Jan. 12, 2017 @ GEOSS Asia-Pacific Symposium, Tokyo

GHGs emissions from tropical peatlands through wildfires and land-use change

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Outlines

1. What is peat or tropical peat?
2. Current conditions of tropical peat (under severe human pressures)
3. GHGs emission from tropical peatlands

What is peat?

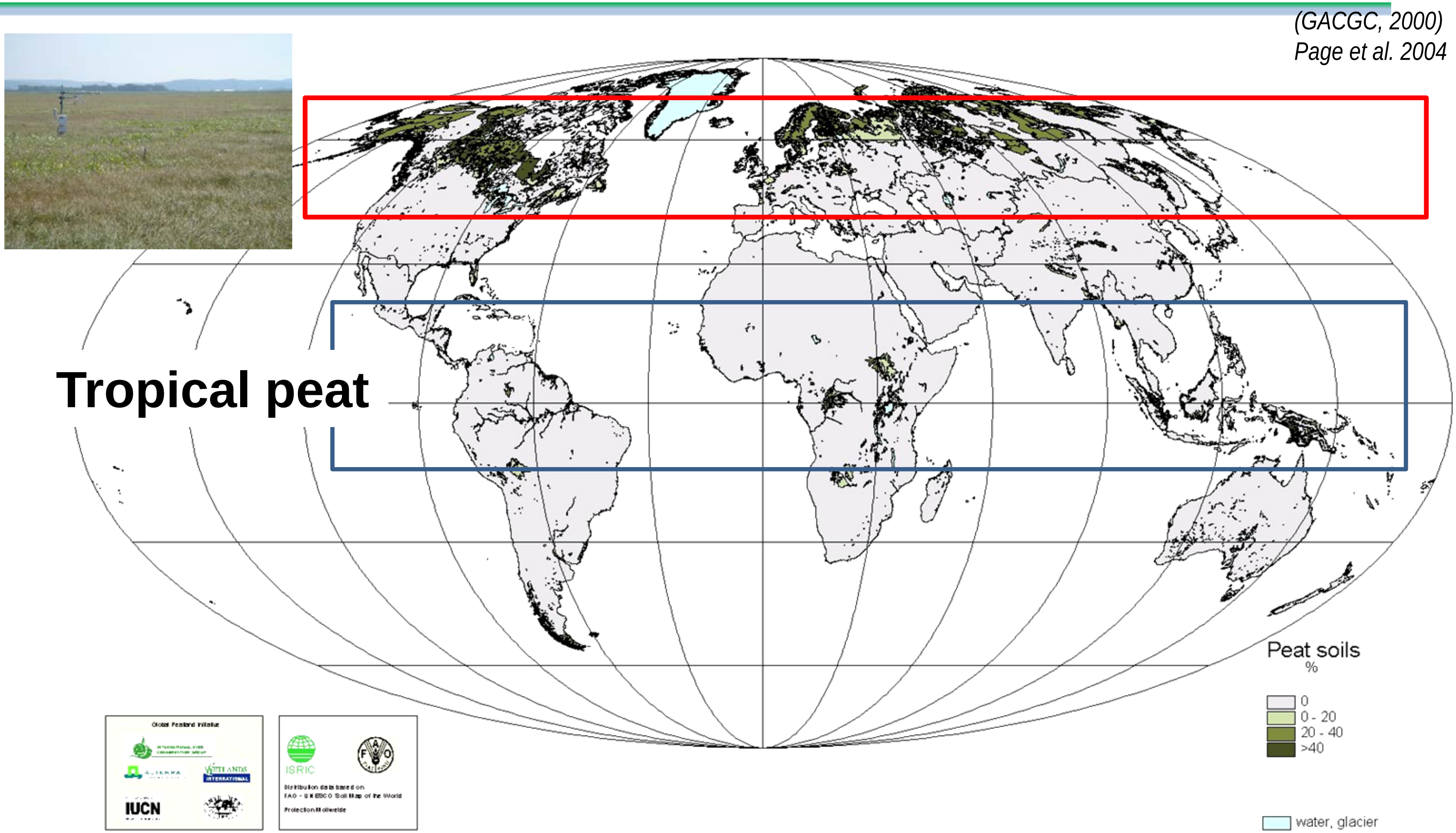
- **Peat** is an accumulation of partially decayed vegetation matter or histosol (a soil consisting primarily of organic materials).
- **Peat** is distributed in about 4 million km^2, which accounts for 2-3% of world land area.
- Carbon stored as soil organic matter in **peat** is estimated at 600-700 Gt, which accounts for about 25% of world soil carbon (Turetsky *et al*., 2014).

