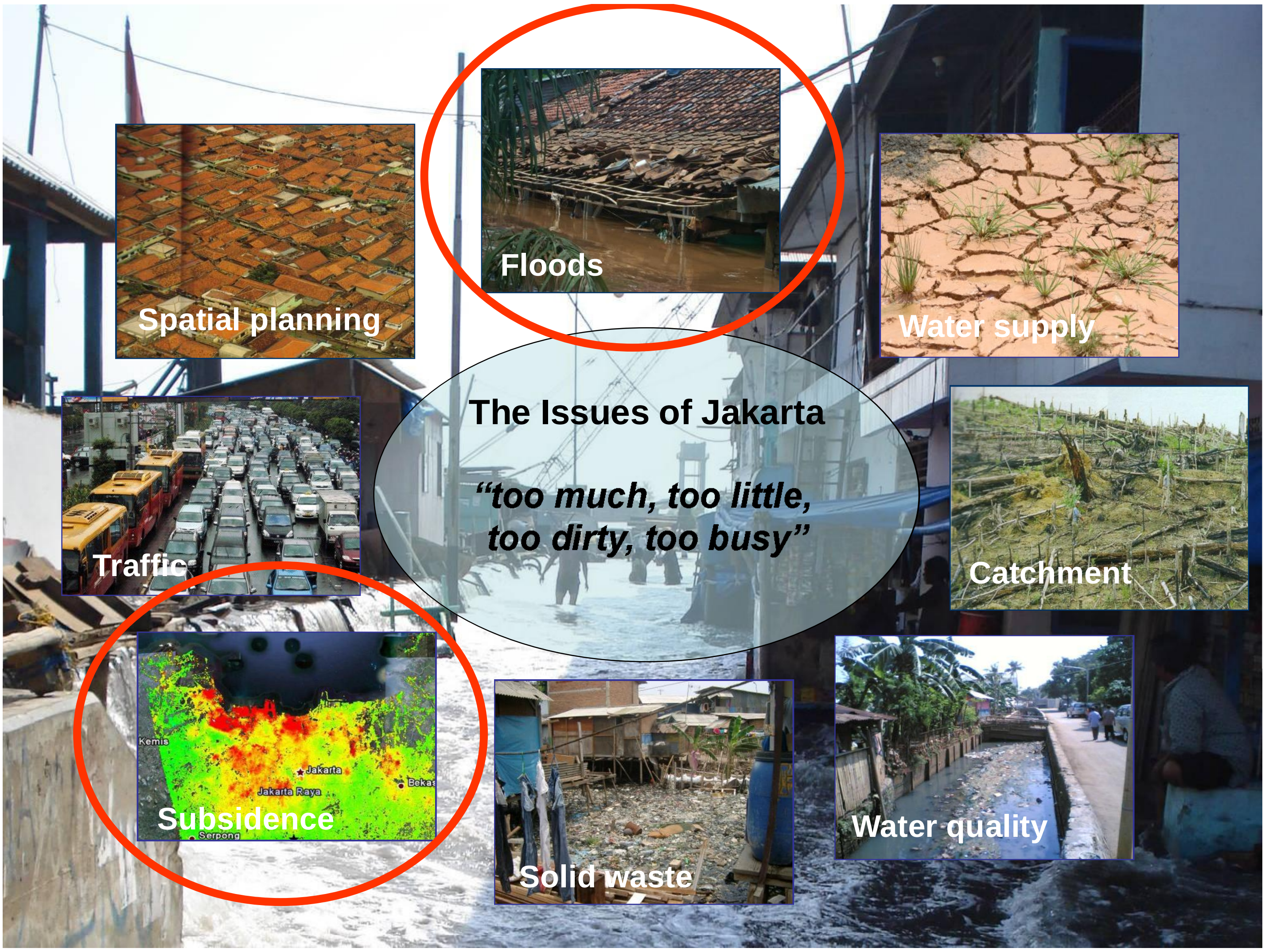


Indonesia is also changing - the urban area
2000 - 2025



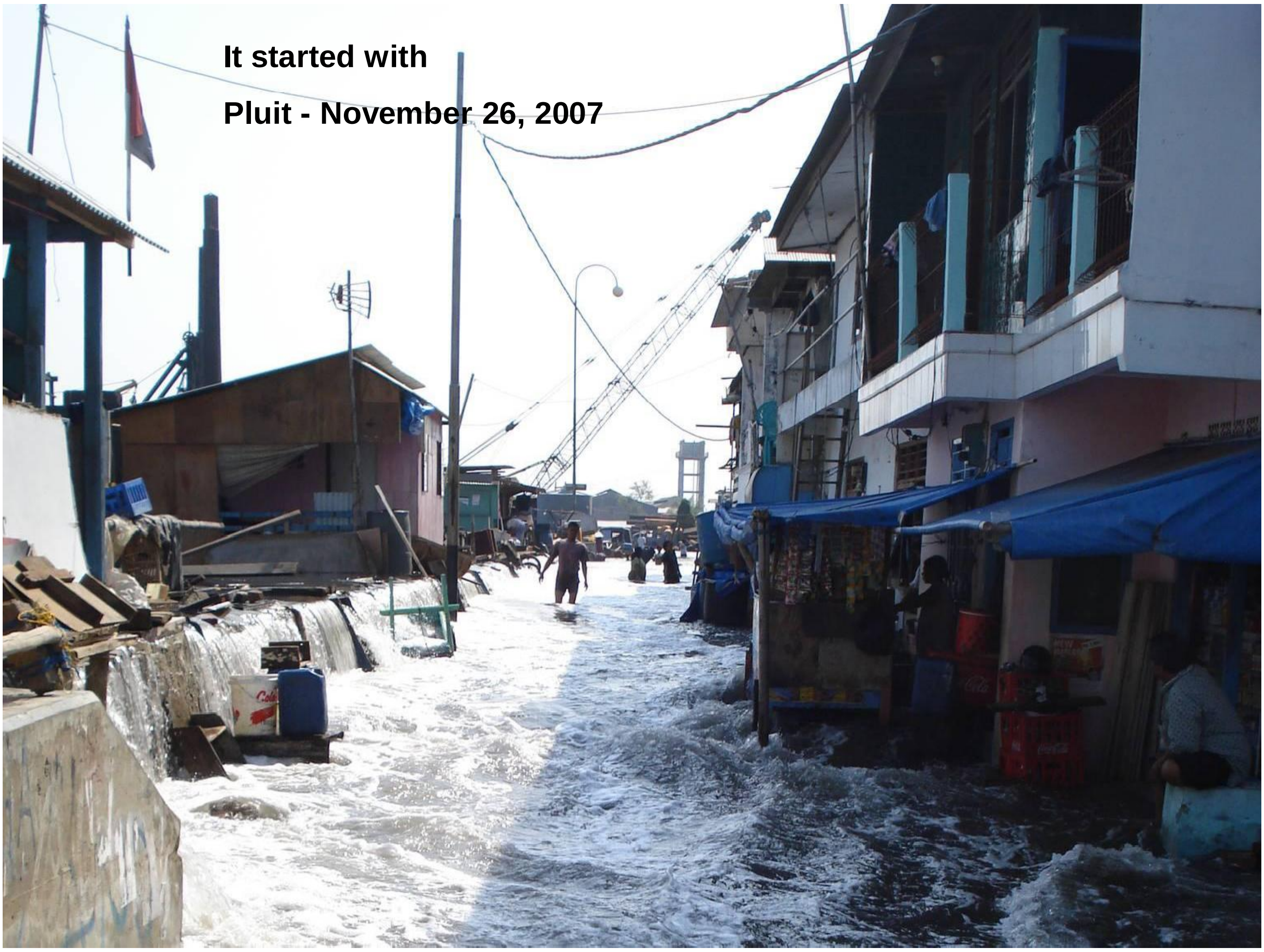
Including large change in the delta of Jakarta
2000 - 2025



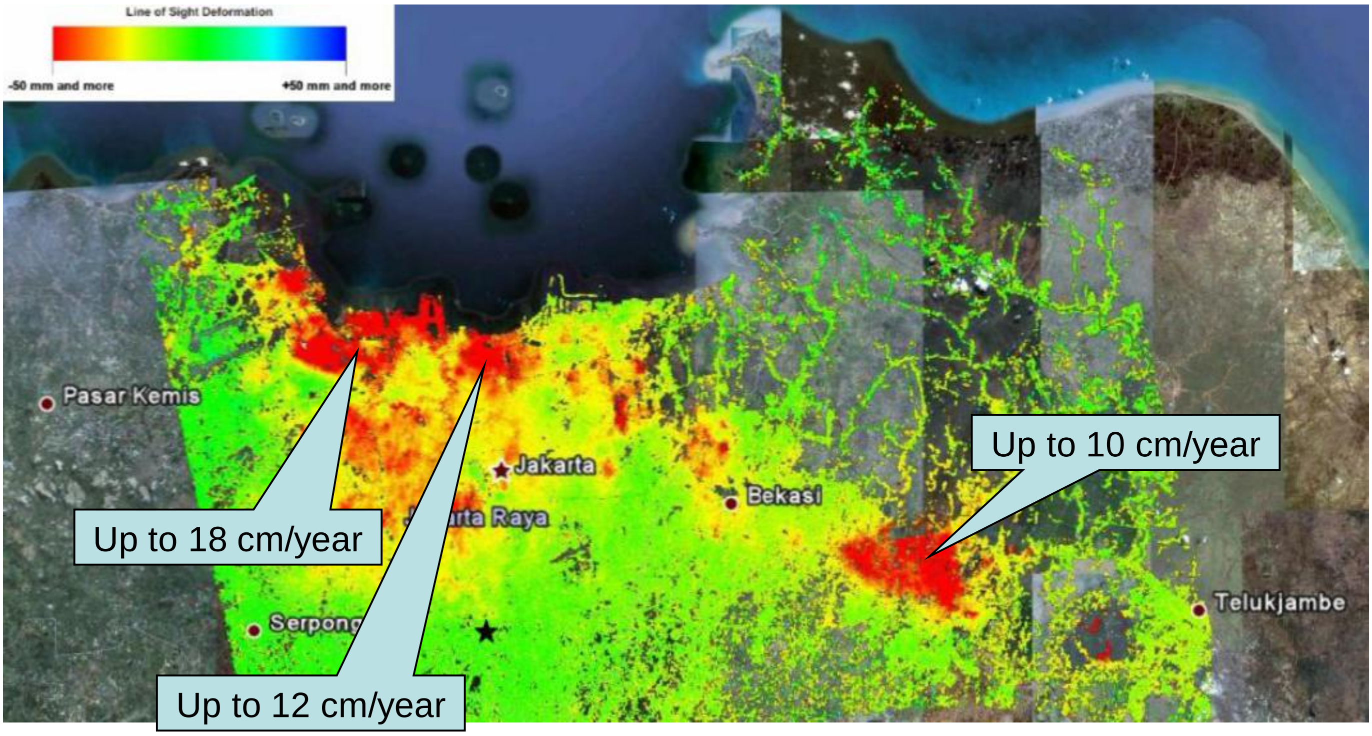


The floods of Jakarta

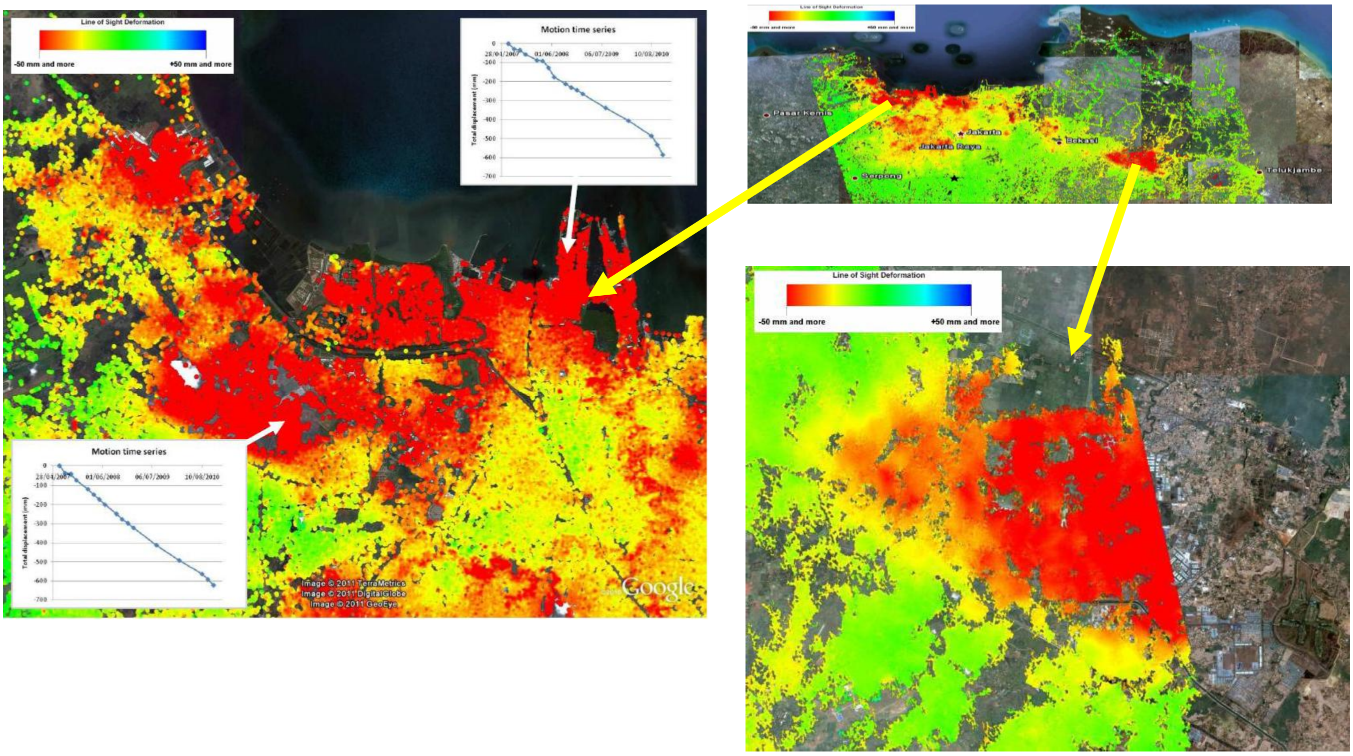
- Floods from the rain (2007 – 2009)
  - Towards Jakarta Flood Management - JFM
    - Flood Hazard Mapping – FHM
    - DKI / BBCilCis – City flood rehabilitation
    - World Bank: JEDI/JUFMP
- Floods from the sea (2010 – 2014)
  - Towards Jakarta Coastal Defence Strategy and Master Planning (JCDS)



ESA – Jakarta subsidence



ESA – Jakarta subsidence



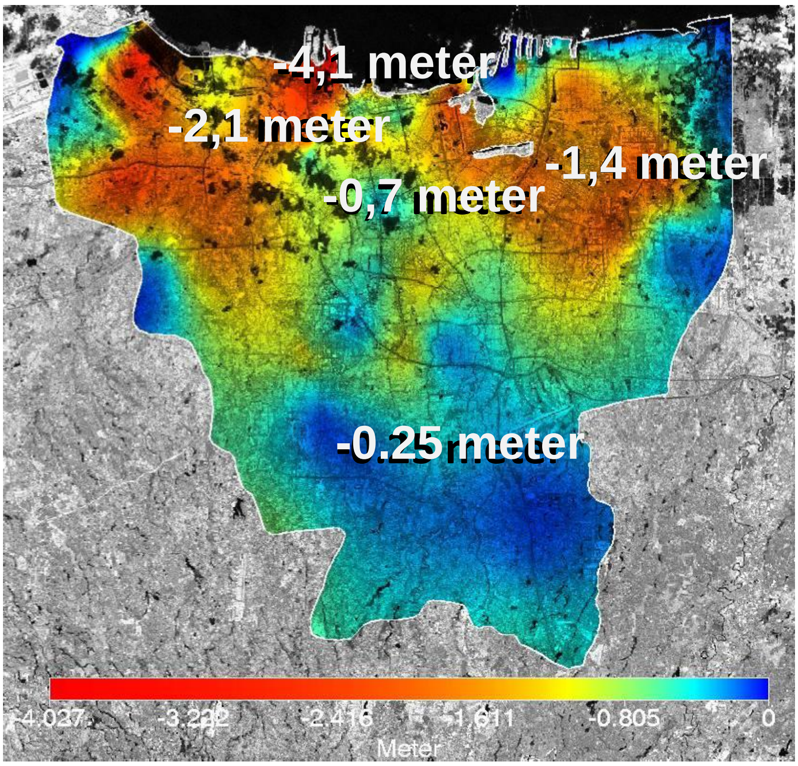
Subsidence Map

Subsidence map of Jakarta 1974-2010:

Total subsidence -25 up to -400 cm ; rate -0.5 up to -17 cm/year

First recorded of leveling data were in 1974. Base on acumulated data, interpolation and extrapolation we can make subsidence map of Jakarta from year 1974 up to 2010.

Base on latest analysis of piezometric surface data found that initial condition of subsidence were probably on 1965. In this case in the near future we will try to modeled subsidence map of Jakarta for year 1965 up to 2011



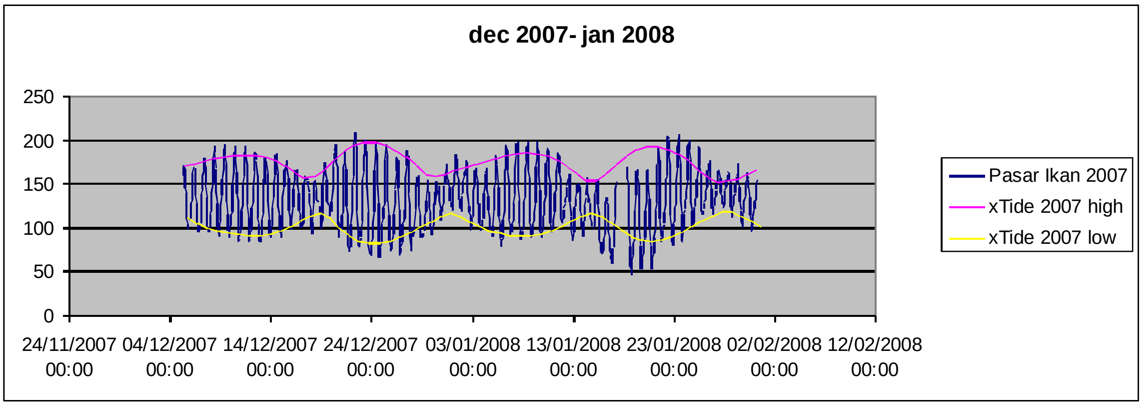
Rob November 25, 2011

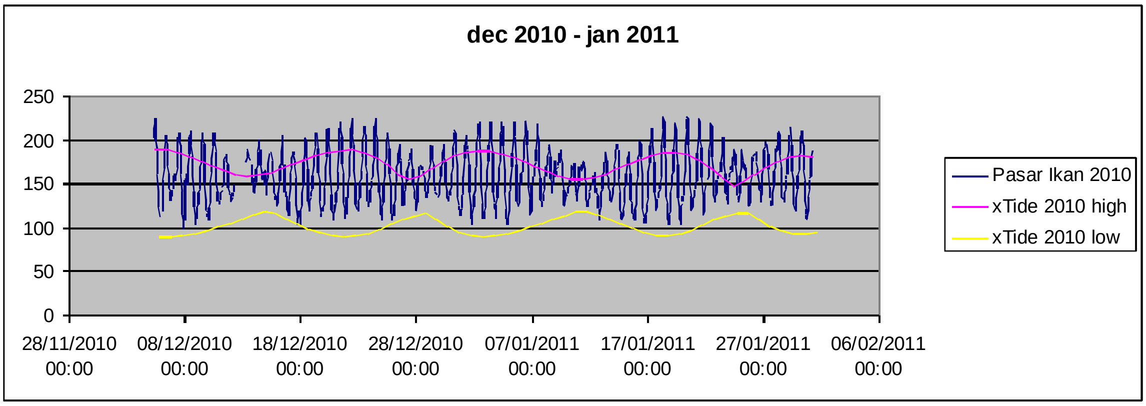
With thanks
pak Hermanto – Pasar Ikan
pak Hendry Kurniawan - Pluit

November 25, 2011

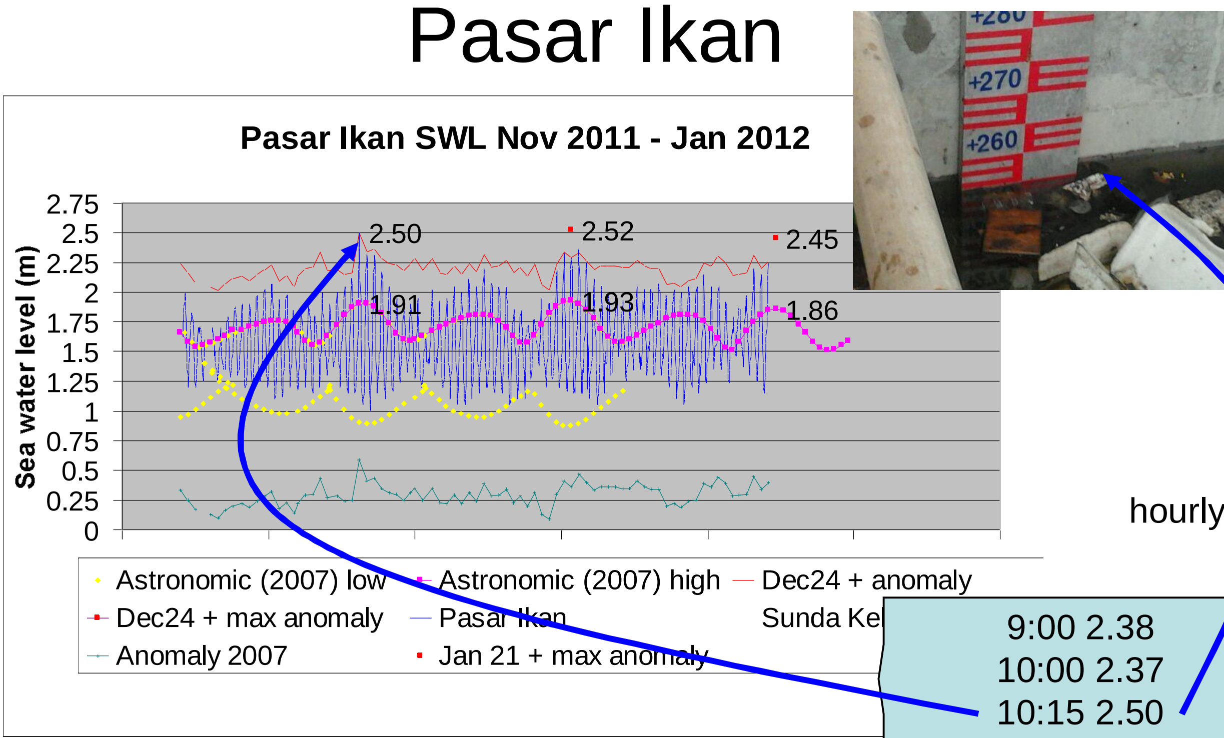
November 26, 2007

Pasar Ikan 2007 - 2010



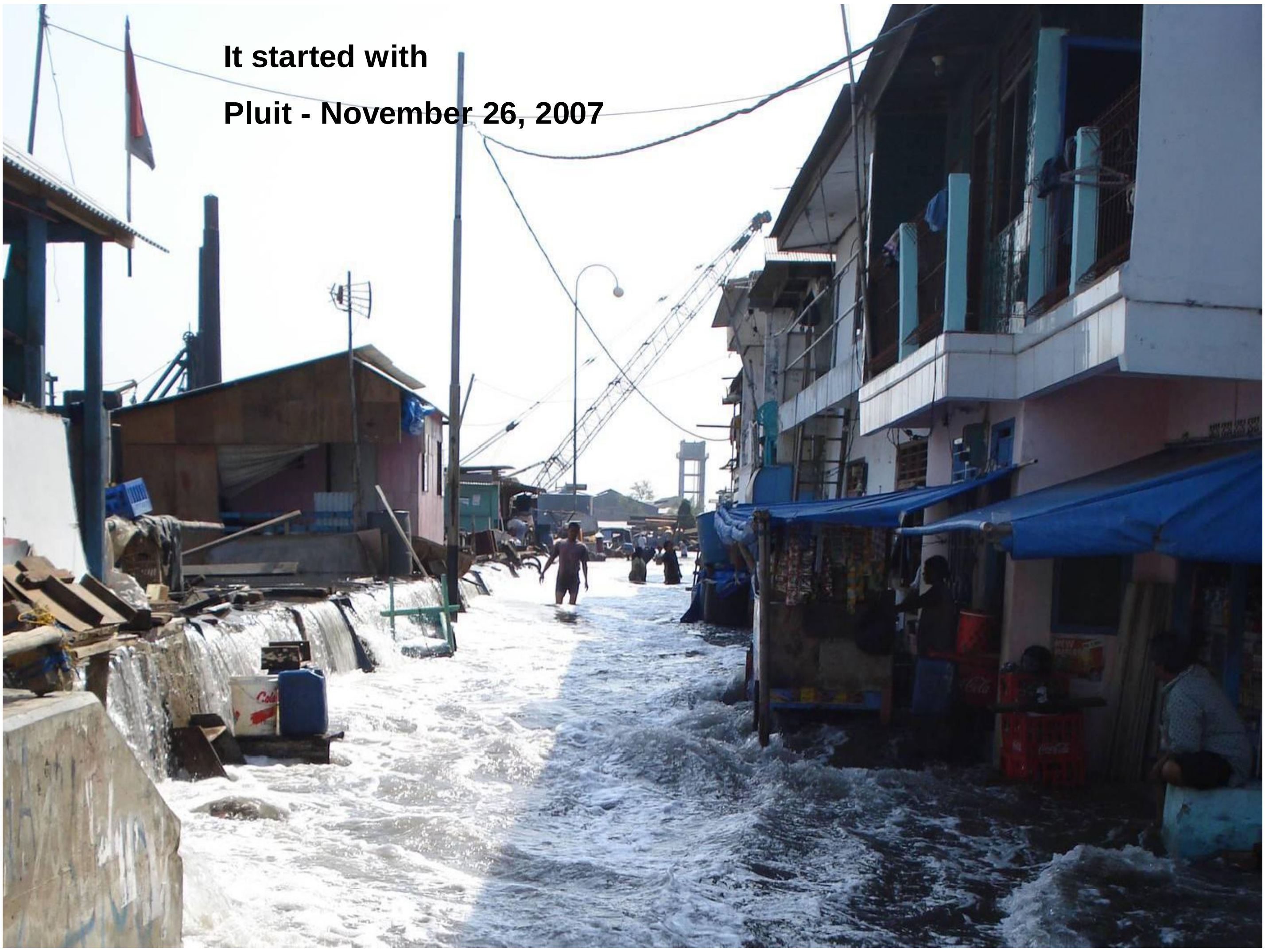


Nov 1 – Dec 14, 2011
Pasar Ikan



hourly

9:00 2.38
10:00 2.37
10:15 2.50
10:45 2.40
11:00 2.17
12: 2.10



Immediate government response

November 26, 2007

December 23, 2007

November 15, 2008

November 15, 2008

"Sea level versus River and Sea Wall" somewhere in Jakarta

Pluit pumping station

Dermaga Pelindo Limpas

Pluit Pumping Station

Banjir Kanal Barat

Still open Channel

Need to be closed in future, because of subsidence

Needs pumping station and storage pond

May 2009:

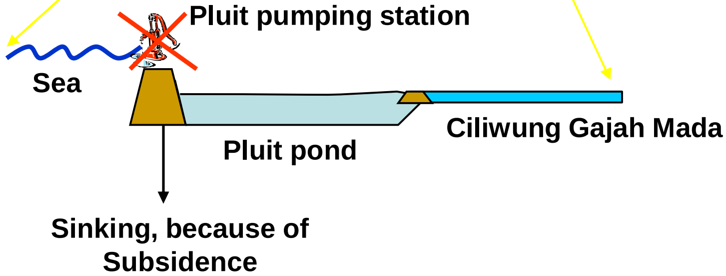
•Sea water level 2.50m (pasar ikan (pi))

•Pluit Pump stopped pumping!

•In future no more pumping

•Pluit pump needs heightening

•Ancol pumping station stops pumping at sea water level 1.90m (pi)!



Pasar Ikan gate

Pasar Ikan gate – towards sea

Pasar Ikan Kampung

Marina gate

December 11, 2011

Already heightened and repaired

Pantai Mutiara

Pantai Mutiara

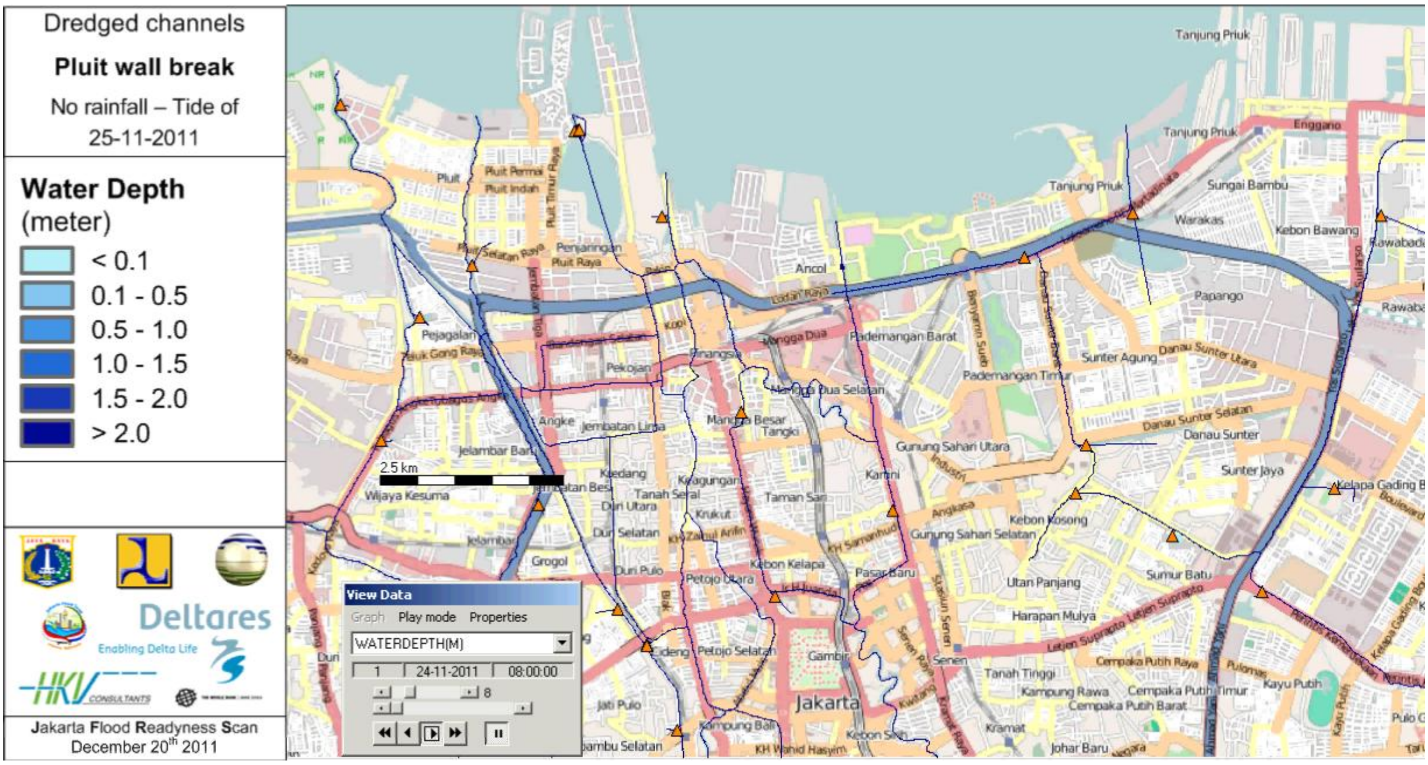
Pantai Mutiara

Pantai Mutiara

Pluit wall break

November 25, 2011

(what could have happen…)

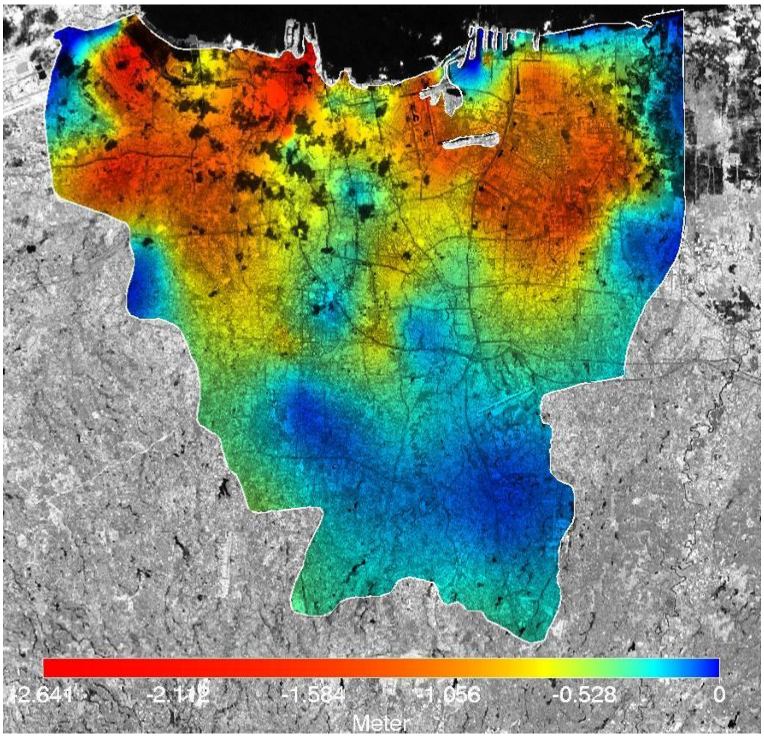


Future subsidence

FUTURE LAND SUBSIDENCE JAKARTA

When deep groundwater abstraction continues at current rate, Jakarta will sink 5-6 meters till 2100

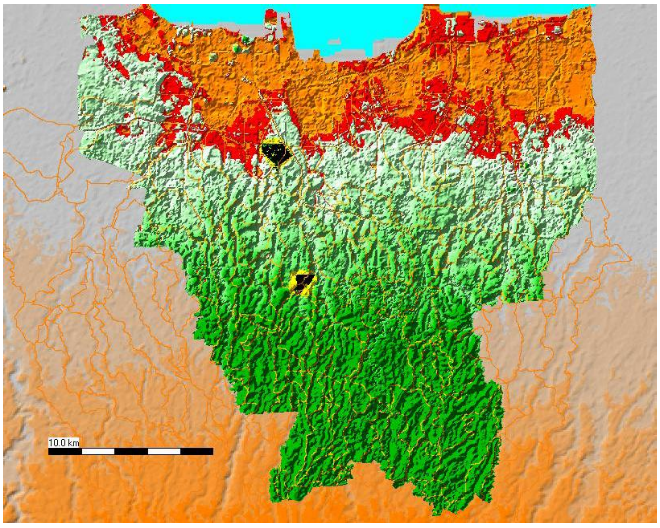
When deep groundwater is stopped in 2020, Jakarta sinking can be limited to 1.5 - 2 meters



PERIOD 2010-2030

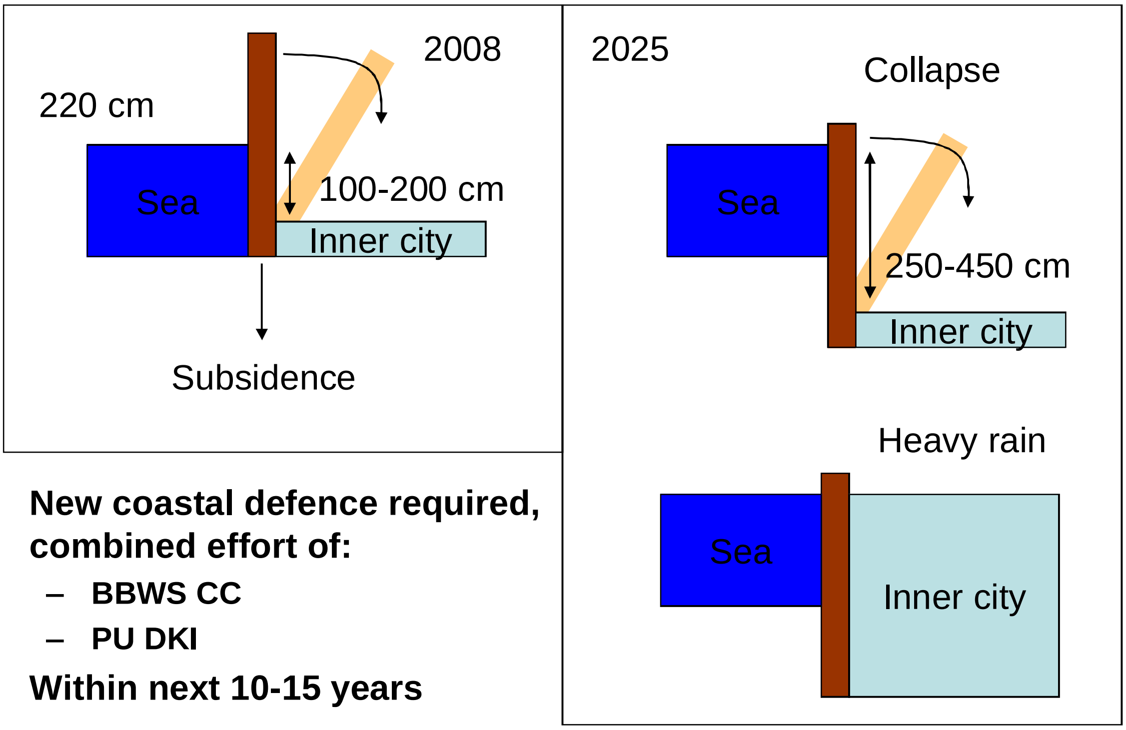
Protection against floods from the sea

"Large scale intervention required for a resilient Jakarta"



Pluit	1989-2007	2007-2025	Total
Sea level rise	4-6 cm	4-6cm	8-12 cm
Minimum Subsidence	100-200 cm	100-200 cm	200-400 cm

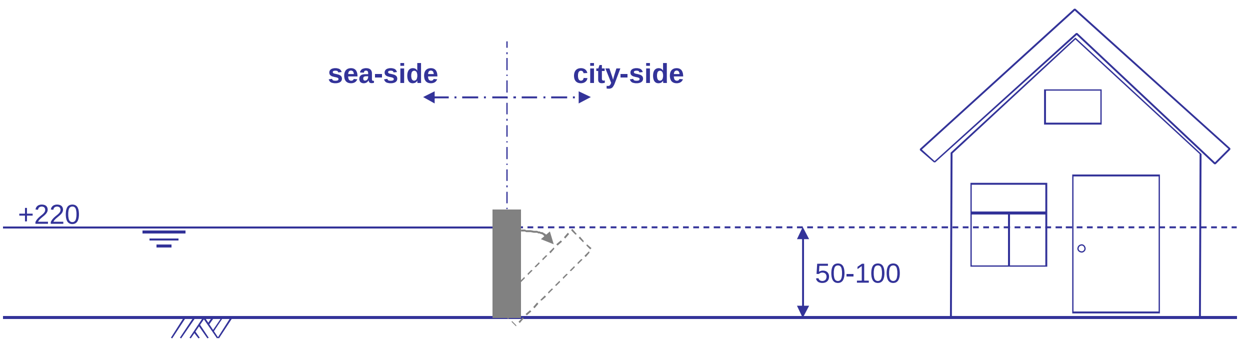
Jakarta
Flood from the sea, very critical.



- **New coastal defence required, combined effort of:**
  - **BBWS CC**
  - **PU DKI**
- **Within next 10-15 years**

Continue urgent measures

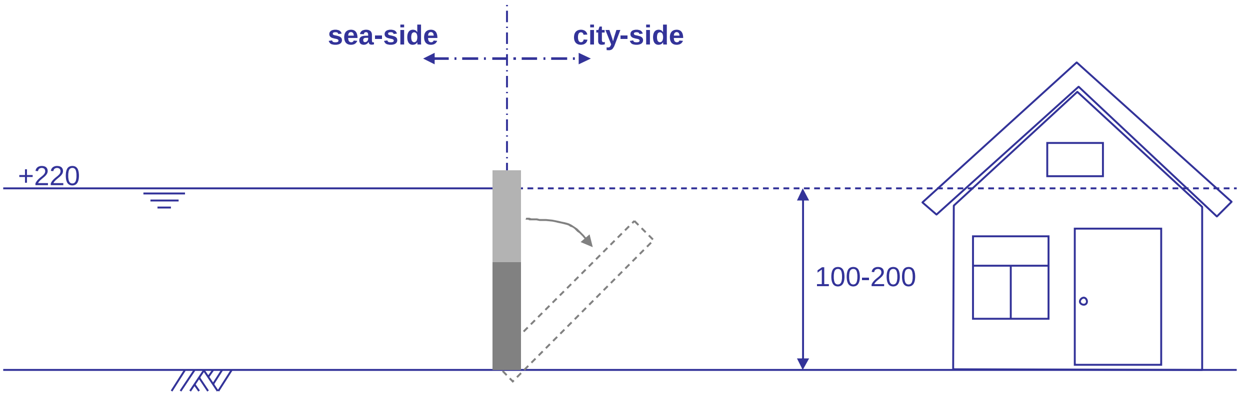
Up to 2007



levels and distances in cm

Continue urgent measures

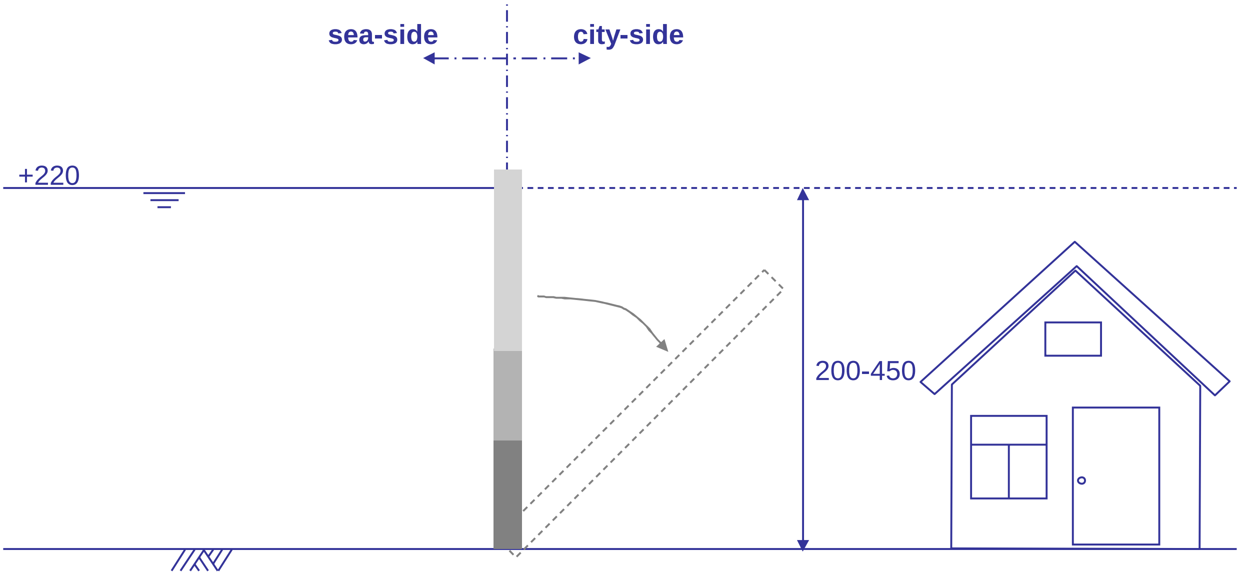
Urgent measures, 2008-2010



levels and distances in cm

Continue urgent measures

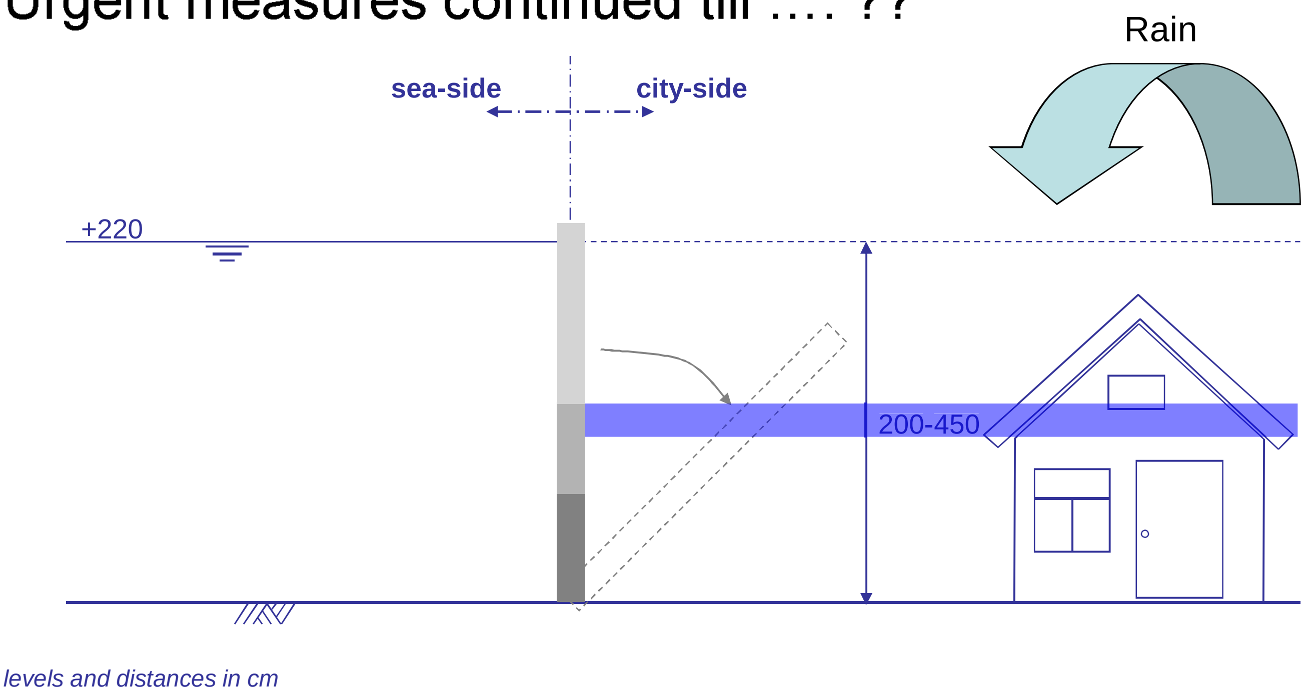
Urgent measures continued till …. ??



levels and distances in cm

Continue urgent measures

Urgent measures continued till …. ??

