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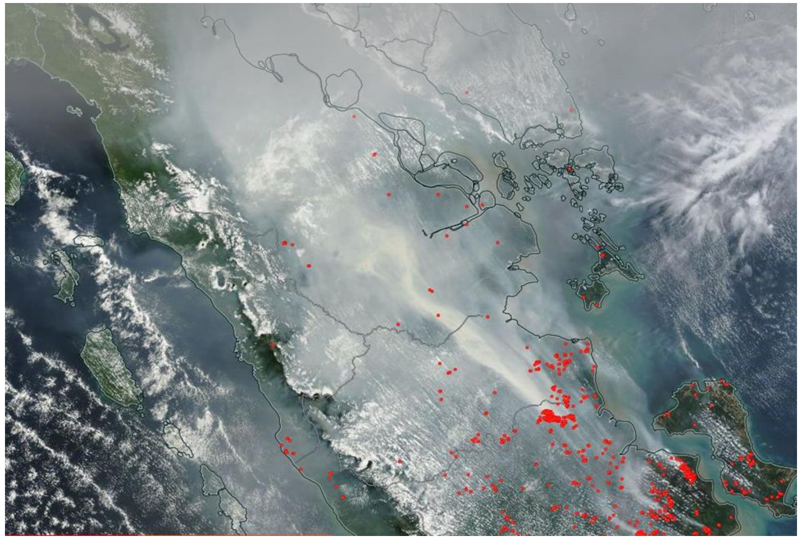
Vulnerable biomes: Tropical peatlands
Fires, emissions, uncertainties



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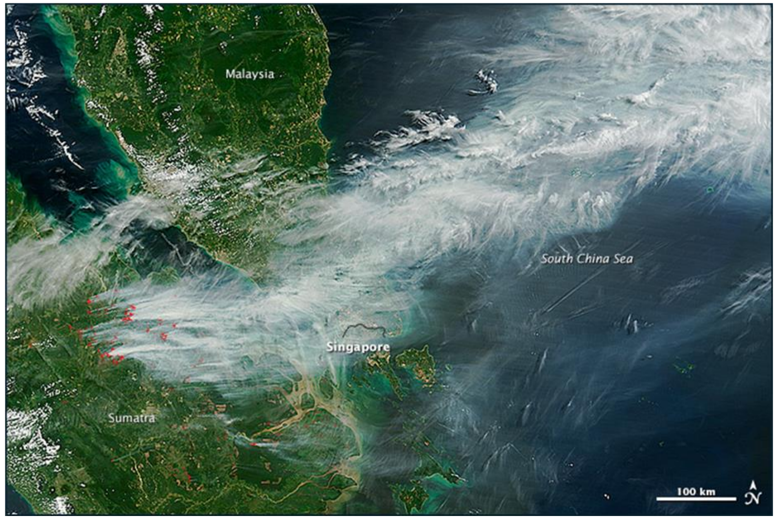
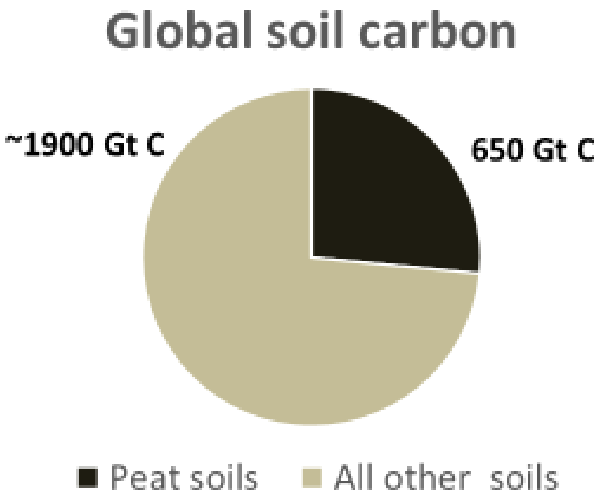
Overview

- Tropical peatlands
  - Efficient carbon capture & storage systems
  - Increasingly vulnerable
- The tropical peatland fire dynamic
  - Climate change
  - Other human impacts
- Emissions
- Uncertainties



Peatland carbon stocks



Some other global C pools (Gt):

- CO_2 in the atmosphere: 830
- All vegetation: 550
- Known oil reserves: 220

Tropical peat carbon (Gt)