⇒ **Huge carbon pool**

1 Gt = 10^9 t = 10^{15} g = 1 Pg

Peat stack in Scotland

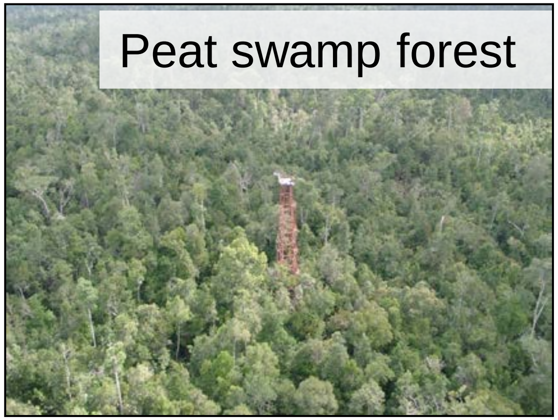
Distribution of peat

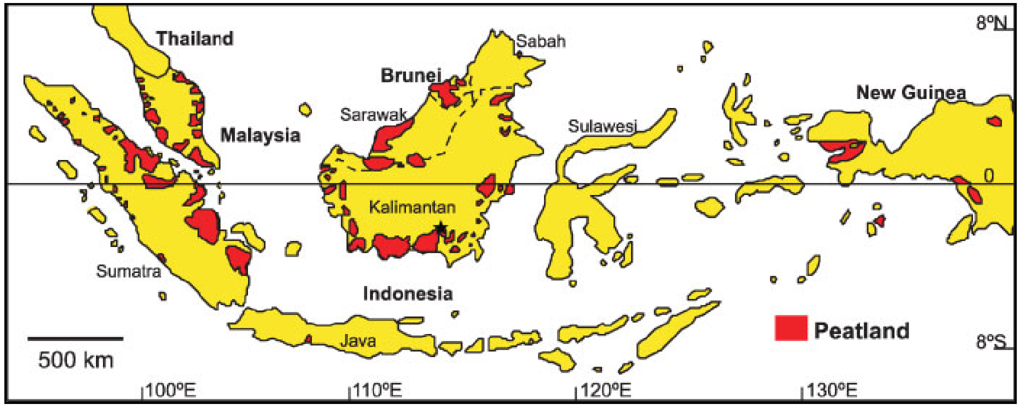


Cool climate → More than 80% of peat is distributed in high latitudes in the northern hemisphere

Tropical peatland in SE Asia

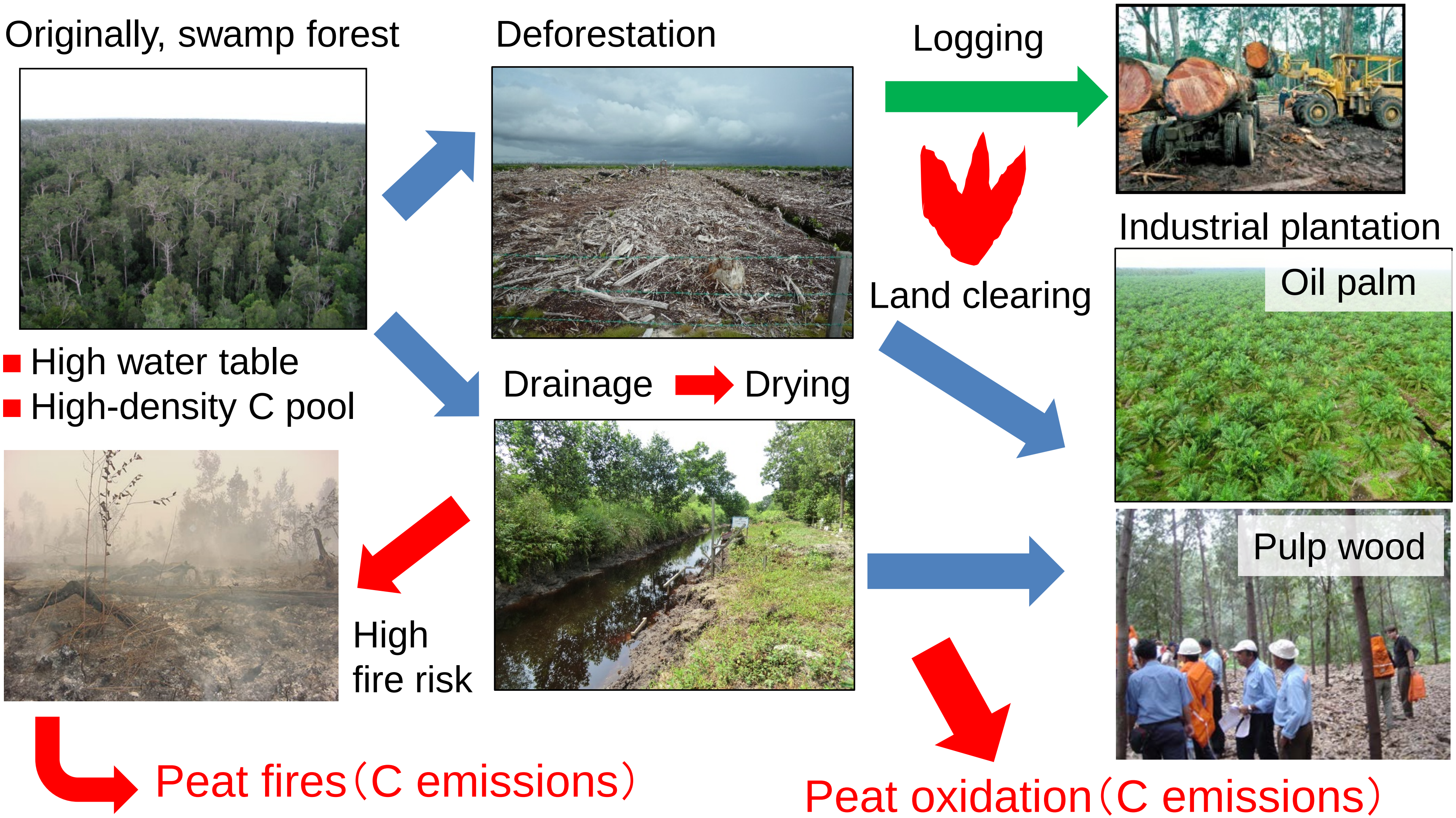
- In SE Asia, pealtlands are widely distributed in the area of about 250,000 km^2 and store 68.5 Gt of soil carbon, which accounts for 11-14% of global peat carbon (Page *et al*., 2011).
- Although the tropical petalands naturally coexist with swamp forest, the peatlands have been devastated by logging and land development since the 1970's, and 20% of peat swamp forest has been deforested and mostly drained during the last decade (Miettinen *et al.*, 2011).
- The risk of large-scale fires increases with disturbance, because such disturbances typically dry peat and leave much plant debris, which are flammable (Page *et al.*, 2002), especially in El Niño years.