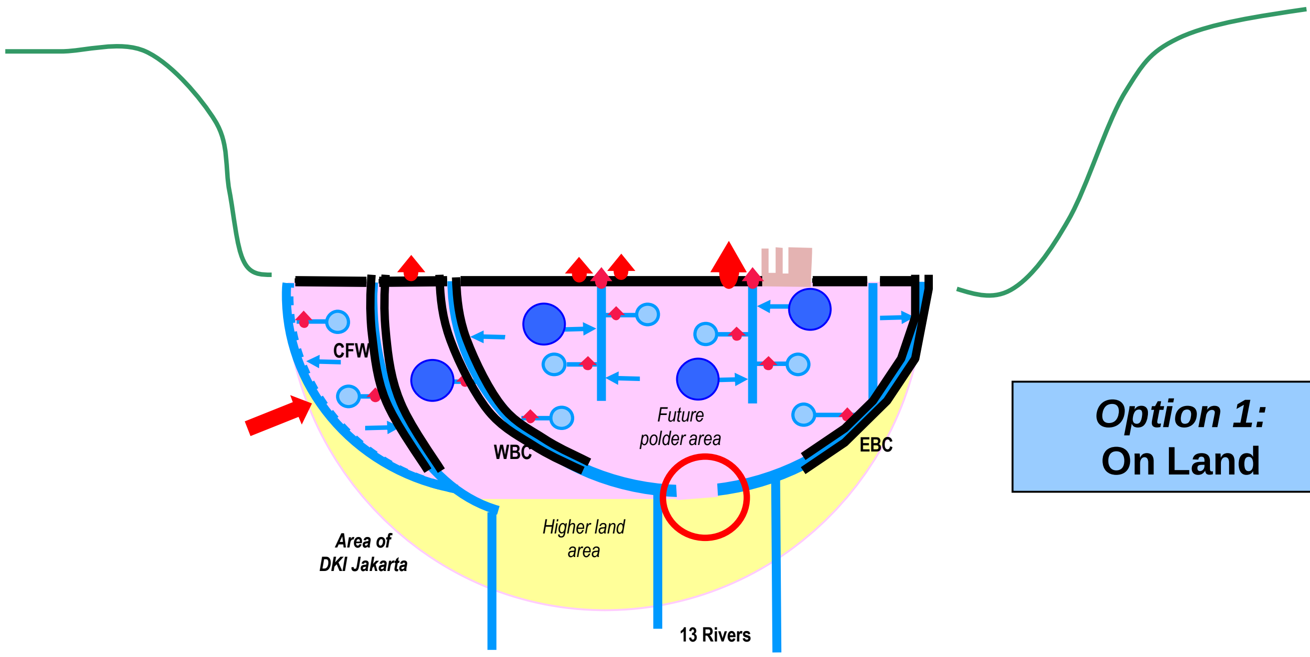


JCDS Strategic Direction

Strategic direction

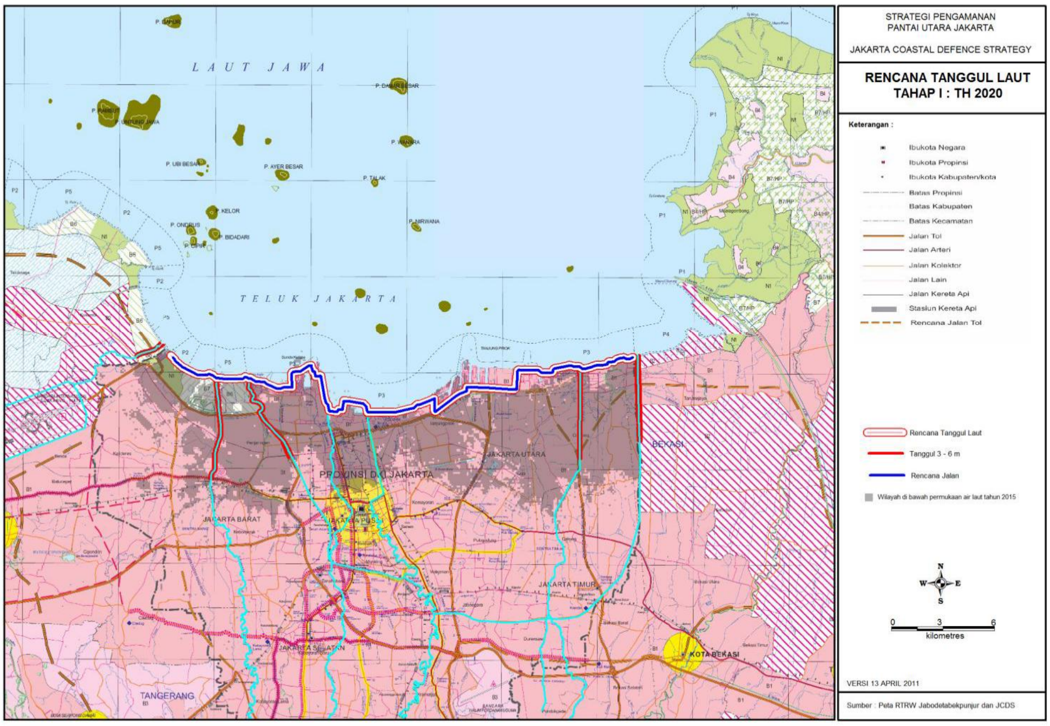
- **Effectiveness** of flood control based on phased implementation of Coastal Defense Infrastructure
- **Sustainability** based on Additional Measures to stop land subsidence and control water quality
- **Feasibility** based on Investment Opportunities for private sector

Jakarta Coastal Defense Strategy



Option 1:
On Land

Stage 1 (until 2020)

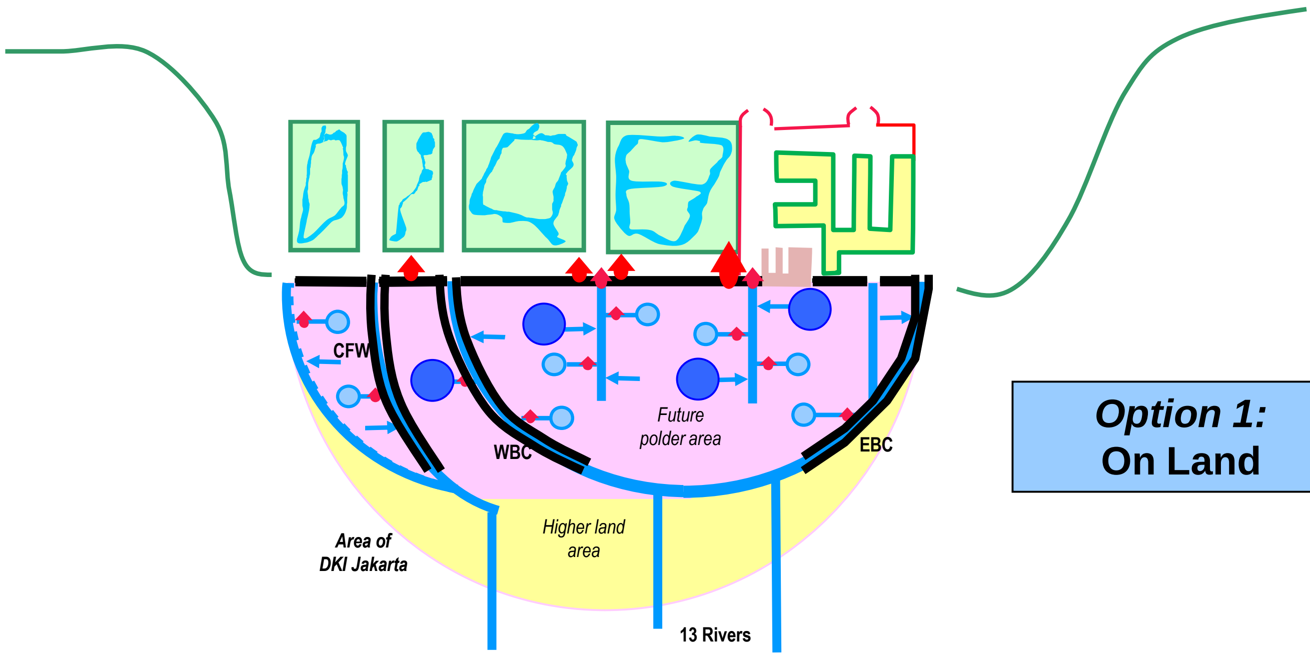


Sea and River Dikes

Retention Ponds

Pumping Stations

Jakarta Coastal Defense Strategy

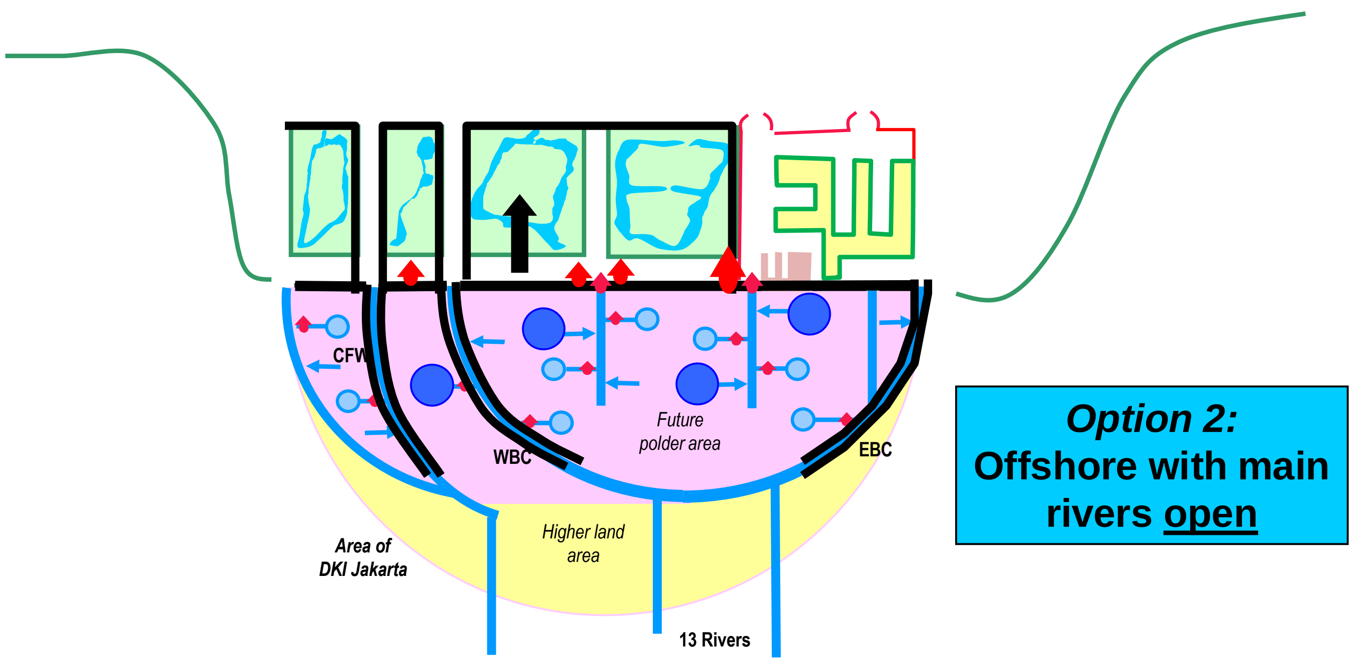


Option 1: On Land

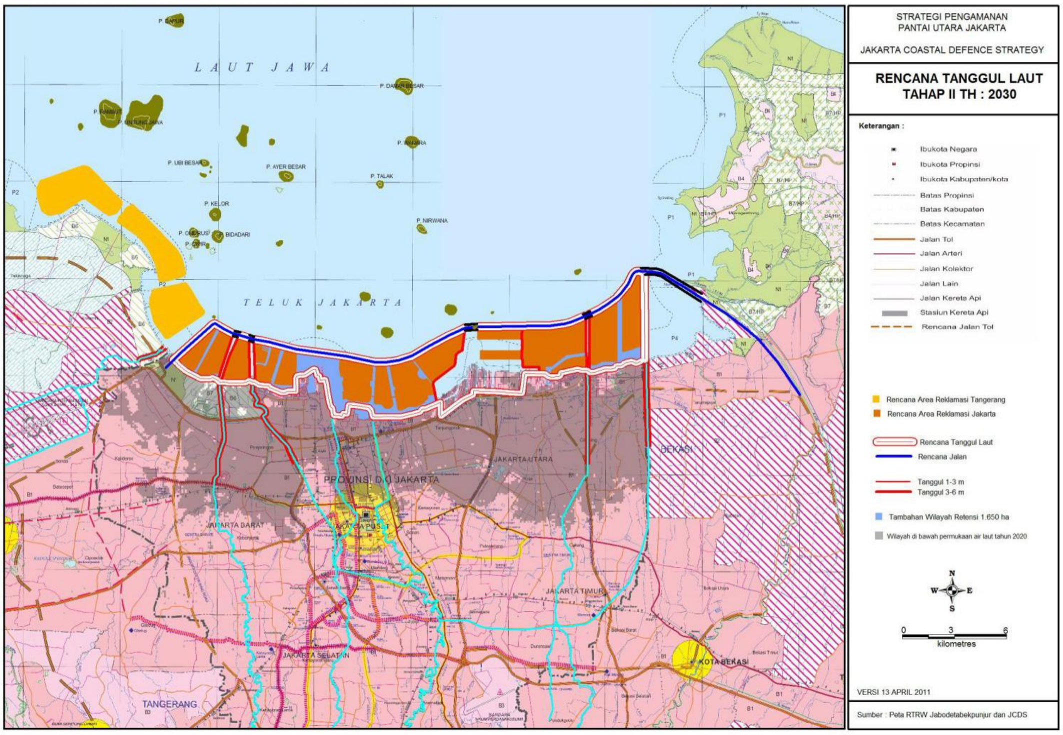
Option 2

With land reclamation
Offshore with main floodways <u>open</u>

Jakarta Coastal Development Strategy



Stage 2 (Until 2030)



Sea and River Dikes

Retention Ponds

Pumping Stations

Option 3

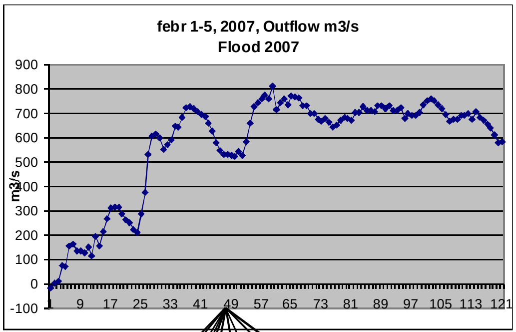
When Jakarta keeps sinking

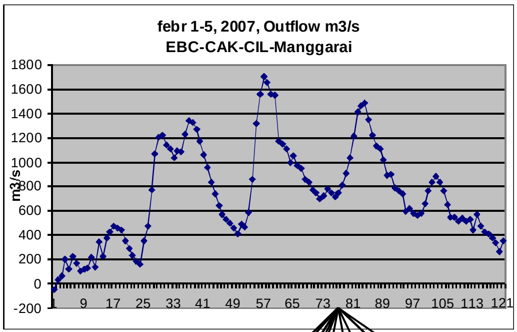
Offshore with main floodways <u>closed</u>

The flood characteristics of 2007

Pump capacity 200 and 500 m3/s

Pump storage area 100 and 50 km2



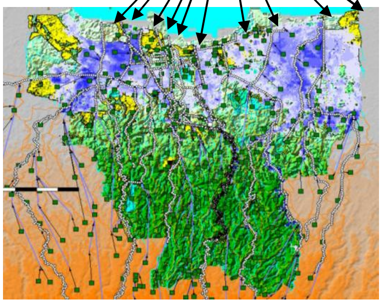


Flood volume

Outflow

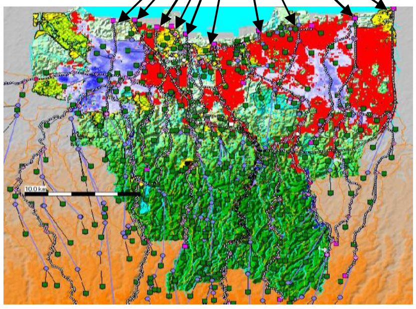
249,312,490 m3

321,440,052 m3



Inflow	01-Feb	05-Feb	321,440,052	m3
Storage area	30,000	3,300	99,000,000	m2
Increase			3.25	m
pump m3/s	5	200	86,400,000	m3
Inflow - pumping			235,040,052	m3
m increase			2.37	m

Inflow	01-Feb	05-Feb	321,440,052	m3
Storage area	30,000	1,600	48,000,000	m2
Increase			6.70	m
pump m3/s	5	500	216,000,000	m3
Inflow - pumping			105,440,052	m3
m increase			2.20	m

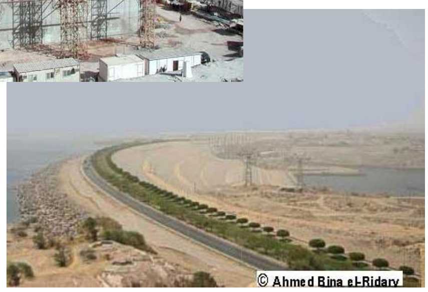


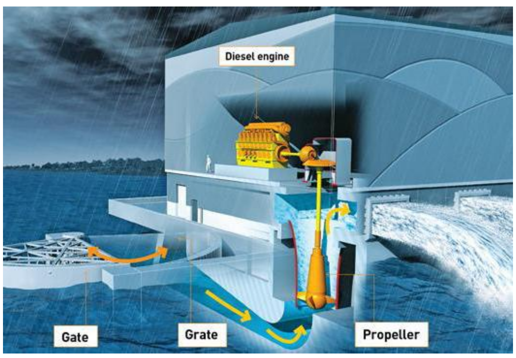
Still many areas flooded

Largest pumping stations in the world

- 330 m^3/s: Toshka Project - Mubarak Pumping Station, Egypt

- 570 m^3/s New Orleans

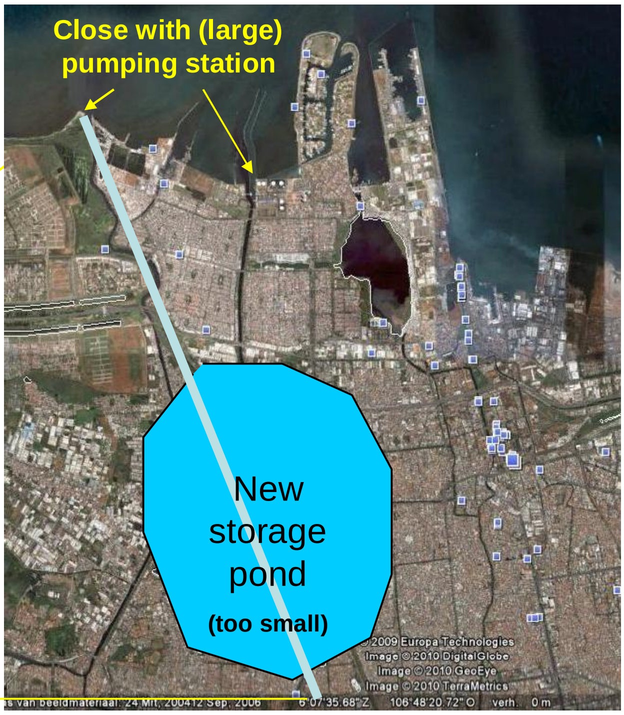


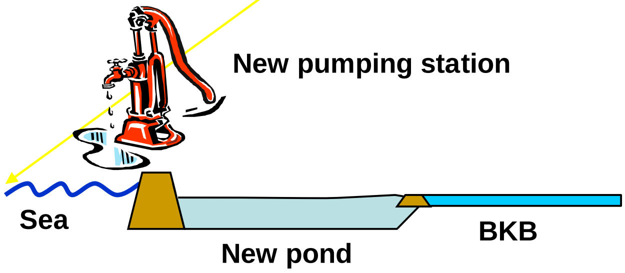


On-land – closed channel

Required:

- **Whole North Jakarta good polders with strong dikes**
- **Close open channels with pumping stations**
- **Create pumping storage ponds**
- **Large construction in the city**





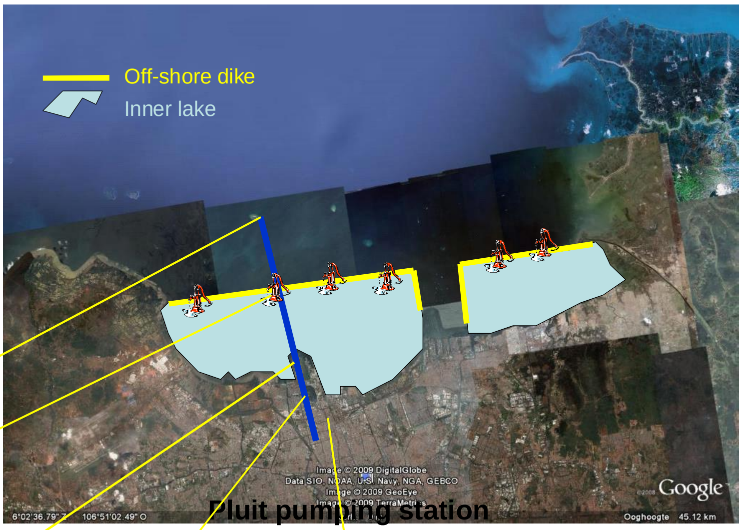
Off-Land direction

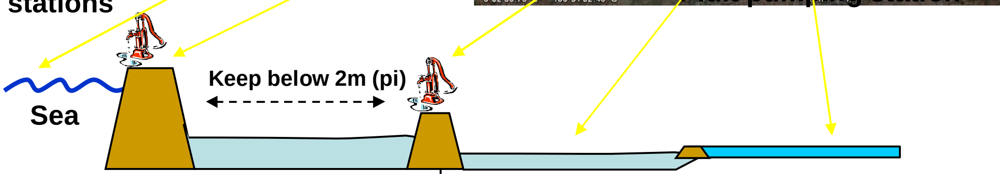
e.g. Petersburg, Venice, New Orleans, The Netherlands

Off-land direction, pumping stations
Pluit, Ancol

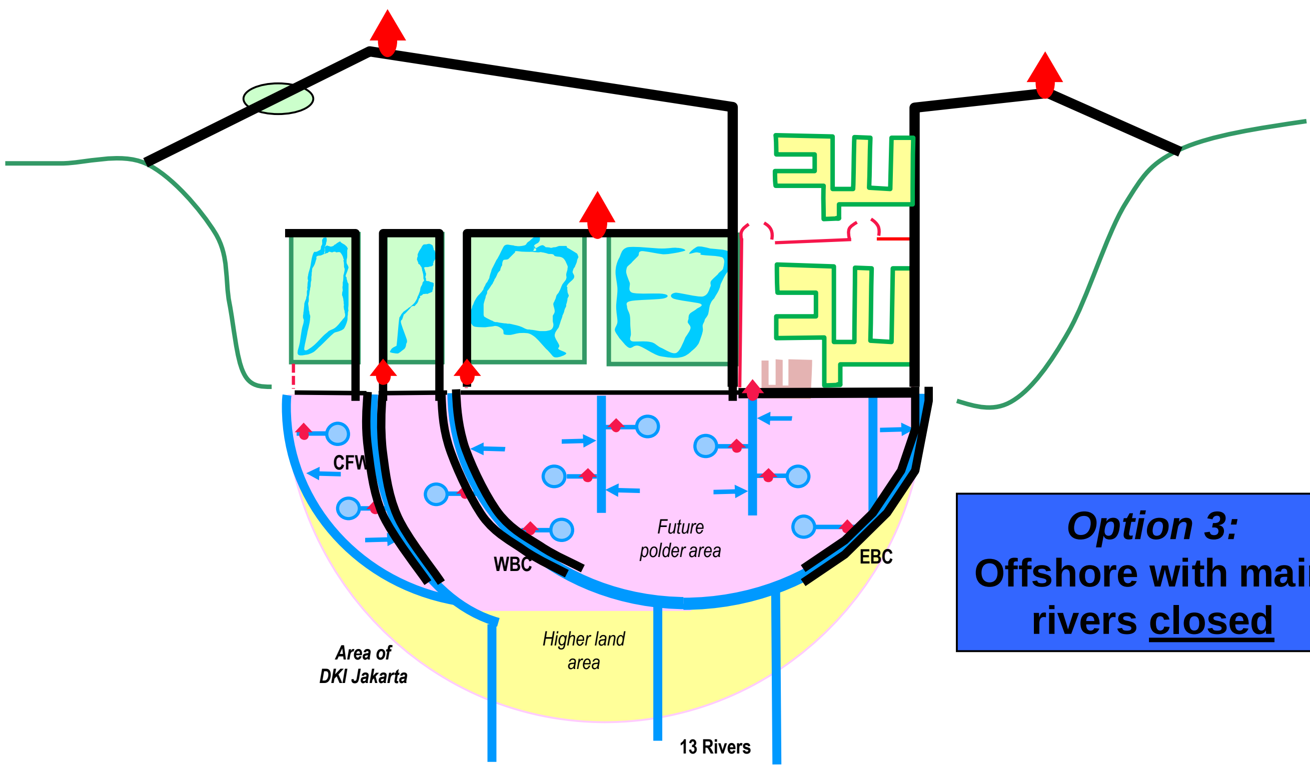
Required:

- **Off-shore dike to create inner lake**
- **No heightening of pumping stations**
- **Smaller pumping stations along dike**



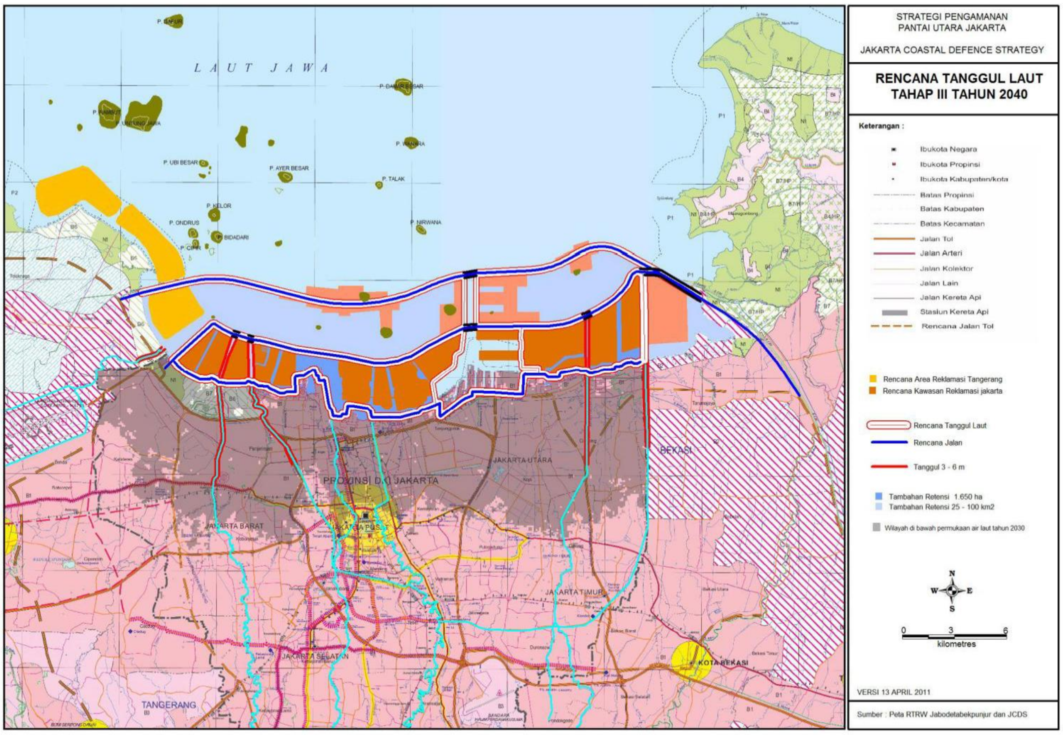


Jakarta Coastal
Development nse Strategy



Option 3:
Offshore with main rivers <u>closed</u>

Stage 3 (beyond 2030)



Sea and River Dikes

Retention Ponds

Pumping Stations

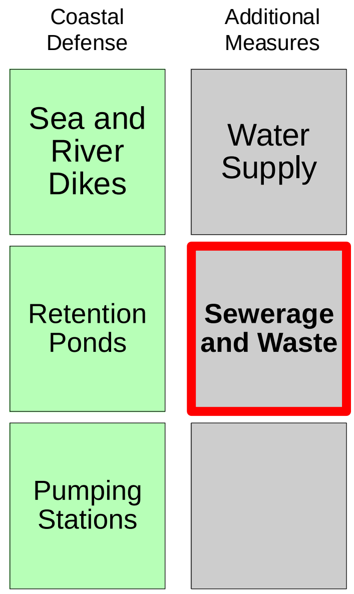
How can land subsidence be stopped?

- **Land subsidence can only be stopped, if deep ground water extraction is replaced by piped Water Supply**

Coastal Defense	Additional Measures
Sea and River Dikes	**Water Supply**
Retention Ponds	
Pumping Stations	

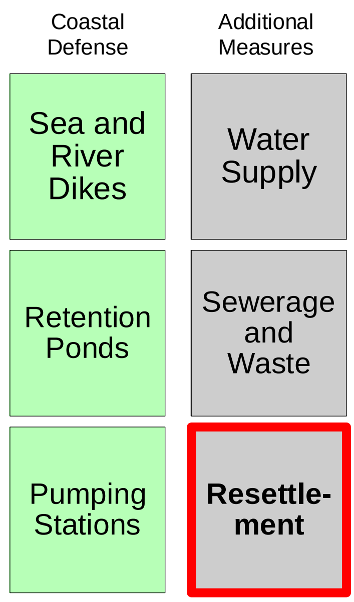
How can we improve the water quality in the retention basin?

- **Improve water quality of rivers that discharge into retention basin**
- **Improve household and industrial waste collection and disposal, and conduct awareness campaigns among communities on river banks**
- **Develop flushing scheme and dry 'weather flow' cleaning**



How can we prevent that resettlement becomes a social and political obstacle?

- **Minimize need for land acquisition and resettlement, and provide fair compensation**
- **Allocate 300 hectares, or 10% of the land reclamation area of 3'000 hectares for resettlement of 60'000 people**
- **Develop alternative locations along new sea dikes for fishing ports, ship repair, coastal recreation**

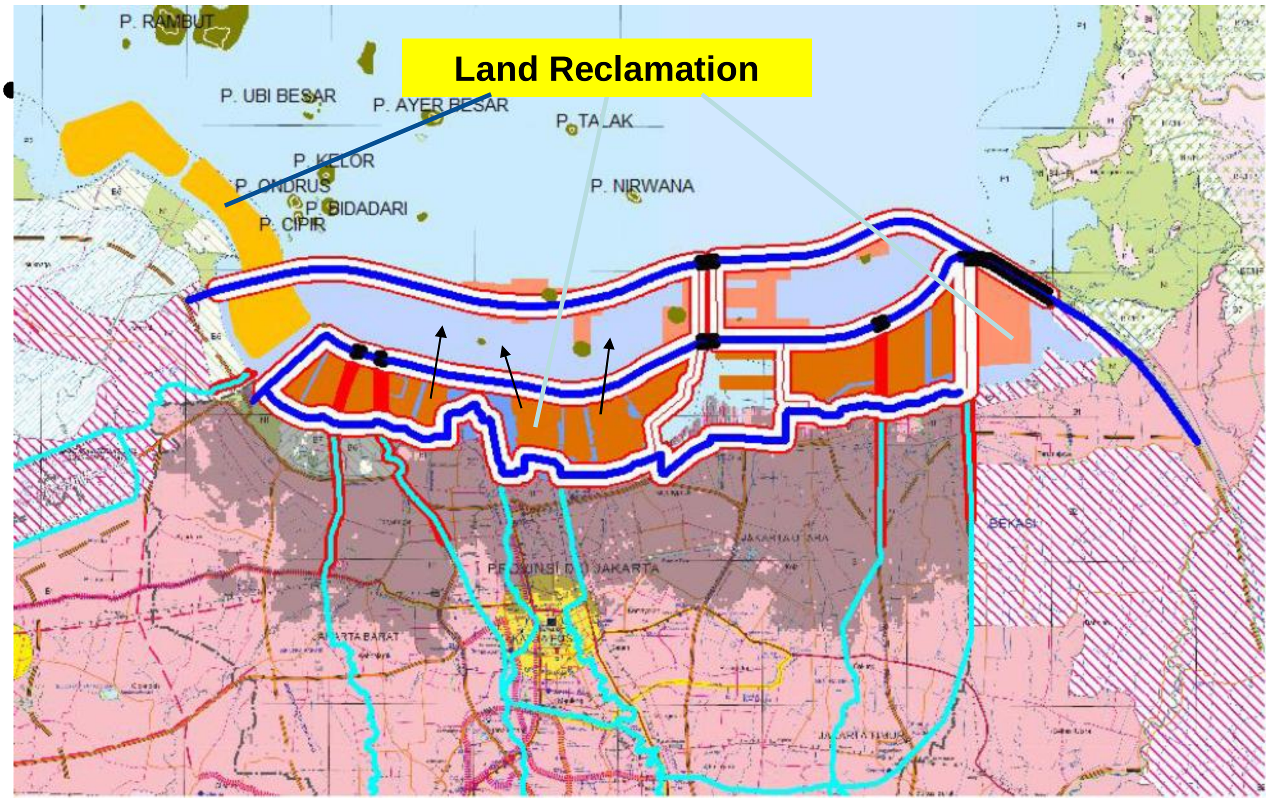


What are investment opportunities between the dikes?

- **Land reclamation of 3’000 ha between dike on existing coast line and dike at -8 m depth and dike at -14 m**
- **Water recreation, water transport, fish-farming, fresh water storage, etc. in retention basin**

Coastal Defense	Additional Measures	Investment Opportunities
Sea and River Dikes	Water Supply	**Land Recla-mation**
Retention Ponds	Sewerage and Waste	
Pumping Stations	Resettle-ment	

Land Reclamation

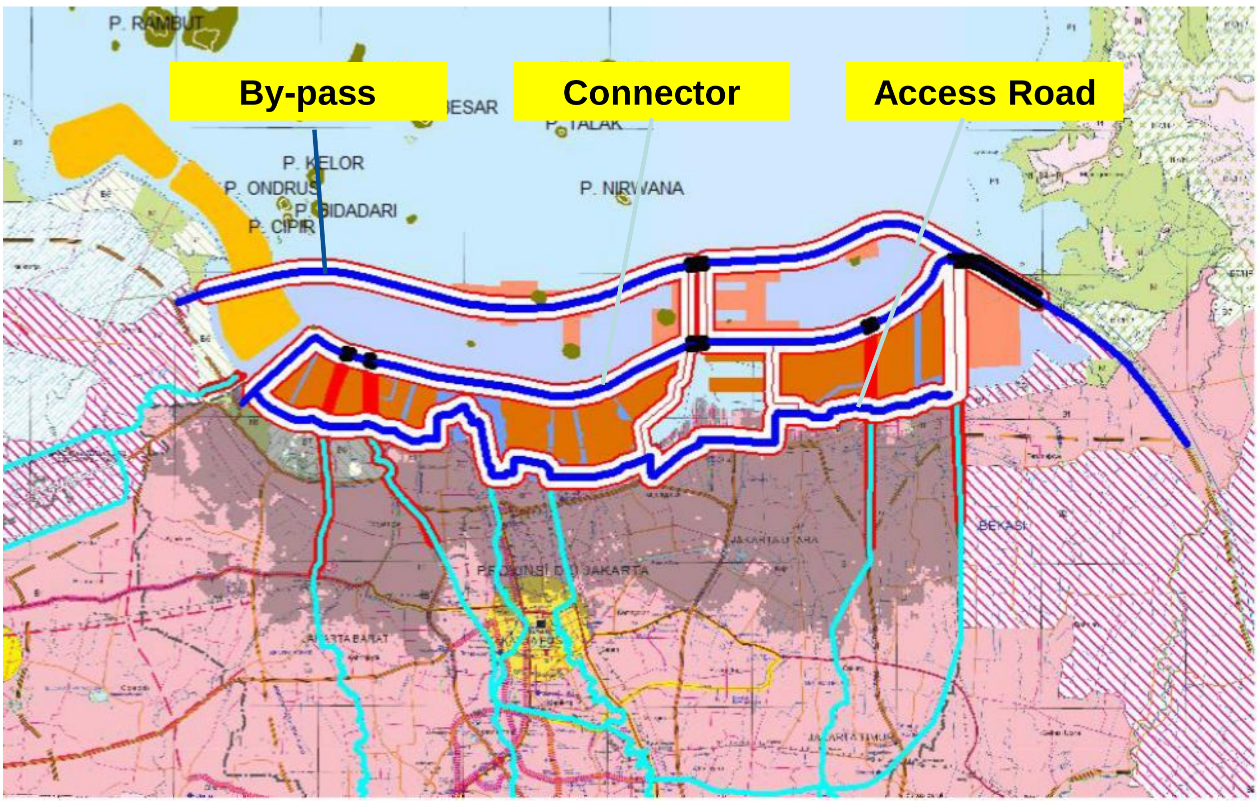


What are investment opportunities on top of dikes?

- <u>Access</u> road on top of dike along existing coast line
- Toll road and double railway track on top of dike along land reclamation as <u>connection</u> between airport, seaport, industrial zones
- Toll road on top of sea dike at 6 km from existing coast line as <u>by-pass</u> that is part of the national Merak-Surabaya toll road

Coastal Defense	Additional Measures	Investment Opportunities
Sea and River Dikes	Water Supply	Land Recla-mation
Retention Ponds	Sewerage and Waste	**Toll Roads**
Pumping Stations	Resettle-ment	

Roads and railway tracks

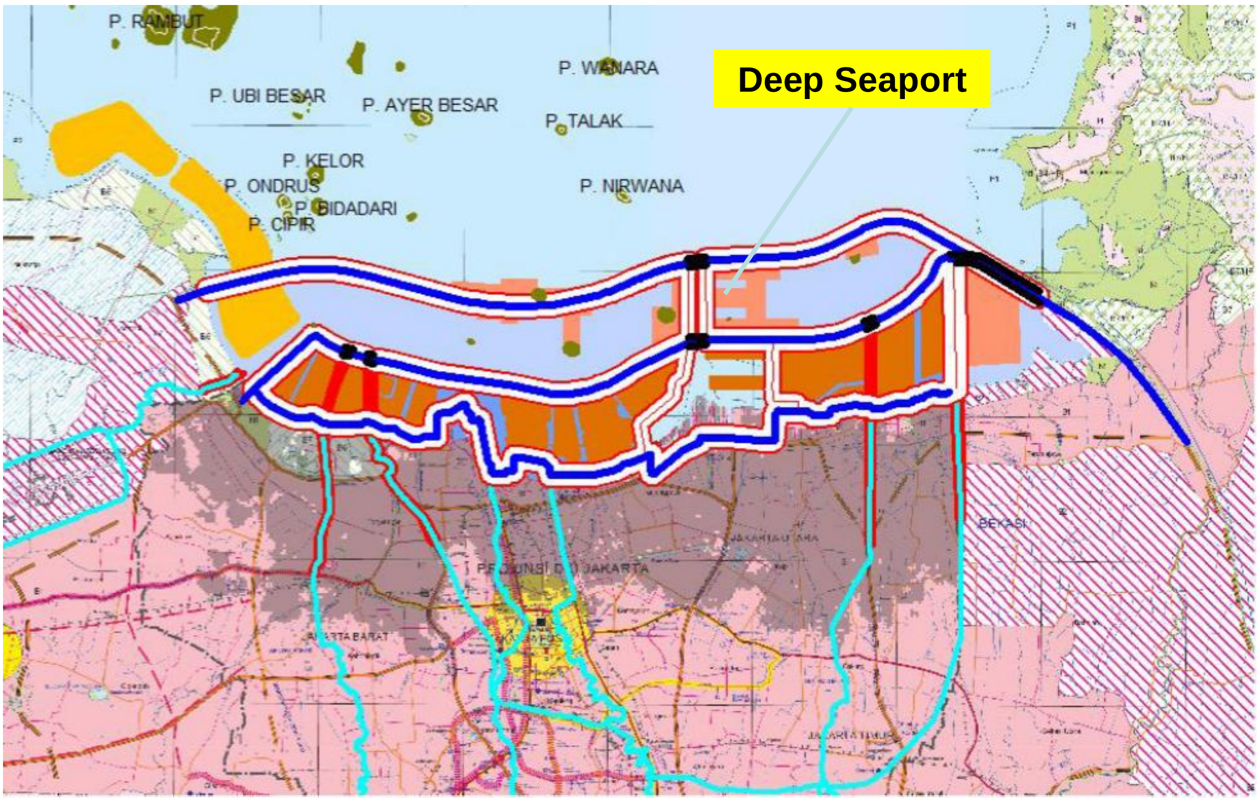


What are investment opportunities outside dikes?

- **Deep seaport between outer sea dike at -14 m depth and sea dike along land reclamation at -8 m depth.**

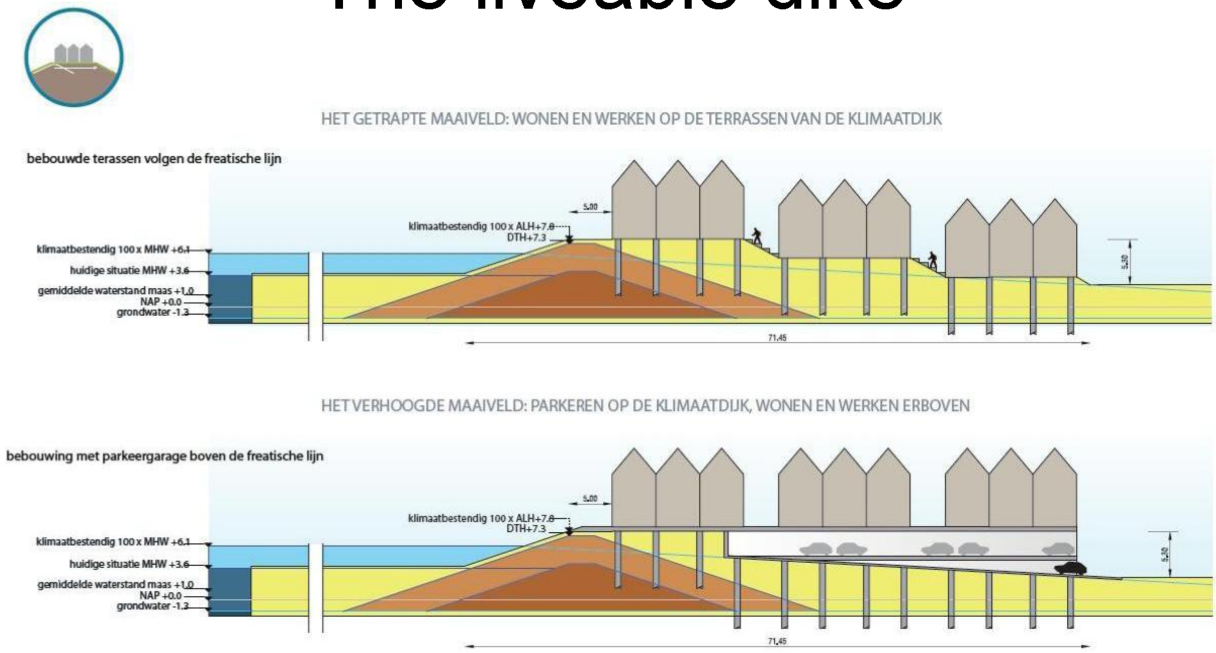
Coastal Defense	Additional Measures	Investment Opportunities
Sea and River Dikes	Water Supply	Land Recla-mation
Retention Ponds	Sewerage and Waste	Toll Roads
Pumping Stations	Resettle-ment	**Deep Seaport**

Deep Seaport



To new concepts

Combine safety and development
‘The liveable dike’



With all stakeholders

With the private sector

PPP

Why is Integrated Strategic Solution attractive for Public-Private Partnership?