- Total (mostly SE Asia, Congo): 105

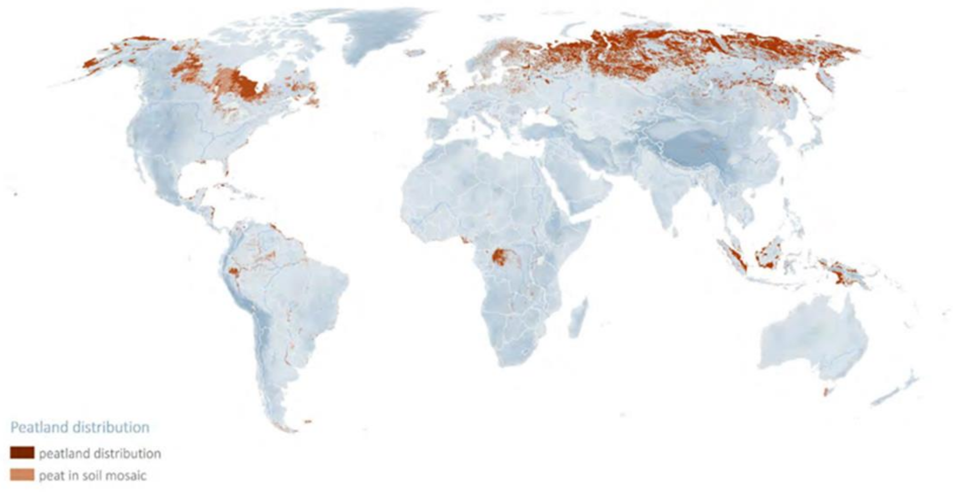


Figure 0.2: The Global Peatland Map 2.0.
Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Size of the global peatland C stock is not widely recognised or understood – even by scientists

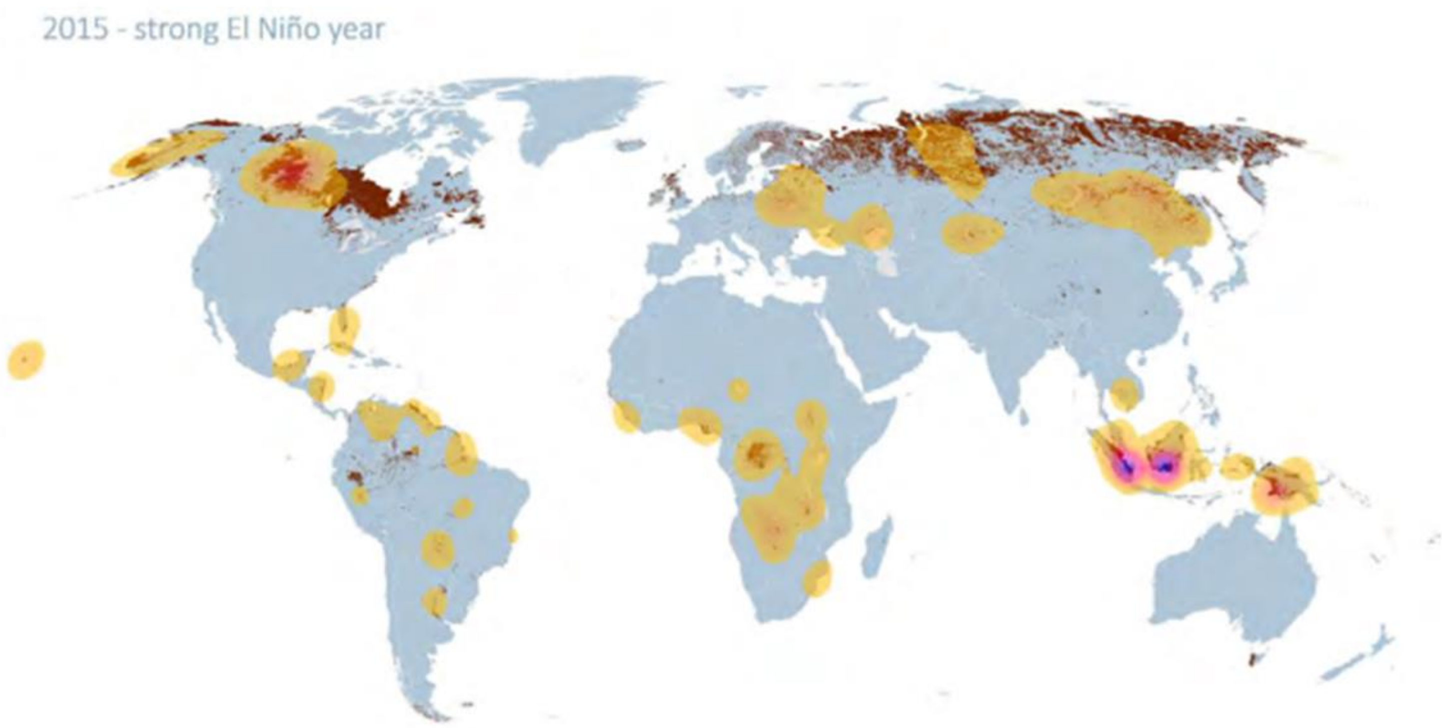
Page et al. (2011), IPCC (2013), Dargie et al. (2017)

Tropical peatlands : Vulnerable carbon pools

- **SE Asian region:**
- Rapid land use change - very large scale
- Agricultural conversion (smallholder → industrial-scale)
- Drainage
- Use of fire - cheap & widely used land clearance tool
- Presence of ignition sources (people) in previously uninhabited landscapes
- Climate – ENSO/IOD droughts, regional climate change



Global peatland fire ‘hotspots’ : 2015 El Nino



Source: Global Peatlands Assessment data retrieved from the Global Peatland Database compiled by the Greifswald Mire Centre.