Distribution of tropical peatlands in SE Asia (Page *et al.*, 2004)

Land-use change in tropical peatlands

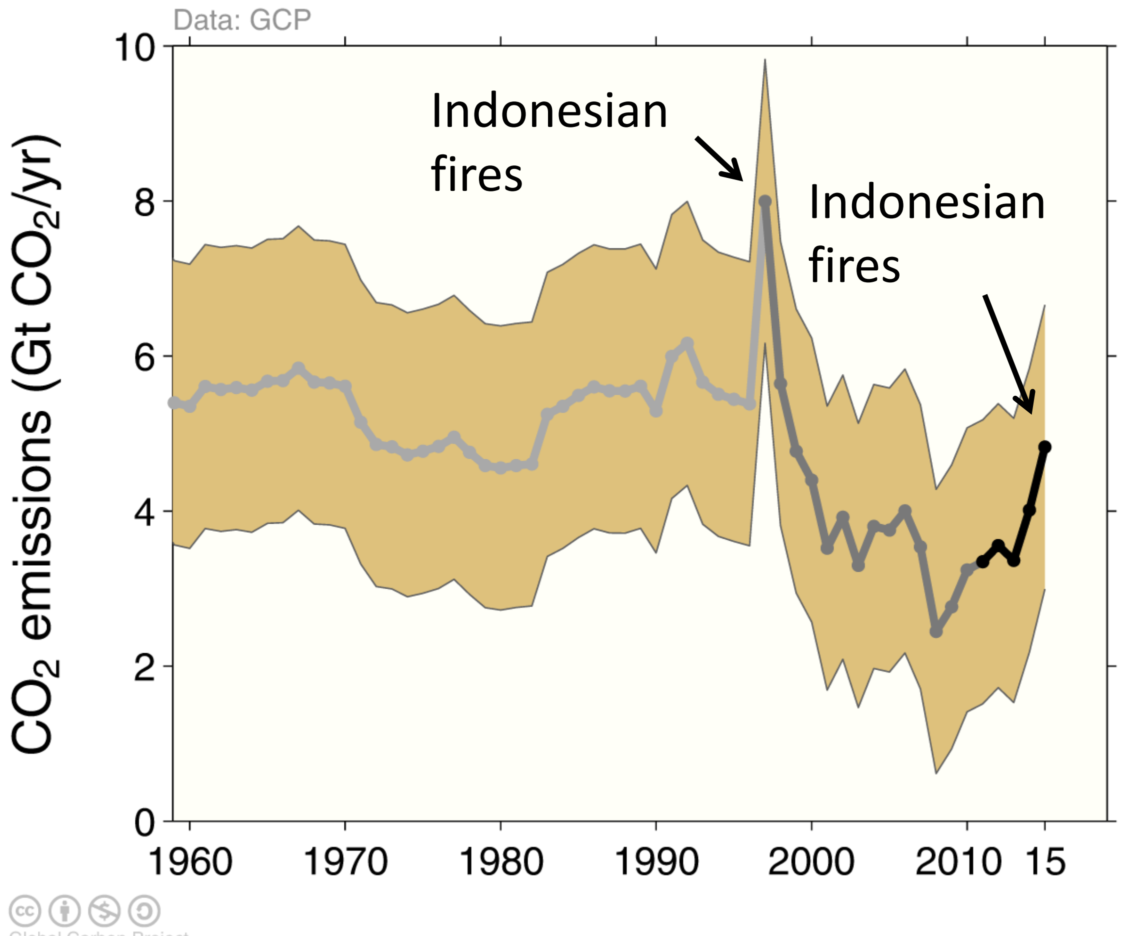


- Tropical peatland is a global hot spot of C sources in this century（Global Carbon Project)

Land-use change emissions

Emissions in the 2000s were lower than earlier decades, but highly uncertain

Higher emissions in 2015 are linked to increased fires during dry El Niño conditions in Asia



Three different estimation methods have been used, indicated here by different shades of grey

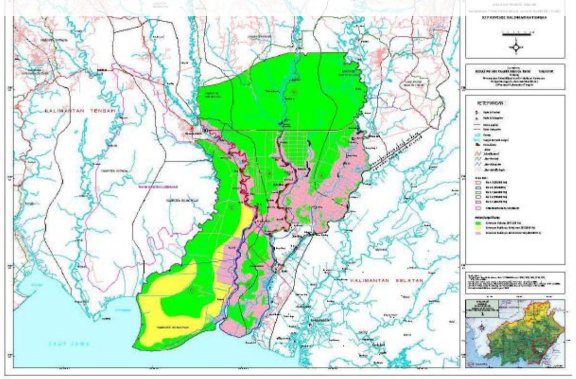
Land-use change also emits CH_4 and N_2O which are not shown here

Source: Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2016; Global Carbon Budget 2016

Large-scale disturbance: Mega Rice Project (MRP)

- A large-scale national project (MRP) was implemented to develop paddy fields in tropical petlands in Central Kalimantan, Indonesia. Through the project, large area was deforested and long canal (drainage) was excavated (4500 km).
- However, the project was abandoned in 1999 mainly by the Economic Crisis, leaving a vast devastated petlands.
- Drying & plant debris increased the risk of large-scale peat fires.
- Lowering of groundwater level enhanced oxidative peat decomposition.