- **Coastal Defense infrastructure and Additional Measures are not profitable (-) and depend on public funding. Business Investment Opportunities are profitable (+) and depend on private funding.**
- **Based on an overall Cost-Benefit Analysis, each investment in itself is not financially feasible, but combined into an integrated strategic package the overall investment becomes feasible.**
- **Moreover, the integrated strategic solution will not only protect North Jakarta against flooding, but also solve its drinking water shortage, river water pollution and notorious traffic jams.**
- **Protection against flooding, combined with reclamation of land, provision of infrastructure, and environmental improvements, are expected to turn North Jakarta into an attractive place to live, work and invest.**

Coastal Defense	Additional Measures	Investment Opportunities
Sea and River Dikes (–)	Water Supply (–)	Land Recla-mation (+ + +)
Retention Ponds (–)	Sewerage and Waste (–)	Toll Roads (+ +)
Pumping Stations (–)	Resettle-ment (–)	Deep Seaport (+ +)
Public funding	Public funding	Private funding

JCDS – Outputs & guidelines

Facts and trends

Solution and strategy

Institutional setting
The leadership
The ownership
The PPP players

Atlas, Agenda, Aturan Main,

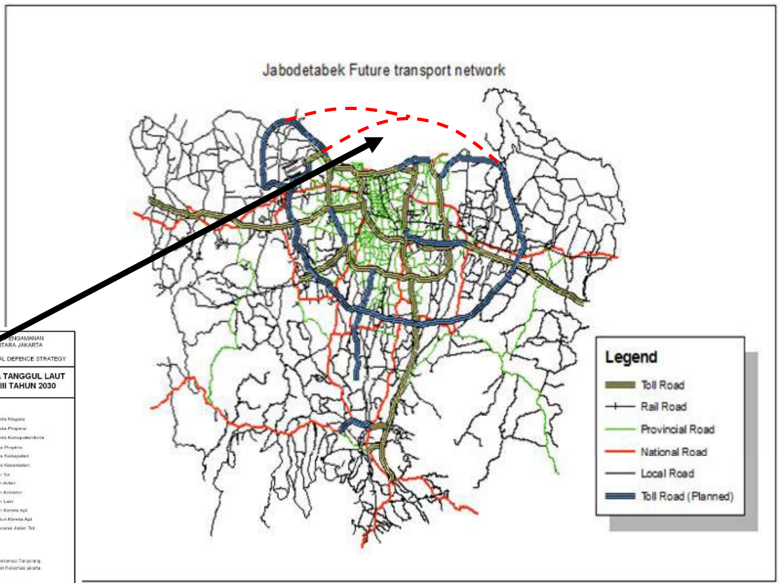
The integrated guidelines and reference of the JCDS process for the rethinking and synchronisation of all (sector) plans.

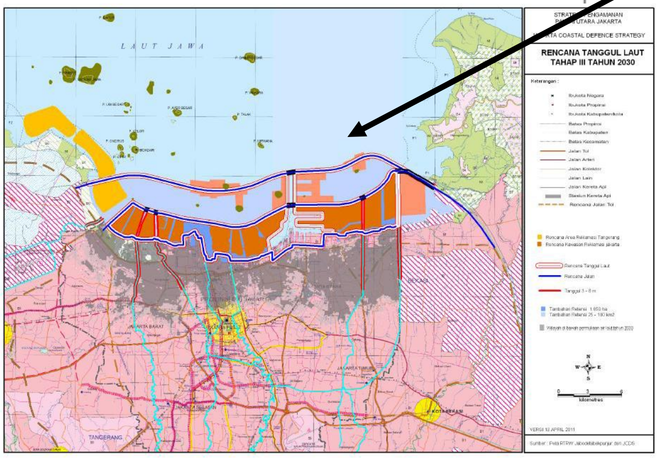
2011 – 2014 ------ 2014 – 2030

The way forward

Synchronisation Sector Plans: Transportation Master Plan (JUTPI)

- Planned road system till 2030
- Requires integration and synchronisation

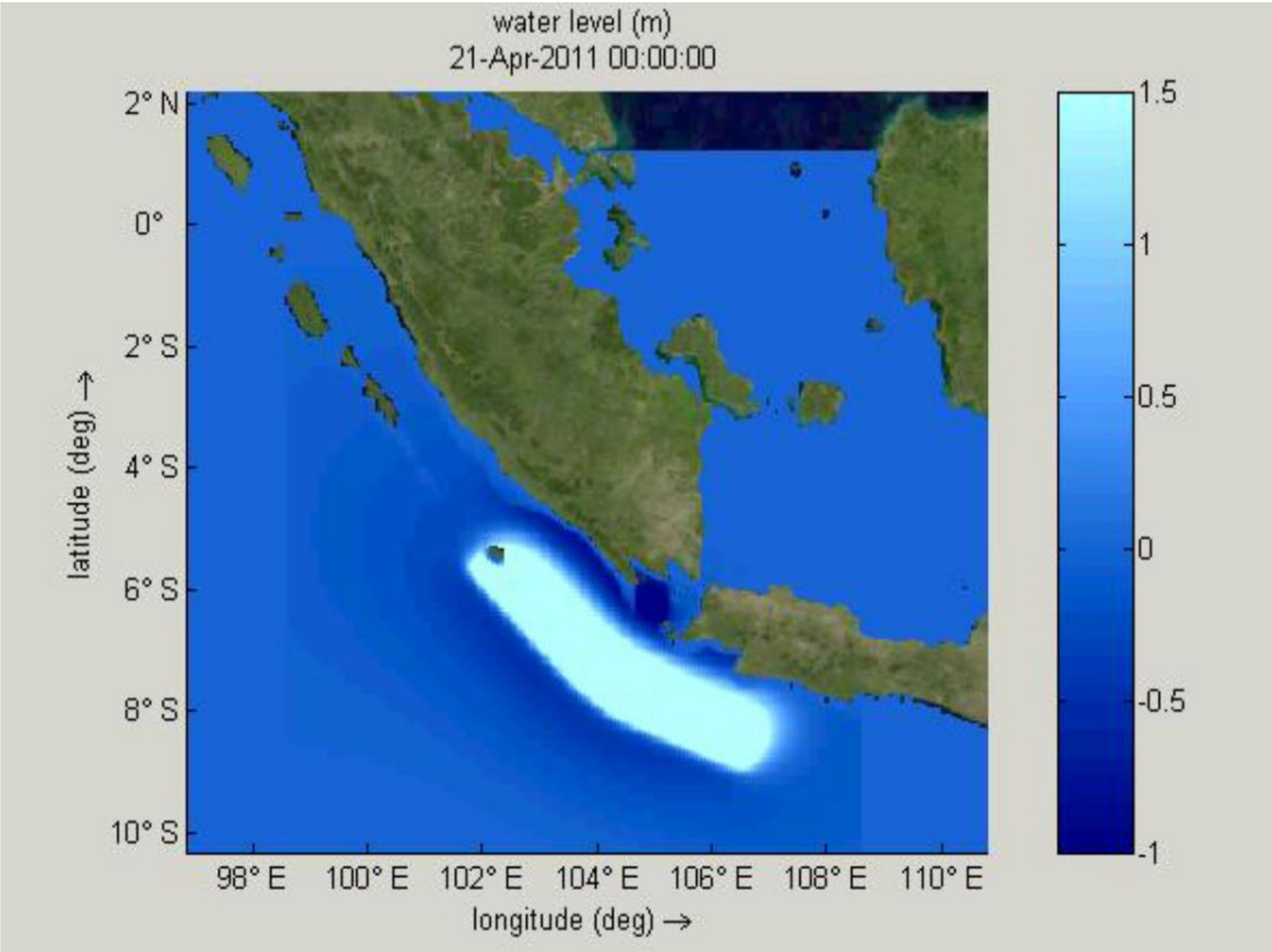


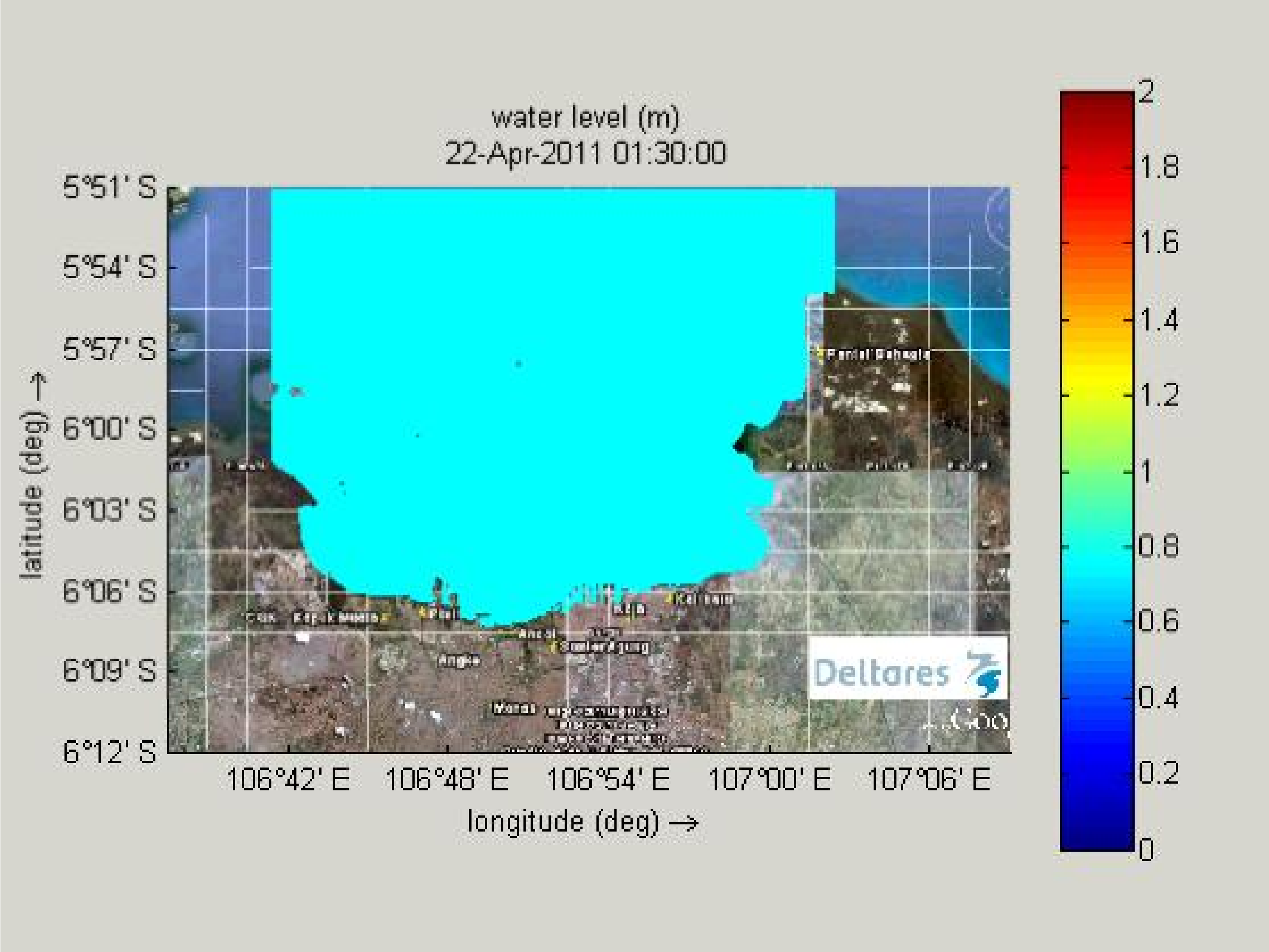


- How to synchronize
- MPA relation?

And even more to go…

Tsunami protection?




water level (m)
22-Apr-2011 01:30:00
5°51' S
5°54' S
5°57' S
6°00' S
6°03' S
6°06' S
6°09' S
6°12' S
latitude (deg) →
106°42' E
106°48' E
106°54' E
107°00' E
107°06' E
longitude (deg) →
Deltares
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

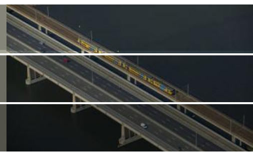
Deltares
Enabling Delta Life

International perspective: peatland subsidence, water management and research in the Netherlands

Dimmie Hendriks, Gilles Erkens, Aljosja Hooijer

Deltares – Geological Survey of the Netherlands – Utrecht University

Contents



Introduction: drowning landscapes due to subsidence
Introduction: double trouble in peatlands

PART ONE:
The consequences of longer term peatland management in the Netherlands

PART TWO:
Current situation:
- How much subsidence occurs?
- Which problems occur due to peat oxidation and soil subsidence?

PART THREE:
Which measures can be taken to reduce peat oxidation and soil subsidence?

The above will be illustrated with examples mainly from the Netherlands.

Subsidence is widely debated

LETTERS

Mississippi Delta subsidence primarily caused by compaction of Holocene strata

TORBJÖRN E. TÖRNQVIST[1*], DAVIN J. WALLACE[1†], JOEP E. A. STORMS[2‡], JAKOB WALLINGA[2§], REMKE L. VAN DAM[2‖], MARTIJN BLAAUW[2¶], MAYKE S. DERKSEN[2#], CORNELIS J. W. KLERKS[2*], CAMIEL MEIJNEKEN[2**] AND ELS M. A. SNIJDERS[2††]

NEWS & VIEWS

GEOMORPHOLOGY

Survive or subside?

Deltas are among the most valuable coastal ecosystems, but they are very dynamic and the factors that influence their health are complex. The rate of compaction of underlying sediments might be a more significant factor than was thought.

John W. Day[1] and Liviu Giosan[2]

nature geoscience — PROGRESS ARTICLE

PUBLISHED ONLINE: 20 SEPTEMBER 2009 | DOI: 10.1038/NGEO629

Sinking deltas due to human activities

James P. M. Syvitski[1*], Albert J. Kettner[1], Irina Overeem[1], Eric W. H. Hutton[1], Mark T. Hannon[1], G. Robert Brakenridge[2], John Day[3], Charles Vörösmarty[4], Yoshiki Saito[5], Liviu Giosan[6] and Robert J. Nicholls[7]

commentary

Dutch coasts in transition

Pavel Kabat, Louise O. Fresco, Marcel J. F. Stive, Cees P. Veerman, Jos S. L. J. van Alphen, Bart W. A. H. Parmet, Wilco Hazeleger and Caroline A. Katsman

LETTERS — nature geoscience

PUBLISHED ONLINE: 28 JUNE 2009 | DOI: 10.1038/NGEO553

Drowning of the Mississippi Delta due to insufficient sediment supply and global sea-level rise

Michael D. Blum[1*†] and Harry H. Roberts[2]

Introduction: drowning deltas

Many deltas (and coastal plains) are now drowning as a result of (Syvitski et al., 2009):

- Subsidence/compaction (due to extraction of resources)
- Sediment starvation (due to upstream reservoir construction)
- Global sea-level rise

The human aspects:

- Half a billion people live on deltas and coastal plains
- Human activities in the coastal zone or hinterland are the main cause for the drowning

Low-lying lands

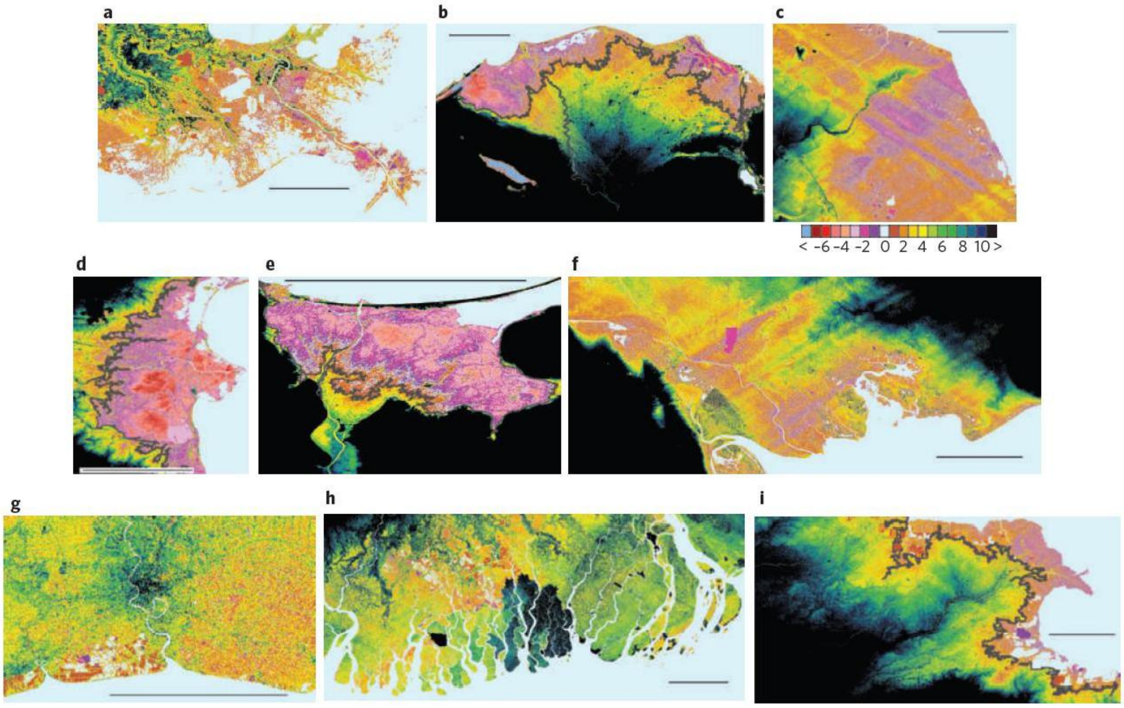


Figure 1 | Topography of representative deltas. SRTM altimetry is binned at 1-m vertical intervals, starting at sea level (light blue), to a height of 10 m, then black. Topography below mean sea level is in shades of pink. **a**, Mississippi, USA; **b**, Nile, Egypt; **c**, old abandoned Yellow, China; **d**, Po, Italy; **e**, Vistula, Poland; **f**, Shatt al Arab, Iraq; **g**, Chao Phraya, Thailand; **h**, Ganges-Brahmaputra, Bangladesh; and **i**, modern (since 1855) Yellow, China. Scale bar on images represents 50 km. For **b**, **d**, **e** and **i** examples, the 2-m best-fit isoline is provided as a grey line.

The role of peat in subsidence

A less recognised contribution comes from:

Subsidence of peatlands after drainage to create arable land

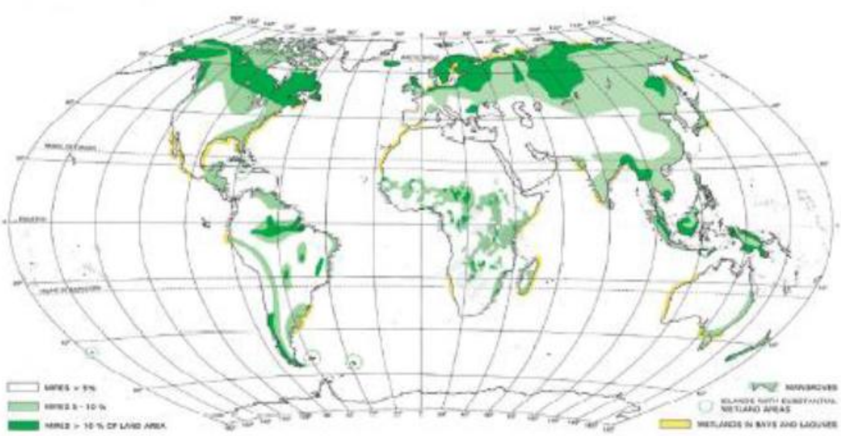


Figure 2.4: Extent and location of global mires and peatlands. (From Lappalainen, 1996).

Introduction: drainage of peatlands

Drainage causes oxidation of peat, and results in:

- **land subsidence** *and*
- **CO_2-respiration**

This is double trouble, because of:

- Local increased risk of flooding
- Global increased atmospheric greenhouse gas concentrations

Quantifications of these effects are rare, and this is even more true for:

- Larger areas (regional scale)
- Longer time scales (more than a decade)

Main question:

What are the quantitative effects of large scale and *long term* drainage of deltaic and coastal peatlands?

Case study: the Dutch coastal lowlands

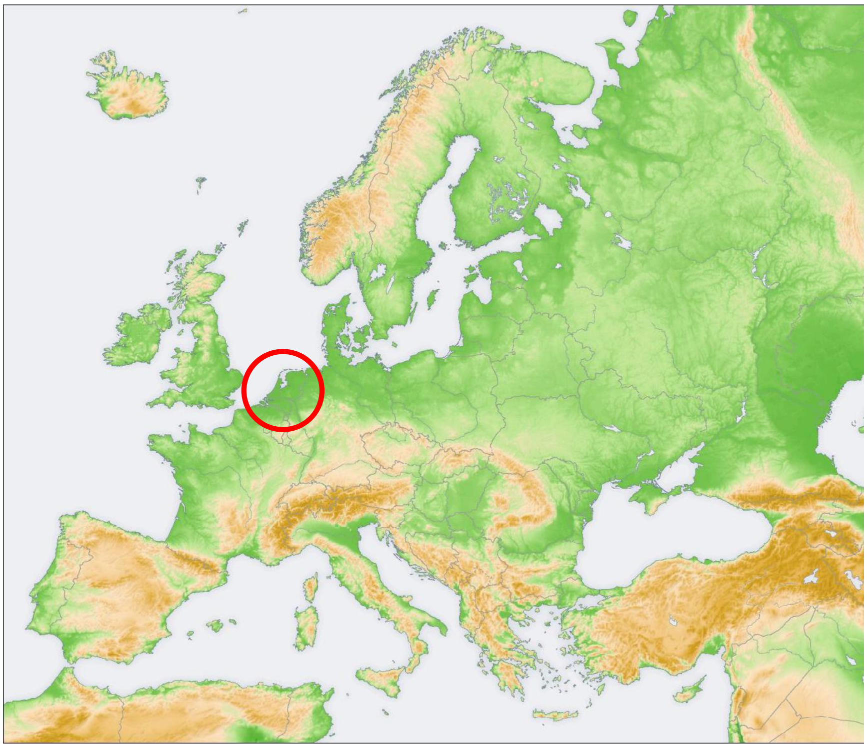
We use the Dutch coastal and deltaic plain as a case study because:

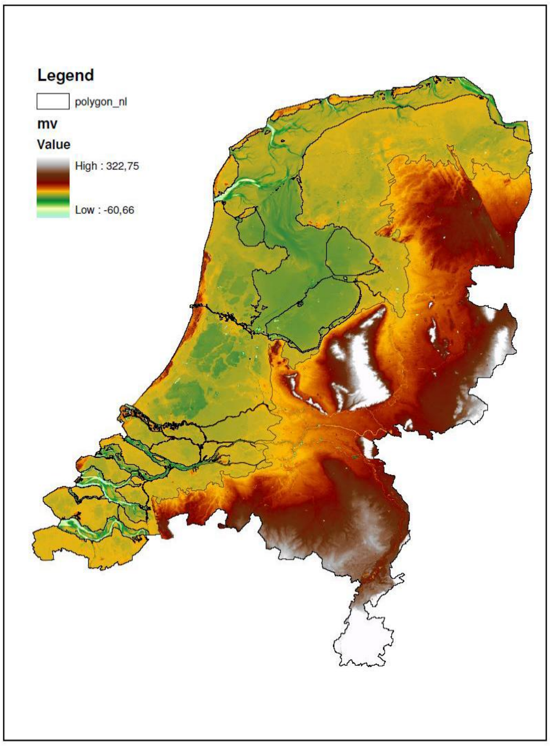
- The shallow subsurface is characterised by large volumes of peat
- From ca 1000 AD onwards, the Dutch actively drained these peatlands *in an organised manner* to create arable land

The outcomes of this research are important because it provides information on:

i) The vulnerability of coastal and deltaic peatlands to subsidence
ii) The contribution of drained coastal peatlands to global atmospheric CO_2 levels
iii) the potential future subsidence and CO_2 release from peatlands elsewhere that are under (increasing) human pressure

The Dutch coastal zone





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13 juni 2013

The metamorphosis of The Netherlands

BEFORE


Photo: G. Erkens

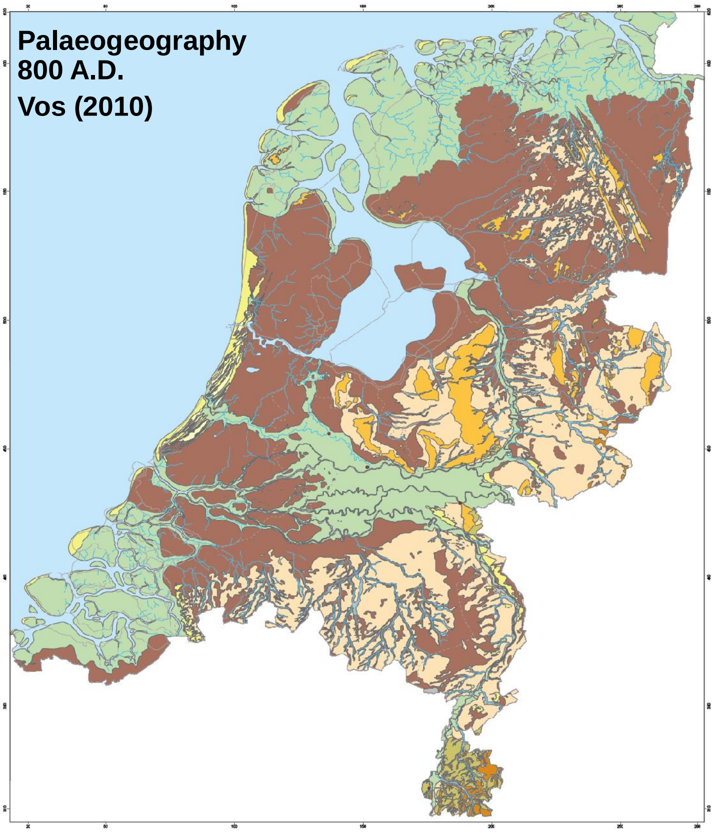

Photo: G. Erkens

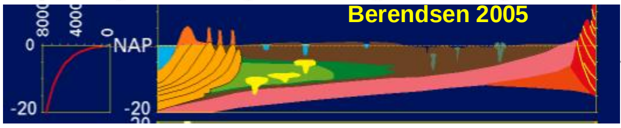
AFTER

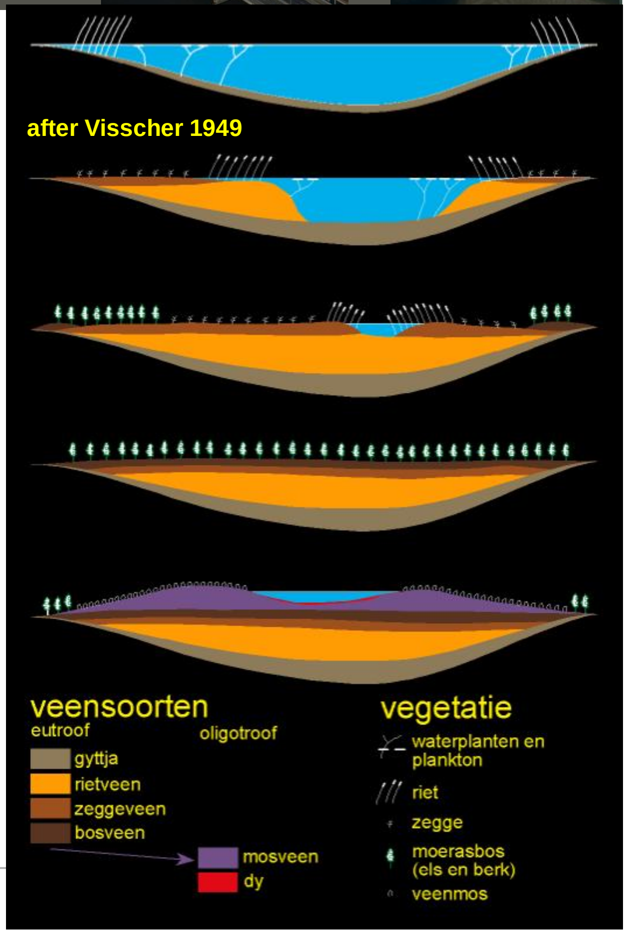

Photo: H.J.A. Berendsen


Photo: D. Hendriks

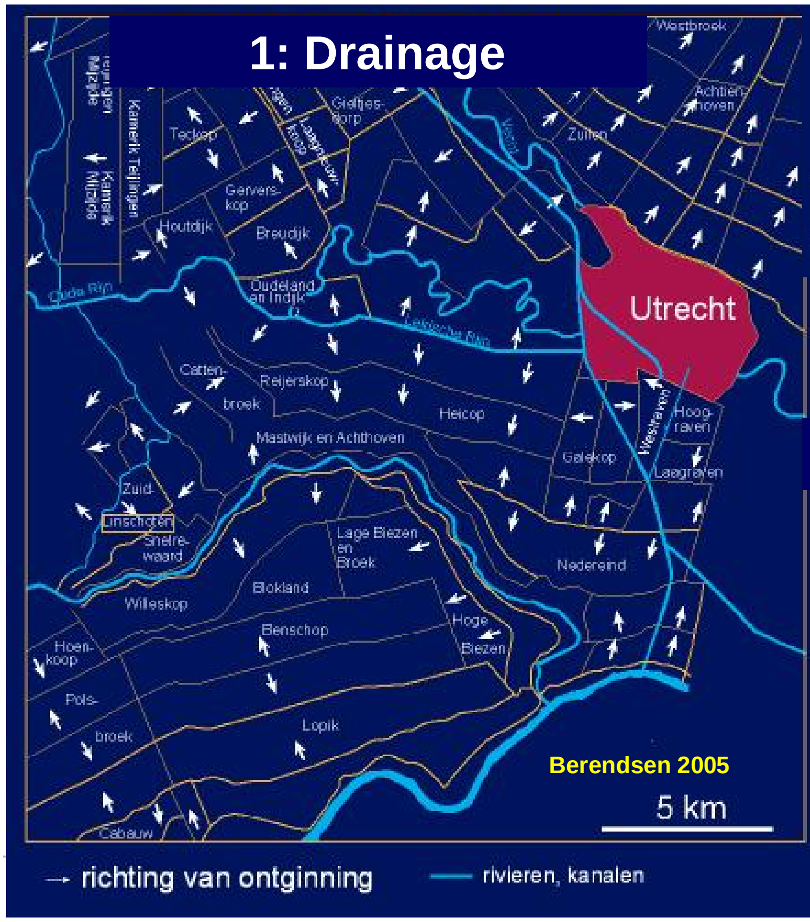
The peaty history of The Netherlands





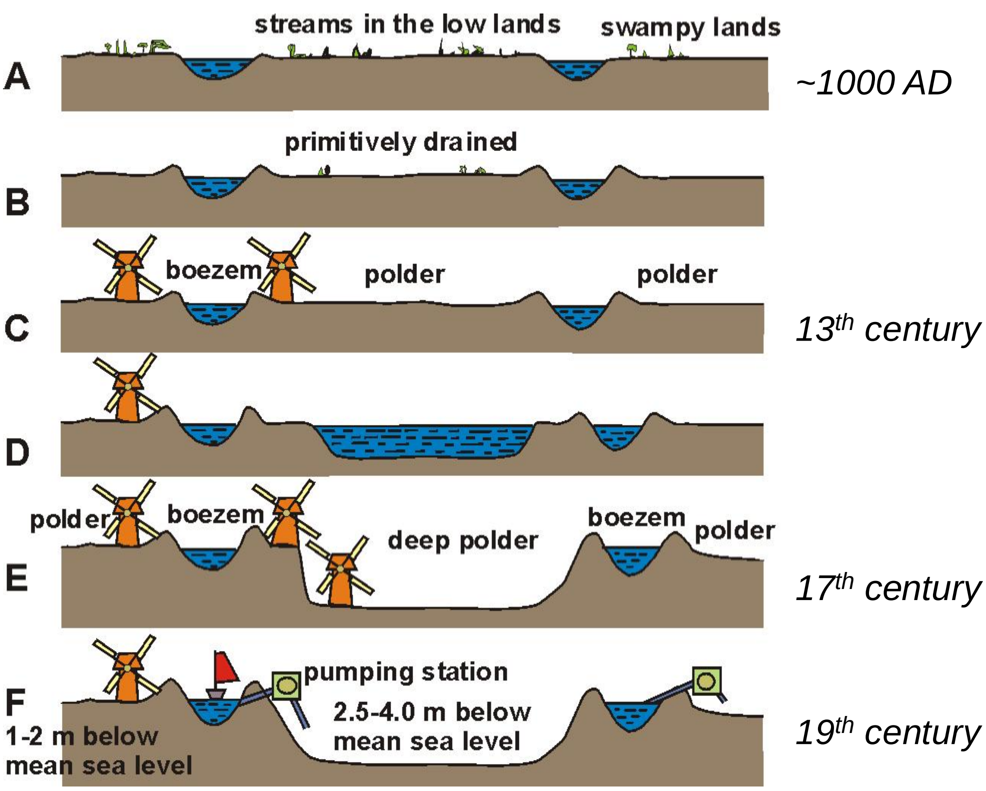


The history of human impact in the Dutch peatlands



2: Excavation

Development of the Dutch 'Polder' Landscape



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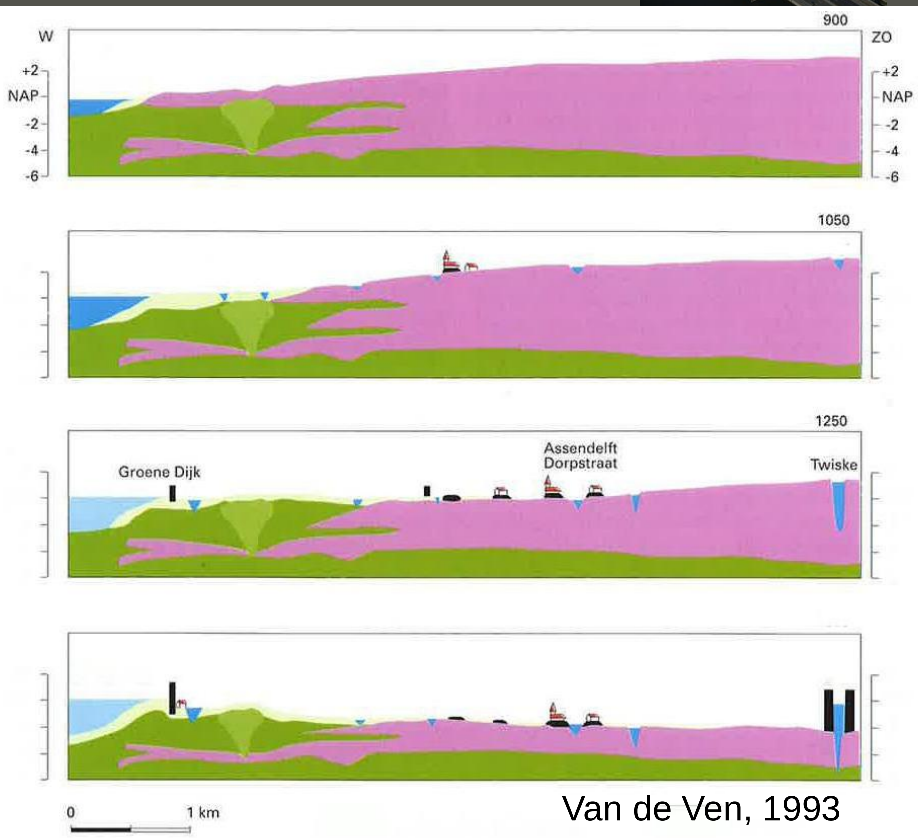
Land surface lowering in time



Van de Ven, 1993

Drainage = oxidation of peat = land surface lowering

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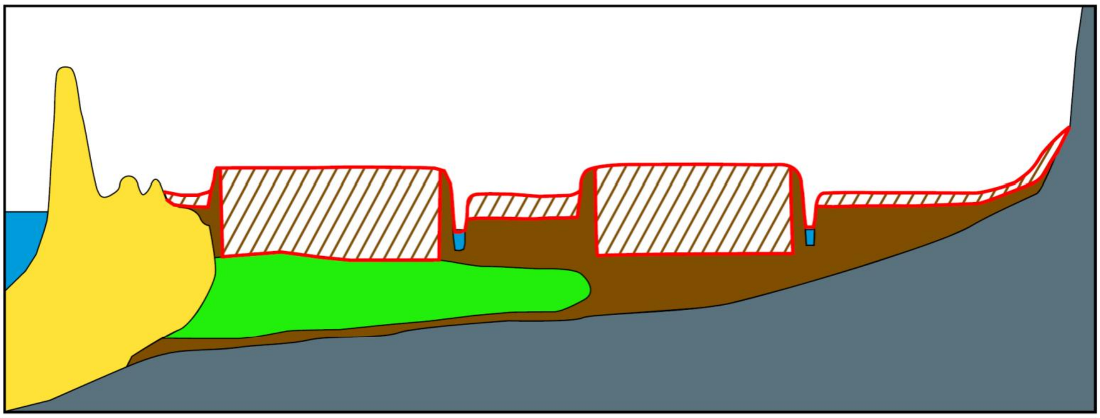
The lost volume calculations

The first question: How much peat was lost during 1000 years of land use?

Land use → peat oxidation → land subsidence *over a certain area*

→ **certain peat volume lost**



Essential information:

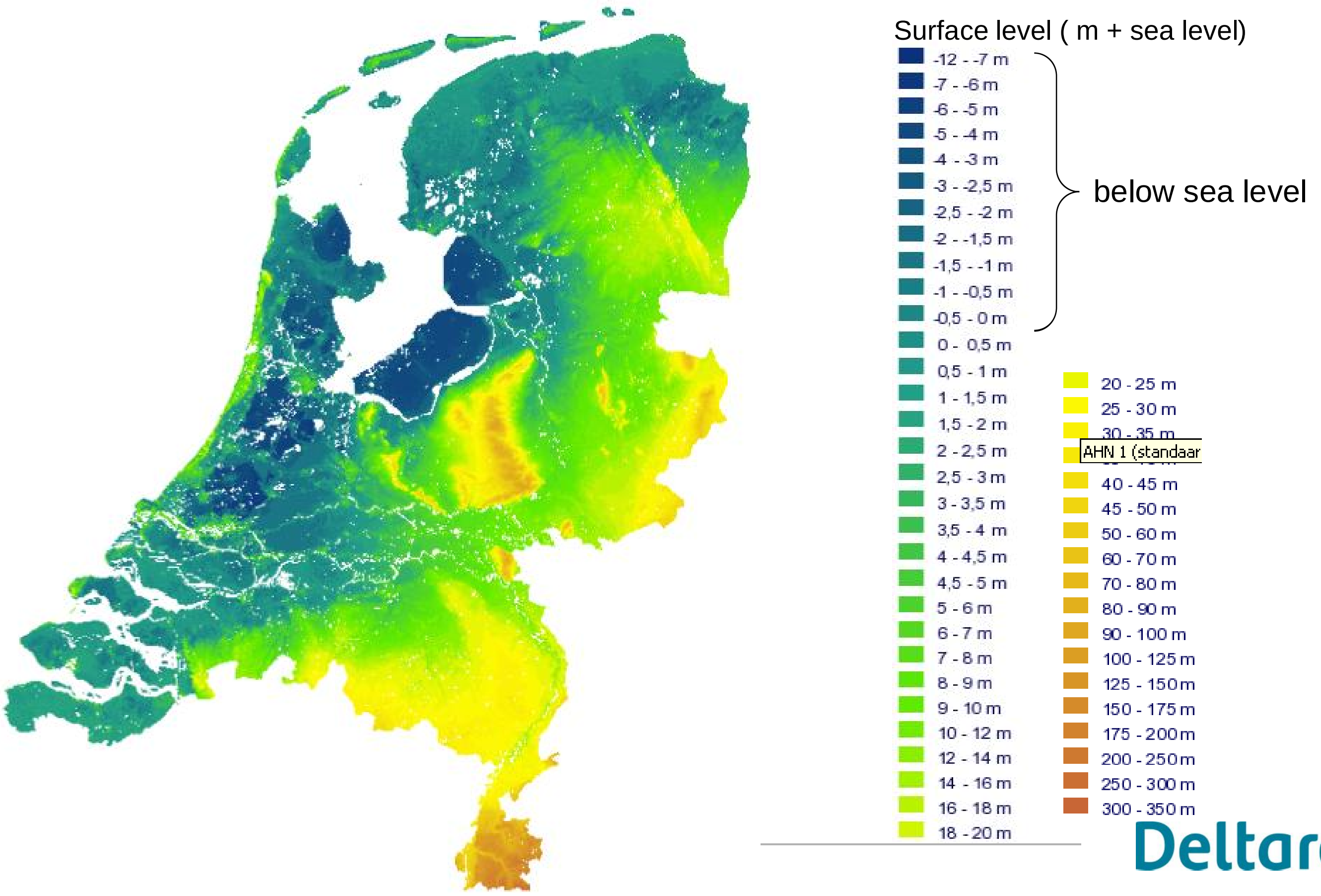
i) Elevation of current land surface

ii) Elevation of land surface 1000 years ago

Main presumption:

All land elevated presently under MSL used to be elevated at or above MSL.

Surface elevation of the Netherlands



Input 1: elevation of current land surface

Input data: digital elevation model of The Netherlands (AHN)

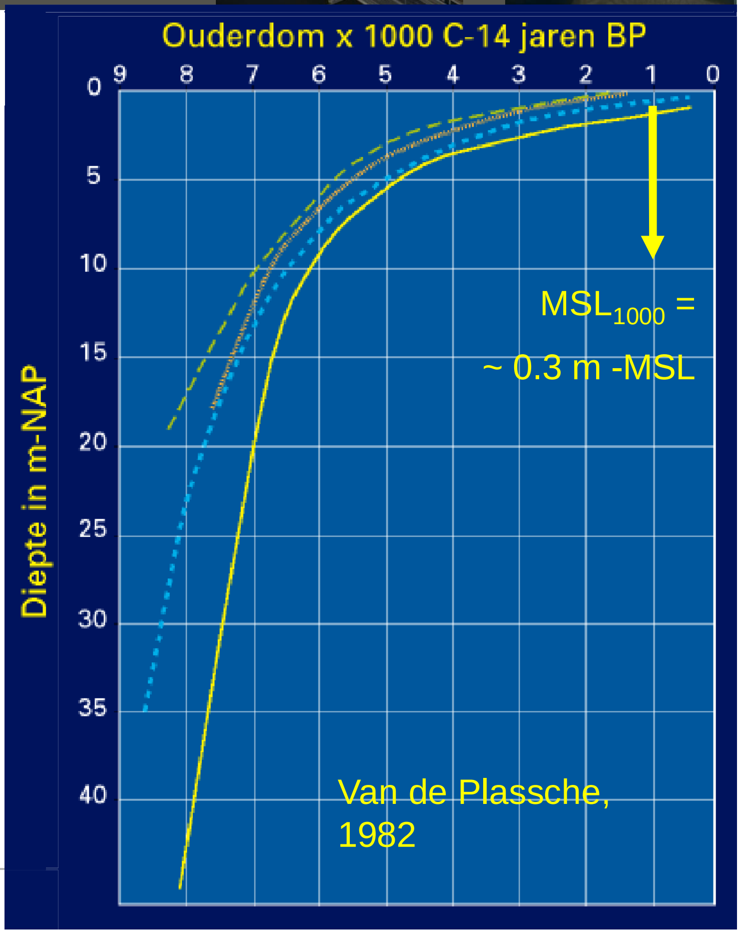
- Laser altimetry data (LIDAR)
- Nation-wide
- High-resolution of 1x1x0.05 m

We excluded:

i) Upland peatlands (above 1 m + MSL_{1000})
ii) Areas of open water
iii) Lowland with no subsurface peat
iv) Tectonic subsidence (30 cm in 1000 years)

Disclaimer:

All estimates and assumptions in this study are conservative!