Peatland fire: SE Asia

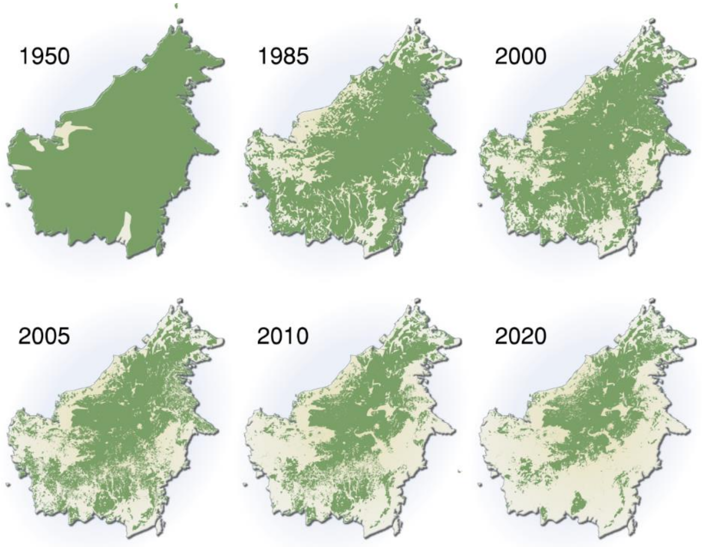
The climate change peat fire dynamic

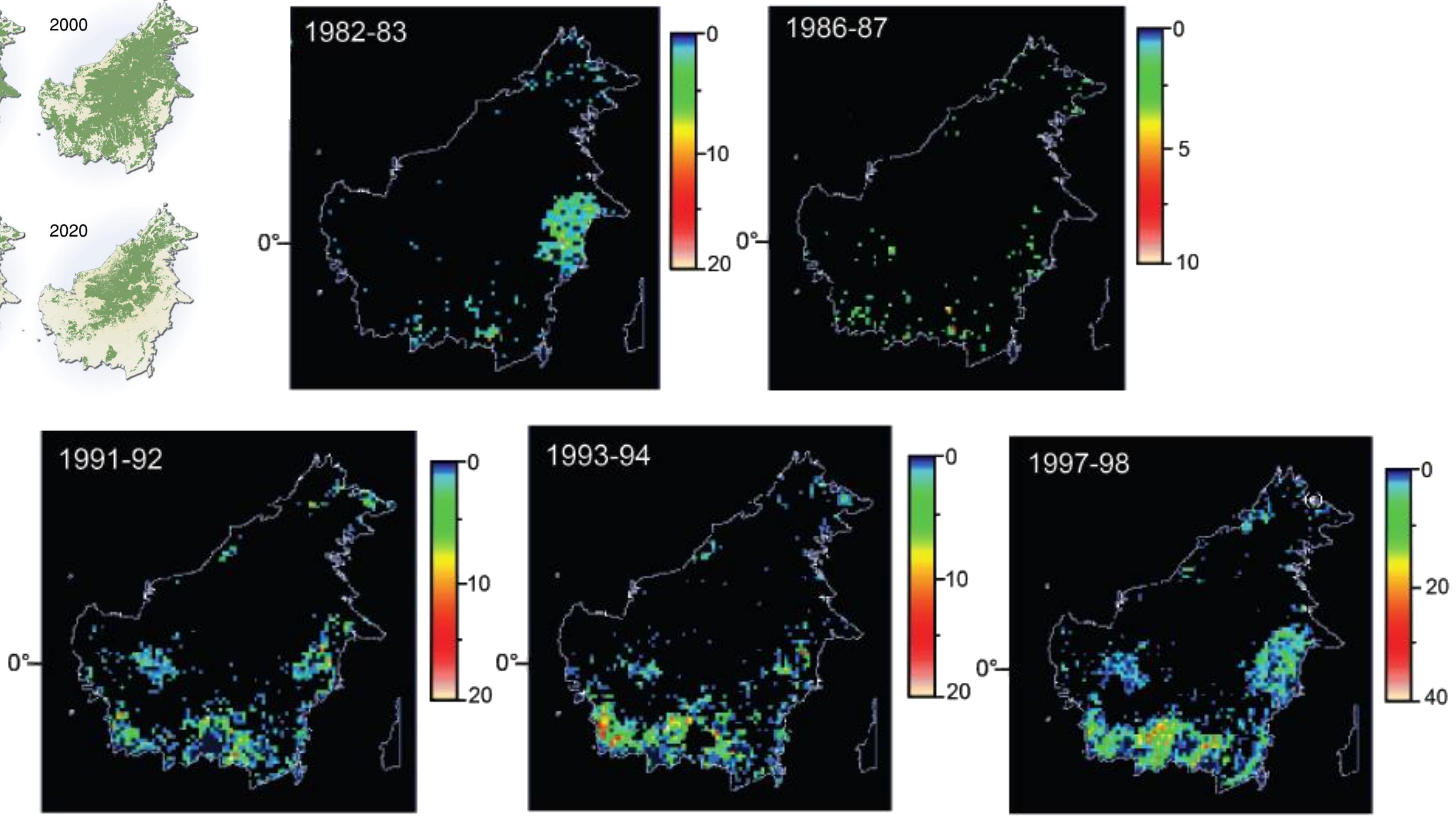
- A) *Direct effects* on fire weather : drought, higher temperatures, increasing incidence/strength of ENSO
- B) *Indirect effects* : land-use and climate driven changes in nature and availability of fuel / biomass