Area of MRP: 17000 km^2

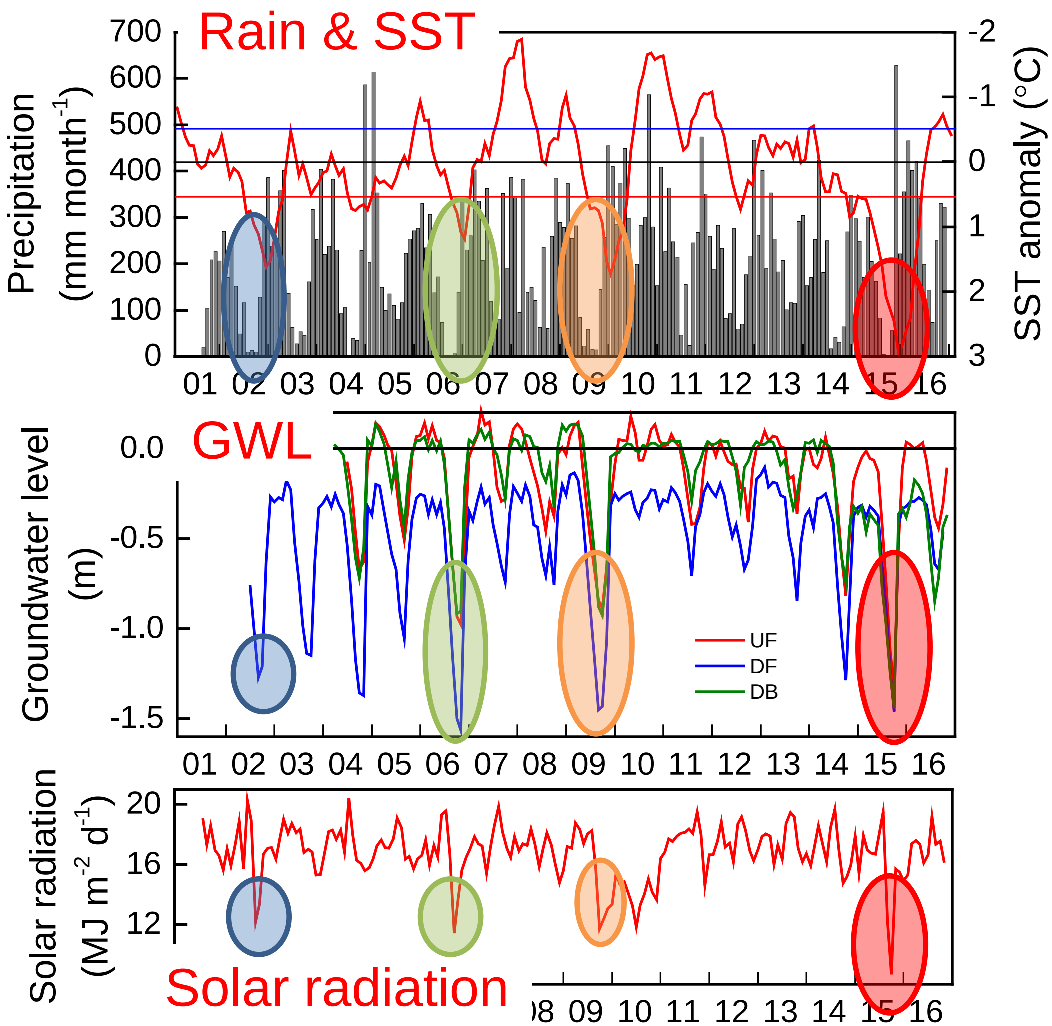


Devastated area

Large canal system

Prolonged dry season due to ENSO

- Precipitation, groundwater level (GWL) and solar radiation along with SST anomaly (Nino 3.4) at Palangkaraya, Central Kalimantan, Indonesia



Monthly values from 2001 to 2016

- SST rise (El Niño)

⇒ Prolonged dry season

⇒ GWL lowering

⇒ Large-scale peat fires

⇒ Dense smoke

⇒ Solar radiation attenuation

Triggers of peat fires

1. By accident (cigarettes etc.)
2. For land clearing (plant debris and re-growth vegetation)
3. Agricultural practice by small farmers, including asserting land tenure rights

Fires for weeding and natural fertilization

Normal years

Onset of the rainy season → under control within farmland

El Niño years

Prolonged dry season → out of control

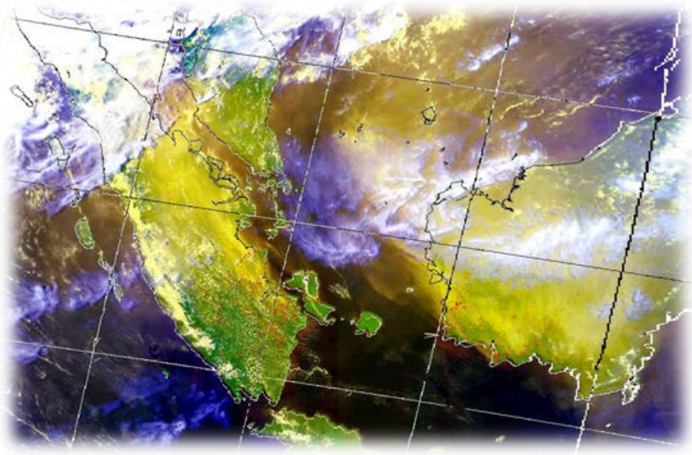
Large fire scars

Peat burning (flaming and smouldering)

- Peat is burnt by flaming and smouldering.
- Flaming is burning aboveground with flame.
- Smourldering is burning underground in the conditions of lower temperature, lower O_2 and higher moisture.
- Smourldering is the main process of peat burning.
- Smouldering continues for long time and is difficult to extinguish.
- Through smouldering, some harmful pollutants are emitted (PM, VOC etc.)