Input 2: elevation of land surface 1000 AD

Input:

palaeogeographical and palaeobotanical reconstructions

- Based on core-derived and historical information
- Nation-wide
- Low resolution

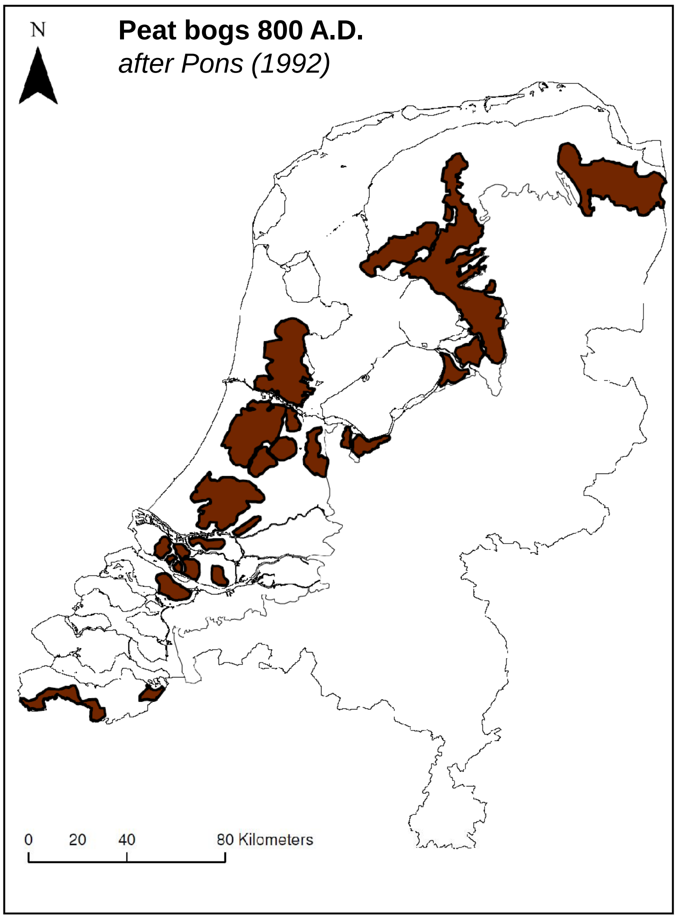
Two types of peat are distinguished:

i) Domes (bogs)
(elevated 2 m + MSL)

ii) Planes (fens)
(elevated 0.8 m + MSL)

Subsidence calculations:

Subtracting present-day land surface from the 1000 AD land surface



Results (i): total subsidence

Subsidence values because of anthropogenic land use:

On average: 2.0 m

Maximal: 12 m

This resulted in:

56 % of the Netherlands being below MSL

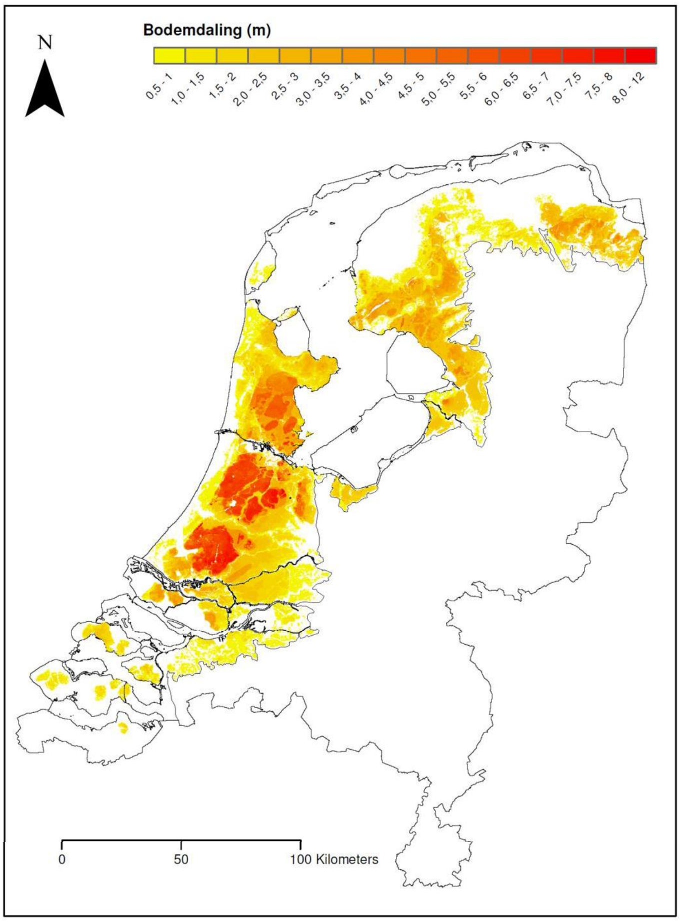
The need for continuous pumping

Reversal of drainage systems

Steps to obtain CO_2 respiration:

Calculate lost volume of peat

Calculate carbon content of the lost peat (using bulk density)



Results (ii): volumes

Peat type		Area (km^2)	Height (m)	Volume (km^3)
Older peat (below MSL_{1000})		**6661**	-	**8.3**
Bogs (above MSL_{1000})	**best estimate**	**4360**	**2**	**8.7**
	range	-	1 - 4	3.7 – 14.8
Fens (above MSL_{1000})	**best estimate**	**3534**	**0.8**	**2.9**
	range	-	0.5 – 1.5	1.8 – 5.3
Total	**best estimate**	**7895**	**-**	**20.0**
	range	-	-	13.8 – 28.4

Total ***volume*** of peat lost by anthropogenic land use : **~20 km^3**

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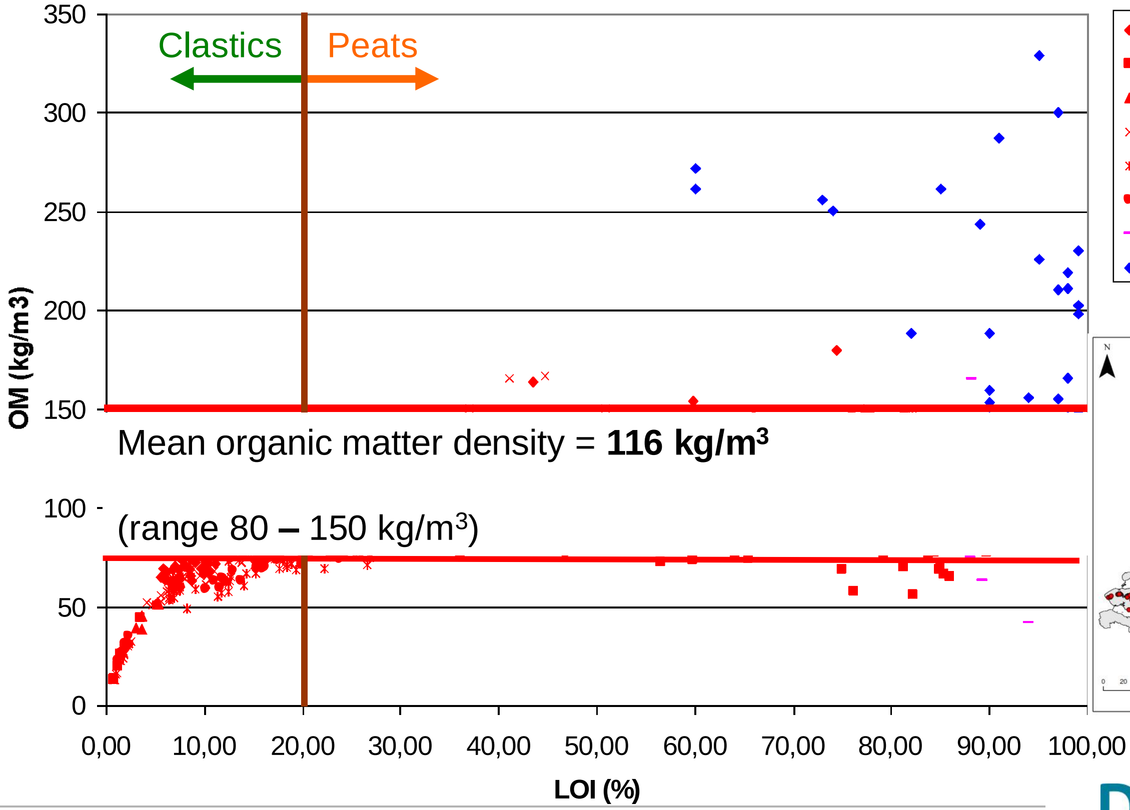
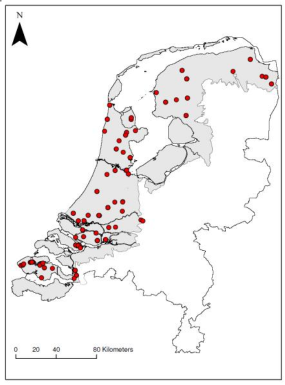
Input 3: Bulk density values

Organic matter mass per m³ from subsurface samples (n = 664)





Data from S. van Asselen, W.Z. Hoek, UU, Deltares, and TNO

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Subsidence ≠ CO_2 emission

Subsidence = **CO_2 emissions**

in case of combustion (in furnaces) ~ 20% of total volume

Subsidence ≠ CO_2 emissions

1. erosion of ditch banks after peat digging ~ 9% of total volume
2. drainage ~ 71% of total volume

Drainage of peat leads to:

1. shrinkage (negligible at longer time scales)
2. compression/compaction (~ 15 % at longer time scales)
3. **oxidation** (~ 85 % at longer time scales) **= CO_2 emission**

Deltares

Oxidation versus compression/compaction

Experimental field	Depth of ditch-water level (cm—surface)	Surface subsidence (mm)	Compression (mm)	Oxydation (mm)	Irreversible shrinkage (mm)
Zegvelderbroek	25	45	15	14	16
	75	92	27	29	36
Bleskensgraaf	35	10	0	12	−2
	70	52	16	19	17
	100	101	38	46	17
Hoenkoop	40	20	7	14	−1
	70	40	14	24	2
	100	64	24	38	2

Data from Schothorst, 1977

Please note: relatively low oxidation because of:
- short measurement period
- extreme drainage
- a single drainage event

Total CO_2 respiration

Soil carbon released during the past 1000 years:

1.0 Gton (10^{12} kg) *(0.5 – 2.0 Gton)*

CO_2 emitted to atmosphere* by land use in the Netherlands in 1000 year:

3.6 Gton (10^{12} kg) *(1.7 – 7.3 Gton)*

** 1 kg soil carbon = 3.67 kg atmospheric CO_2*

The net increase of atmospheric CO_2 concentration is **0.23 ppmv***

** gross increase is 0.46 ppmv, but 50 % of the CO2 emissions are taken up by the worlds oceans and biosphere.*

Discussion: world wide impact?

In comparison with the total global *land use* related CO_2 emissions:

The Dutch peat has caused **2.3 %** of the total CO_2 emissions
(while the area covers only **0.1 %** of the global peat surfaces).

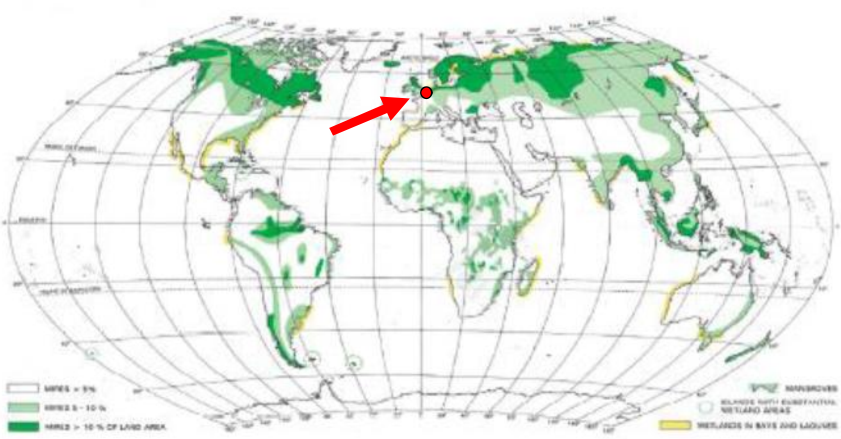

Figure 2.4: Extent and location of global mires and peatlands. (From Lappalainen, 1996).

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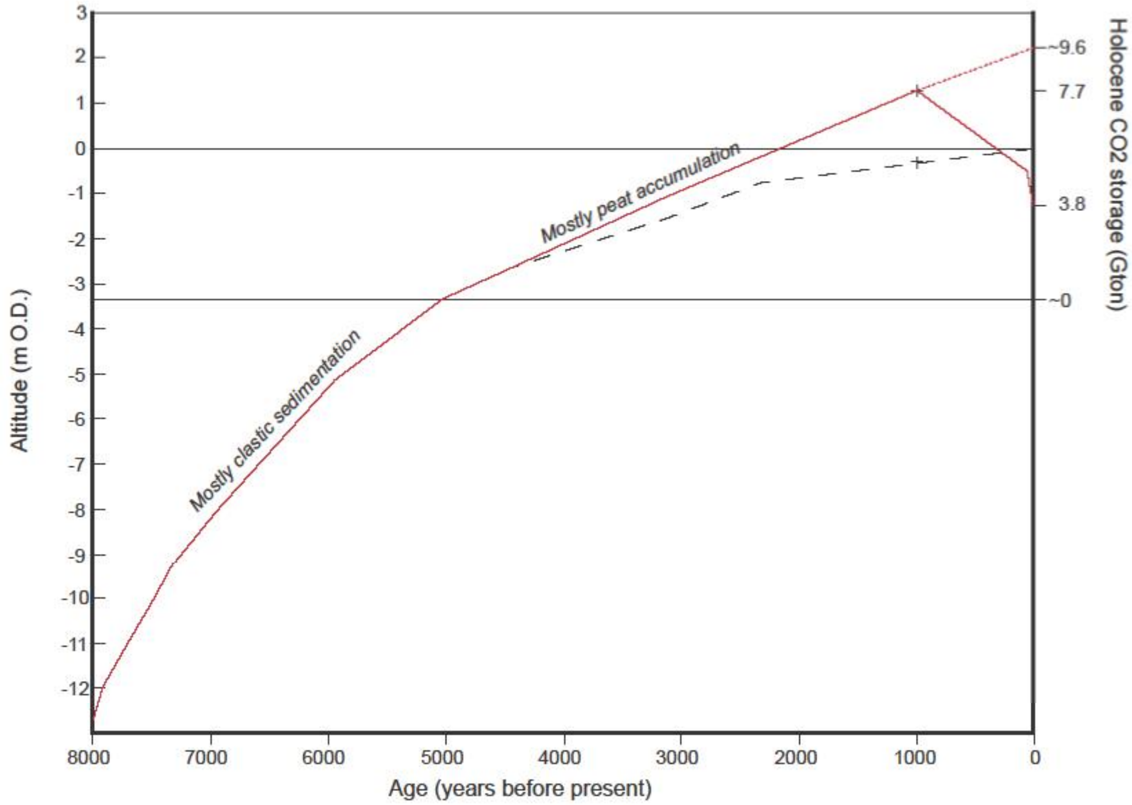
Loss in carbon storage



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Living behind dikes……

and below mean sea level…..

this implies careful water management (24-7!)

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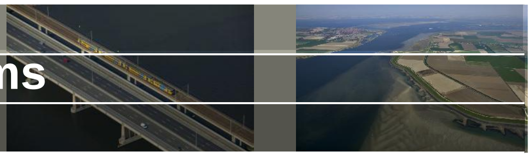
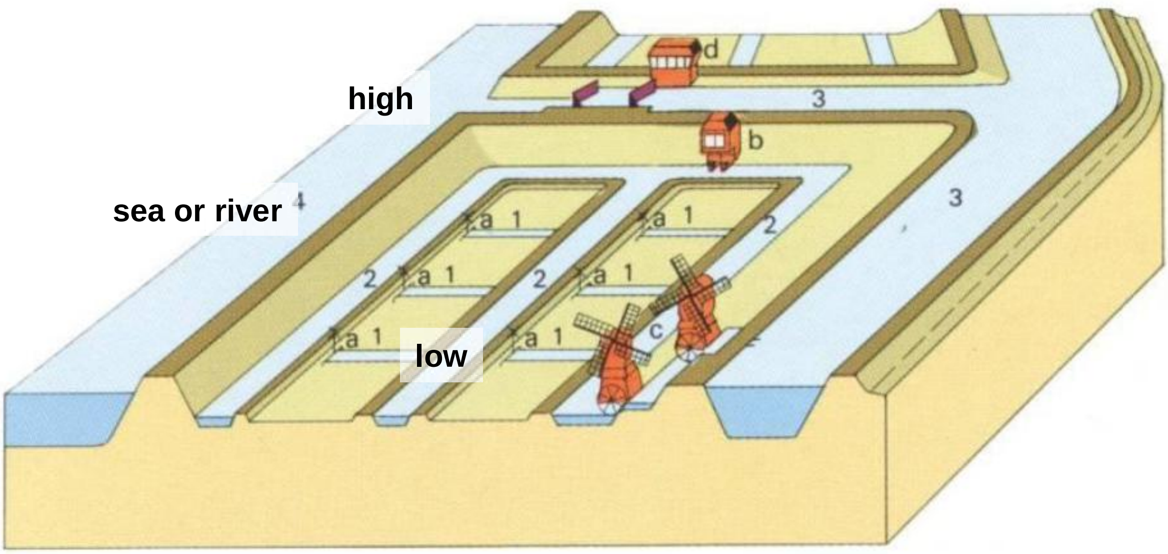
Polders: water management systems in the coastal areas



A polder is:
a sophisticated system to drain the excess of water in a low-lying area



In the field….

shallow
lakes and
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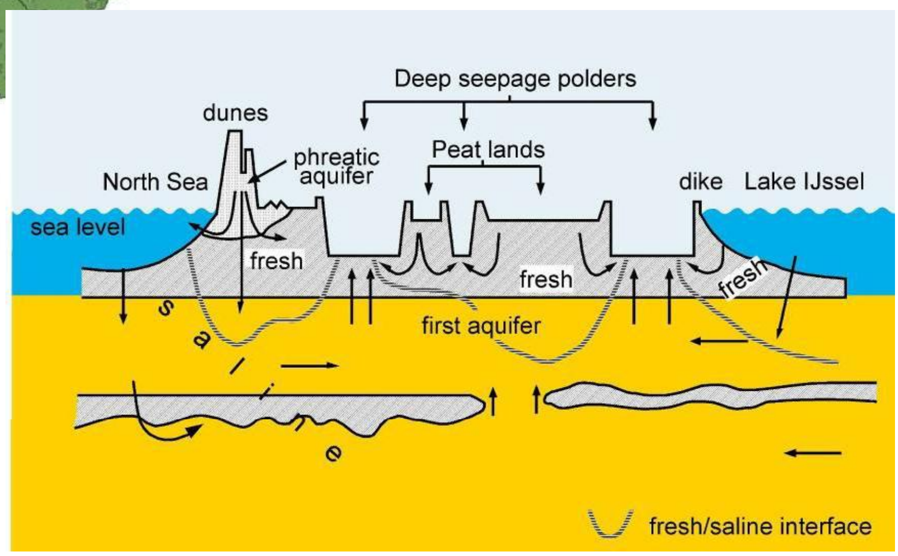
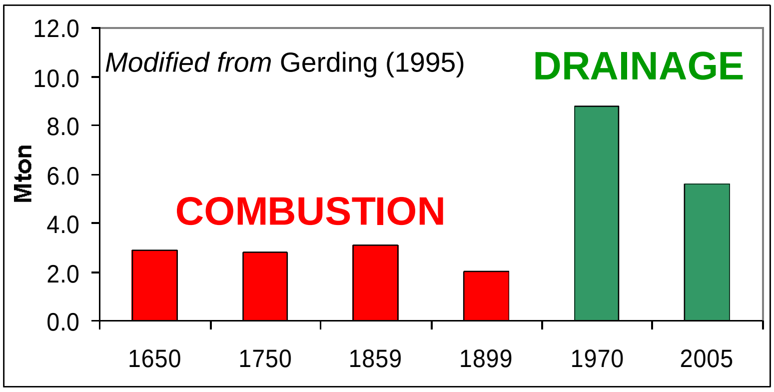
13 juni 2013

Land below sea level

Approximately 40% of the Netherlands below sea level (blue areas).

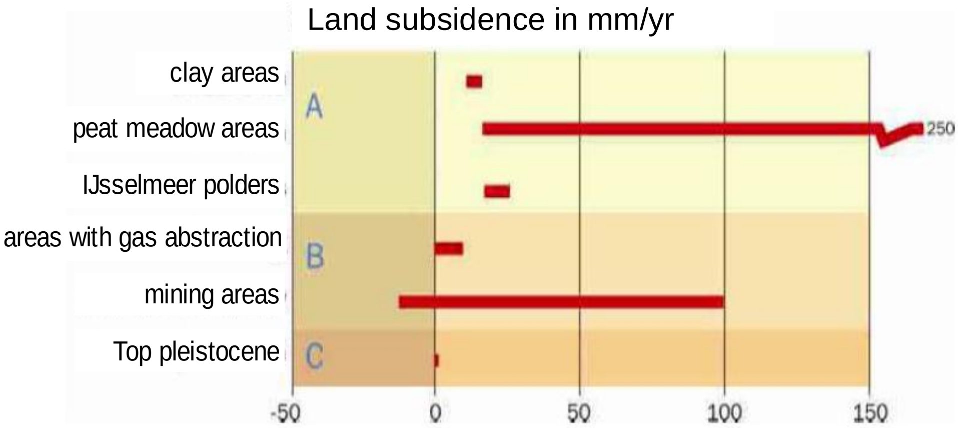


Lessons for present-day land management



Lesson 1:

The highly effective present-day drainage of the Dutch peatlands is still a large source of CO_2



source: De Lange et al., 2006

Lesson 2:

Subsidence rates in the peat area are by far the highest in the coastal plain.

Deltares

Conclusions PART ONE

1. Using geological data, it is possible to determine changes in peat volume over time.

2. Drainage and excavation of peat has caused 2.0 m land subsidence in the coastal and deltaic plain of The Netherlands

3. Long period of intensive drainage in areas with thick peat layers (*often coastal areas*) causes significant CO_2 emissions

4. The outcomes of this research can be used to estimate the potential CO_2 emission in coastal peat areas in other parts of the world.

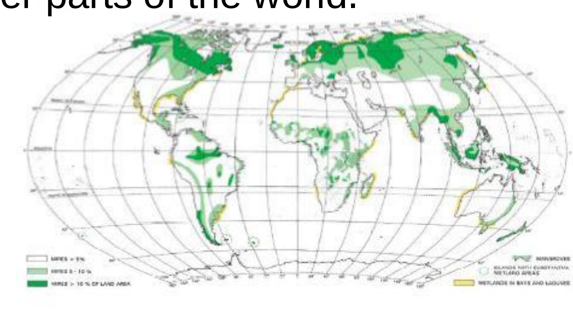


Figure 2.4: Extent and location of global mires and peatlands. (From Lappalainen, 1996).

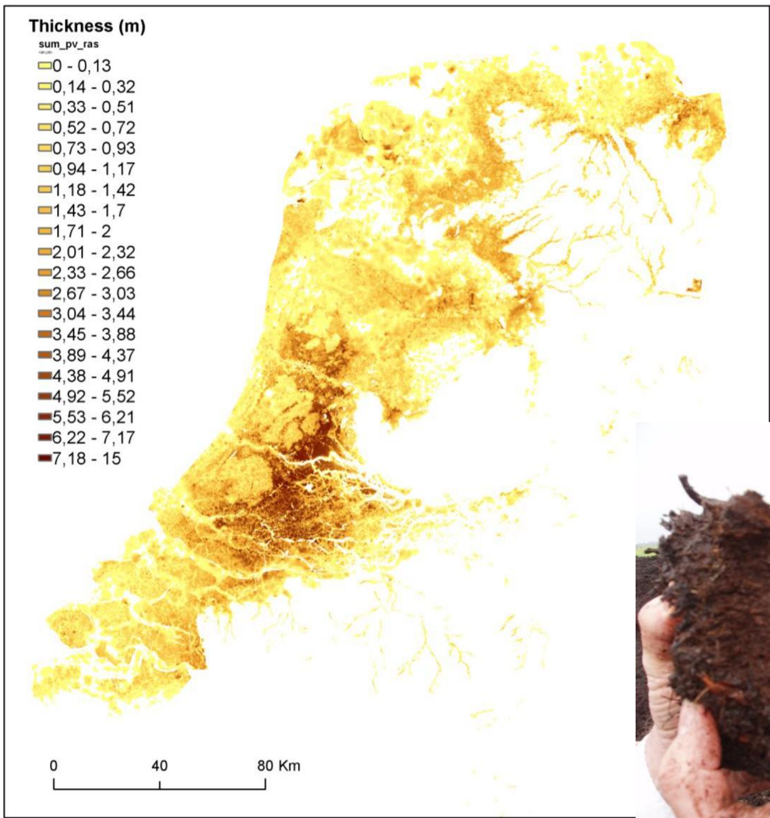
PART TWO: current situation

Which problems occur due to peat oxidation and soil subsidence?

illustrated with examples from the Netherlands

Deltares

How much peat is left in the Netherlands?



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Which problems occur?

- **Large area below see level**
  → continuous protection against water to reduce risks (high costs)

- Polder areas: continuous pumping of water (high costs)

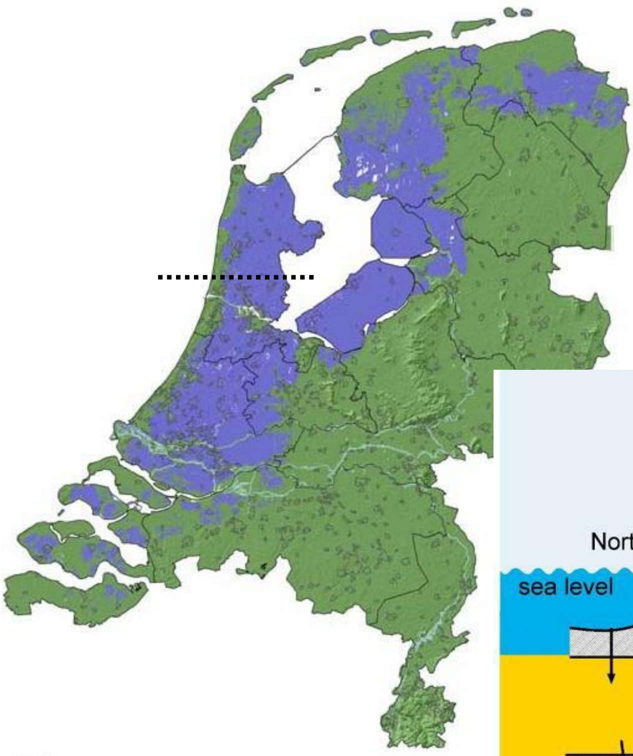
- Continued soil subsidence due to pumping
  → problems increase!!

- Damage to constructions

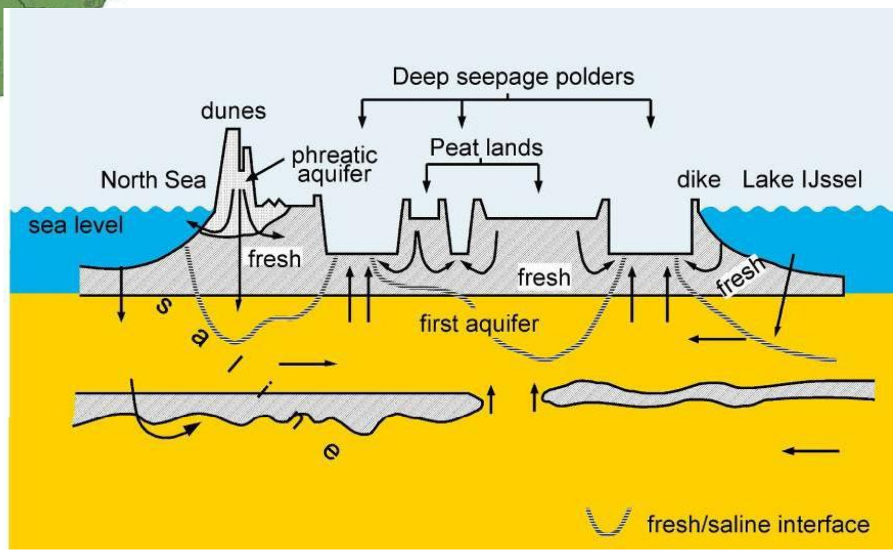
- Deep polder areas: salt water seepage (diffuse and via boils)
  → problem for agriculture

- High greenhouse gas emissions (CO_2, N_2O and CH_4)

Our land below sea level

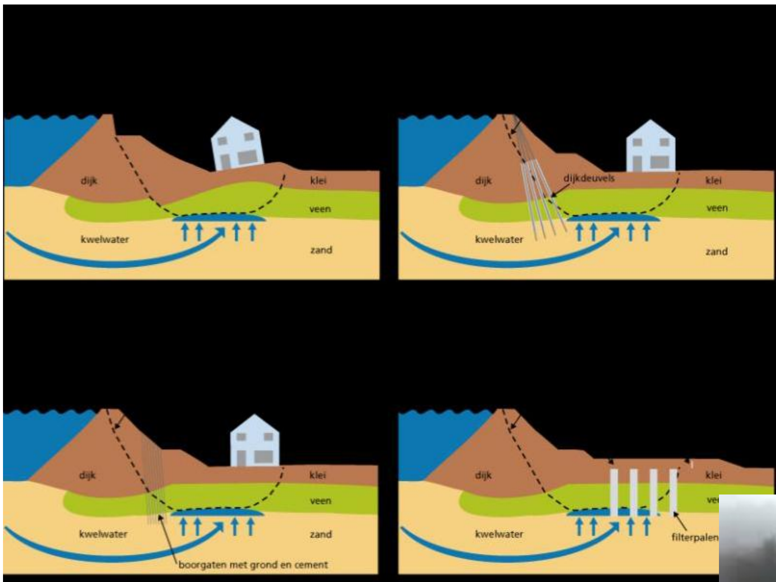


Approximately 40% of the Netherlands below sea level (blue areas).

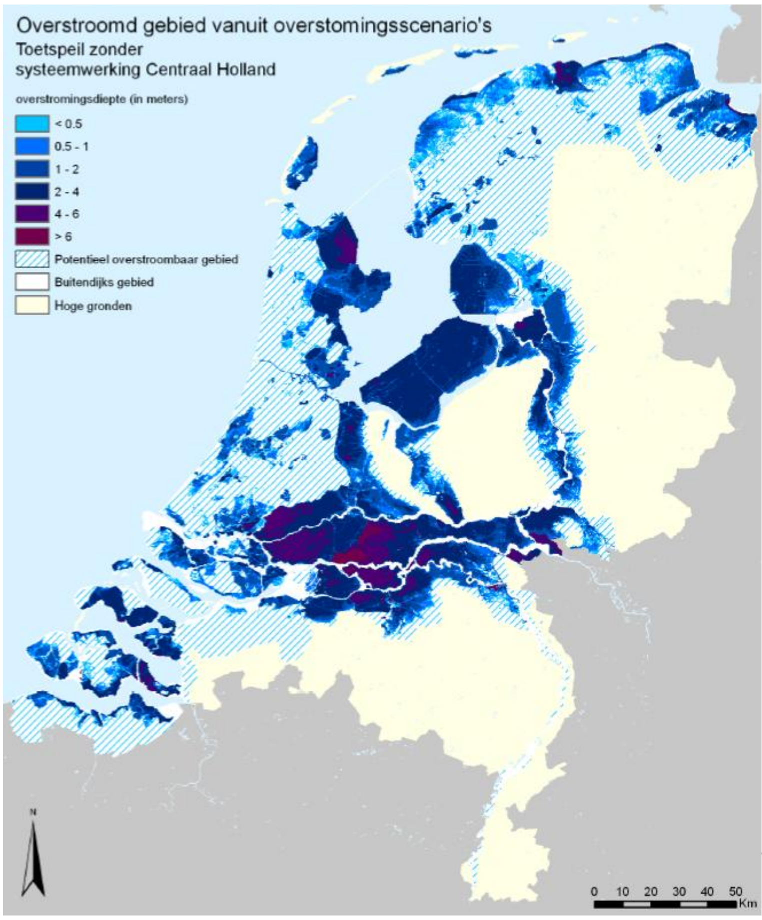


Extensive protection against water (high costs)

Problem: possible failure of dikes…



Inundated area after dike failure (Deltares 2011)

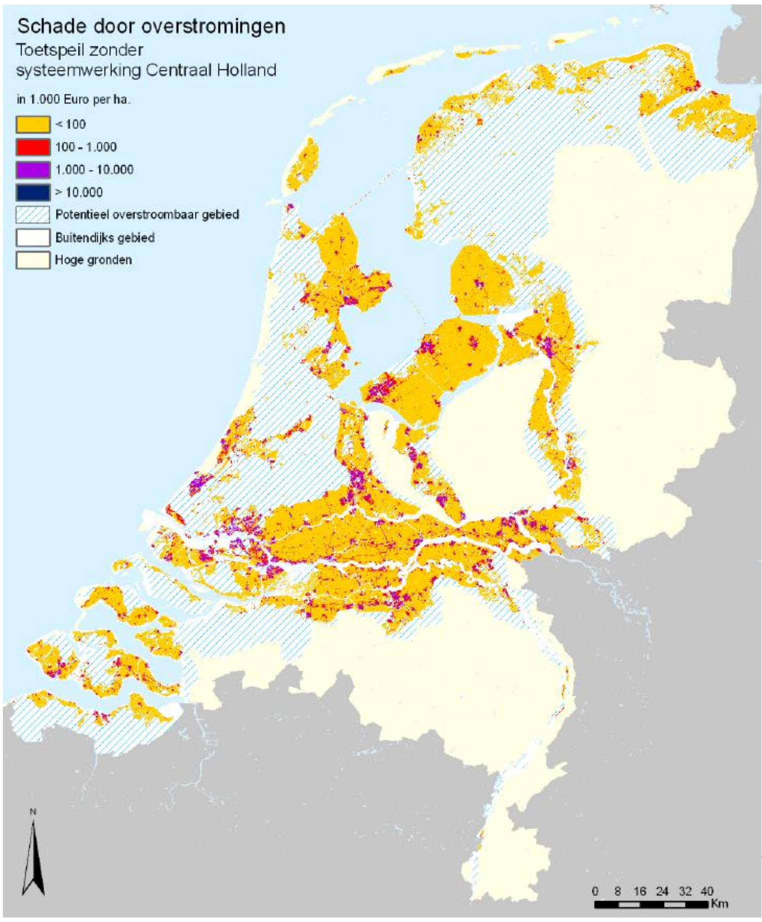


Inundation depth (meters)

- < 0.5
- 0.5 - 1
- 1 - 2
- 2 - 4
- 4 - 6
- > 6
- potential inundation areas future
- areas outside dike rings (along rivers)
- high areas

From: De Bruijn & Van der Doef (2011)

Potential damage resulting from inundation



damage (kEuro / hectare)

- < 100
- 100 - 1.000
- 1.000 - 10.000
- > 10.000
- potential inundation areas future
- areas outside dike rings (along rivers)
- high areas

From: De Bruijn & Van der Doef (2011)

Which problems occur?

- Large area below see level
  → continuous protection against water to reduce risks (high costs)

- **Polder areas: ongoing pumping of water (high costs)**

- **Continued soil subsidence due to drainage**
  → subsidence still continues!!

- Damage to constructions

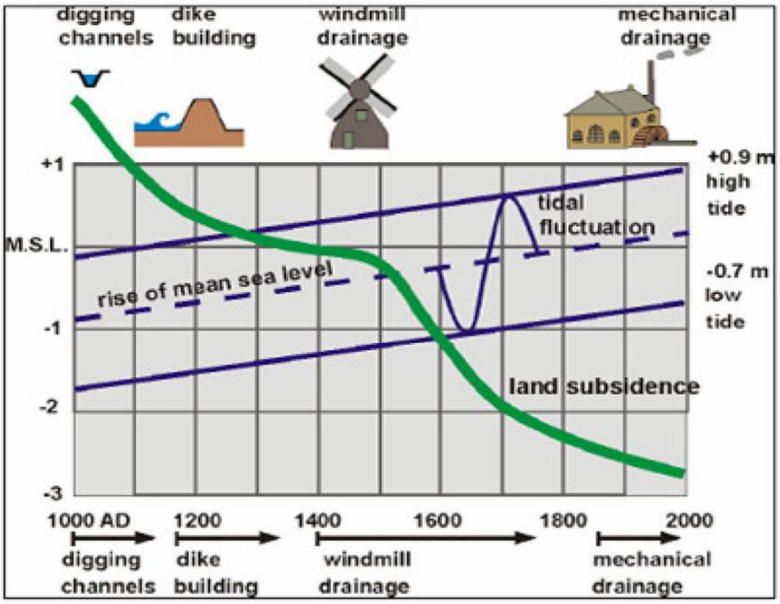
- Deep polder areas: salt water seepage (diffuse and via boils)
  → problem for agriculture

- High greenhouse gas emissions (CO_2, N_2O and CH_4)

Continuous pumping of water from polder areas

… to maintain (low) groundwater level that is needed for agriculture and inhabitance

Continuous pumping of water from polder areas



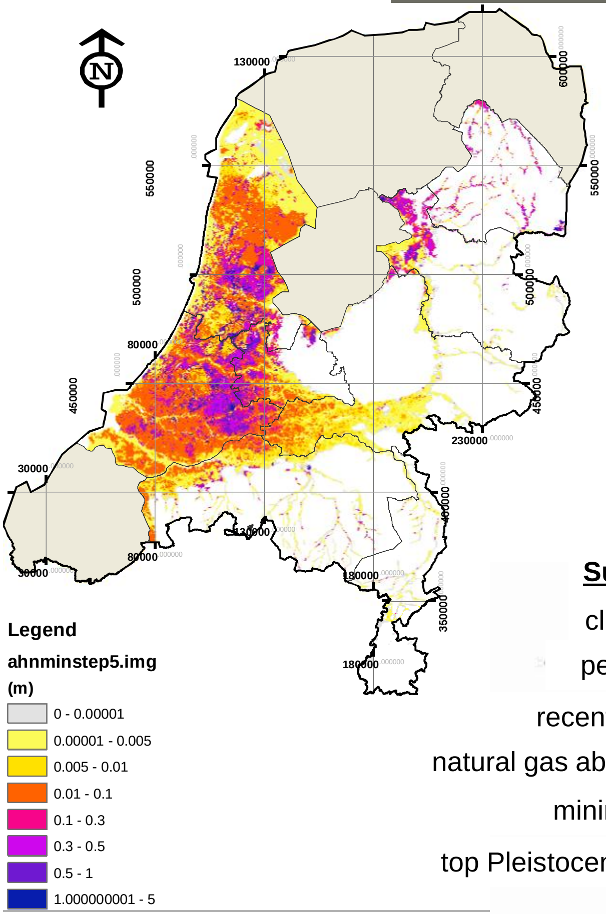
Pumping of water increases land subsidence through:

- enhanced peat oxidation

- enhanced consolidation and shrinkage

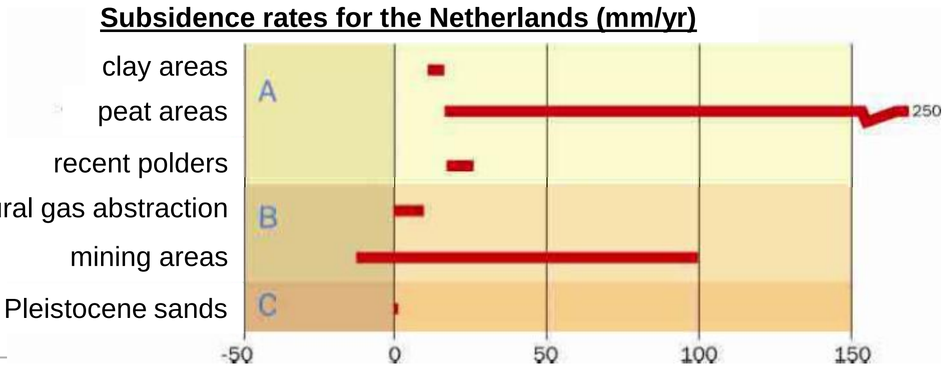
Soil subsidence in 2050

From: De Lange et al. (2011)



Soil subsidence prognoses for the Netherlands

peat areas: 0 to 60 cm in 2050 depending on soil composition and local water management



From: De Lange et al. (2006)

Which problems occur?

- Large area below see level
  → continuous protection against water to reduce risks (high costs)

- Polder areas: continuous pumping of water (high costs)

- Continued soil subsidence due to pumping
  → problems increase!!

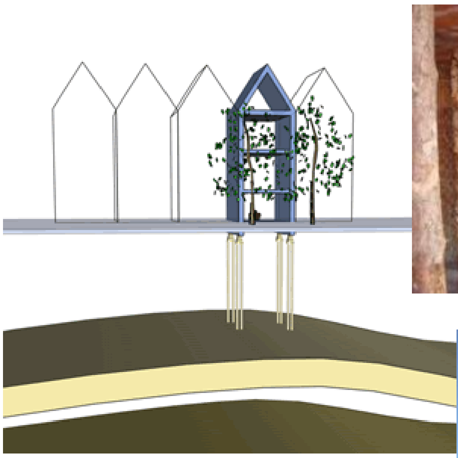
- **Damage to constructions**

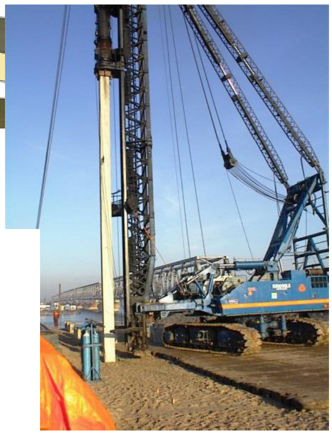
- Deep polder areas: salt water seepage (diffuse and via boils)
  → problem for agriculture

- High greenhouse gas emissions (CO_2, N_2O and CH_4)

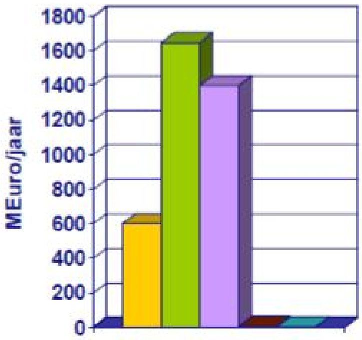
Subsidence and damage of constructions

Extensive foundations of buildings and roads





high costs!!



Deltares

Which problems occur?

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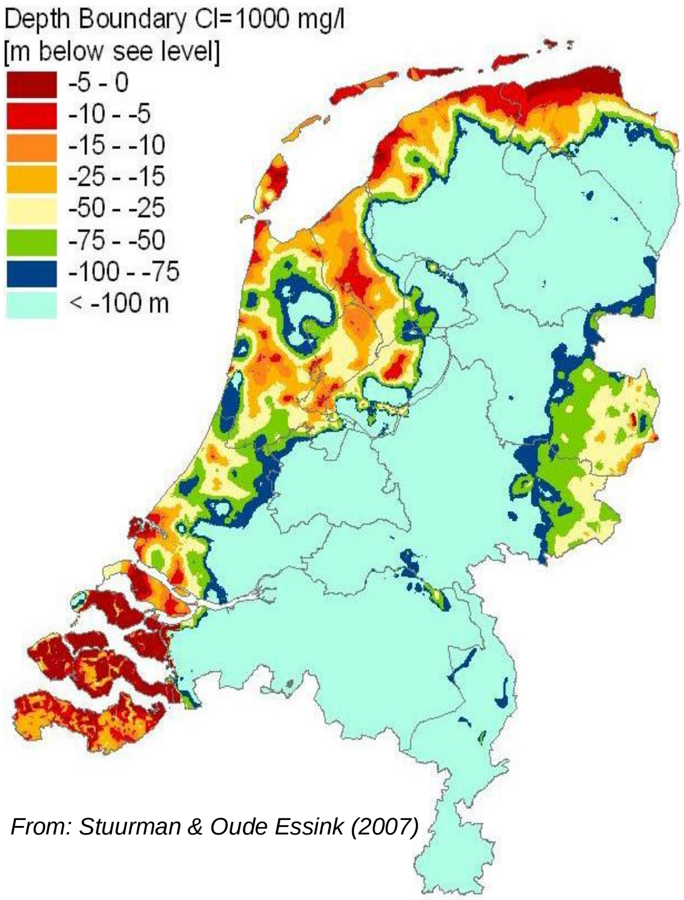
- Subsidence and damage constructions

- **Deep polder areas: salt water seepage (diffuse and via boils)**
  → problem for agriculture

- High greenhouse gas emissions (CO_2, N_2O and CH_4)

Deltares

Salt water upconing and seepage (salinization)

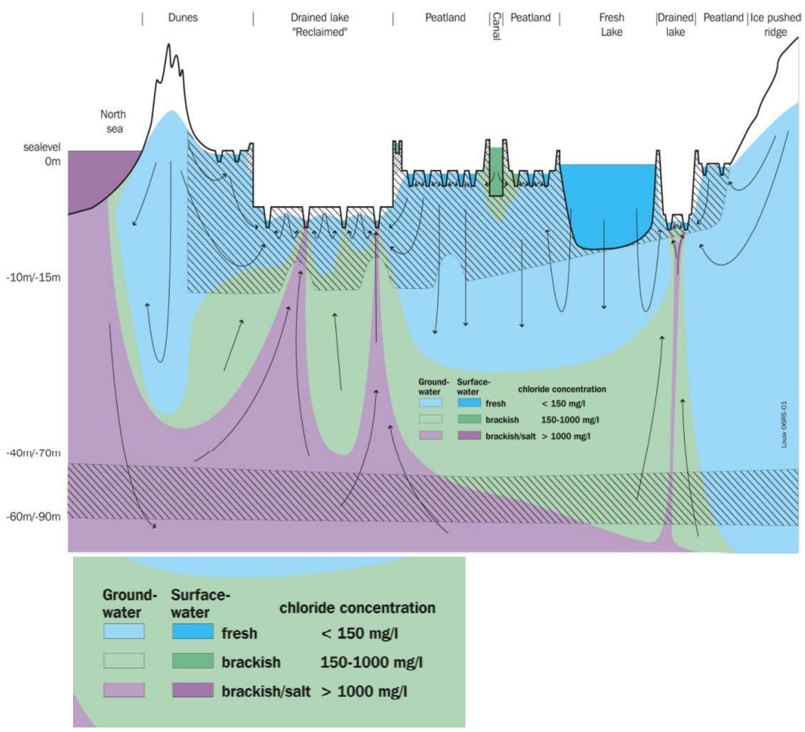


- As a result of continuous pumping the salt groundwater is drawn to the surface.
- In low lying polder areas, the salt water contaminates the fresh surface water and soil (red zones).
- High chloride concentrations are harmful for plants and agriculture.