The anthropogenic peat fire dynamic

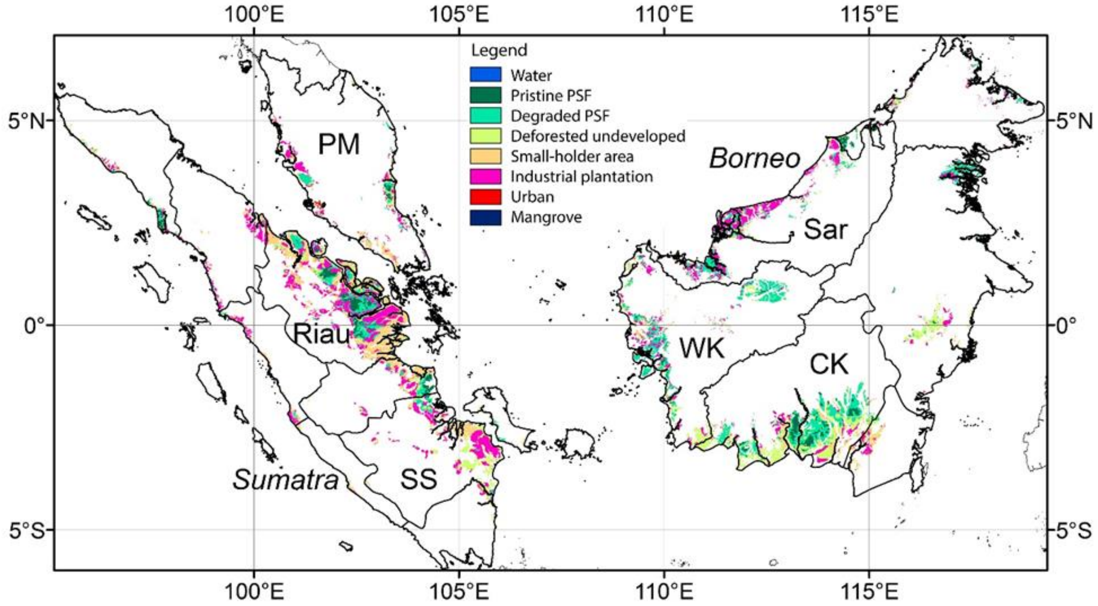
- A) *Direct effects* : accidental/purposeful ignitions
- B) *Indirect effects* : anthropic ignitions in landscapes that are increasingly flammable