Environmental problems due to fires other than C

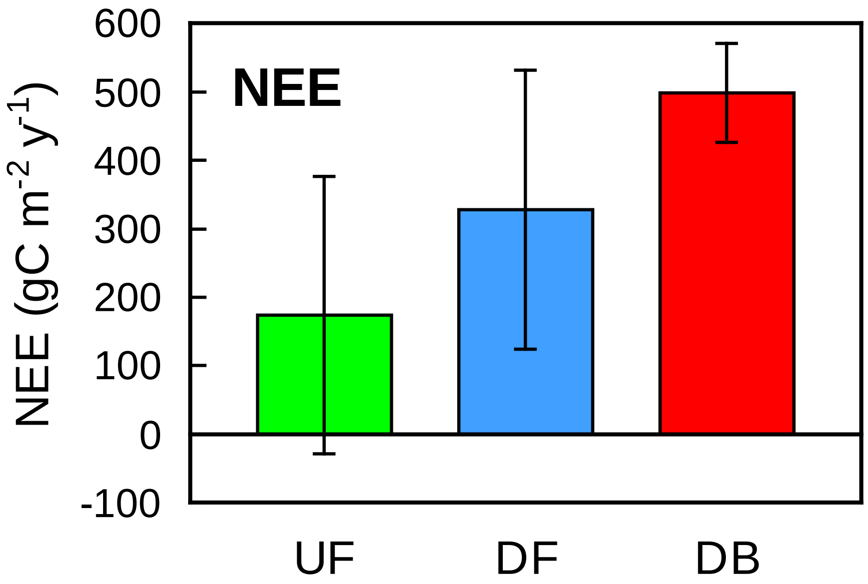
- Transboundary issue
- Serious economic impacts (traffic problems, business income loss etc.)
- Human health problems: additional deaths > 10000 persons/year due to $PM_{2.5}$ and O_3 (Marlier et al., 2012)
- It's very difficult to extinguish peat fires. 'Focus on fire prevention rather than fire fighting with a recognition that the haze problems dose not disappear until the onset of the rainy season (Page & Hooijer, 2016).'



Carbon balance on ecosystem scales

- Comparison of net ecosystem CO_2 exchange (NEE) in three peat swamp forests with different disturbances

Annual net CO_2 emissions (4 yrs from 2004 to 2008)



Flux tower

Undrained (UF)

Drained (DF)

Burnt (DB)

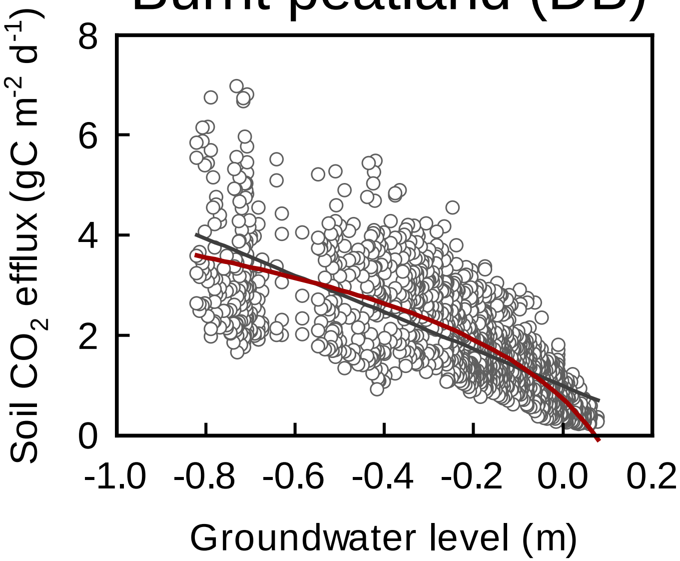
- Net CO_2 emission: DB > DF > UF
- NEE > 0 even in the UF site, partly because of the shading by dense smoke

Hirano et al., 2012

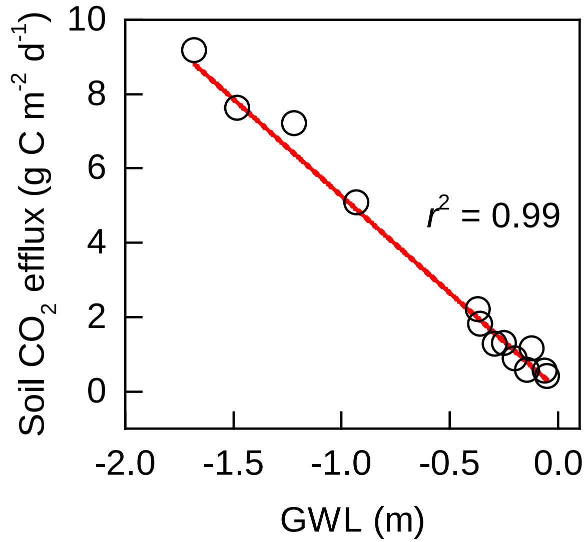
Oxidative peat decomposition (chamber method)

- Oxidative peat decomposition is controlled by groundwater level.