From: Stuurman & Oude Essink (2007)

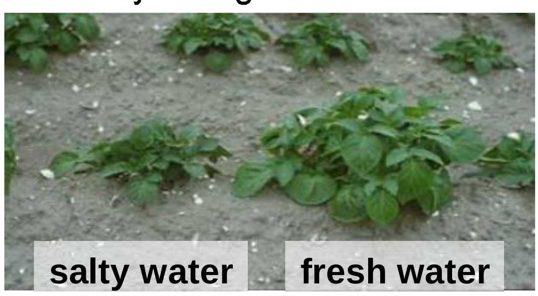
Deltares

Salt water upconing and seepage (salinization)



From: De Louw et al. (2010)

Effect on plants and low yield agriculture….



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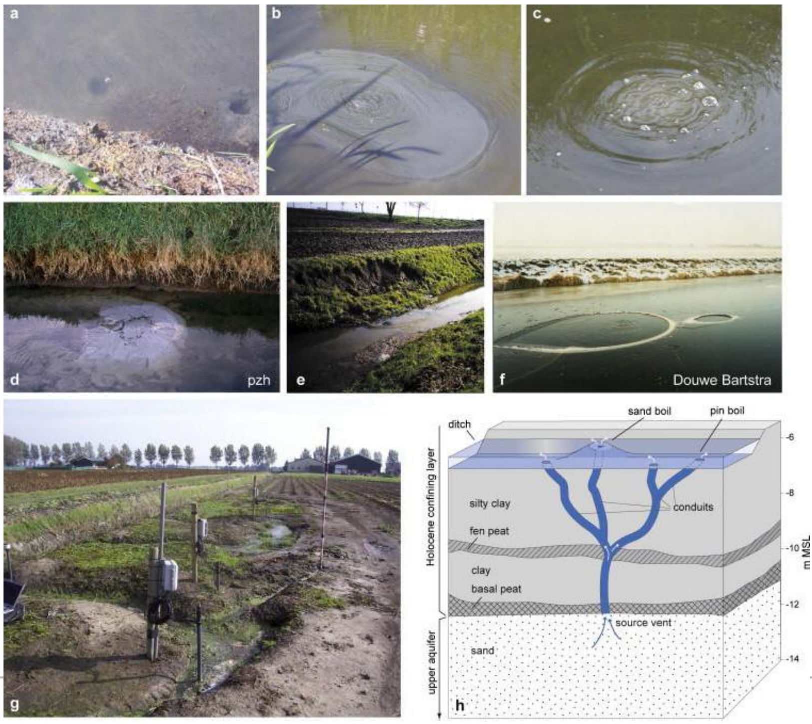
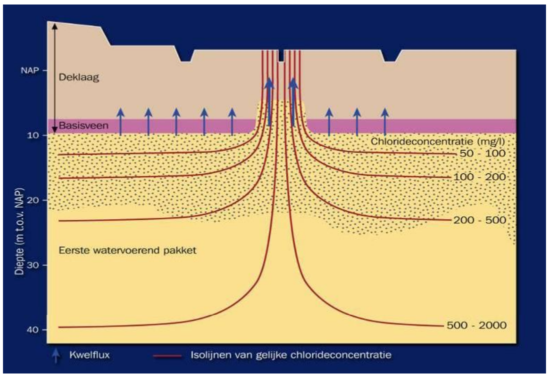
Salt water upconing and seepage (salinization)

If the Holocene peat and clay deposits are thin, the counter-pressure of the peat and clay layer may become too small:
→ seepage water creates holes in the confined layer
→ salt water flows towards the surface through boils.





From: De Louw et al. (2010)

Deltares

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  → problems increase!!

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- Deep polder areas: salt water seepage (diffuse and via boils)
  → problem for agriculture

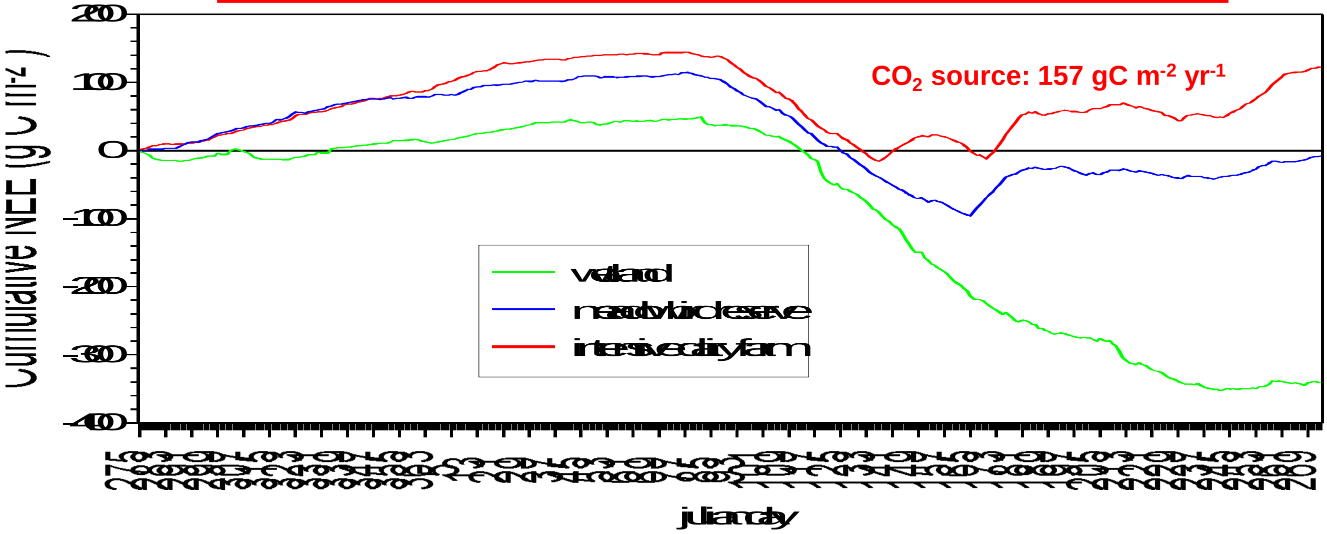
- **High greenhouse gas emissions (CO_2, N_2O and CH_4)**

Deltares

Greenhouse Gas Emissions

Dutch peat meadow areas with low water table (agricultural) have high rates of peat oxidation and high CO_2 emissions.

emission



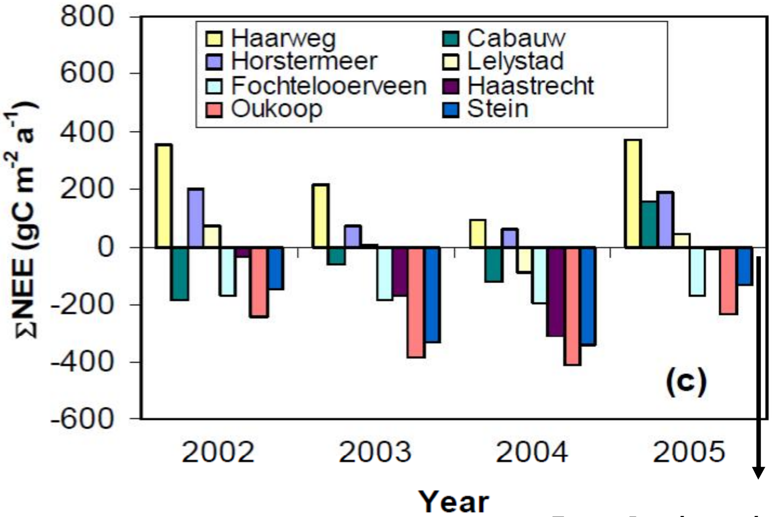
uptake

NEE = net ecosystem exchange of CO_2

Deltares

Greenhouse Gas Emissions

Name	Type	Soil (FAO)	OC-content (%)	Fertilizer Use	Land Use	Year
Haarweg	WMO-Grassland	Eutric gleyic Fluvisol	3	No	Mowing	2002–2005
Cabauw	WMO-Grassland	Eutric Fluvisol	5	No	Grazing sheep	2002–2005
Horstermeer	Grassland/Wetland	Eutric Histosol	20	No	Semi-natural permanent grassland	2005
Fochterlooërveen	Natural Grassland	Eutric Histosol	50	No	Natural grassland	1994–1995
Haastrecht	Production Grassland	Eutric Fibric Histosol	n/a	Yes	Intensively managed permanent grassland	2003(July)–2004(May)
Oukoop	Production Grassland	Fibric Eutric Histosol	15	Yes	Intensively managed permanent grassland	2005
Stein	Meadow Bird Reserve	Fibric Eutric Histosol	15	No	Natural grassland	2005
Lelystad	Production Grassland	Calcaric Eutric Fluvisol	3	Yes (6 times a year)	Intensively managed permanent grassland	2004



uptake

emission

NEE = net ecosystem exchange of CO_2

From: Jacobs et al. (2007)

PART 2: Conclusions

Which problems occur due to peat oxidation and soil subsidence?

- Large areas have **inundation risk**
- Protection and continuous pumping create **high costs**
- Agriculture suffers from **salinization**
- Subsidence causes **damage to constructions**
- Peat oxidation causes **CO_2 emission** (climate warming)
- Problems still aggravate due to lowering water tables causing **ongoing oxidation and subsidence**

PART THREE: measures and solutions

Which measures can be taken to reduce peat oxidation and soil subsidence?

illustrated with examples from the Netherlands

Which measures can be taken …

… to reduce peat oxidation and soil subsidence??

Research has been done on the following management strategies:

- Increase surface waterlevel and change to extensive agriculture
- Rewet and change to nature area
- Dynamic water management
- Change of tile drainage systeem
- Forming of embankments
- Large scale changes land-use for peat regeneration

For most strategies water management and inherent land-use change is most important.

Example 1: increase surface waterlevel and change to extensive agriculture

Example 1: increase surface waterlevel

Intensive agriculture with low water table

Extensive agriculture with low – high water table

Example 1: increase surface waterlevel

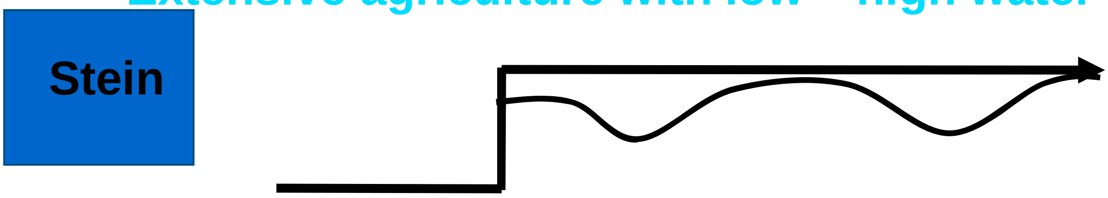
[illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

Intensive agriculture with low water table

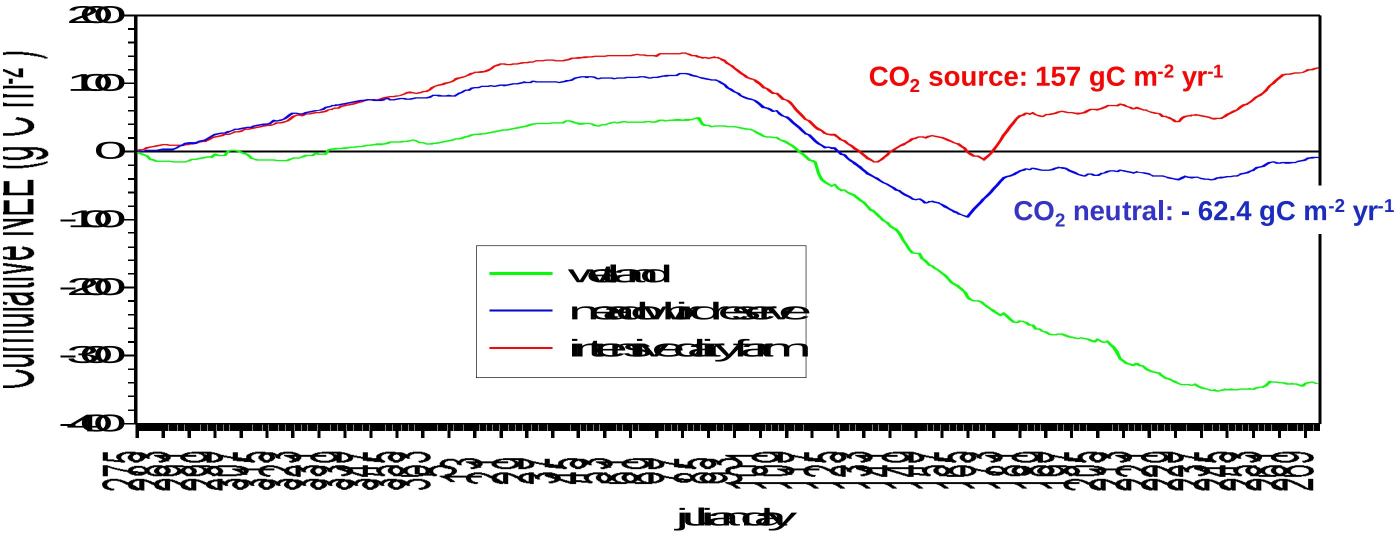
Example 1: increase surface waterlevel

Extensive agriculture with low – high water table



Example 1: increase surface waterlevel

Dutch peat meadow areas with adjusted water table management (generally wetter) have reduced rates of peat oxidation and are approximately CO_2 neutral

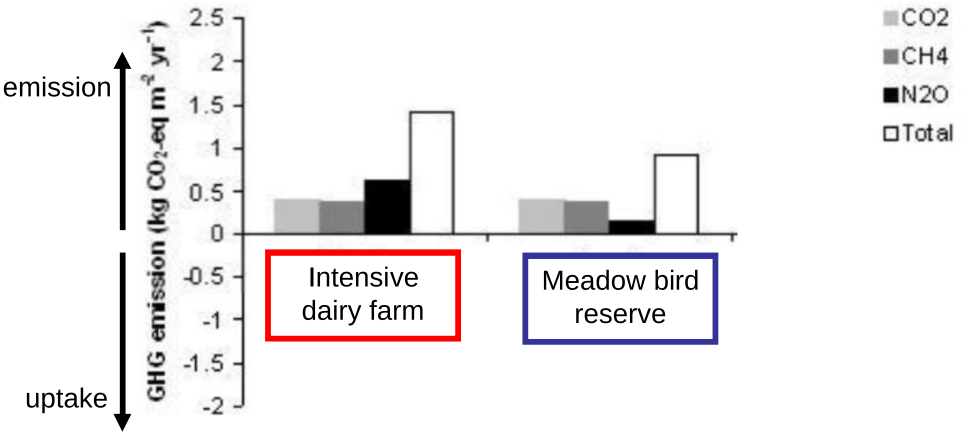


→ **Soil subsidence due to peat oxidation reduced**

Example 1: increase surface waterlevel

BUT…other GHGs of importance in agricultural area:

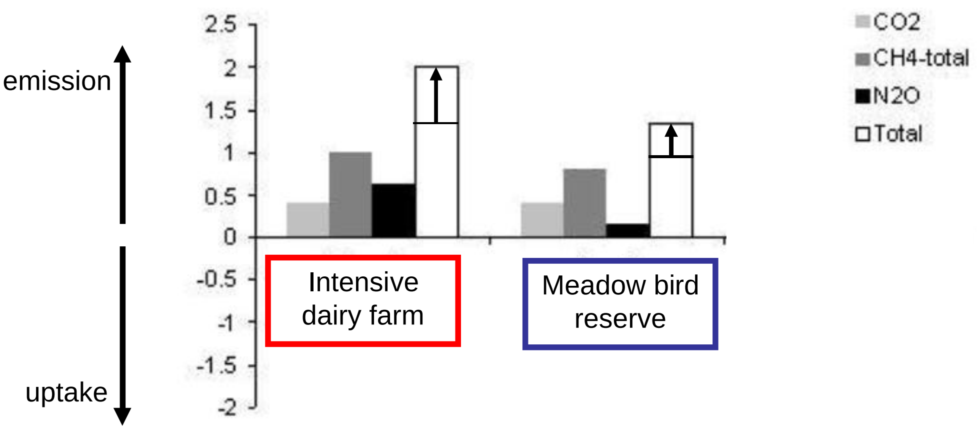
- methane (CH_4) *25 times stronger GHG than CO_2 (25 CO_2-equivalents)*
- nitrous oxide (N_2O) *300 times stronger GHG than CO_2 (300 CO_2-equivalents)*
- CO_2 emission through mowing



From: Schrier et al., to be submitted

Example 1: increase surface waterlevel

In agricultural areas, farm based GHG emissions, like cattle (CH_4) and manure deposits (CH_4 and N_2O), take up a large part of the balance:



From: Schrier et al., to be submitted

Example 2: rewet and change to nature area

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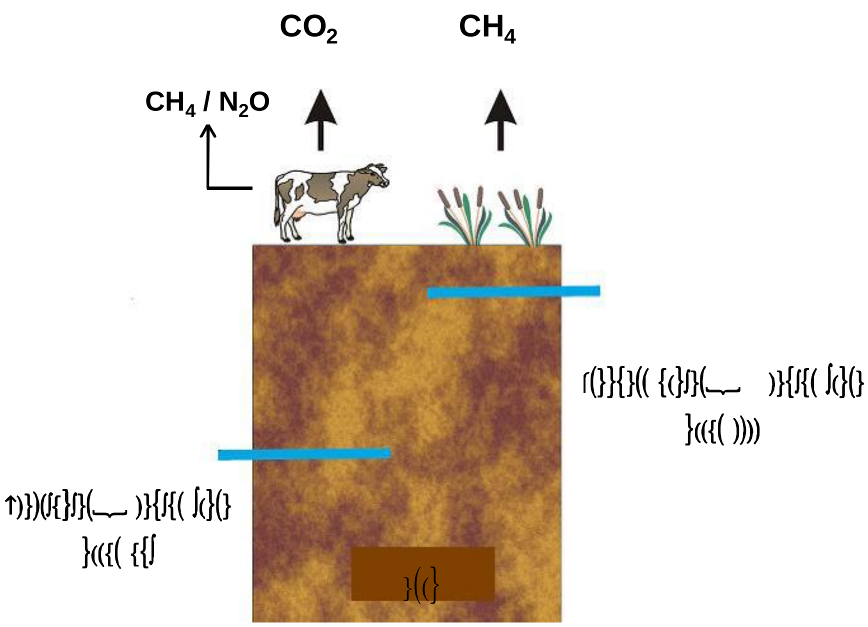

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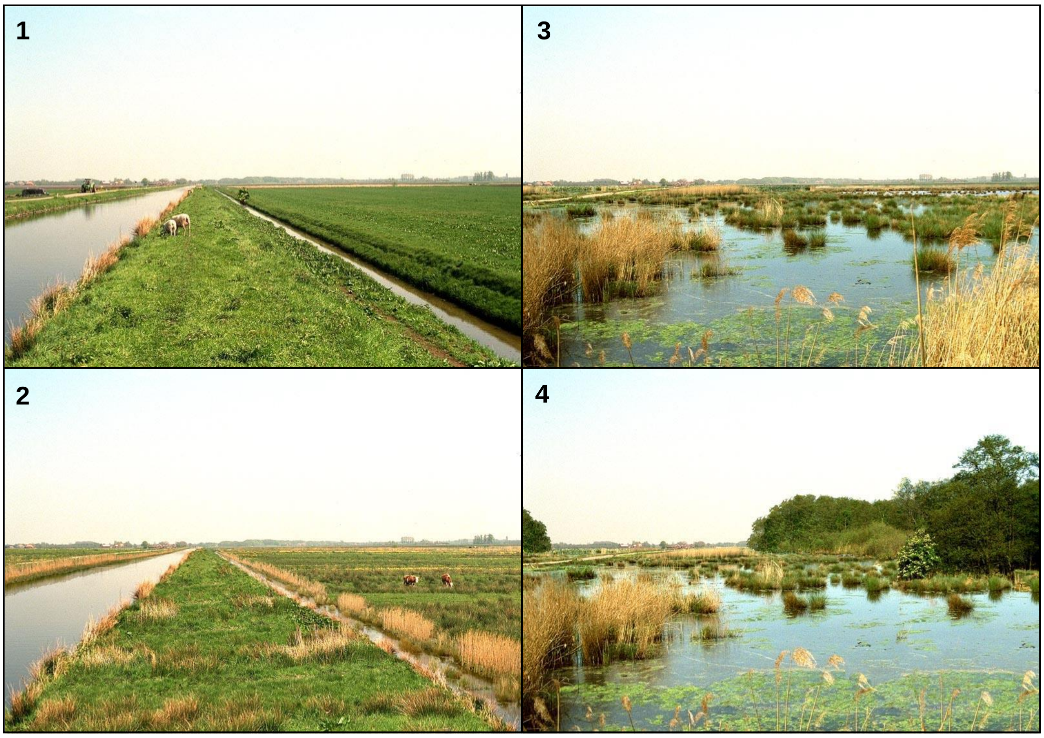

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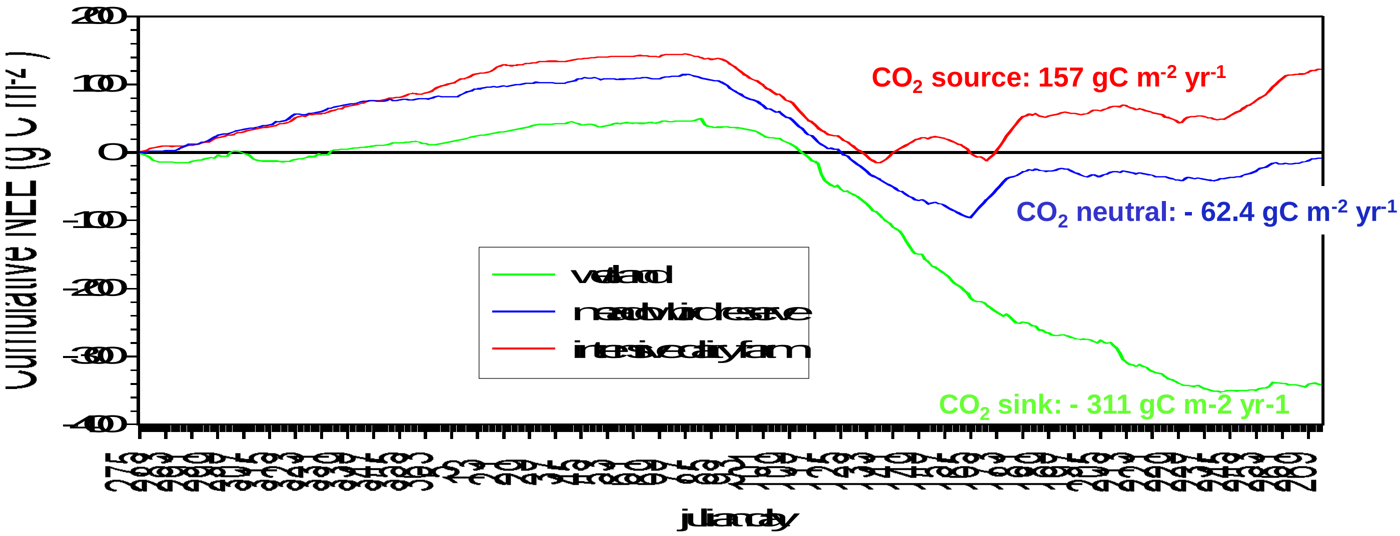
Example 2: rewet and change to nature area

Dutch peat meadow areas with increased water table have strongly reduced rates of peat oxidation and CO_2 uptake.



→**Soil subsidence due to peat oxidation reduced**

→ **Potentially peat re-growth**

(accumulation organic material below water level)

Example 2: rewet and change to nature area

BUT…other GHGs of importance in agricultural area:

- methane (CH_4) *25 times stronger GHG than CO_2 (25 CO_2-equivalents)*
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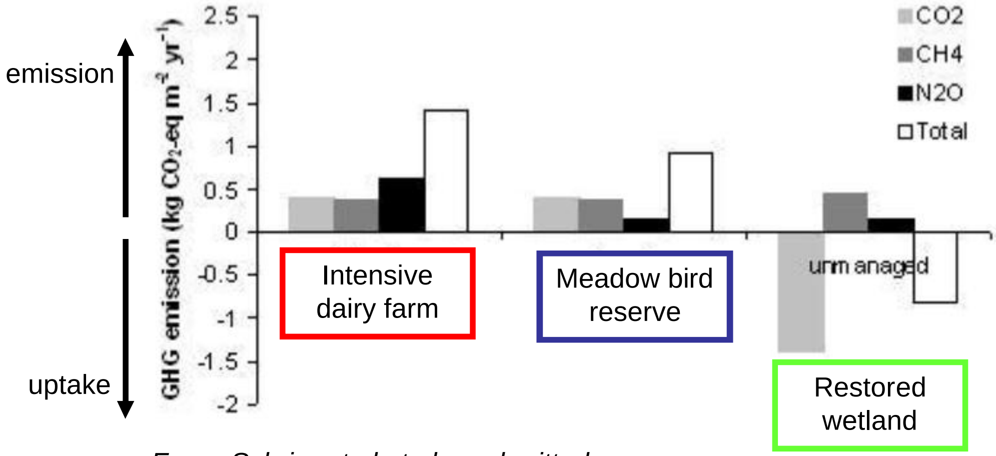


From: Schrier et al., to be submitted

Remarks

Nutrient rich conditions cause high fluxes of all GHGs!!

CH_4 emissions from lakes and ditches can be very high!!

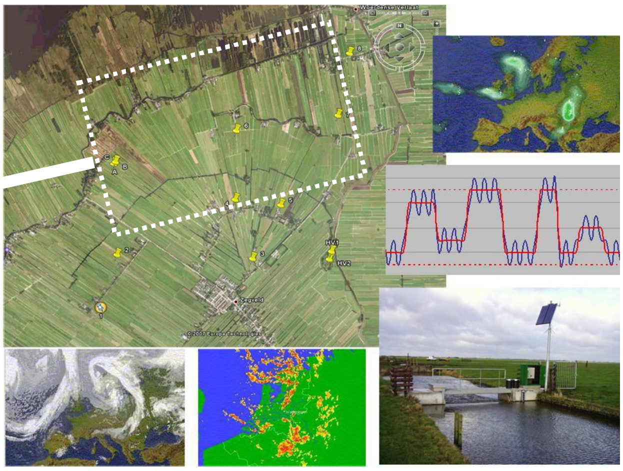
Example 3: dynamic water management

Example 3: dynamic water management

Aims of farmers and water managers:
- reducing drought problems
- minimizing peat oxidation and soil subsidence
- maintain normal crop production

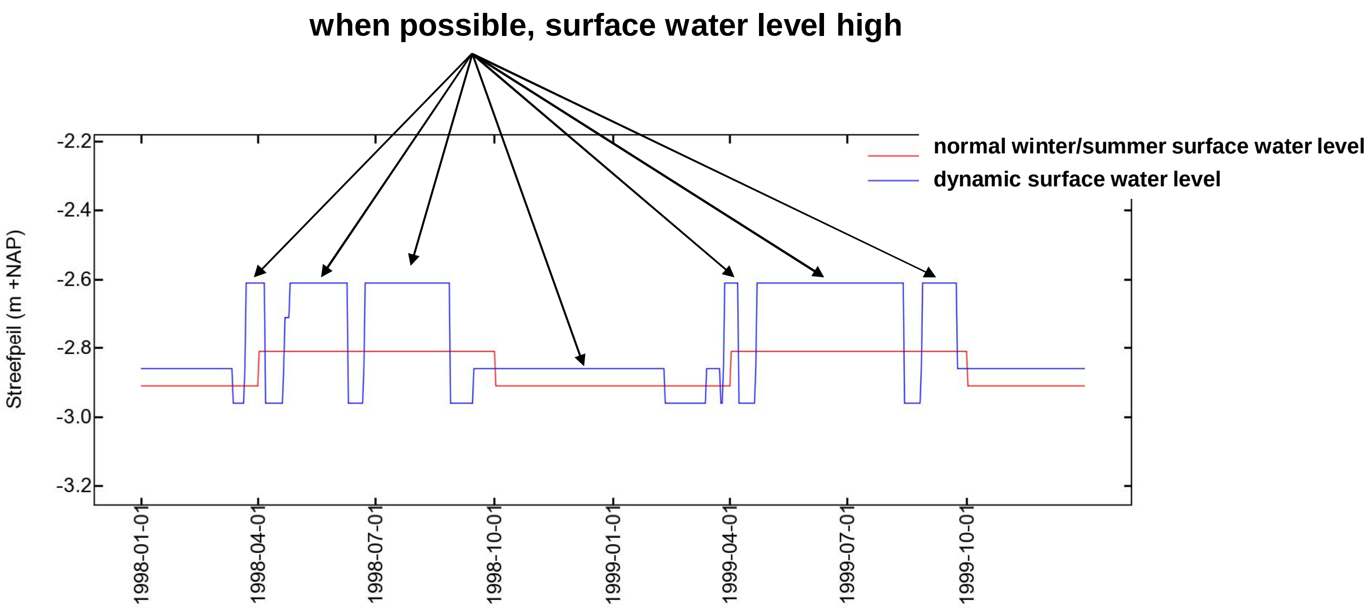
Farmers decide on surface water level, based on:
- Phase of growing season (soil conditions required for crop)
- Required activities on land
- Weather predictions

Example: study polder Zegveld



Example 3: dynamic water management

→ Water level in polder is evaluated and adjusted every week …



Example 3: dynamic water management

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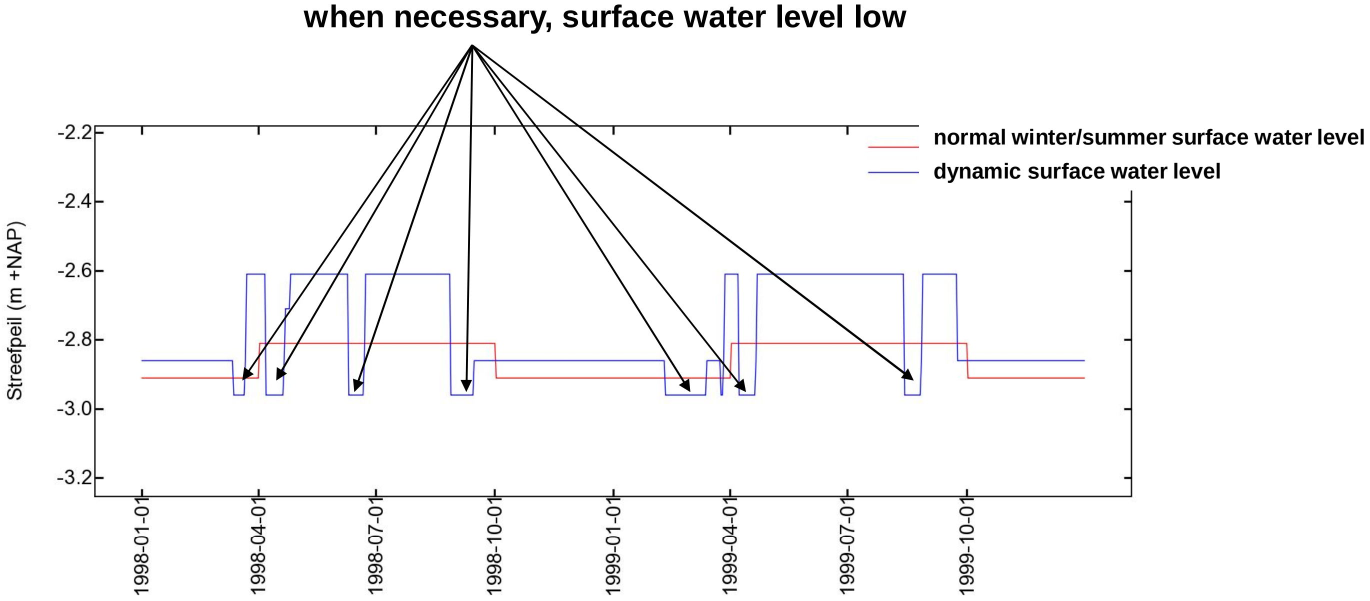
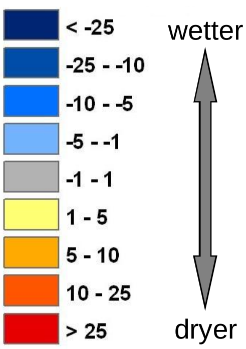
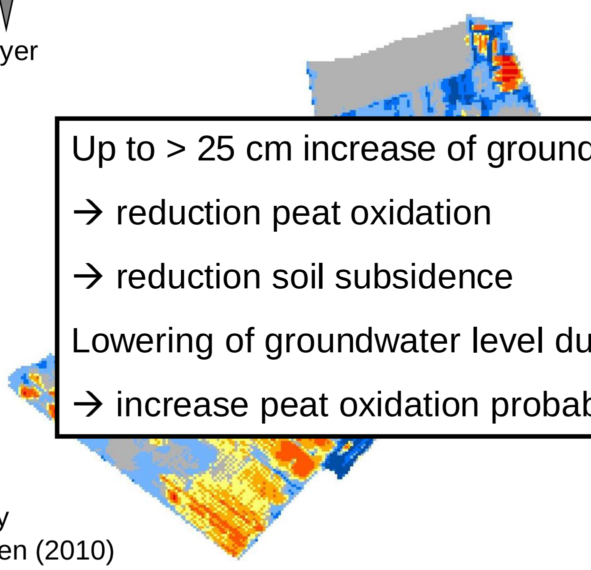


Example 3: dynamic water management

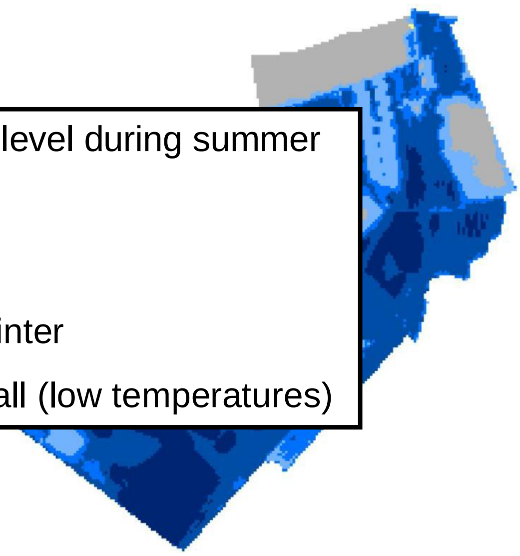
change in groundwater level (cm) = normal water management – dynamic water management



winter period



summer period



Up to > 25 cm increase of groundwater level during summer

→ reduction peat oxidation

→ reduction soil subsidence

Lowering of groundwater level during winter

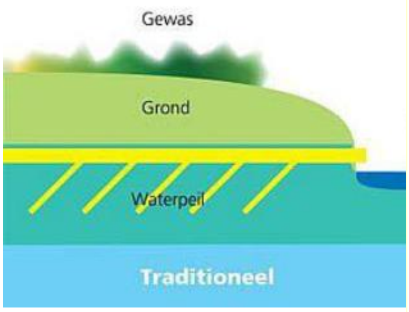
→ increase peat oxidation probably small (low temperatures)

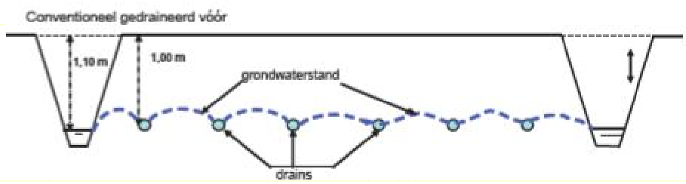
model results by
Sumihar & Borren (2010)

Example 4: change of tile drainage systeem

Example 4: change of tile drainage systeem

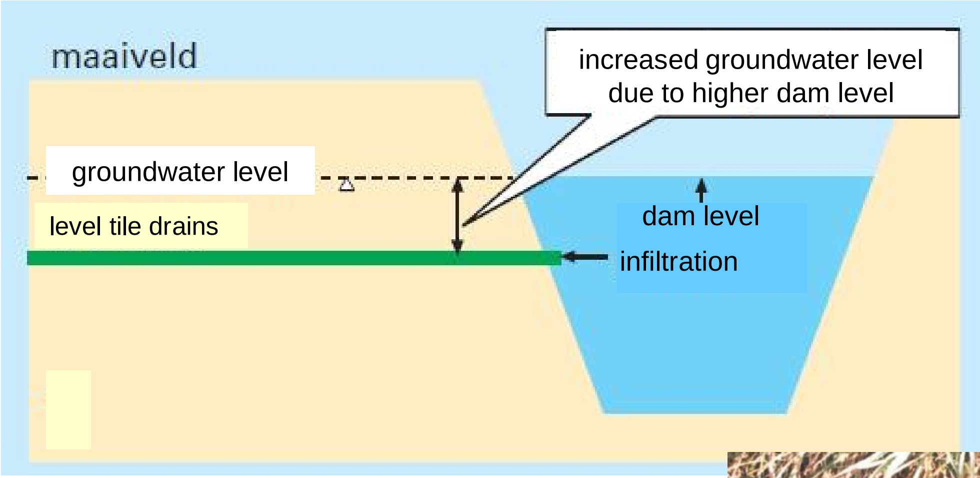
- In many agricultural areas tile drainage is installed.
- Tile drainage is an effective way to reduce groundwater levels further from ditches





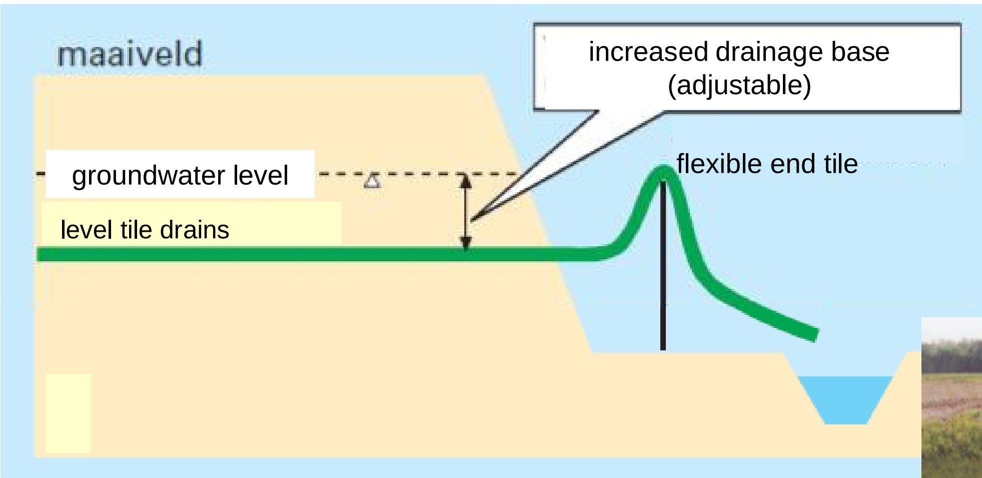
- HOWEVER, due to tile drainage the upper part of the soil is very dry and peat oxidation is enhanced…
- BUT, tile drainage can also be used to increase groundwater levels. Also, in the areas further from the ditches.

Example 4: change of tile drainage systeem



Example of tube drainage below surface water for water infiltration to groundwater.

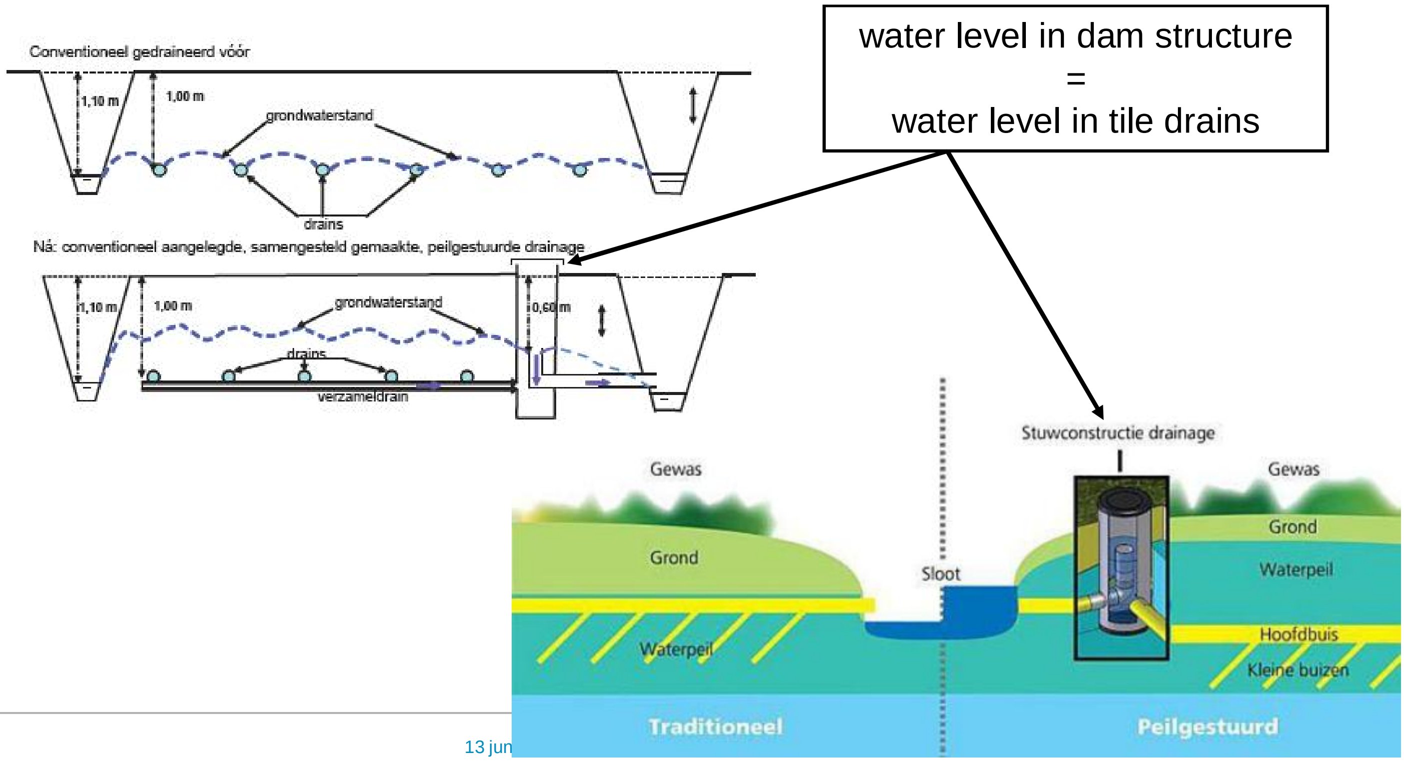
Example 4: change of tile drainage systeem



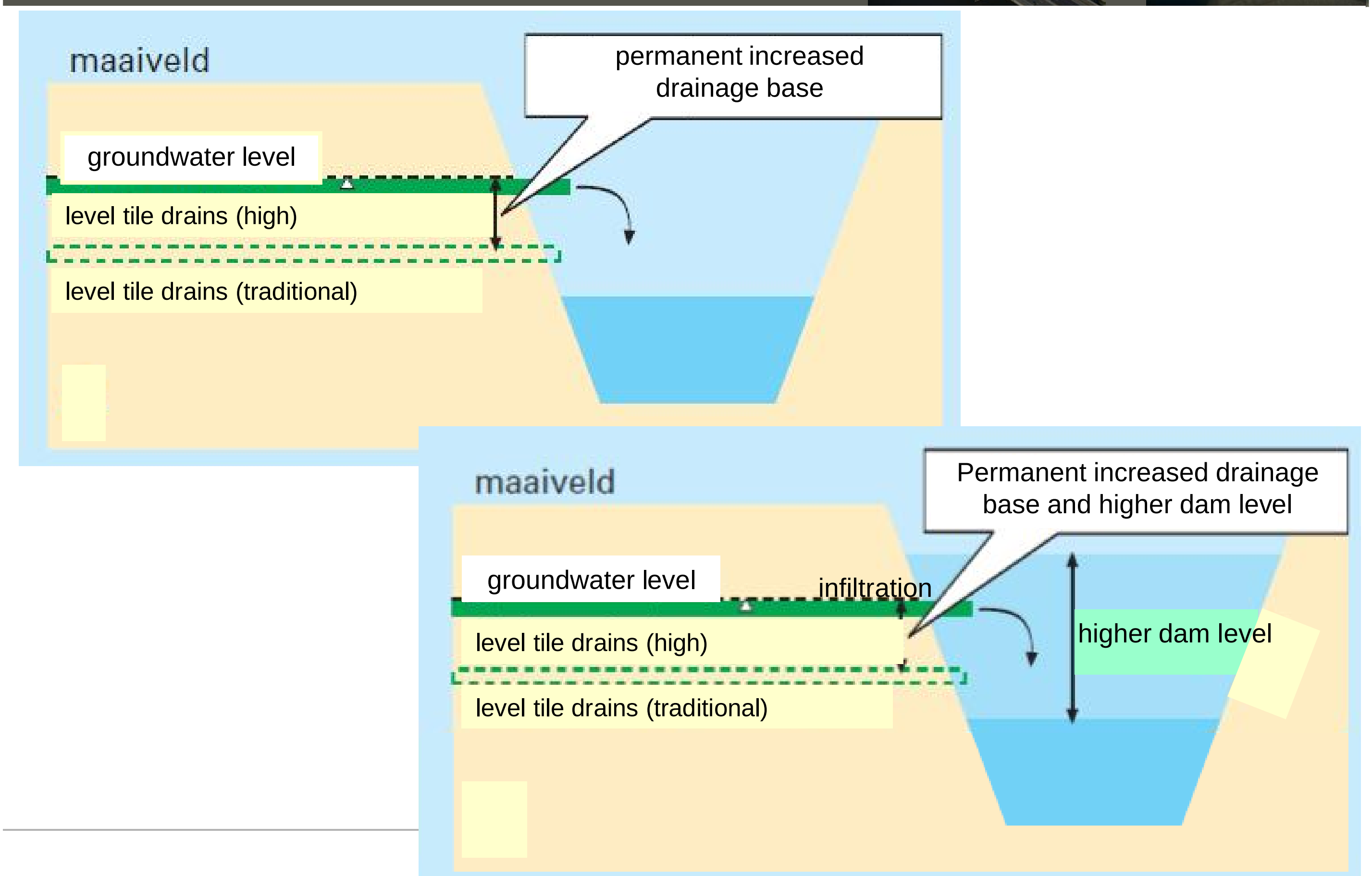
Example of tube drainage with adjustable drainage base.