Deforestation & Degradation = FIRE



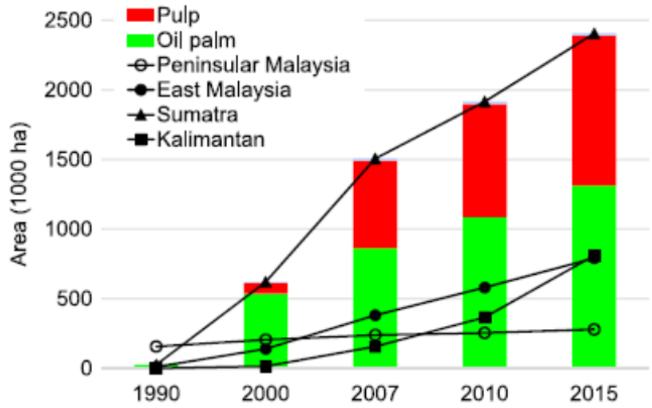


SE Asian peatlands



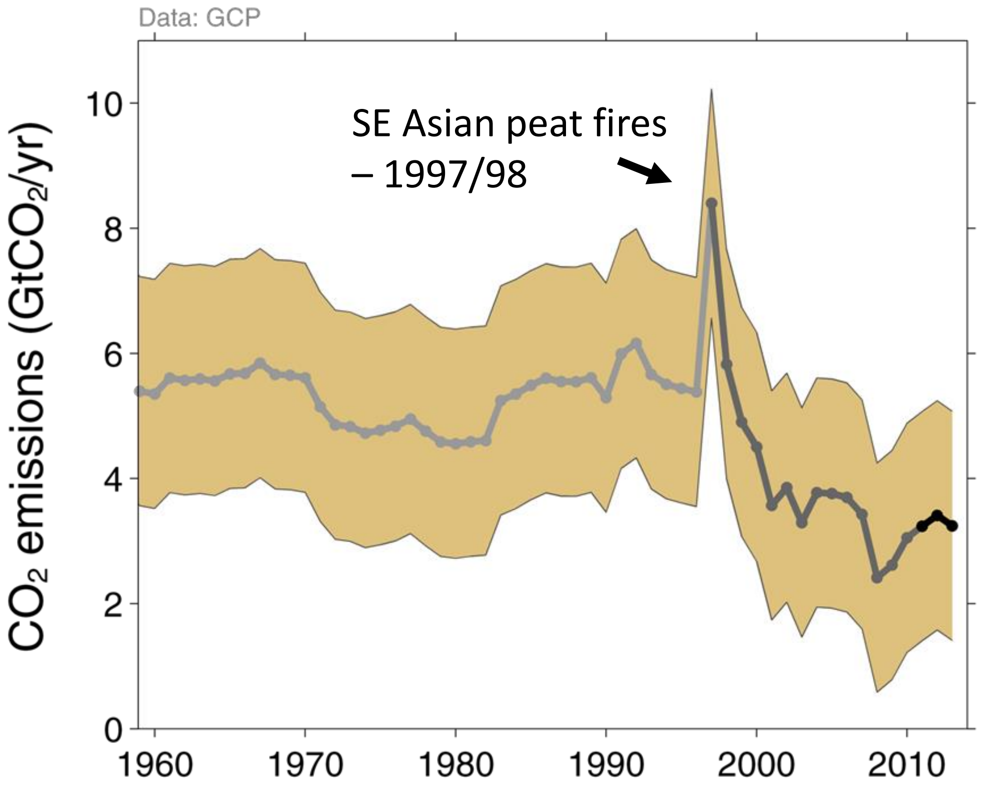
Pristine PSF	Degraded PSF	Tall shrub & 2° forest	Ferns & low shrub	Small-holder areas	Industrial plantations	Other
6.4%	22.8%	11.1%	5.4%	22.4%	27.4%	4.5%

~50%



(Miettinen et al. 2016 Global Ecol. & Cons; Miettinen, Page et al. (2017) Env. Res. Letts.)

1997 / 1998 ENSO + Fire Season



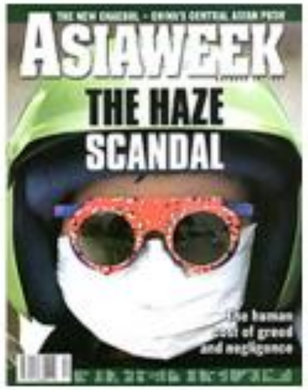
Global CO_2 budget – land use change

Burnt area: 2.6 million hectares
(16 x size of London)
Emissions: 0.8-2.6 Gt carbon ??
(40% of 1997 fossil fuel emissions)

(Source: Global Carbon Project using data from Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2014; Page et al. 2002)

A recurring issue

Sept 2002: "*Smoky haze chokes Southeast Asia …. Again this year hundreds of fires burn deep into the underlying peat layer … spreading smoke across the region*".