Burnt peatland (DB)



Rubber plantation on peat



Drainage

↓

Low GWL

↓

Peat oxidation

↓

CO_2 emissions

Hirano et al., 2014

Wakhid et al., 2017

Carbon emissions through peat fires (Bottom-up)

- Bottom up approach

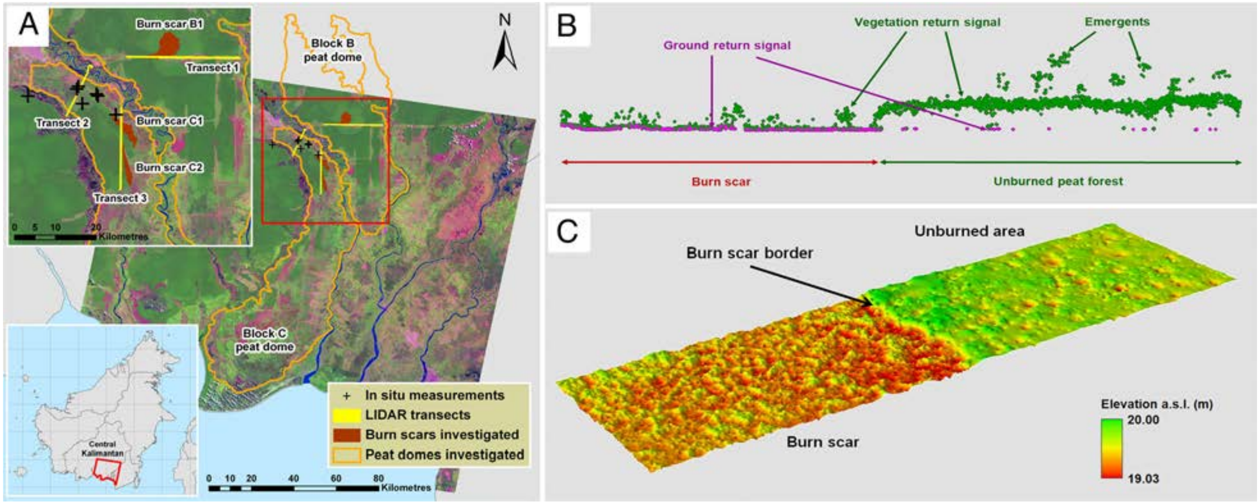
$L_{fire} = A \cdot M_B \cdot C_f \cdot G_{ef}$ (IPCC, 2013)

L_{fire}: C emissions, A: Burnt area, M_B: Mass of fuel available for combustion, C_f: Combustion factor, G_{ef}: Emission factor

or $L_{fire} = A \cdot D \cdot BD \cdot CC$

D: Burnt depth, BD: Peat bulk density, CC: Peat carbon content

Peat fire in 2006 in C. Kalimantan (Ballhorn et al., 2009)



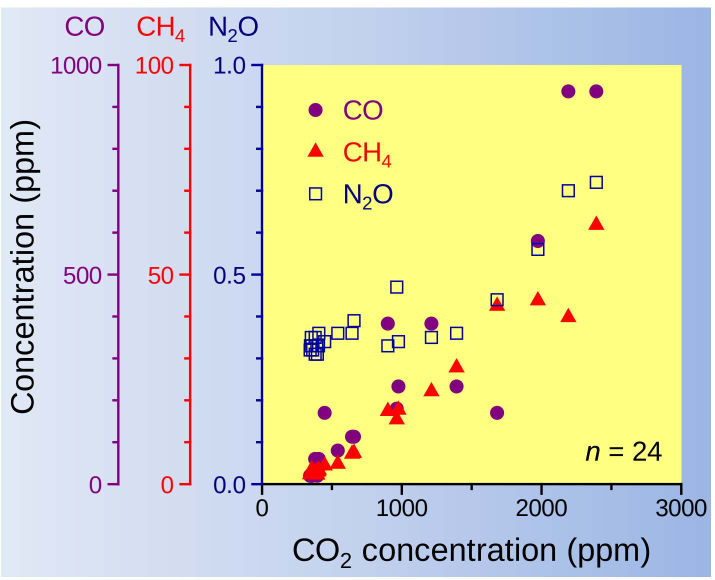
- *A*: Satellite data
- *D*: Airborne LiDAR
- *BD*, *CC*: Field data

Mean D = 33 cm

Carbon emissions through peat fires (Top-down)

- Carbon emissions from fires in 2015 (Huijnen et al., 2016)
  - Atmospheric carbon monoxide (CO), model & data assimilation
  - Ratio of emission factors (CO_2/CO and CH_4/CO)

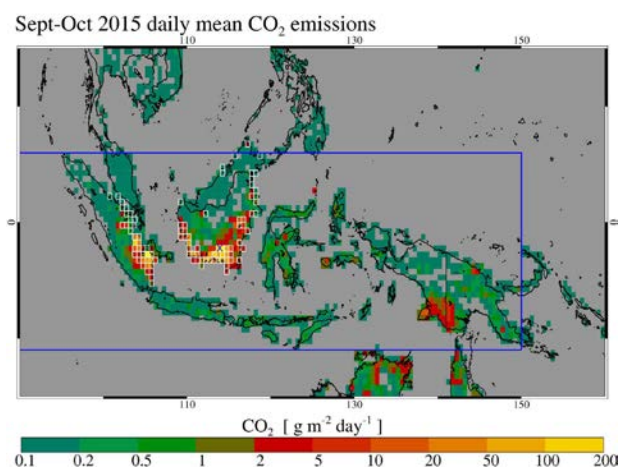
  ➡ Carbon emissions



CO_2 : CO : CH_4 = 1.0 : 0.38 : 0.026

(Hamada et al., 2011)