Example 4: change of tile drainage systeem

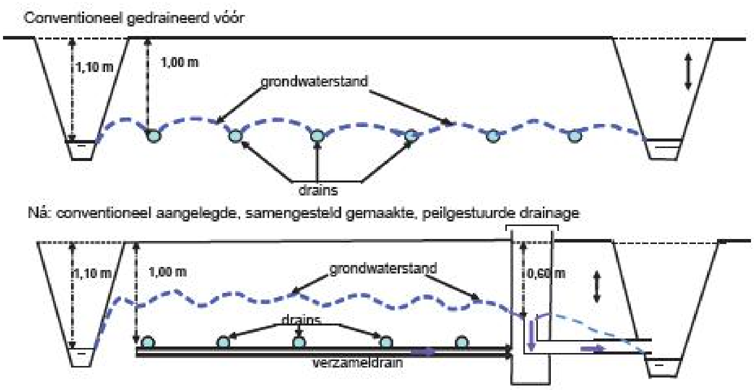
- Tile drainage with "dam structure" that determines the water level in all tile drains of a stretch of land.



Example 4: change of tile drainage systeem



Example 4: change of tile drainage systeem



Increase of groundwater level resulting from new use of tile drainage

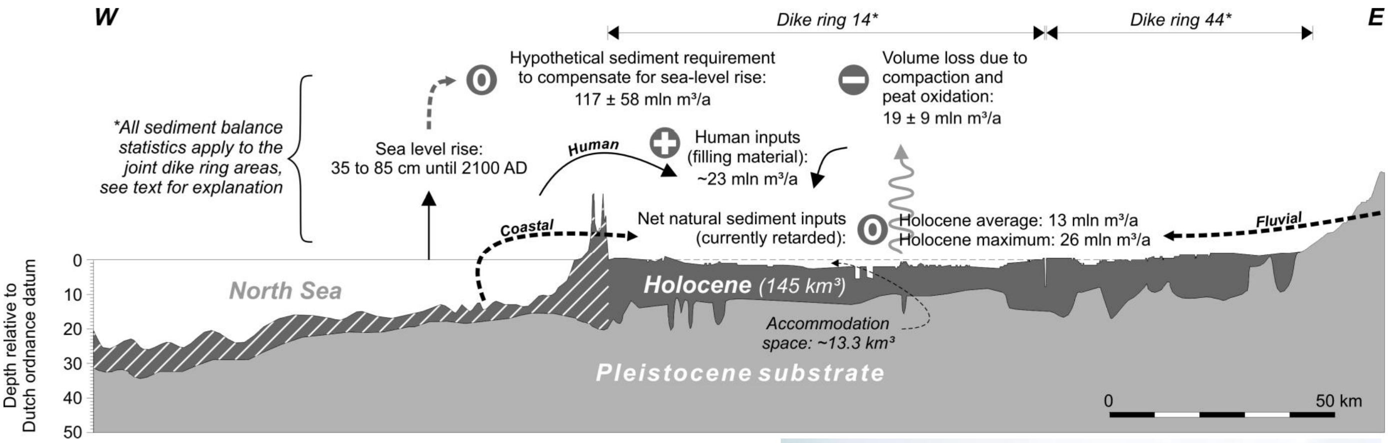
→ reduction peat oxidation

→ reduction soil subsidence

How much reduction is yet unclear; largely depends on new groundwater depth and remaining thickness of aerated soil…

Example 5: forming of embankment

Raising the country



Example 6: Large scale changes land-use for peat regeneration

Example 6: Large scale changes land-use

desired development vegetation of area

- regeneration of active bog peat
- local peat development and wet heather
- dry heather areas
- hydrological support areas
- other nature areas

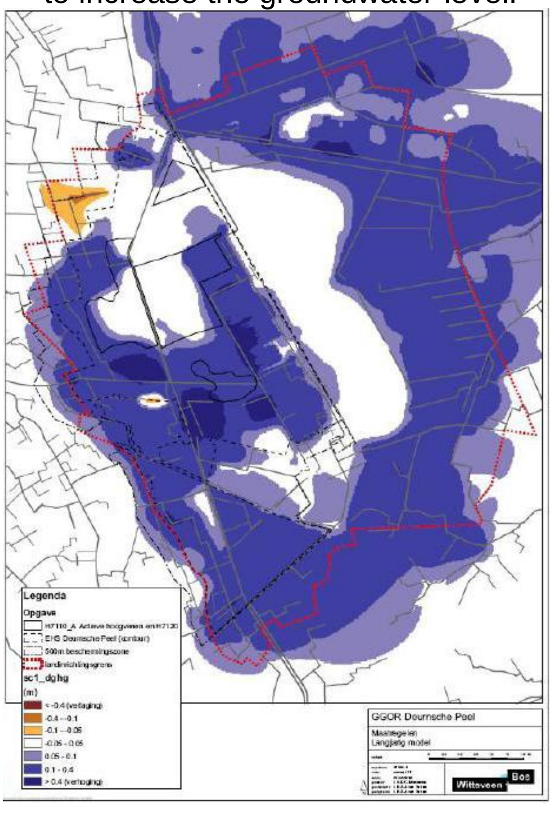
From: Borren et al. (2010)

current land-use and vegetation

first new peat development

Example 6: Large scale changes land-use

Regional geohydrological study →
in whole area measures should be taken
to increase the groundwater level.



Blue areas indicate predicted increase of groundwater level.

Additional measures and effects
specified for subareas

From: Borren et al. (2010)

Example 6: Large scale changes land-use

- In many cases, impossible to directly create appropriate boundary conditions for bog peat …..
- …. the regeneration of a peat ecosystem needs to done in steps and over time.
- In case peat growth is absent and conditions are dry and eutrophic, peat regeneration can take 100 to 200 years.
- Oxidation of peat layers in the subsurface will decrease rapidly after rewetting.
- Methane emissions are generated by the rewetting; however, high emissions are probably only temporary.

Start-off ecosystem	development to bog peat ecostystem under good (water) management			time span (years)
brushwood >	> marsh >	> marsh-forest >	> bog peat	20 - 80
marsh >				20 - 50
reed land >	> peat moss & reed land & marsh heather >			20 - 30
bird meadow >	> herb & grass land	> marsh heather >		30 - 80

Schematic of development sequence in case of the absence of active peat growth. Lower boundary indicates the occurrence of appropriate boundary conditions for the ecosystem, not yet fully developed plant communities.
From: Borren et al. (2010)

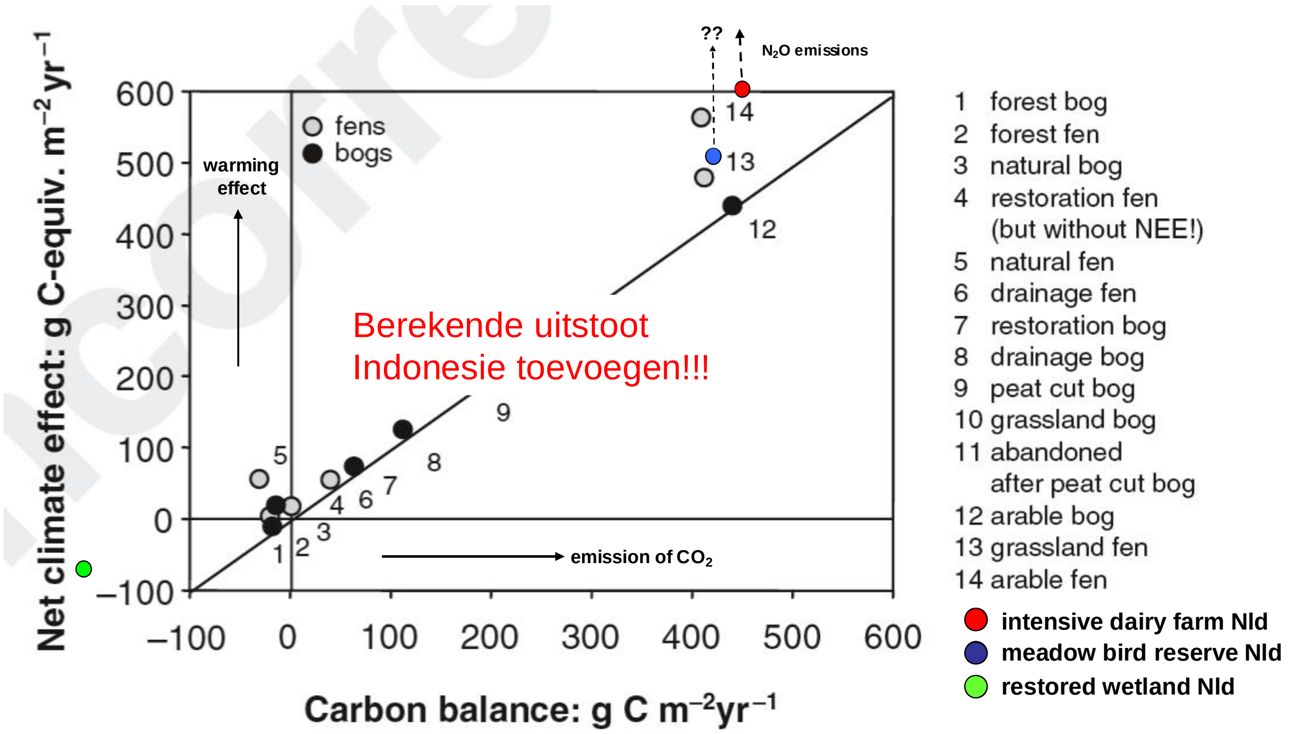
PART 3: Conclusions

Which measures are effective and feasible to reduce peat oxidation and soil subsidence?

- Most strategies include **water management** and inherent **land-use change**
- Water management changes can mitigate both **GHG emissions and soil subsidence.**
- A combination of (limited) **mitigation ánd agricultural** land use might be enabled **by technical measures** (dynamic water management and tile drainage solutions).
- For structural peat re-growth **large scale changes** are required.
- In temperate areas **peat re-growth > 100 years.**

The End…….thank you for your attention

Carbon balance and climate effect in temperate regions



From: Droesler et al. (2008)

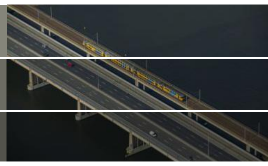
Deltares
Enabling Delta Life

Exercises

Marnix van der Vat

JCP Workshop peatland subsidence
Banjarmasin, January 30 & 31, 2012

Exercise 1: subsidence curves



Annual subsidence per land use category:

1 Natural forest

    2 mm/year growth

2 Degraded forest with dense net of logging tracks/canals 0.6m deep

    subs= 7.06 * drainage depth (subs in cm, drain in m)

    till depth of loggin tracks is reached

3 Plantation drained at 1.2m depth

4 Plantation drained at 0.6m depth

    subs =1.5 + 4.98 * drainage depth (subs in cm, drain in m)

Exercise 1: subsidence curves

Construct a table and a graph of annual subsidence rate and remaining peat thickness for 4 different forms of land use

Duration 100 years

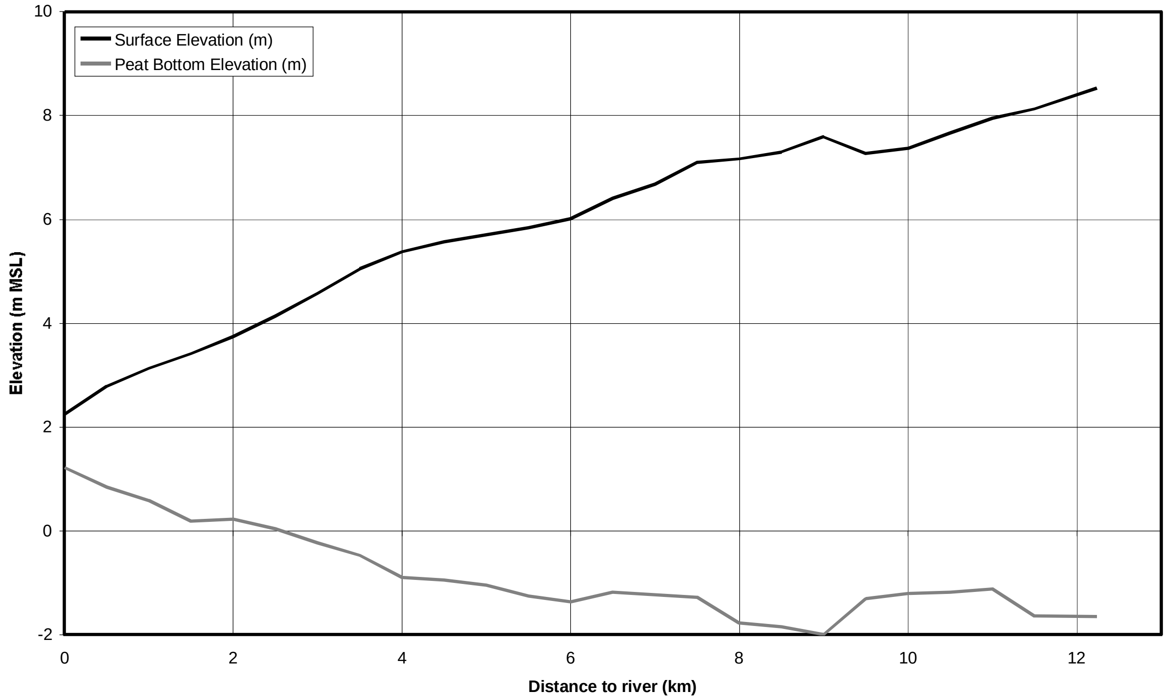
Initial peat thickness 10m

Initial subsidence after conversion:	year 1	70cm
	year 2	45cm

Exercise 1: subsidence curves

- How much peat remains after 100 years for each of the four land uses?
- How do the speed of subsidence and growth of peat compare?
- How does impact of initial subsidence compare to other subsidence on the long term?
- What is the long term impact of different drainage depths in plantations?

Exercise 2: Subsidence on average profile



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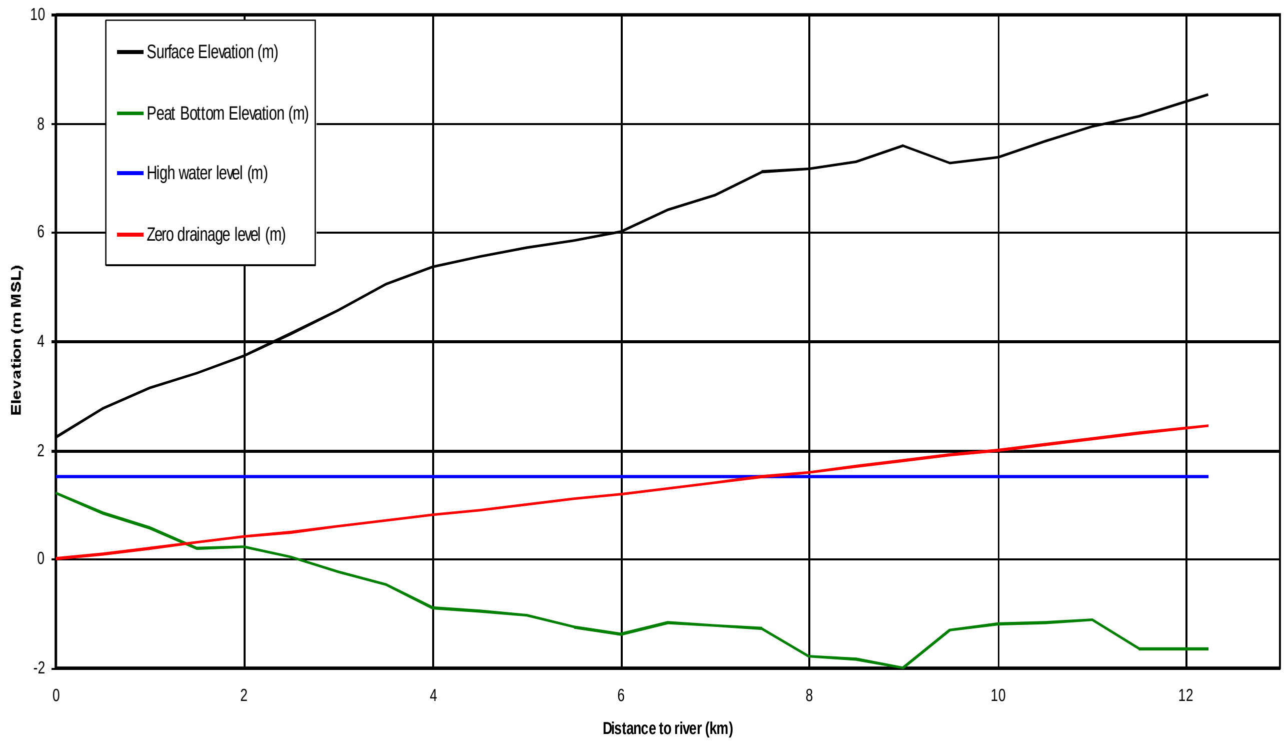
Flooding & drainage



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Exercise 2: Subsidence on average profile

Construct a table of remaining elevation after conversion to plantation during 100 years subisdence (and a graph at 25 years intervals)

Initial peat thickness 10m

Initial subsidence after conversion:	year 1	70cm
	year 2	45cm

Plantation drained at 0.6m depth

subs =1.5 + 4.98 * drainage depth (subs in cm, drain in m)

Exercise 3: Impact of subsidence on flooding & drainability

Add HWL and zero drainage level to graph and tabulate (from graph at 25 year interval) percentage length of profile with flooding and drainability problems

High water level:	1.5 m	
Head loss:	20 cm/km (starting at MSL)	
Drainability classes:	1	< 0 cm
	2	0 – 30 cm
	3	30 – 60 cm
	4	> 60cm

Exercise 3: Impact of subsidence on flooding & drainability

- How many percent of the profile experiences flooding and drainage problems after 50 years?
- How many percent of the profile can be sustainably developed for 100 years?

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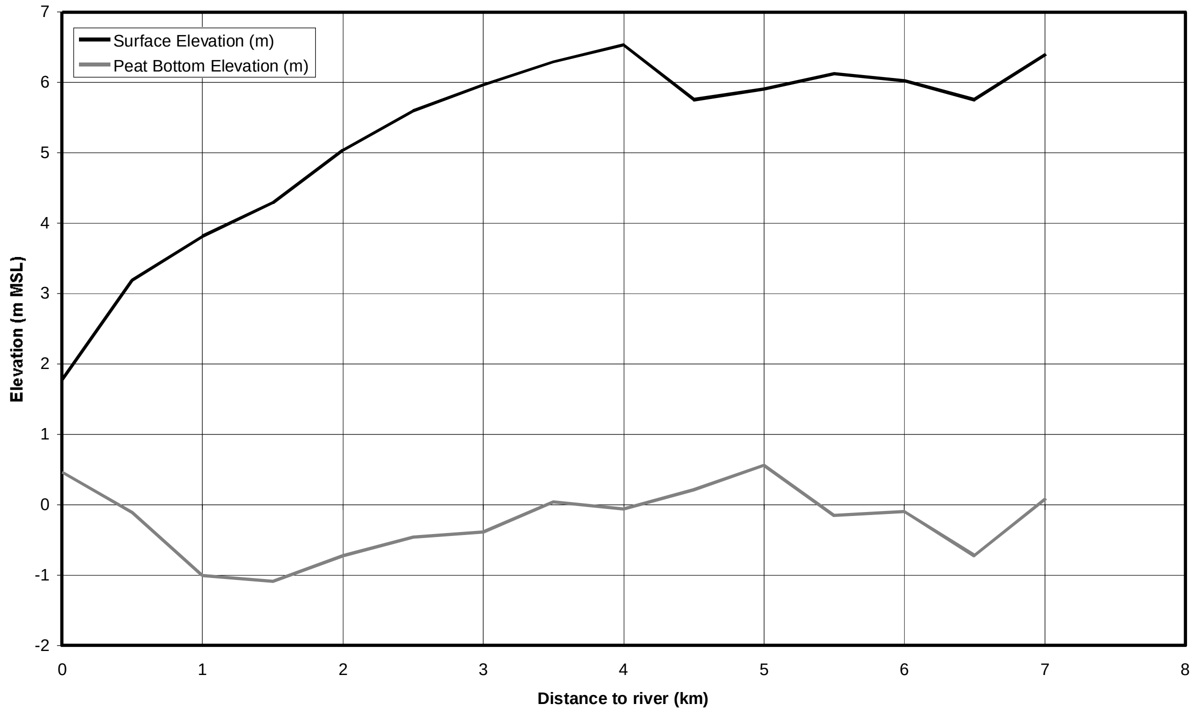
Exercise 4: Sarawak profile



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Exercise 4: Sarawak profile

- Compare results for flood and drainage with Indonesian profile and explain the differences

Exercise 5: Sea Level Rise

Add 1cm per year SLR (high estimate) to the HWL and zero drainage level and repeat the profile analysis of flood and drainage for Indonesia

Compare results in table with and without SLR. What is the influence of SLR? How important is SLR compared to subsidence?

How many percent does now experience problems after 50 years? And how many percent does not have problems after 100 years?

Exercise 6: with 2 types of land use in the profile

Repeat subsidence analysis on Indonesian average profile but now with first 4km from river plantation drained at 1.2m and after that natural forest

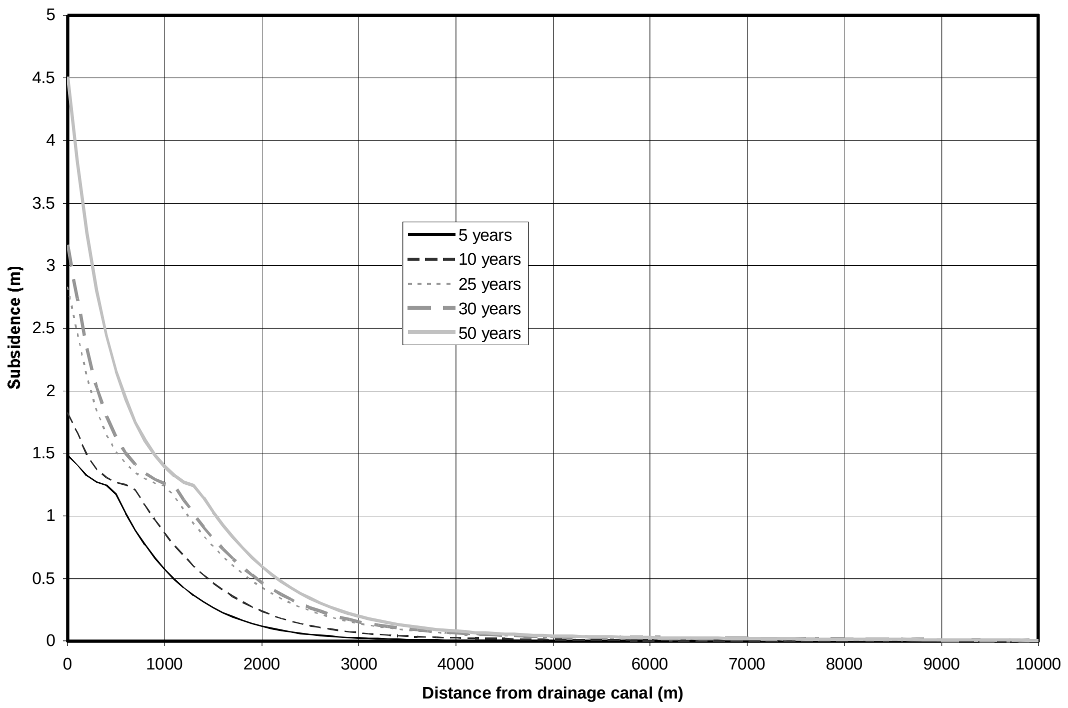
Is this result possible in reality? What will happen in reality to the peat under the forest?

Exercise 7: determine required extent of buffer

- Peat thickness 10m
- Hydraulic conductivity 100m/d
- Drainage depth 1.2m

Determine the required width of the buffer from plantation with 1.2m drainage depth to keep subsidence in conservation area below 5cm over 50 years

Exercise 7: determine required extent of buffer



Exercise 8: Calculate emissions

Use the results of exercise 1 to calculate emissions (rate per year and cummulative) for a period of 100 years for 4 different landuses

Carbon storage: 15.1 ton CO2/ha/cm

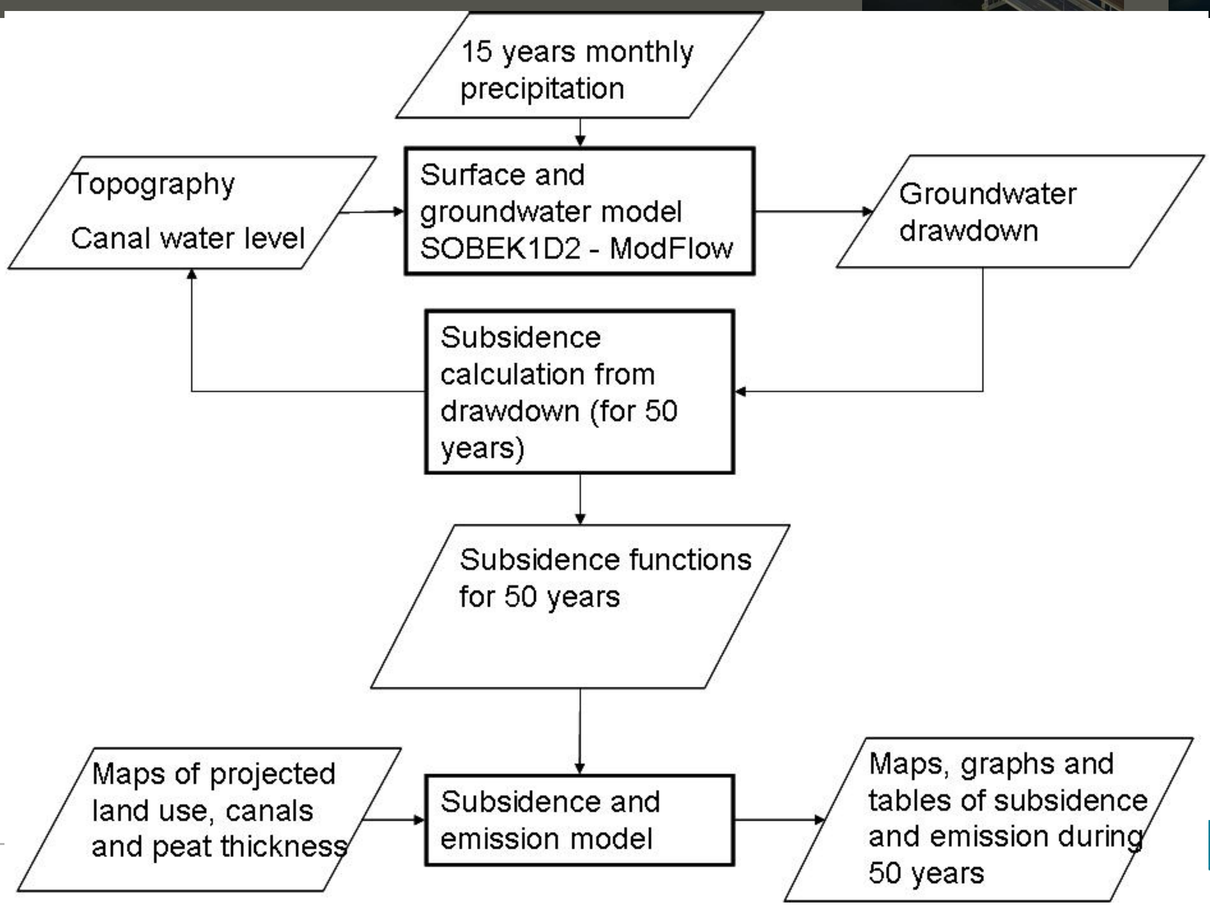
Compare emission rates with the storage under natural forest

Excercise 9: Impact of rewetting

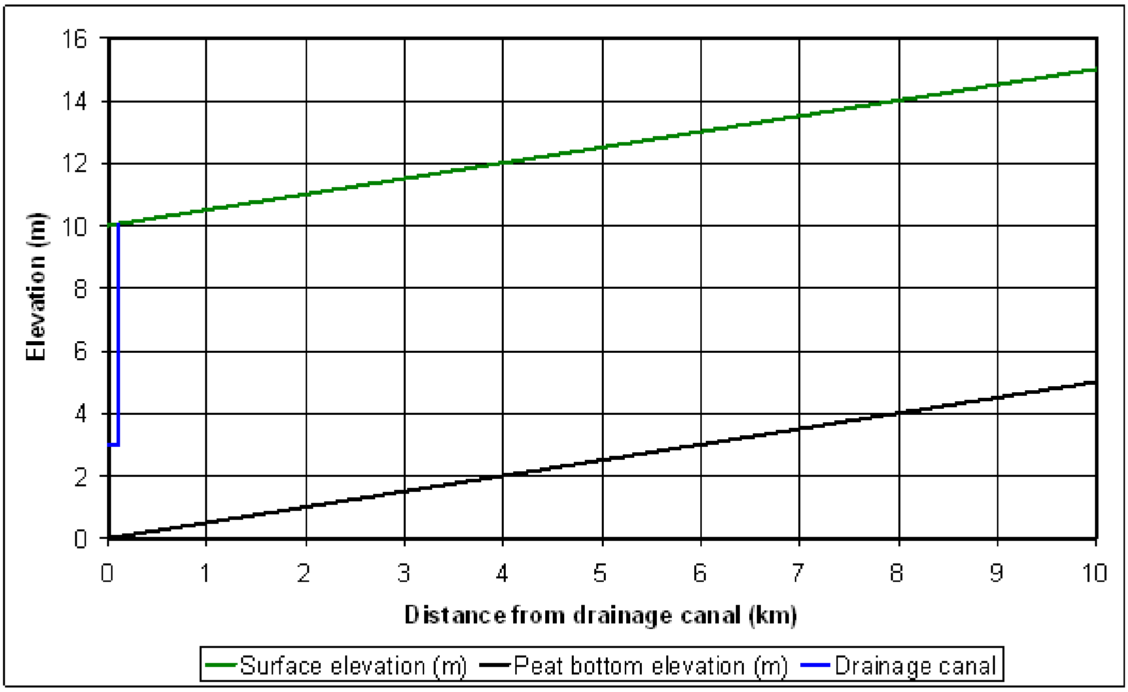
Calculate subsidence and CO2 emission for a profile perpendicular to a canal after 50 years drainage depth 60 cm (rewet) and 120 cm (not rewet)

Initial peat depth	10m
Slope to the canal	0.5m/km
Length profile	10km
Width profile	100m
Hydraulic conductivity	10m/d
No intial subsidence	
Carbon storage	15.1 ton CO2/ha/cm

Peat subsidence model



Theoretical profile



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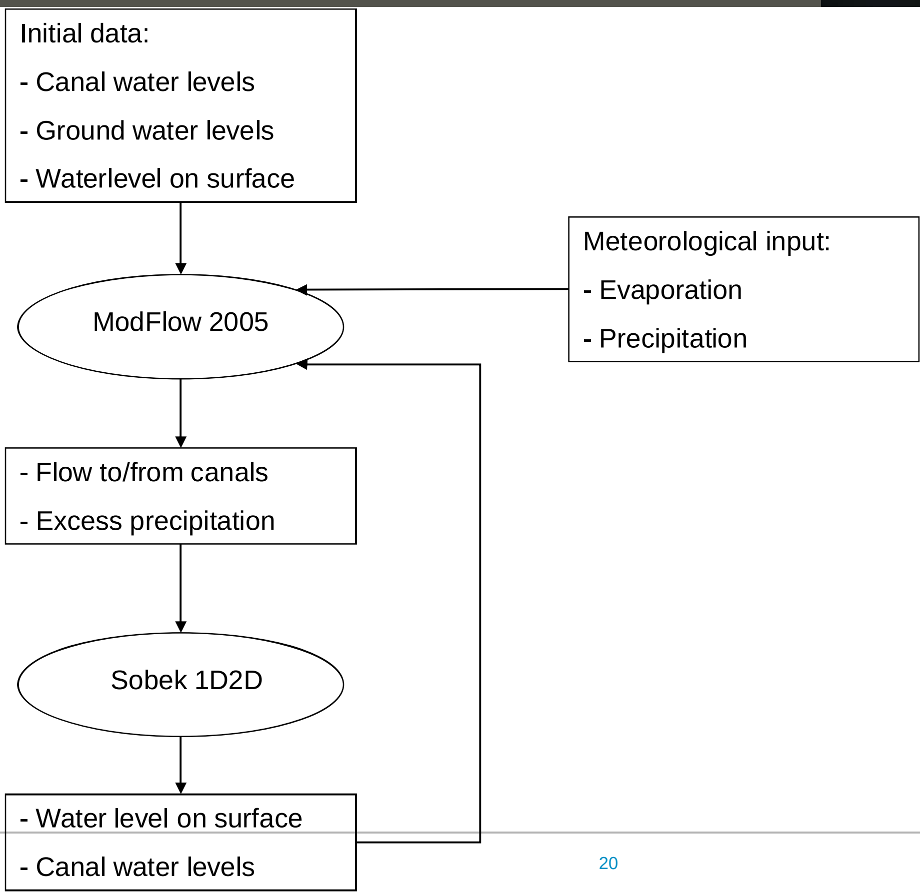
Model



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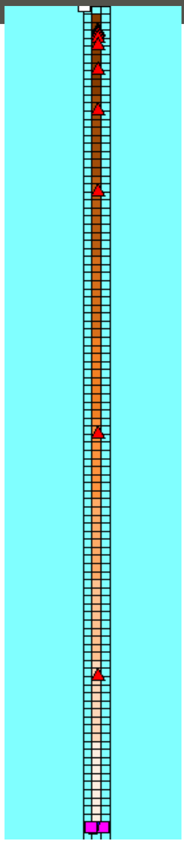
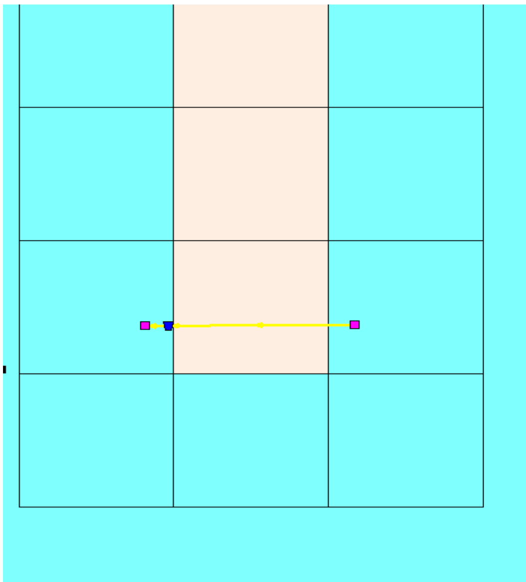
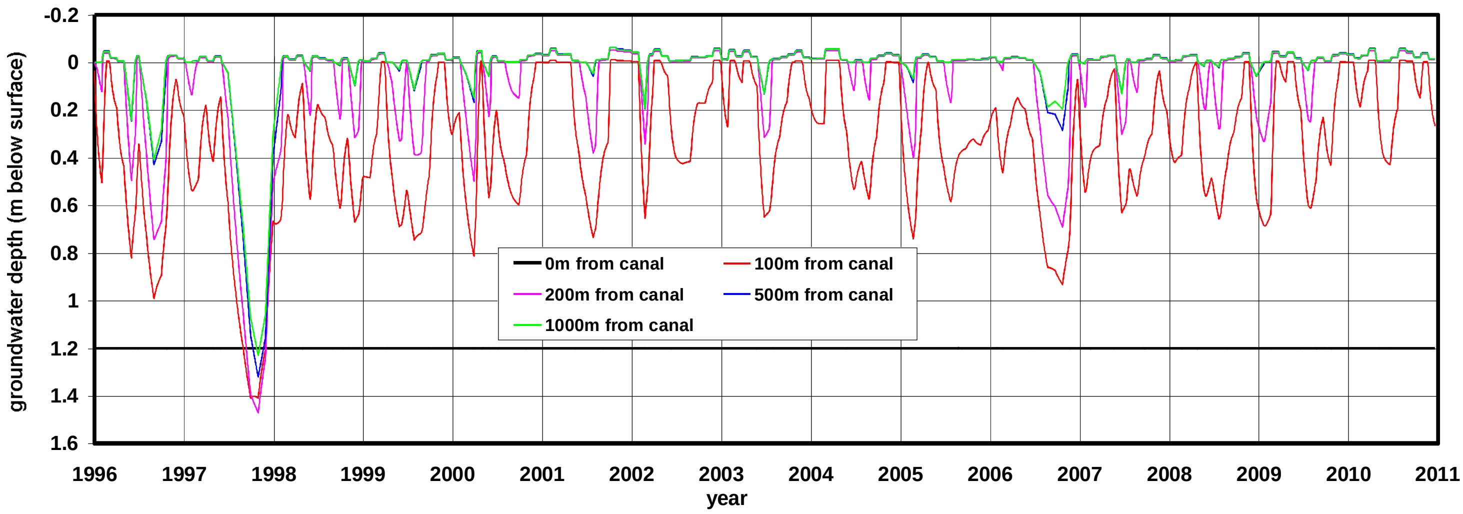
Model schematization





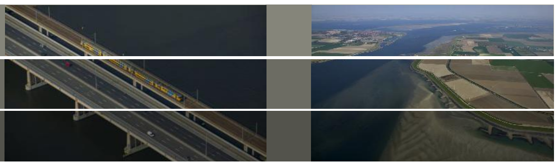
Deltares

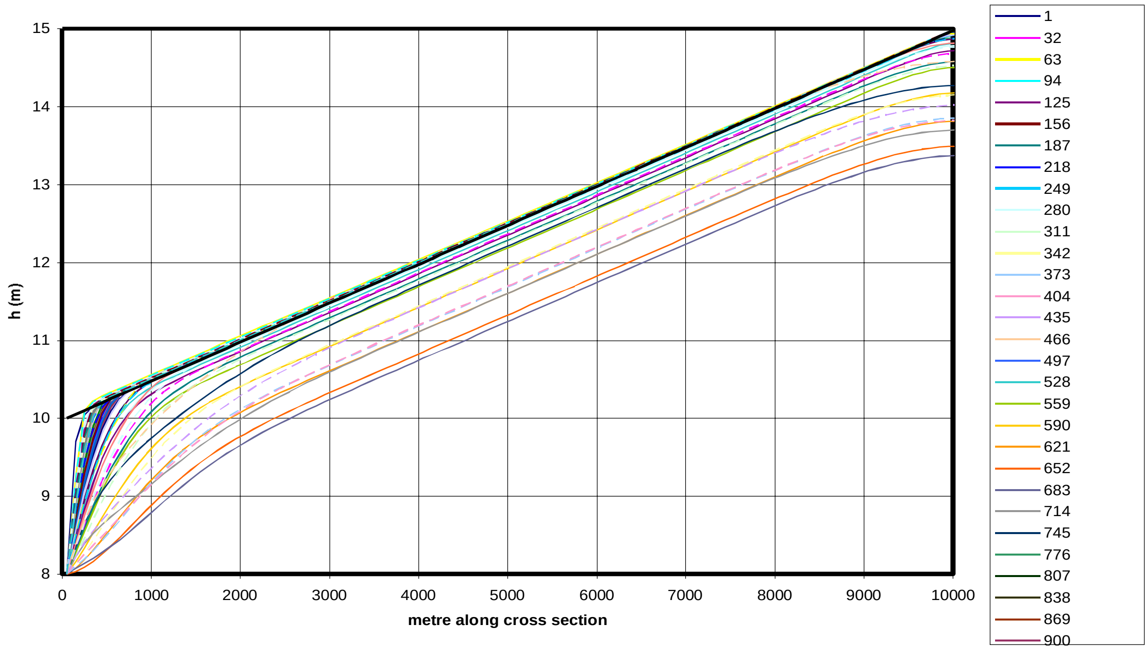
Results (groundwater depth)



Deltares

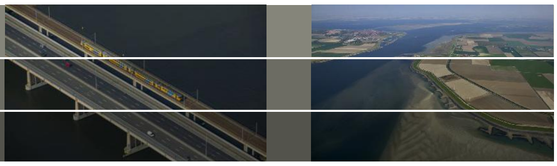
Results (groundwater depth)