Singapore – June 2013

Sept 2015: "*Six Indonesian provinces declare a state of emergency as haze from the wildfires on Sumatra and Kalimantan worsens…*"

(http://www.prokerala.com/news/photos/an-indonesian-student-shows-a-placard-during-a-339799.html)

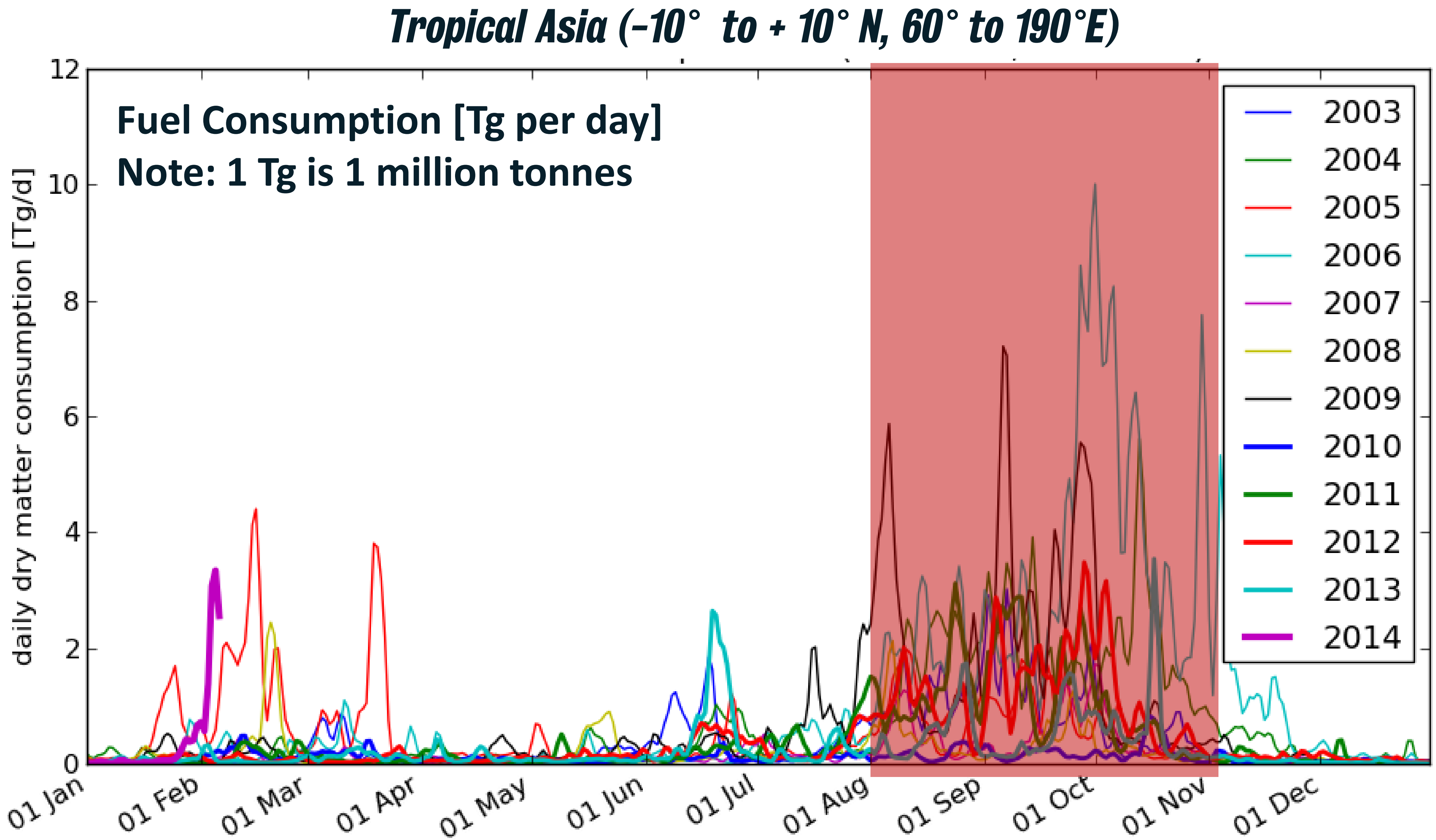
Sept. 2019