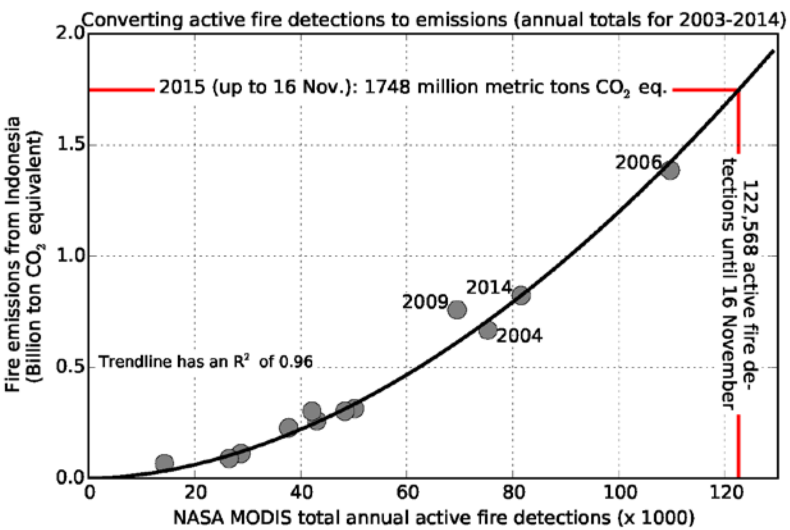
- Carbon emissions: 0.289 GtC (CO_2 83%, CO 16%, CH_4 1%)
- Smaller than that in 1997 (0.87 GtC, Page et al. (2002, bottom up))
- Smaller burnt area: 0.8 Mha vs. 1.7 Mha

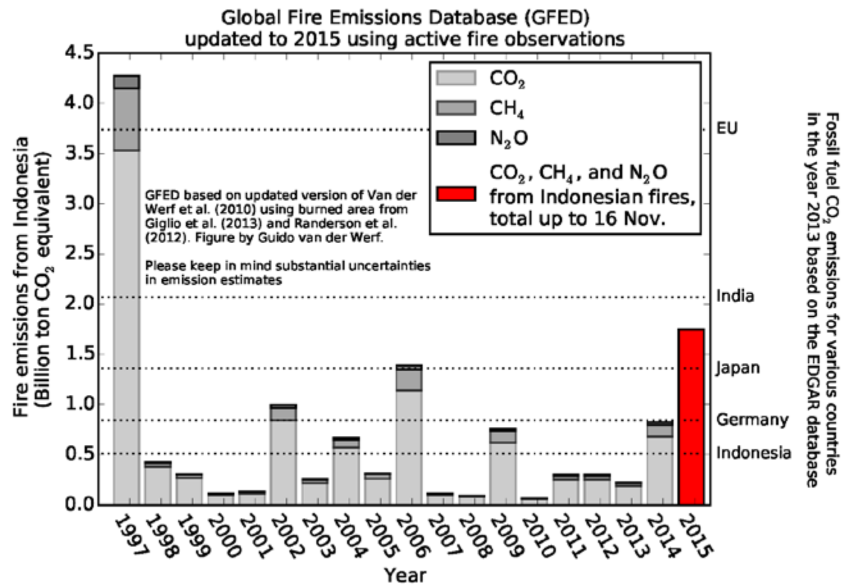


(Huijnen et al., 2016)

Carbon emissions through peat fires (GFED)

- Carbon emissions from fires in 2015 (Global Fire Emissions Database: GFED, http://www.globalfiredata.org/index.html)





- Carbon emissions (until 16 Nov.): 0.48 GtC
- Greater than that (0.289 GtC) of Huijnen et al. (2006)

Summary and conclusions

- Under the human pressures of land-use change and fires, tropical peatlands, a huge carbon (C) pool, have become vulnerable.
- On average for decades, annual C emissions from SE Asia's peatlands through peat mineralization and burning were estimated to be equal at about 0.1 GtC yr^{-1} (Page & Hooijer, 2016). At around 0.2 GtC yr^{-1}, this efflux equals the annual C emissions from Indonesia and Malaysia arising from fossil fuel burning and cement production.
- Oxidative peat decomposition mainly depends on groundwater level.
- Uncertainties both in the bottom-up and top-down approaches are still high for assessing C emission through peat burning.