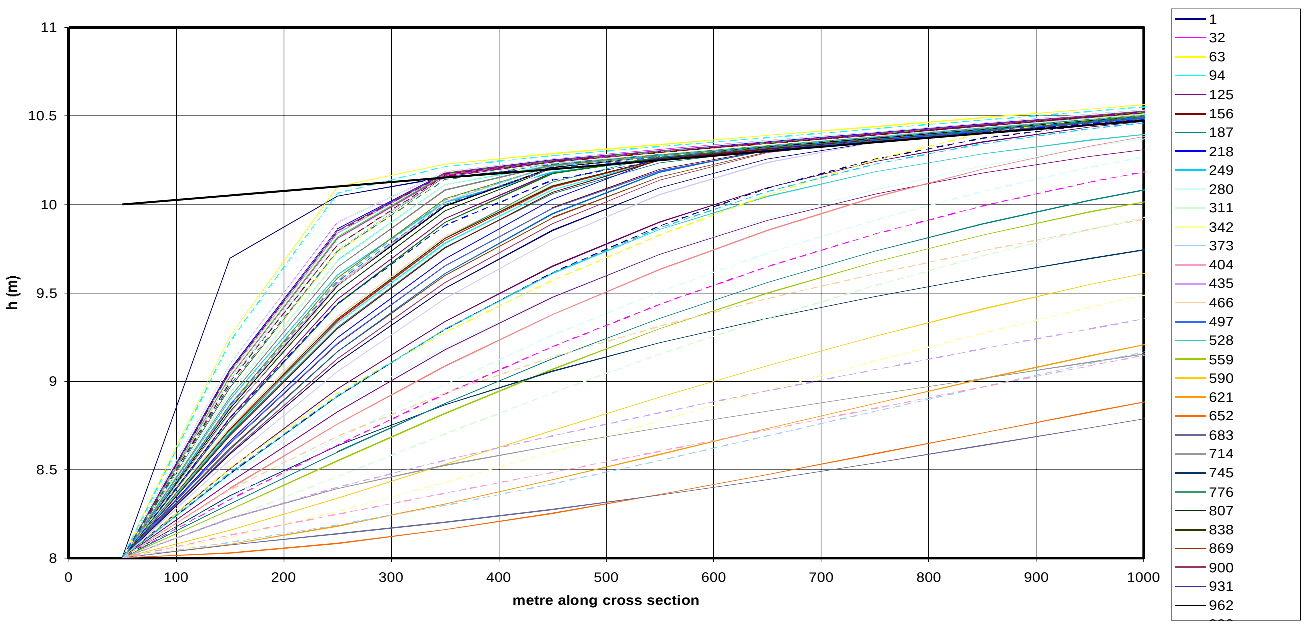




Deltares

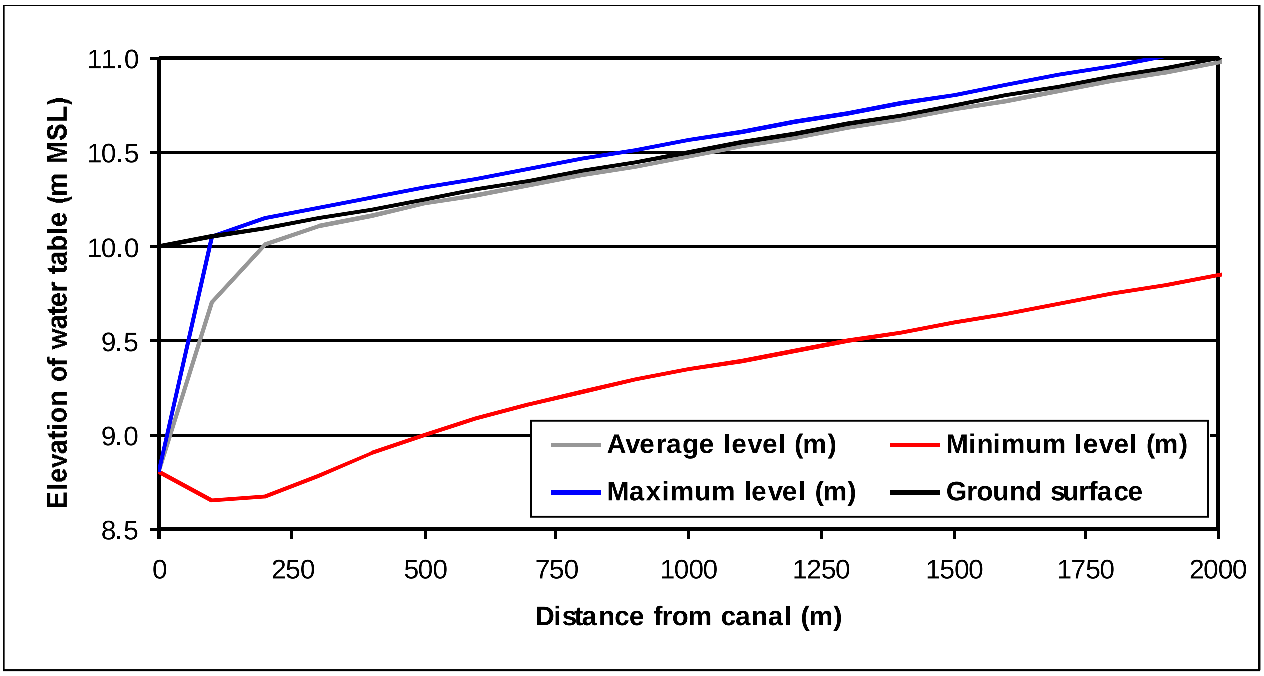
Results (groundwater depth)





Deltares

Results (groundwater depth)



Deltares

Results (water balance)

	Volume (m3)	%
Net boundary out	17679522	100%
Groundwater drainage	3042153	17%
Overland flow drainage	14637369	83%

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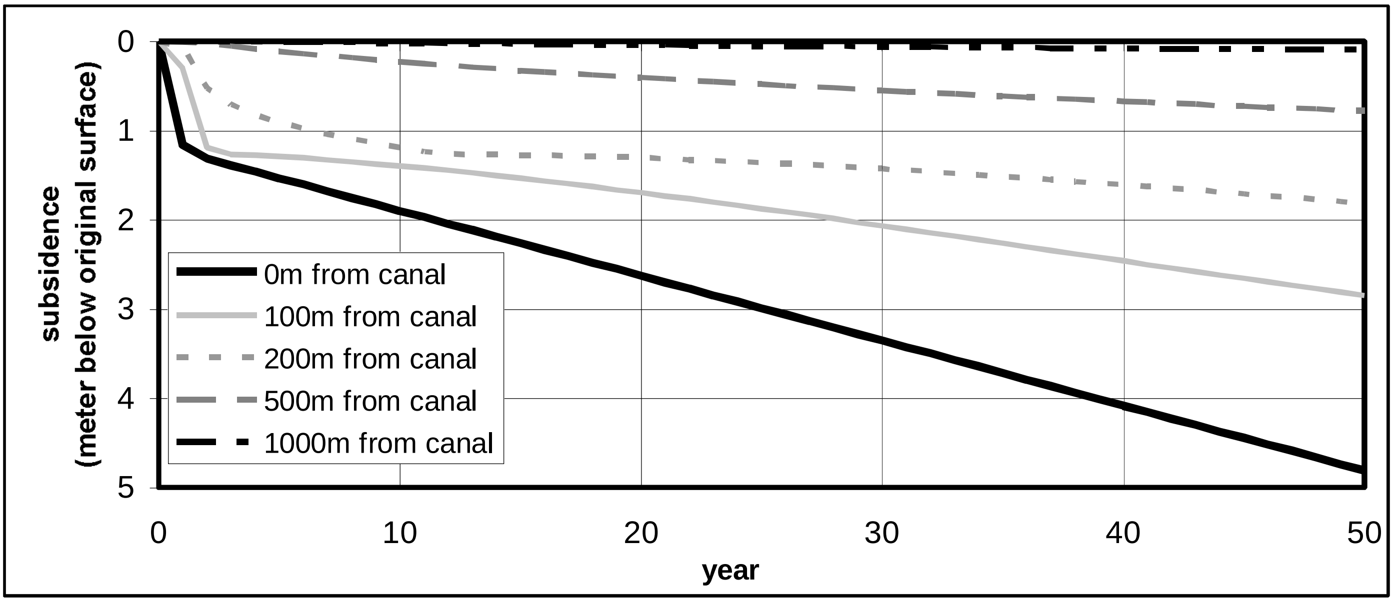
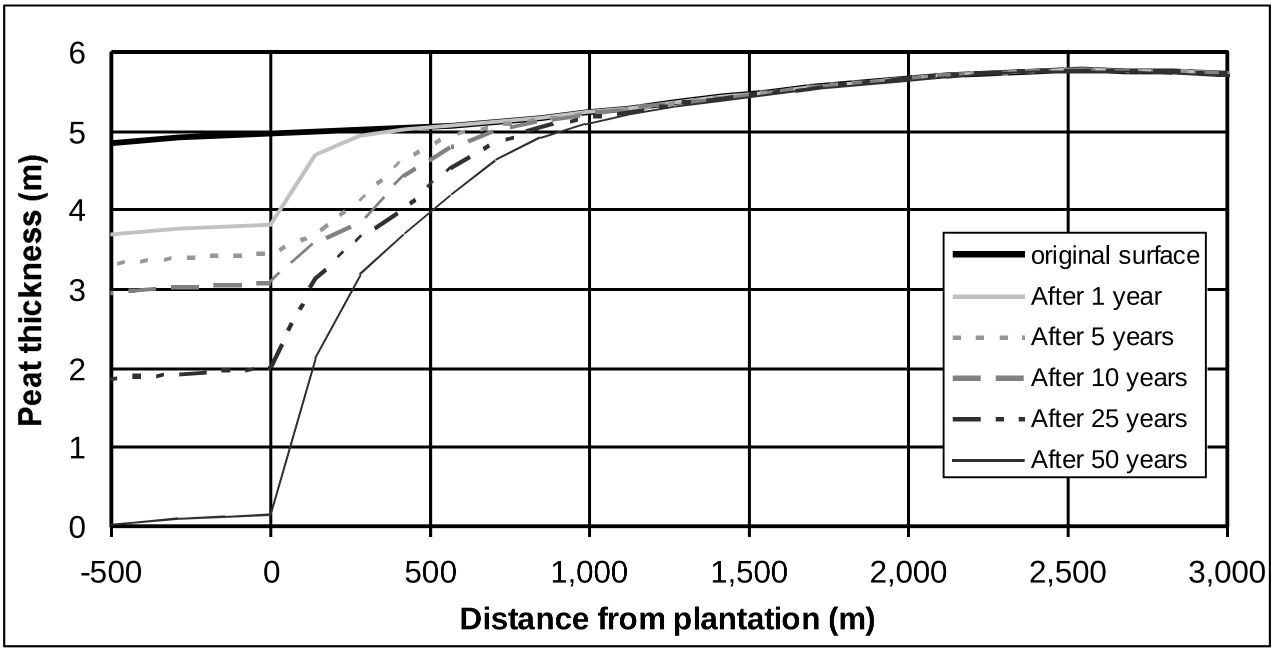
Results (subsidence)



Deltares

Results (subsidence)



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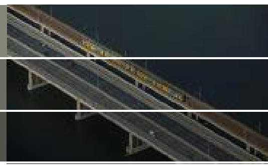
LIDAR & Flood analysis for Kalimantan peat lands

Marnix van der Vat

JCP Workshop peatland subsidence
Banjarmasin, January 30 & 31, 2012

Sources of elevation data



- Levelling surveys
- GPS surveys
- SRTM (Shuttle radar Topographic Mission)
- LIDAR (Light Detection and Ranging)
- DIFSAR (Differential Synthetic Aperture Radar)

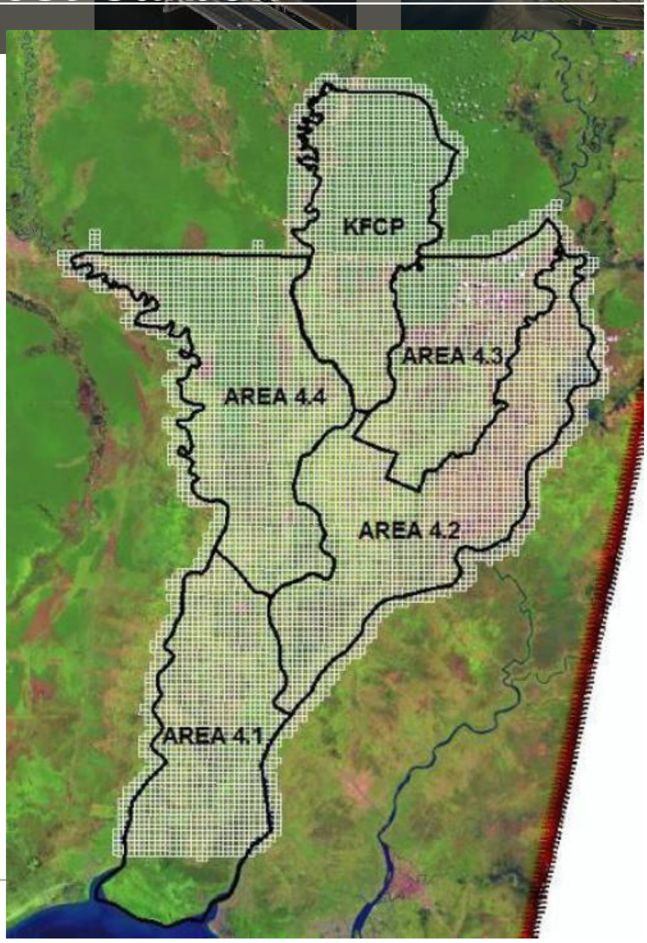
LIDAR

- Helicopter or airplane
- GPS positioning of carrier
- Emits laser beams and measures time to reflection
- Point density between 0.1 – 100 points/m2
- Discrete or full waveform (commonly 4 pulse: first, last, maximum and mean)

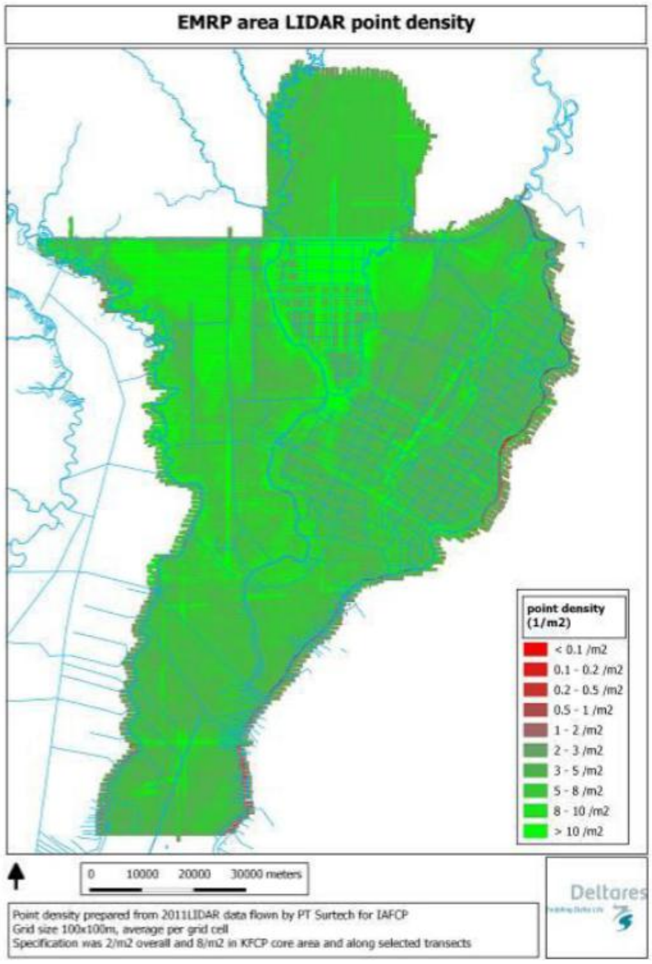
Deltares

KFCP LIDAR (Kalimantan Forest Carbon Partnership)

- Part KFCP core area high density, full-waveform LIDAR and high resolution imagery
- Rest low density
- Executed by RSS and Surtech



Point density



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DGPS survey

Deltares

DGPS survey

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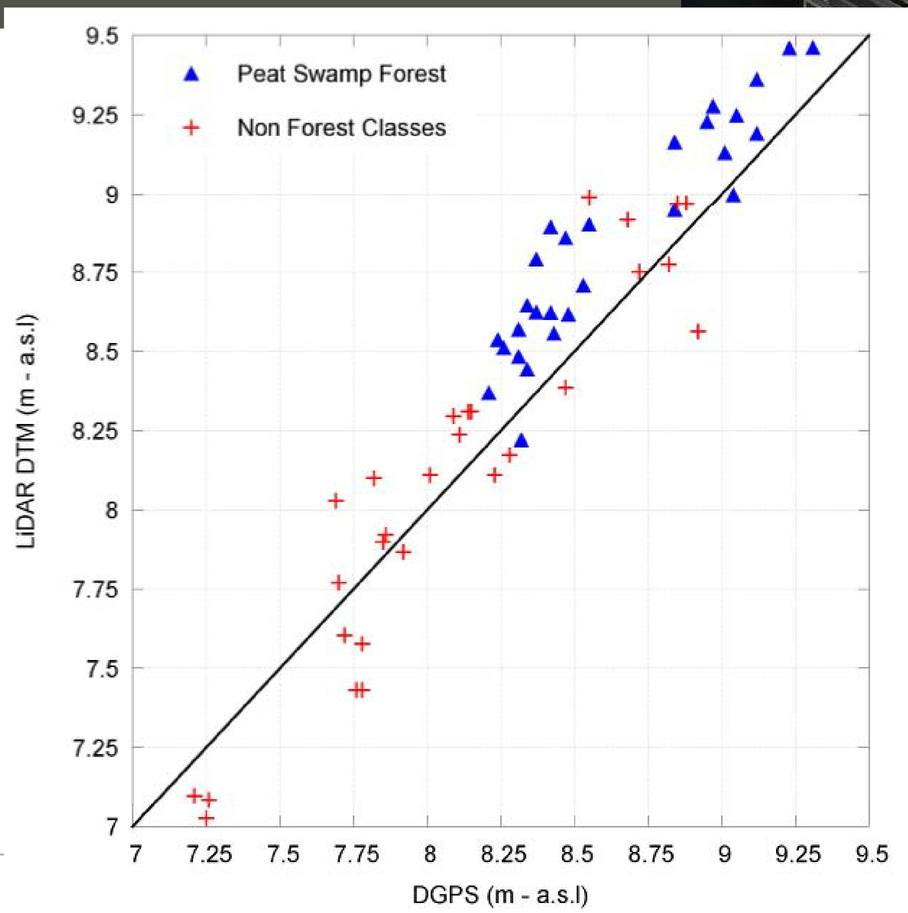
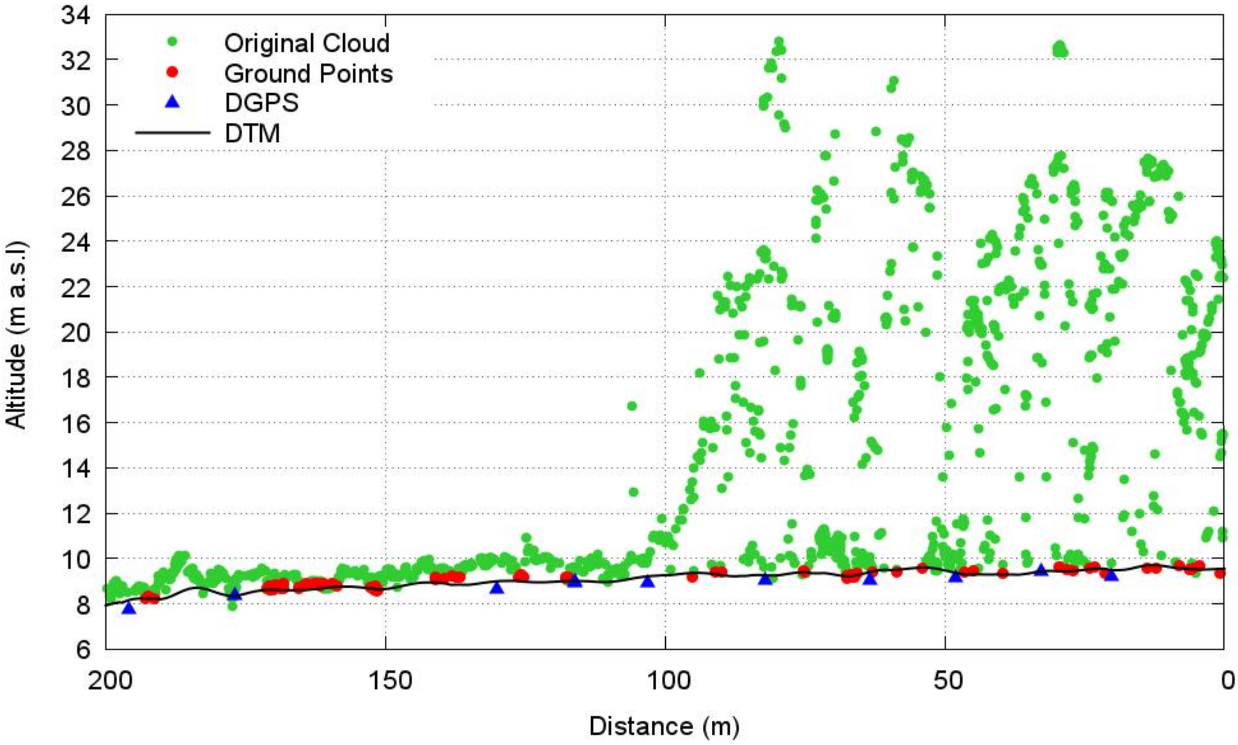
Verification – RMS 0.21m



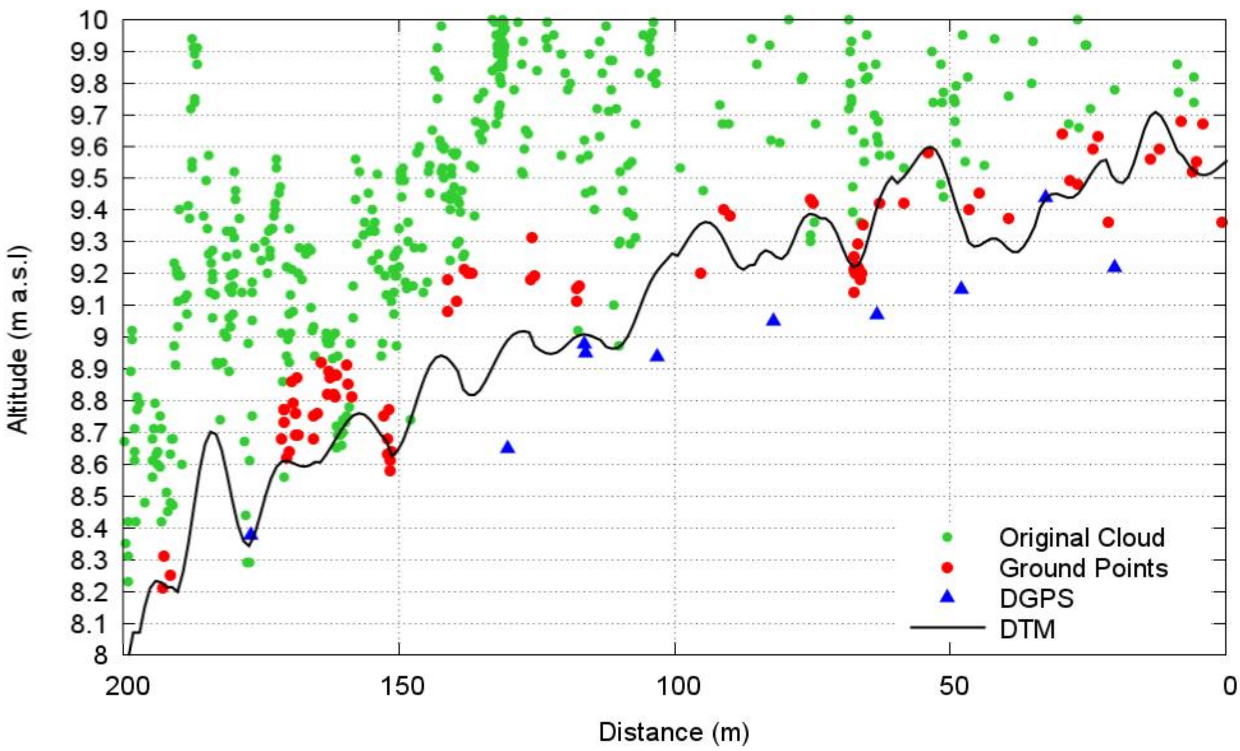
Deltares

Classification on profile



Deltares

Classification on profile



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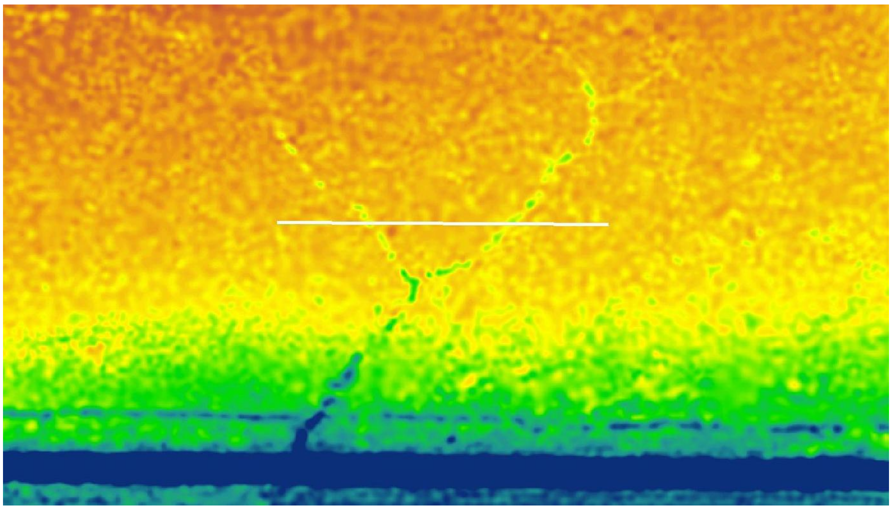
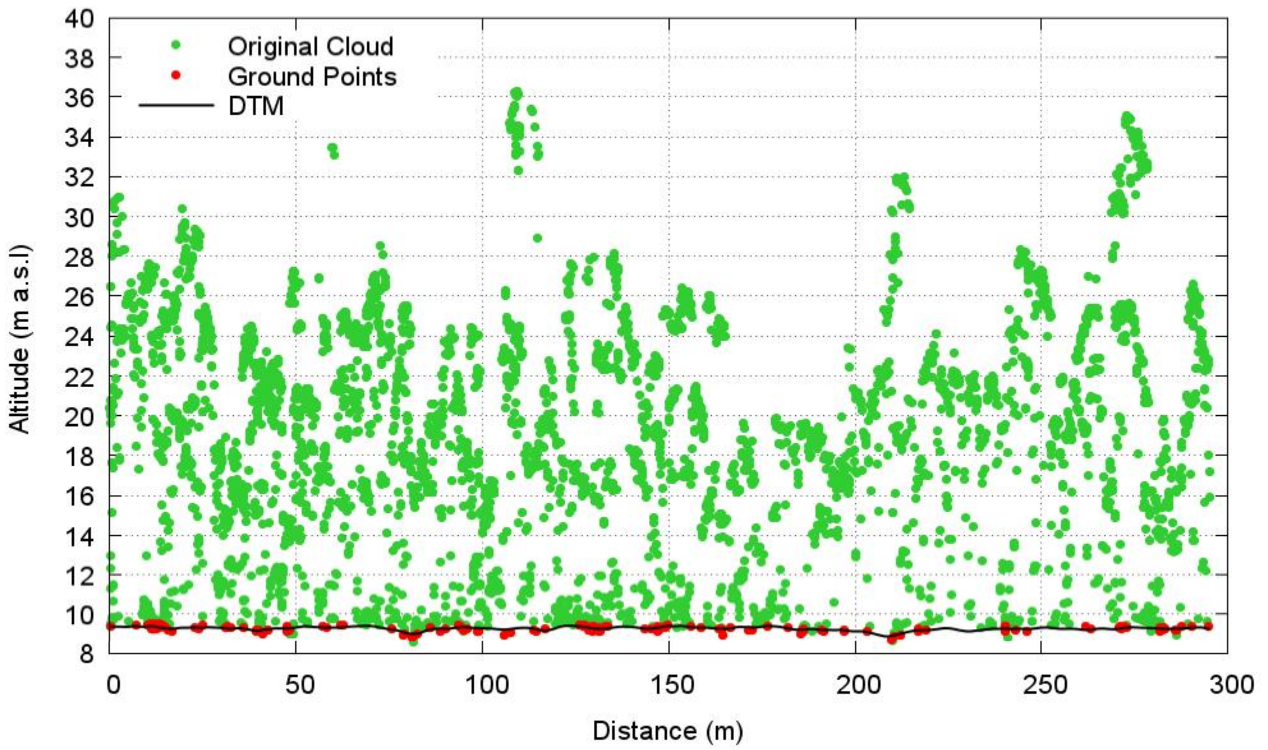
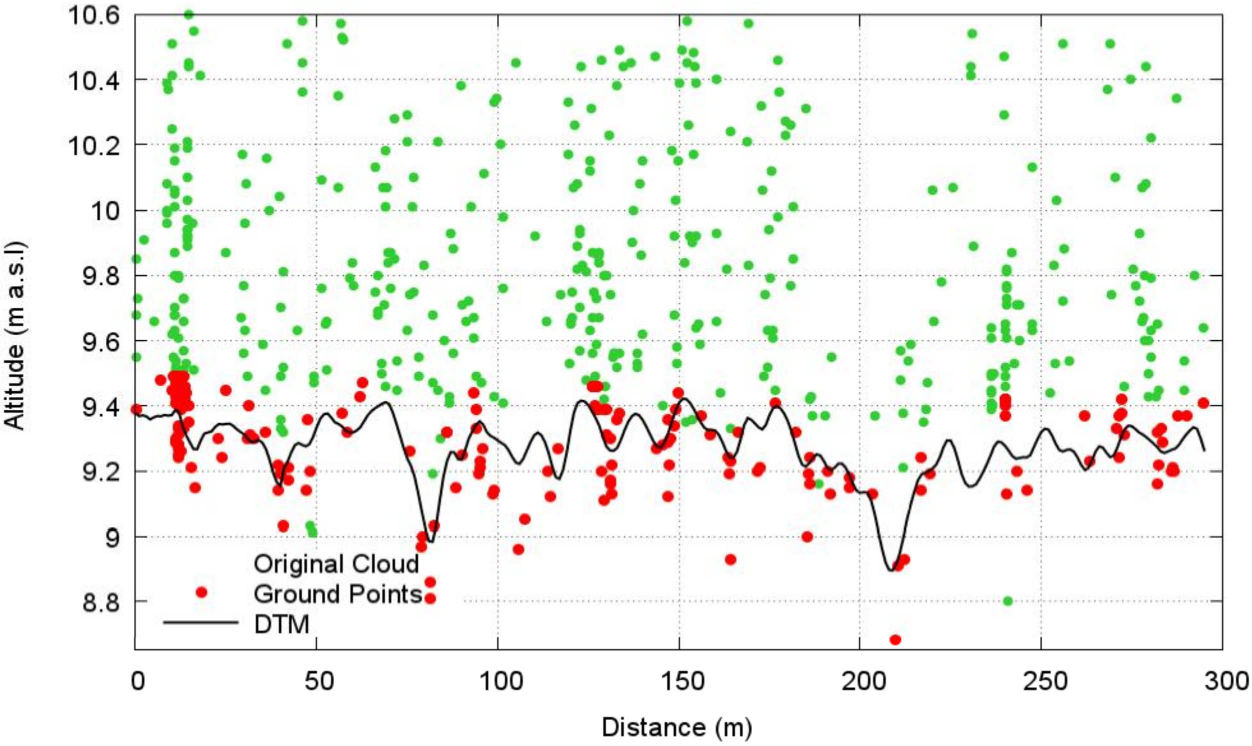
Profile loggin track



Profile along logging track

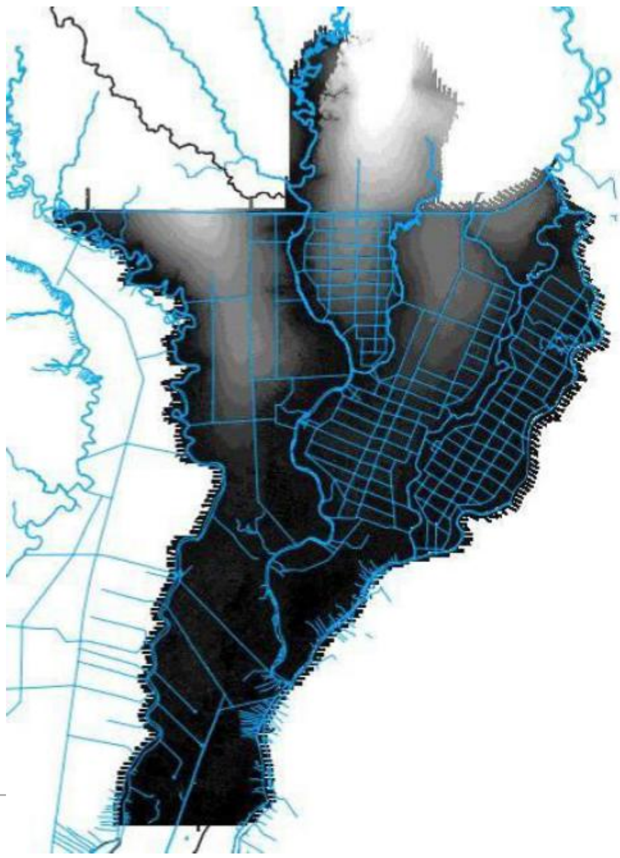


Profile along logging track



Deltares

DEM 10x10m grid, minimum value



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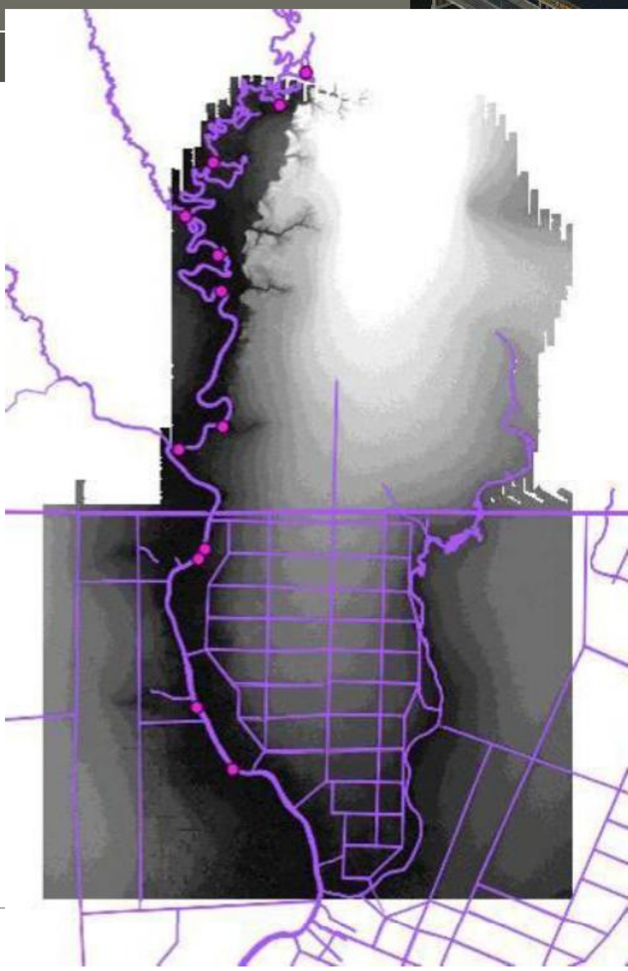
DEM 10x10m grid, minimum value

Deltares

Flood depth data



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Steps to calculate flood depths

- Convert flood depth to flood level
- Interpolate flood level along the river
- Extrapolate flood level based on closest point on the river
- Convert flood level to flood depth

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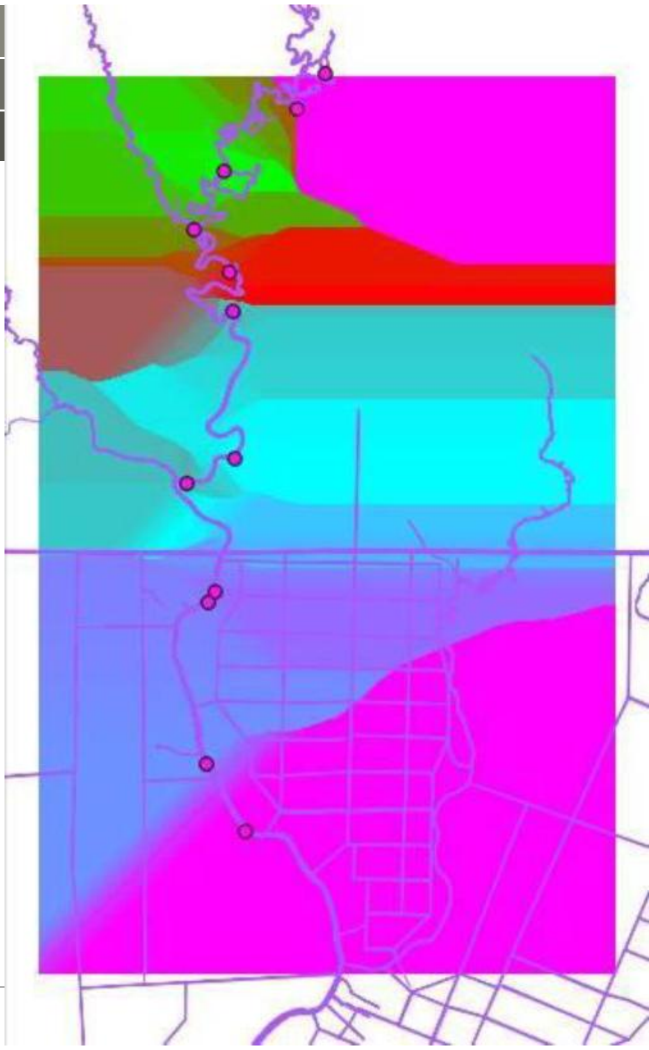
Floodlevel



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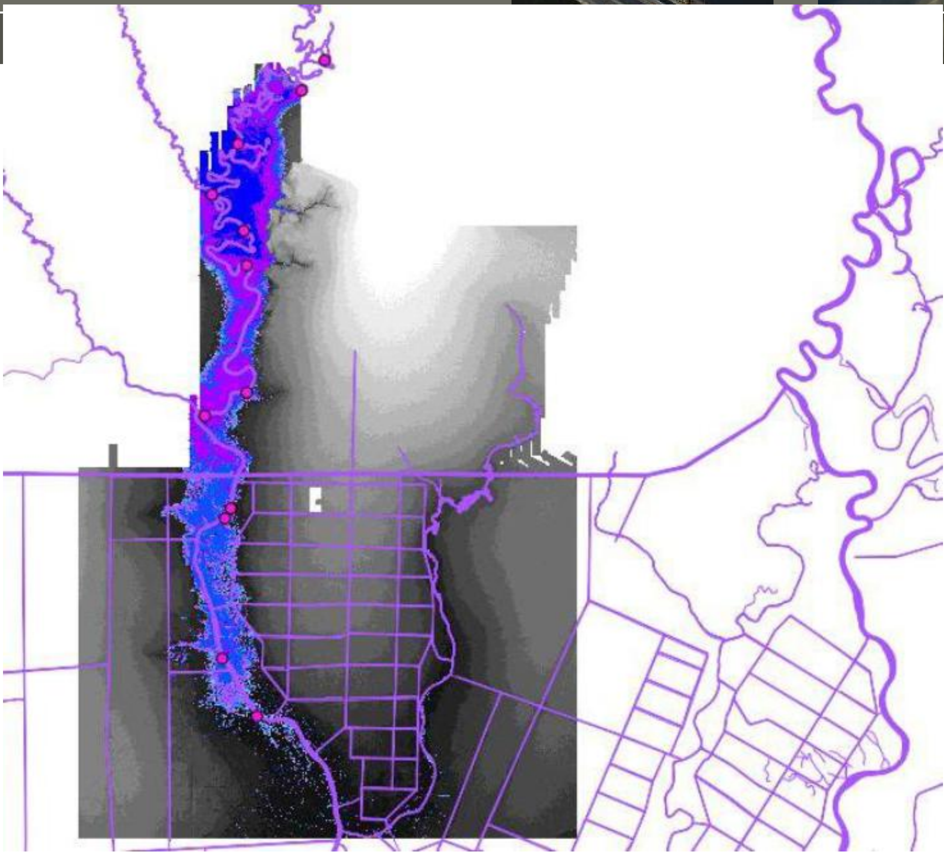
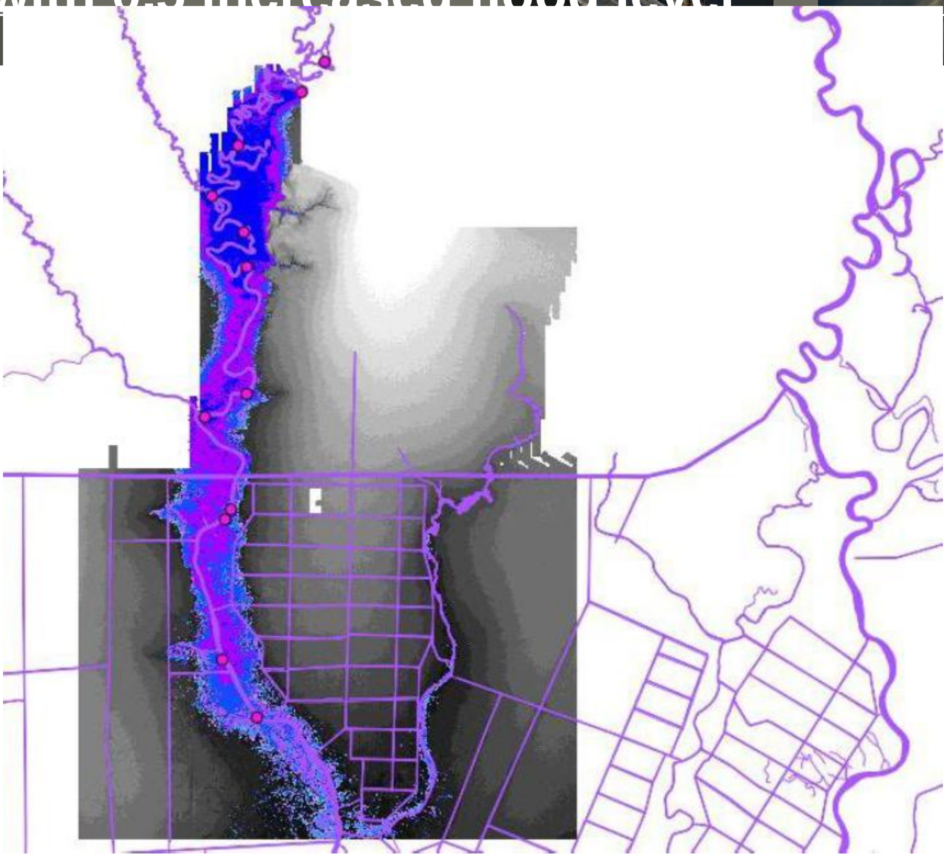
Flood depth



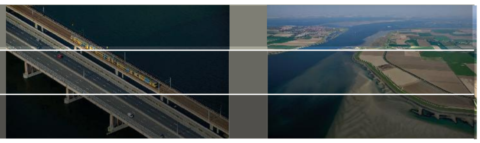
Flood depth with 0.5 increased flood level



Monitoring hydrology and land subsidence to quantify carbon loss from drained peatlands

Ronald Vernimmen, Aljosja Hooijer, Nasrul Ichsan
ronald.vernimmen@deltares.nl

Background



One of the activities within KFCP (Kalimantan Forest Carbon Partnership) is the set up of an extensive hydrological and peat soils monitoring network (> 500 instruments).

The activity started in 2009 and continues until (at least) May 2012.

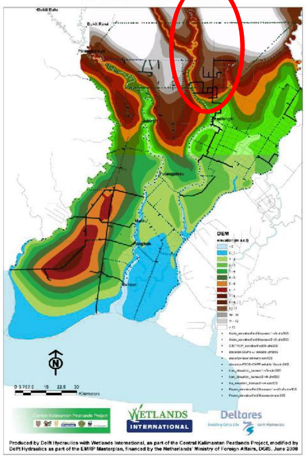
Primary goal: collect long and high-quality data series that will allow quantification of carbon loss from the KFCP area (part of Block A and E of the EMRP area, see next slide)

Second goal: the data will help evaluate the impact of water levels, land subsidence rates and discharges on KFCP canal blocking and other rehabilitation interventions in the system.

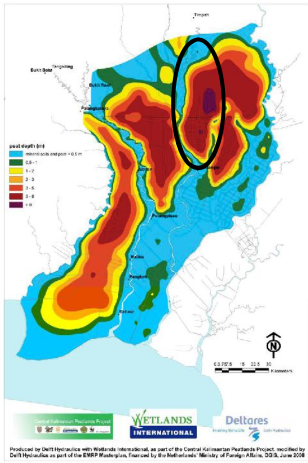
Project area – part of Block A and E of EMRP area

KFCP area (approx. 120.000 ha, Block E 63% or 75.500 ha)

DEM of the Ex-Mega Rice Area in Central Kalimantan



Peat map of the Ex-Mega Rice Area in Central Kalimantan



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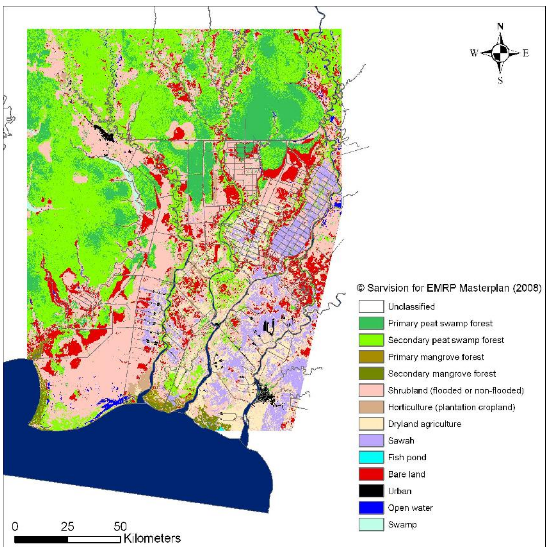
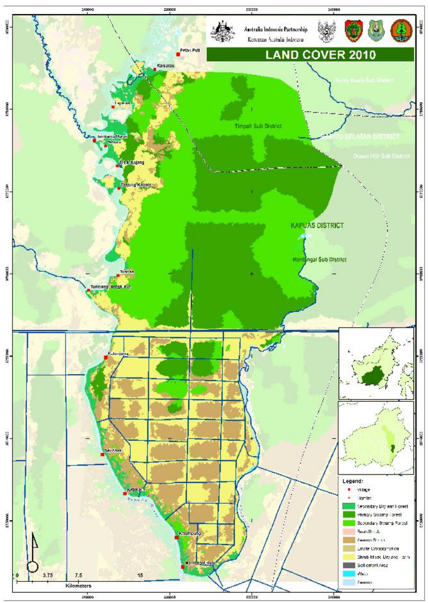
Landcover map



© Sarvision for EMRP (2008), classification using ALOS PALSAR



© RSS for KFCP (2010), classification using Rapid Eye image 21 June 2010

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Ground water and surface water levels

Measuring the **level of the water table below the peat surface and in canals** allows an assessment of the degree of drainage impact in different parts of the system, and therefore of likely carbon emissions and rehabilitation requirements.