Indonesian forest fires putting 10 million children at risk, says Unicef

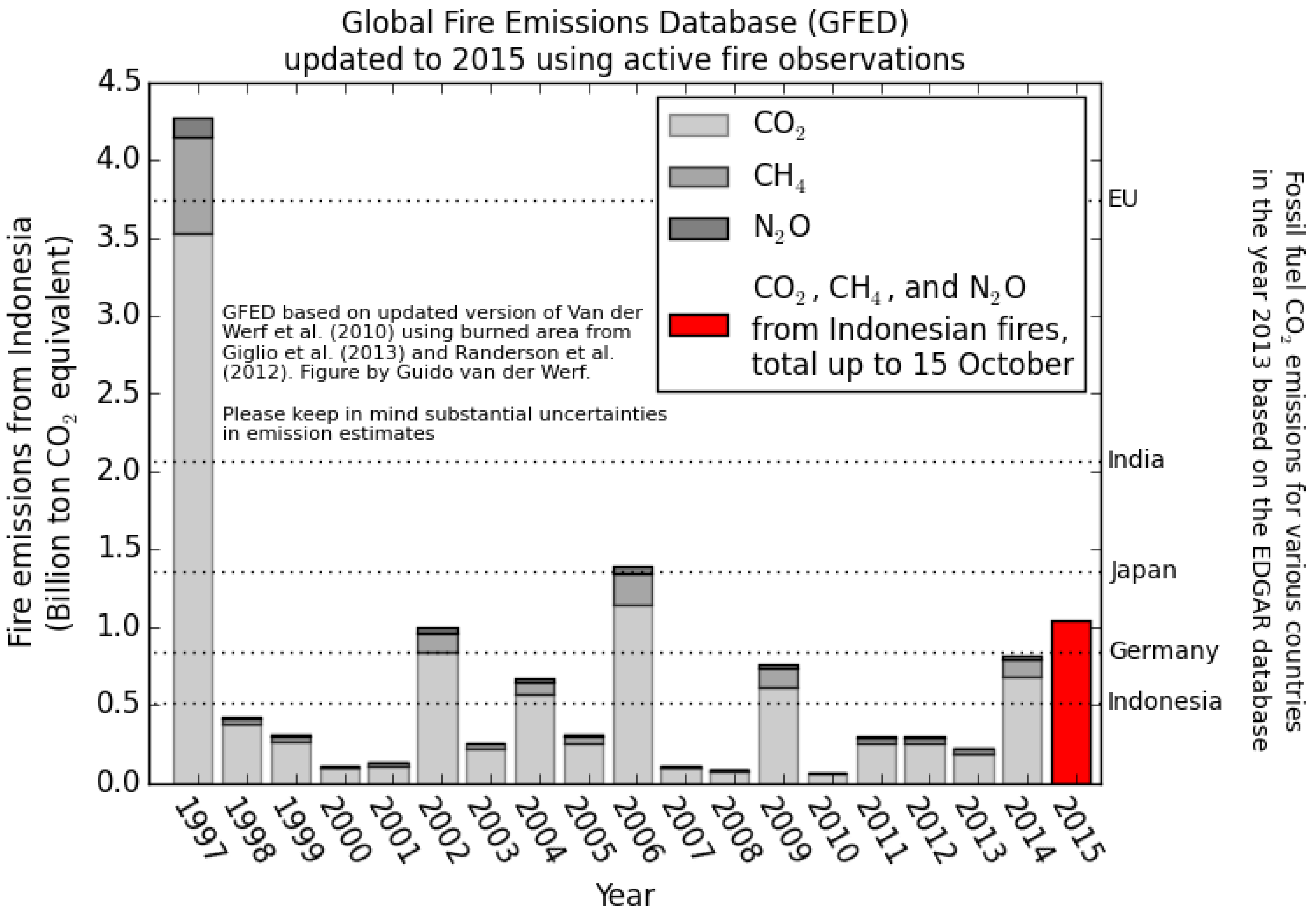
Millions aged under five are particularly at risk from the slash and burn fires due to undeveloped immune systems

Fire fighters try to extinguish fire at a peatland in Kampar, Riau province, Indonesia. Smoke haze