Dipwells are installed into the mineral substrate along ***26 transects*** in which water table depth below the peat surface is measured on a monthly interval since 2009.

The **surface water level in the canals** is measured using ***staff gauges***.

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Installation photographs

Gluing two PVC tubes together. Note the holes in the tube and the green filter gauze.

Using poles to avoid disturbance of the peat surface.

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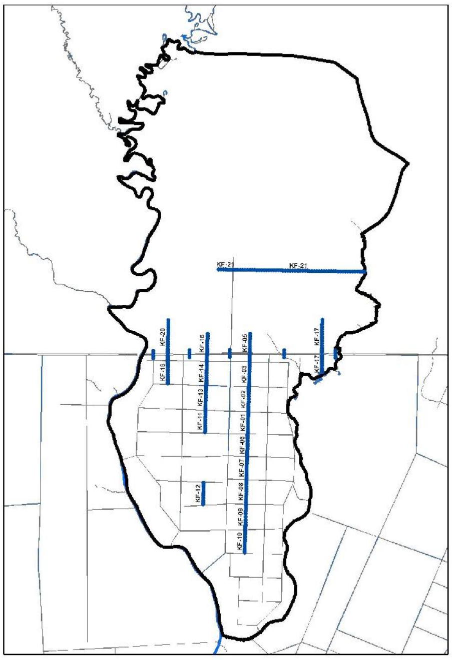
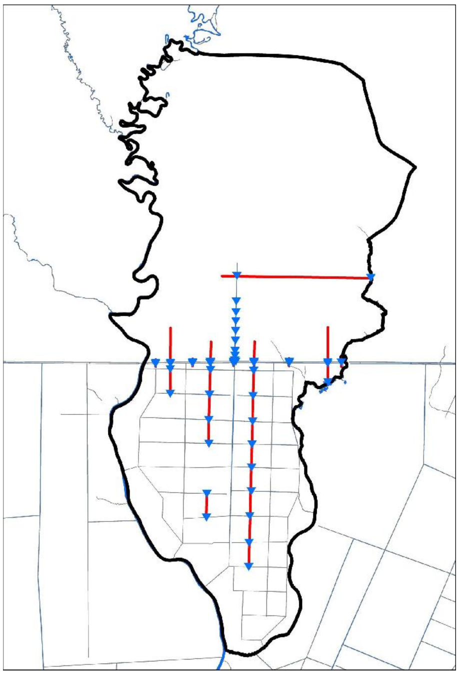
Map of measurements



dipwell locations



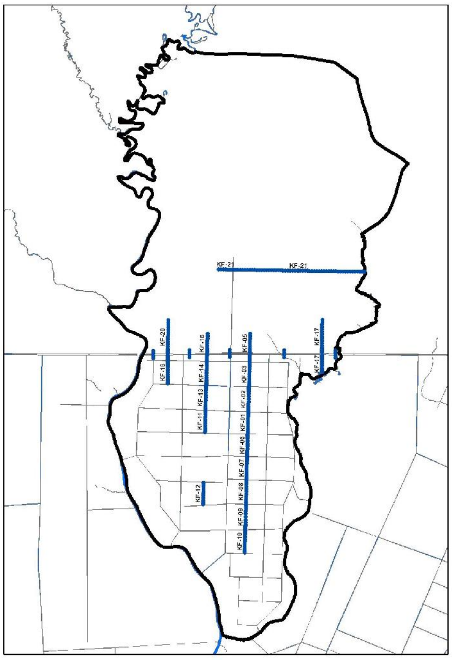
staff gauge locations

Peat subsidence

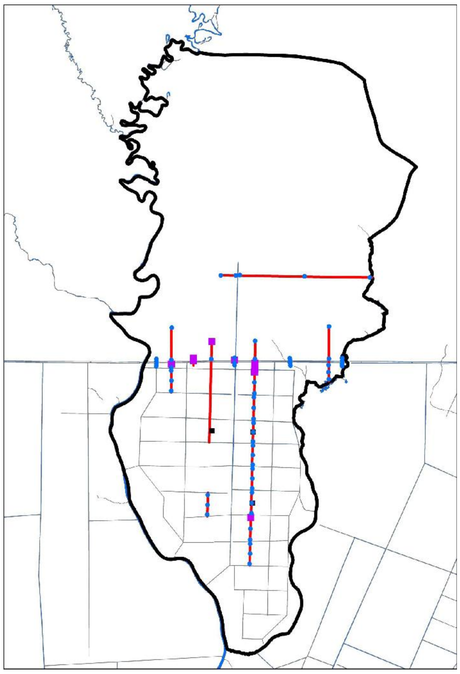
Peat subsidence (i.e. lowering of the peat surface), after correction for compaction and consolidation, is a reliable measure of carbon loss from the peat and therefore of CO_2 emissions to the atmosphere (Hooijer et al., in prep.).

Subsidence is measured using ***dipwells and subsidence poles*** that allow a direct measurement of a change in the position of the peat surface as a result of carbon loss and compaction (and in some cases possibly consolidation) due to A) decomposition and B) fires.

Map of measurements

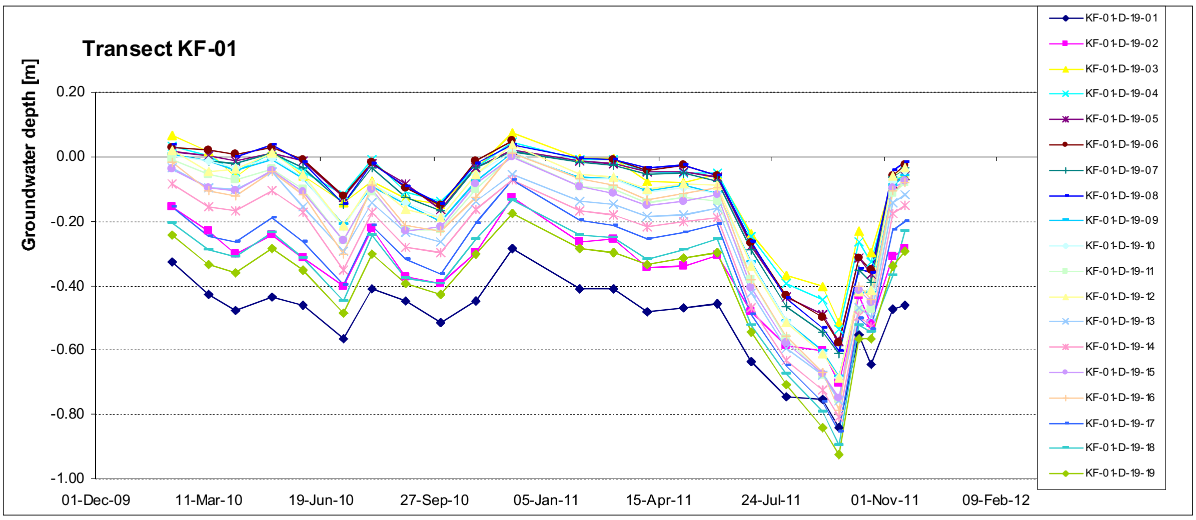


dipwell locations (used as non-permanent subsidence poles) (26 transects, approx. 500)



steel subsidence poles (purple = stolen, black is from EMRP project) (26 transects, approx. 70)

Groundwater depth measurements



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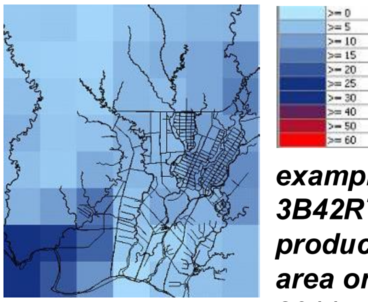
Rainfall

Rainfall data is required to understand fluctuations in water levels and water flows. Such understanding is needed to be able to interpret patterns in peat subsidence and fire risk, which in turn help understand carbon change from the area.

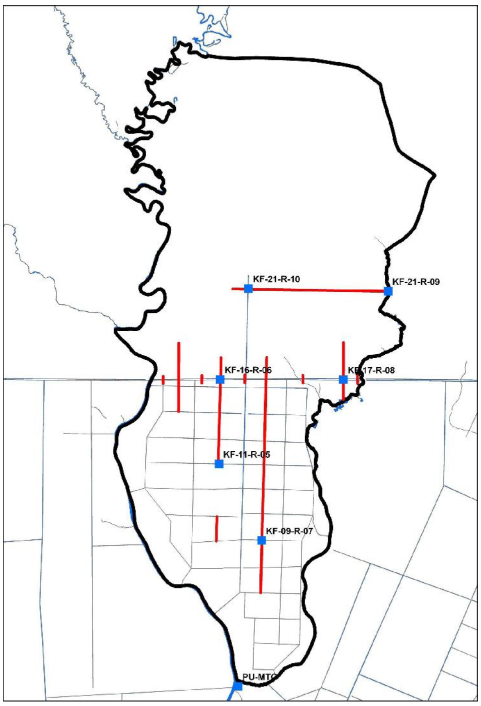
Rainfall in the KFCP area is monitored in two ways. **Manual rain gauges** are placed in and around the area, and complemented with existing ground stations in e.g. Mantangai. However, satellite data from the Tropical Rainfall Measuring Mission (TRMM) are also used, which was recently found by Deltares and BMKG to be highly accurate for drought detection in Indonesian lowlands (Vernimmen et al. 2012).



example of TRMM 3B42RT satellite product over EMRP area on 5 September 2011

Vernimmen, R. R. E., Hooijer, A., Mamenun, Aldrian, E., and van Dijk, A. I. J. M.: Evaluation and bias correction of satellite rainfall data for drought monitoring in Indonesia, Hydrol. Earth Syst. Sci., 16, 133-146, doi:10.5194/hess-16-133-2012, 2012.

Map of measurements



rain gauge locations

Peat characteristics

The oxidation of peat is what causes the carbon emissions that KFCP aims to reduce. Understanding the rate of peat oxidation under different conditions is therefore key to the ability of KFCP to demonstrate its ability to indeed achieve this goal. The 'basic' peat sampling aims to obtain data on **bulk density**, **soil moisture content** and **ash content**, that allow interpretation of subsidence rates in terms of oxidation (carbon loss) versus compaction.

Other measurements

Elevation and peat depth is also being measured.

Monitoring is carried out by 2 teams of 3 persons each.

8 Field camps have been build to facilitate field monitoring

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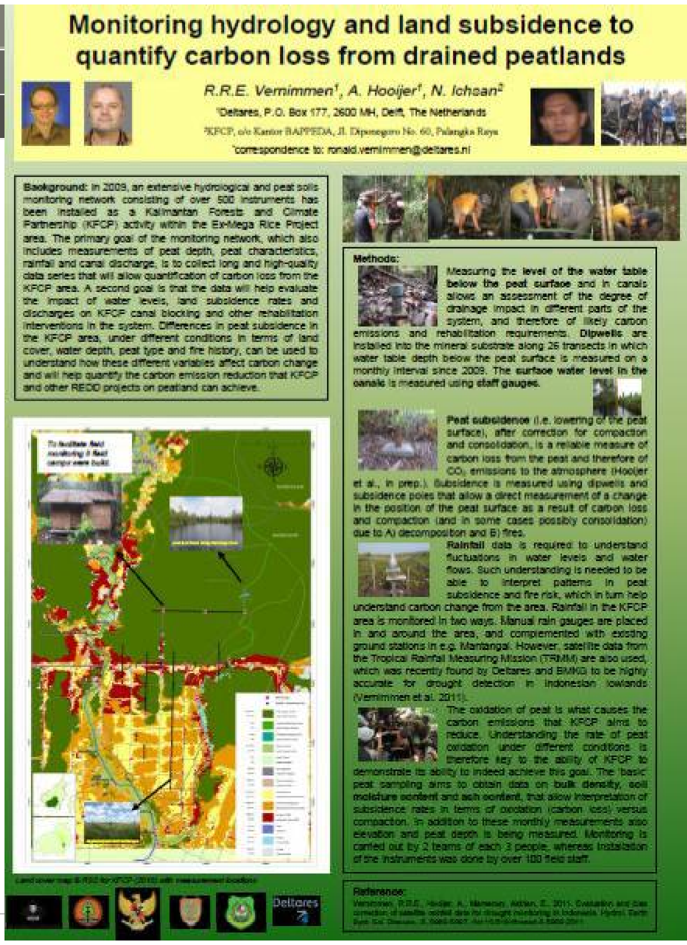
More info



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Enabling Delta Life

Rainfall (TRMM) and fire (MODIS) monitoring in Indonesia and KFCP, as input to subsidence modelling

Ronald Vernimmen
ronald.vernimmen@deltares.nl

Outline

TRMM satellite rainfall + bias correction

Use of corrected TRMM in peatland waterbudget model

MODIS hotspot (fire) data

Relation groundwater depth and fires

Fire and subsidence

TRMM satellite data for improved rainfall monitoring

TRMM - the basics

- Tropical Rainfall Monitoring Mission
- joint project between NASA and JAXA (Japanese space agency)
- launched on November 27th, 1997
- multiple sensors on board of the satellite are combined in various stages using different algorithms and results in various precipitation estimate products
- data also available in near-real time (3B42RT product)
- spatial resolution 0.25º (28 x 28 km near the equator), 40ºN – 40ºS
- temporal resolution of 3 hr, February 2002 – now (for the real time product)
- data source: ftp://trmmopen.gsfc.nasa.gov//pub/merged/mergeIRMicro/
- filetype: binary, projection: geographic, WGS84
- parameter: rainfall intensity
- data are freely available

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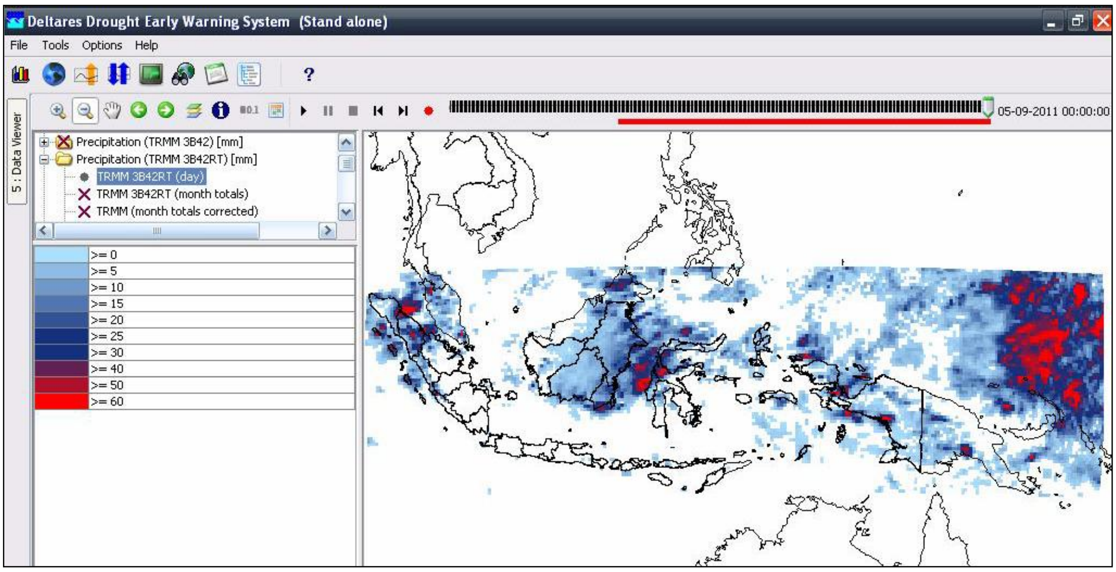
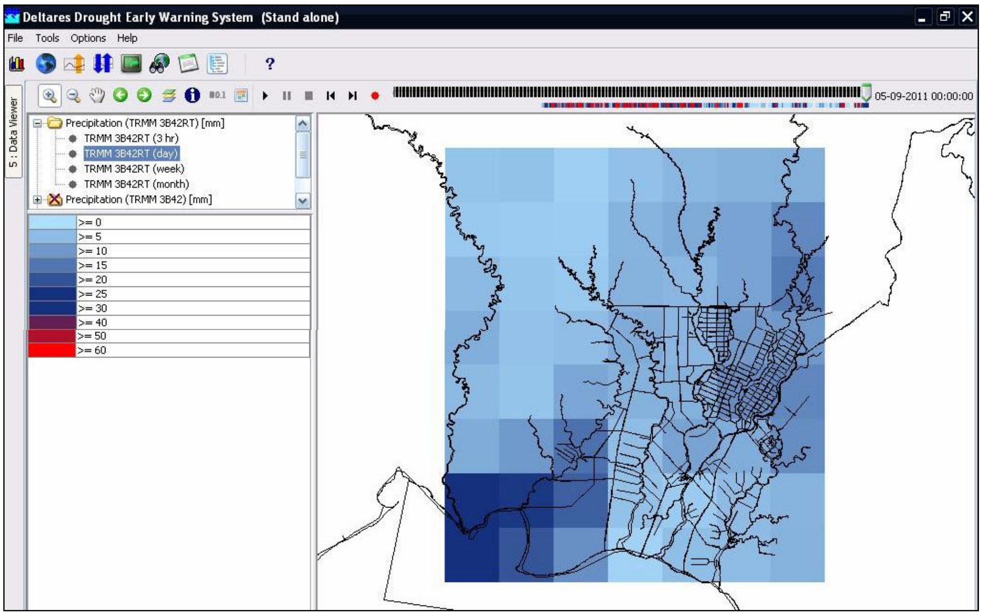
Example - Indonesia



TRMM 3B42RT satellite precipitation (in mm) as observed on 5 September 2011 over Indonesia. Red colors indicate high precipitation on that day. Data are processed and visualised by Deltares Delft-OMS software.

Deltares

Example – Central Kalimantan, Ex-Mega Rice Area



TRMM 3B42RT satellite precipitation (in mm) as observed on 5 September 2011 over the Ex-Mega Rice Project area in Central Kalimantan, Indonesia. Data are processed and visualised by Deltares Delft-OMS software. One square (grid) cell is approximately 28 x 28 km in size or covering an area of approx. 784 km^2.

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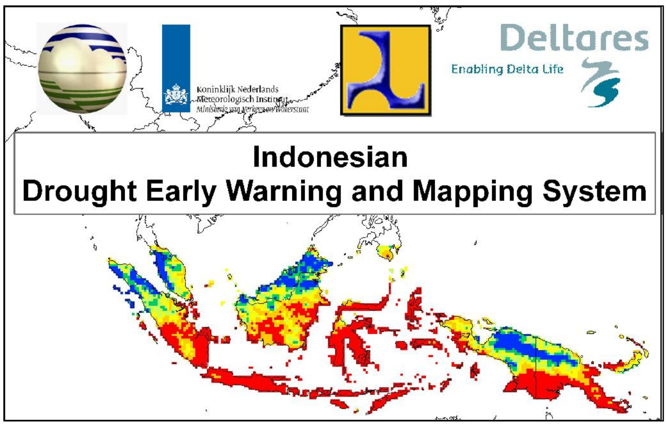
Suitability of TRMM for drought monitoring in Indonesia

Together with BMKG, Deltares has evaluated the suitability of the TRMM 3B42RT satellite precipitation product for drought monitoring and mapping in Indonesia.

The satellite precipitation data were compared with ground station data on a monthly basis and the TRMM 3B42RT product has been corrected for the bias. The method is described in the paper of Vernimmen et al. 2012.

Data are currently used by BMKG, PusAir, Deltares and KNMI in the development of a national Drought Early Warning System.



Vernimmen, R. R. E., Hooijer, A., Mamenun, Aldrian, E., and van Dijk, A. I. J. M.: Evaluation and bias correction of satellite rainfall data for drought monitoring in Indonesia, Hydrol. Earth Syst. Sci., 16, 133-146, doi:10.5194/hess-16-133-2012, 2012.

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Suitability of TRMM for drought monitoring in Indonesia

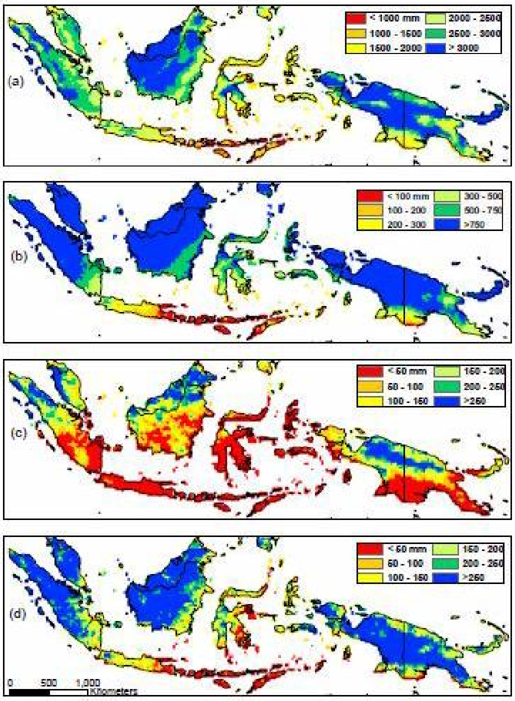

Fig. 11. **(a)** Average annual and **(b)** dry season (June–October) rainfall as determined from monthly bias corrected TMPA 3B42RT over 2003–2008 as well as **(c)** October 2006 and **(d)** October 2007 bias corrected TMPA 3B42RT rainfall.

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Development of a peatland water budget model

The bias corrected TRMM 3B42RT data are being used in the development of a peatland water budget model (run on a daily basis) which is validated with ground water table depth data.

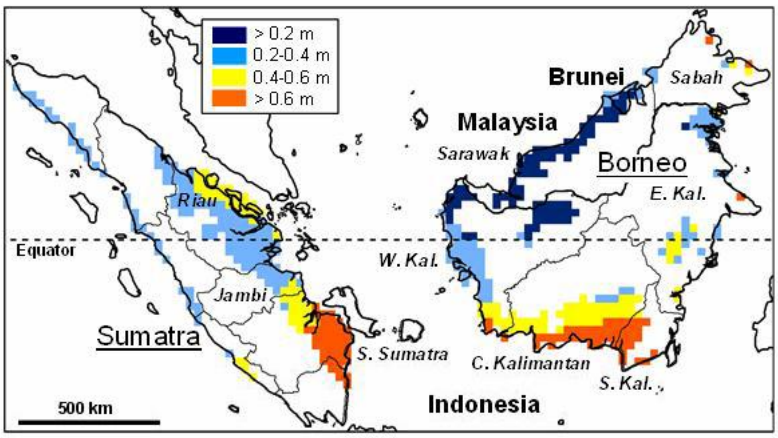

Figure: *Average annual lowest water depth in peatlands, 2002-2008, modelled using TRMM rainfall data and Deltares peatland water budget model (assuming no forest cover and limited drainage, in this case).*

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Dry versus wet years

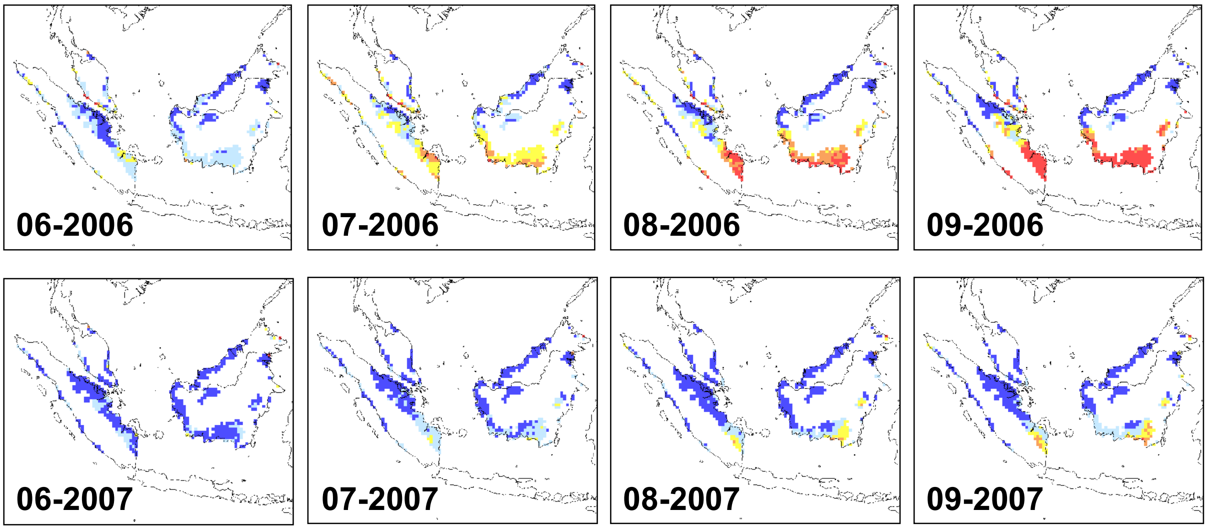

Figure: *Modelled groundwater levels in peat: 2006 (dry) compared to 2007 (wet). Shown is ground water depth on the first of the respective month*

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MODIS satellite data for (active) fire monitoring [1/2]

MODIS - the basics

- Moderate resolution Imaging Spectroradiometer
- 2 NASA satellites: Terra and Aqua
- launched in December 1999 and spring 2002
- multiple sensors on board
- spatial resolution 1000 m, globally, distribution in tiles 10º x 10º
- temporal resolution 2 times a day per satellite
- overpass time equator: Terra at 10:30 am and 10:30 pm, Aqua at 1:30 am and 1:30 pm
- data period: February 2000 – now (Terra), July 2002 – now (Aqua)
- source(s): ftp://e4ftl01.cr.usgs.gov/MODIS_Composites/MOLT/MOD14A1.005/ and ftp://e4ftl01.cr.usgs.gov/MODIS_Composites/MOLT/MYD14A1.005/
- filetype: hdf, projection: sinusoidal
- Science Data Sets: firemask, quality assessment, maximum fire radiative power

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MODIS satellite data for (active) fire monitoring [2/2]

MODIS - the basics

9 classes in the SDS Firemask:

0. not processed (missing input data)
1. not processed (obsolete)
2. not processed (obsolete)
3. water
4. clouds
5. no fire
6. unknown
7. **low confidence fire**
8. **nominal confidence fire**
9. **high confidence fire**

Data need to be processed first prior to utilization:

- reprojection of sinusoidal to UTM50 projection using Modis Reprojection Tool (https://lpdaac.usgs.gov/lpdaac/tools/modis_reprojection_tool)
- conversion of hdf to ArcInfoAscii using HDF2GIS tool (http://laits.gmu.edu/Download/Dn_Tools.htm)

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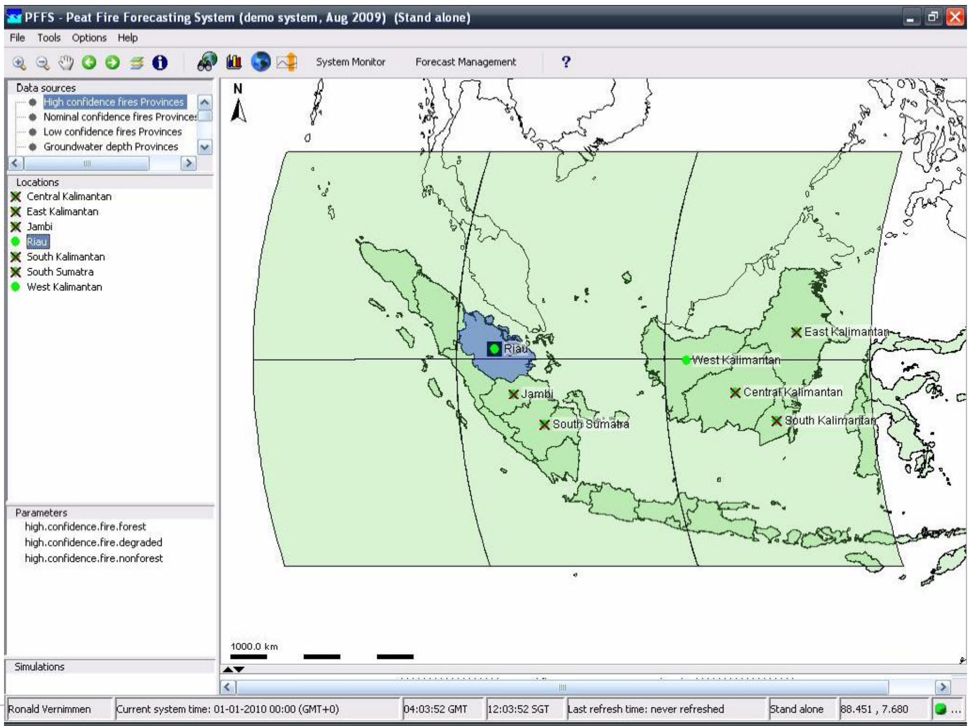
MODIS tiles

MODIS tile location and Indonesian Provinces



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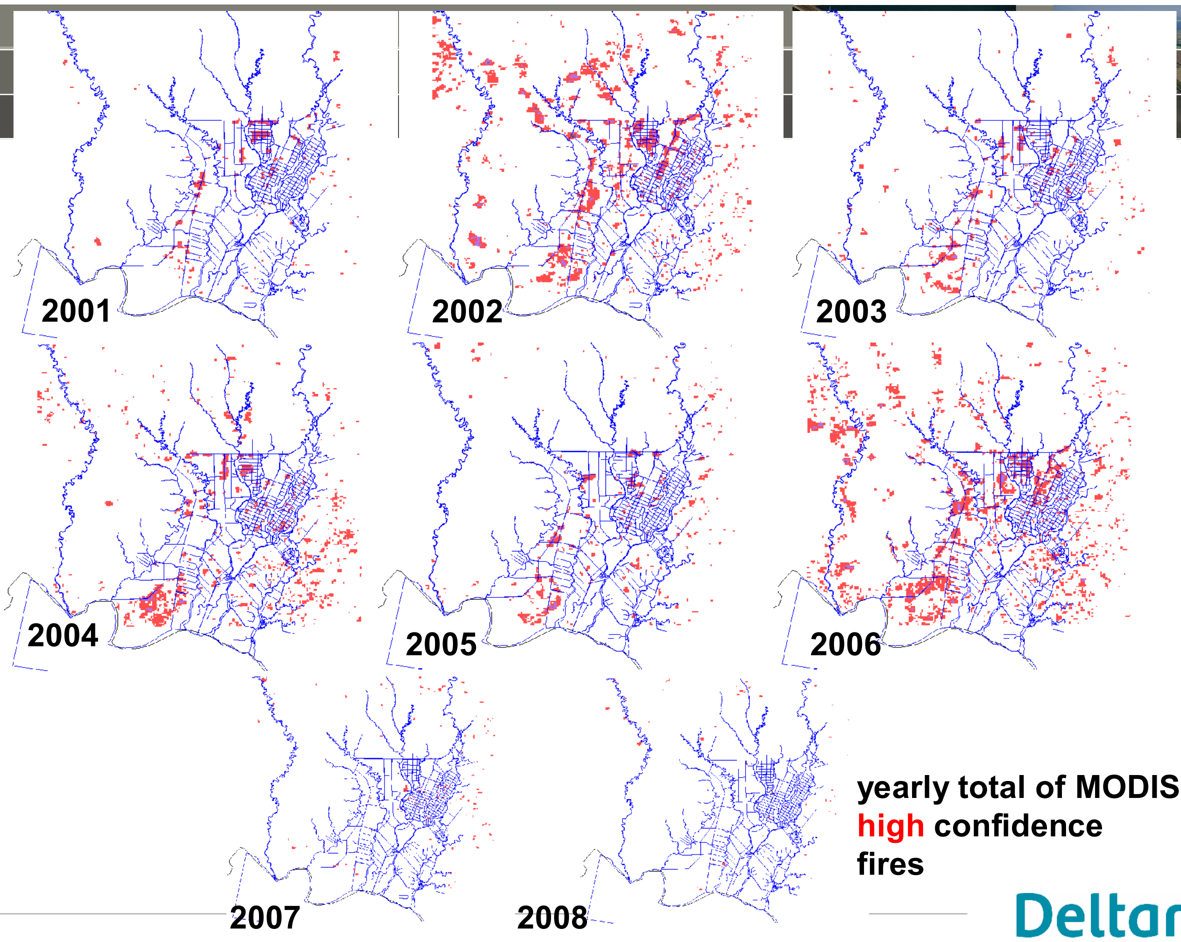

yearly total of MODIS high confidence fires

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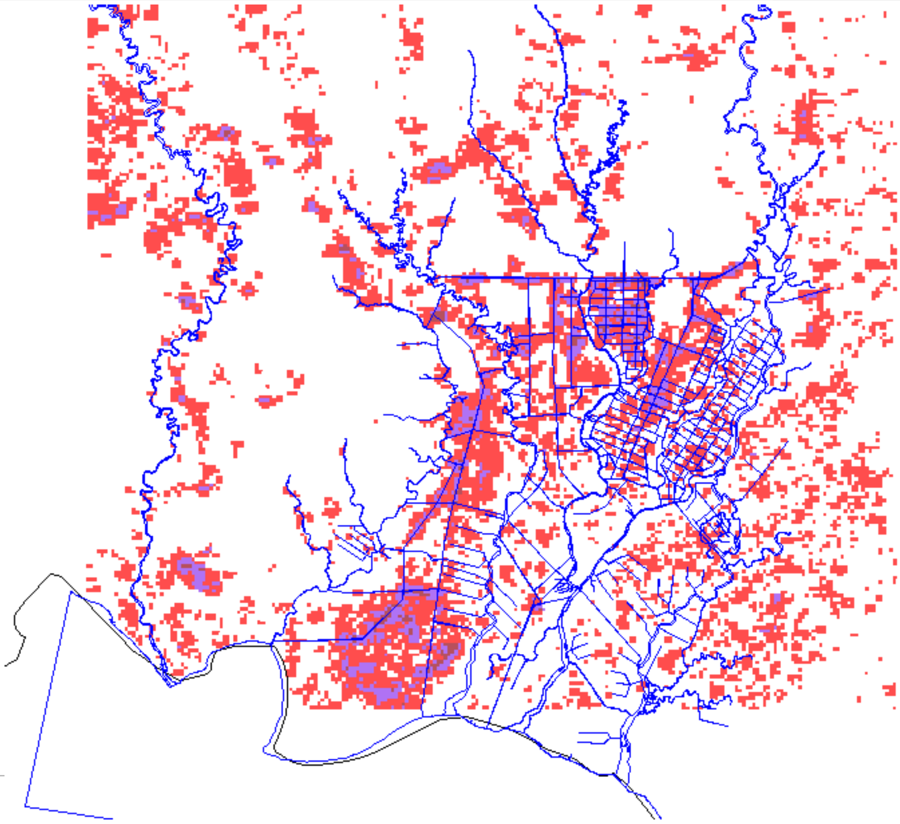
MODIS 10 years of Central Kalimantan high confidence fires



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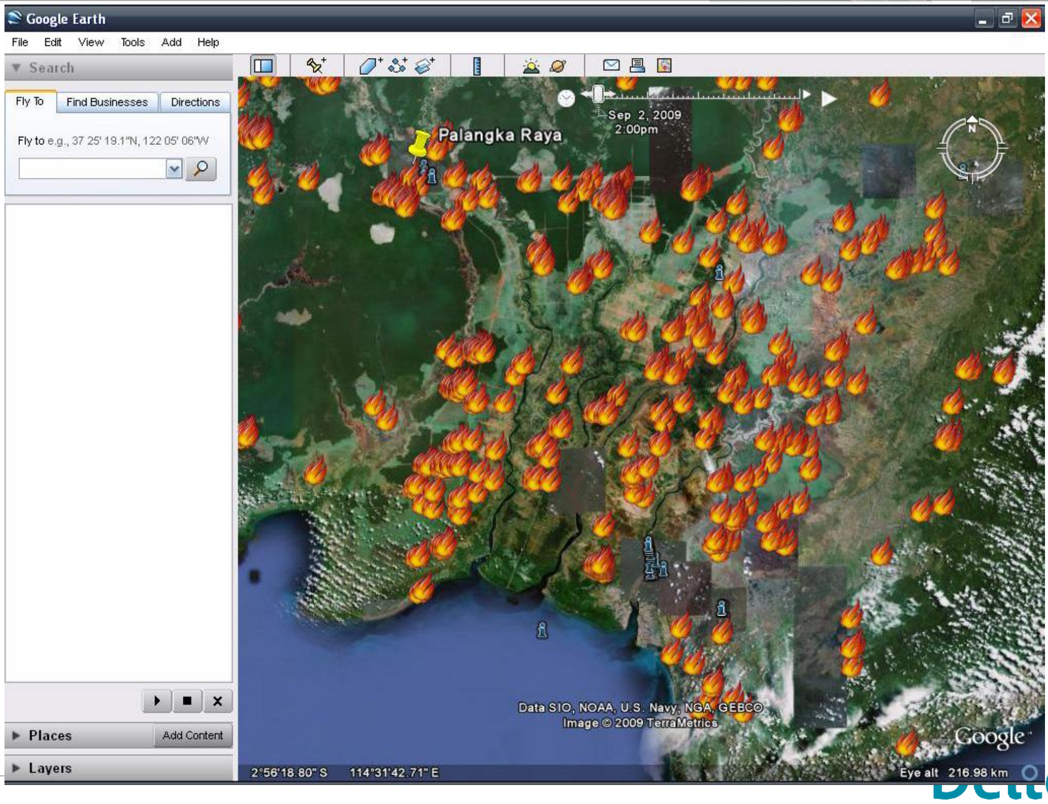
Fire situation can also be monitored via Google Earth



Relate groundwater depth to fire frequency

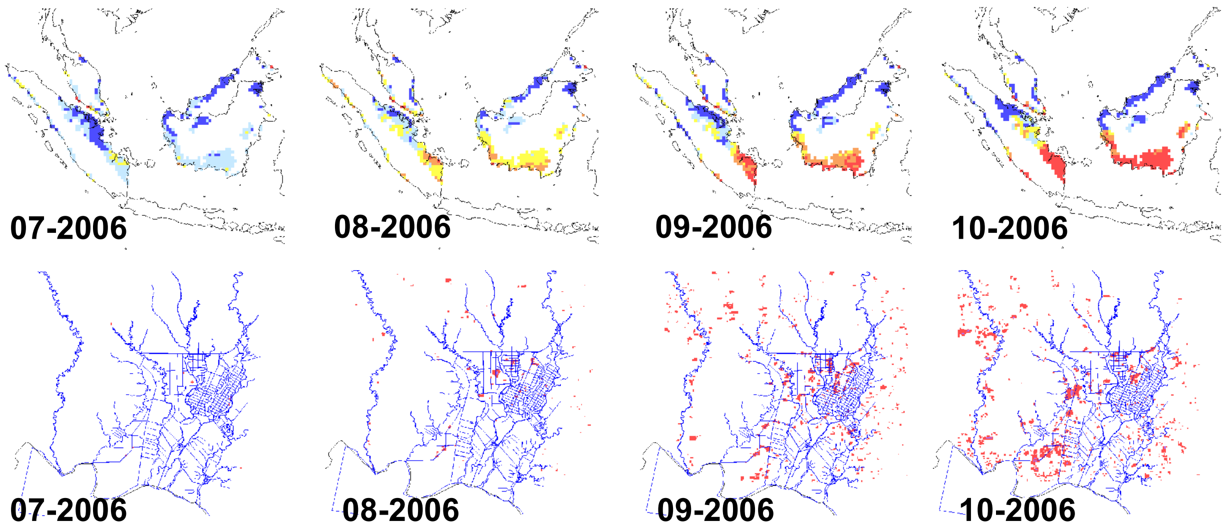


Figure: *Modelled groundwater levels in peat for 1st of each shown month using TRMM and number of observed MODIS high confidence fires for that month*

Relate groundwater depth to fire frequency

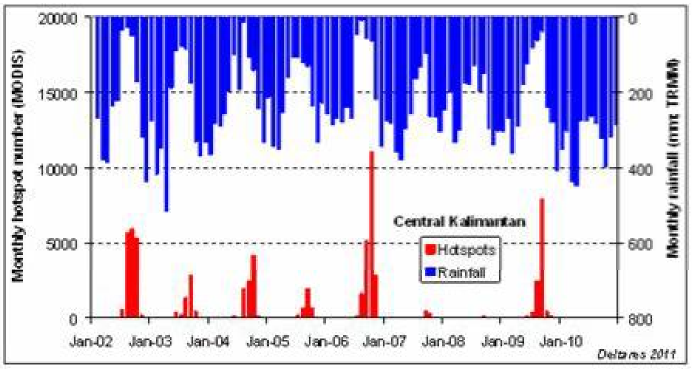


***Figure:** The close relation between hotspots and rainfall shows that fire is used for land clearing especially in dry periods. This explains why the number of fires in the very dry year of 2006 was very high, while the number of fires in the following wet years has been lower.*

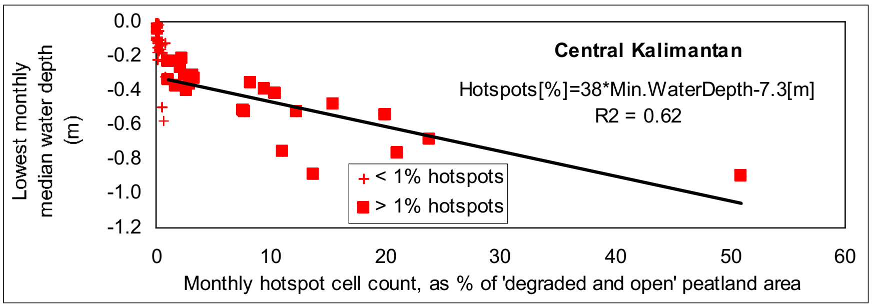


Figure: *Relation between monthly median water depth and monthly hotspot counts, for peatland area in Central Kalimantan with 'open and degraded' land cover.*

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Monitoring and quantification of fire risk

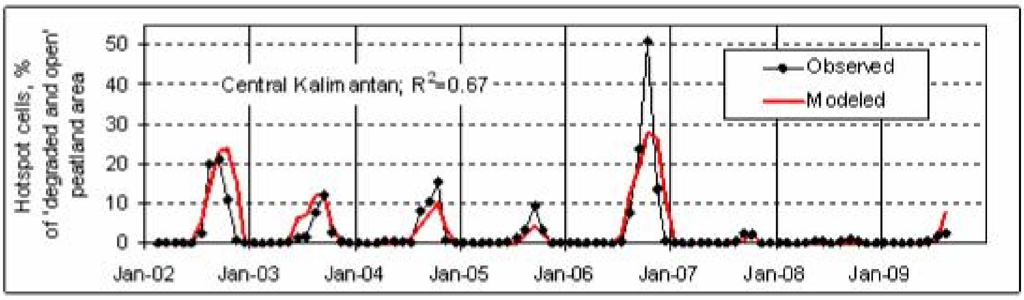
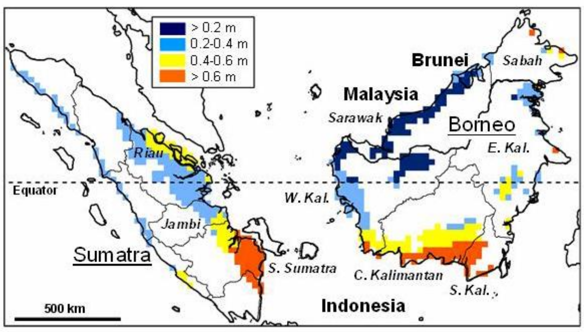


Figure: *Observed and modeled monthly hotspot counts in Central Kalimantan, as a percentage of the 'open and degraded' peatland area in this Province.*



Similar to left figure fire risk can be mapped as well.

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Fire and subsidence

Part of subsidence is due to fires.

Fire and subsidence

The data presented show:

1. TRMM satellite rainfall can be used in drought monitoring (validated with ground measurements)
2. The corrected TRMM satellite data can be used in modelling groundwater table depths in peatlands (validated with ground measurements)
3. Groundwater table depths are related to fire frequency which can be modelled as well

Since we know that part of subsidence is due to fires we can use known relationships between fires *(which we now can model and relate to groundwater depth)* and amount of peat loss (from literature) to model this part of subsidence both historically but also using future projections.