Peat fires = HAZE season

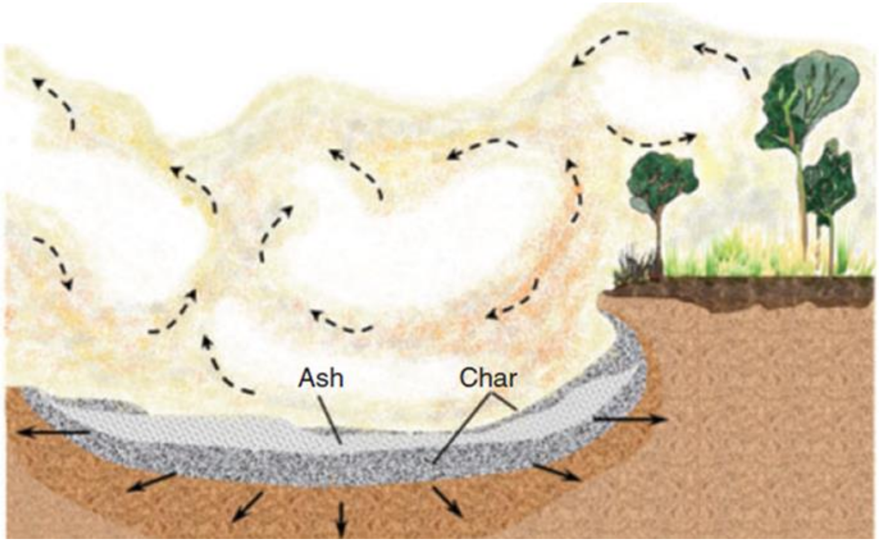


Greenhouse gas emissions…



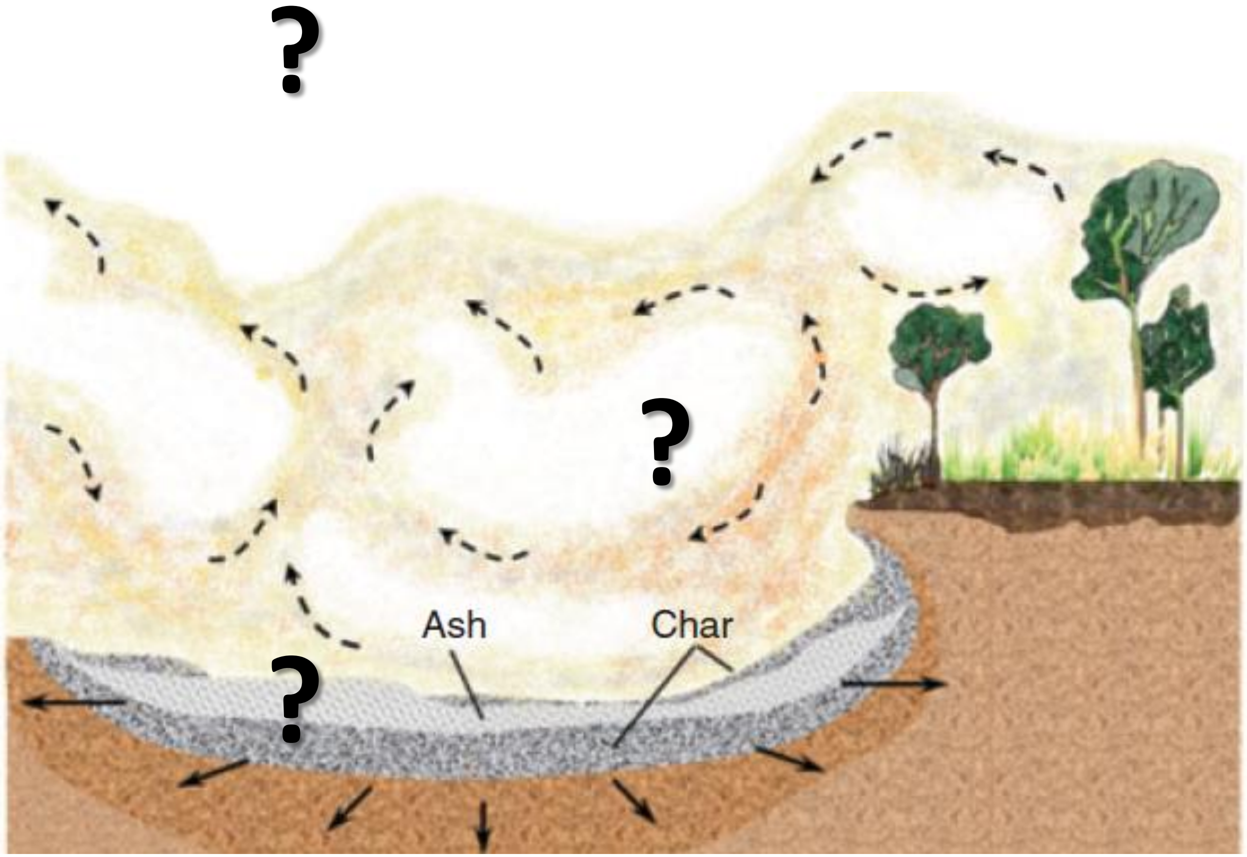
Smoldering Fires

- Peat fires characterised by smoldering (not flaming) combustion
- Peat has a low bulk density – high porosity
- Allows oxygen ingress to fire front
- Peat fires slow moving / relatively low temperature fires
- *But* low thermal conductivity of peat slows heat loss & promotes persistent combustion
- Fires may burn for weeks → months



Hu, Fernandez-Anez, Smith, Rein (2018, IJWF)

Three key challenges for measuring total emissions:



- Where is burning?
- How much burns?
- What’s being emitted?

How do we calculate total fire emissions?

GFED3.1 (Global Fire Emission Database) *(van der Werf et al. 2010)*

"Conventional" Burned Area Approach (Seiler and Crutzen, 1980))

$$E_i\ [g] = A\ [m^2] * B\ [kg/m^2] * C\ [kg/kg] * EF_i\ [g/kg]$$

Dry matter (DM) combusted

E_i: Emission of trace species i
A: Area burned (MODIS burn scars)
B: Biomass density (Fuel load) (CASA biogeochemical model with satellite fAPAR data)
C: Combustion Completeness (CASA biogeochemical model with GPCP precipitation)
EF_i: Emission Factor for species i

Database: monthly, 0.5 deg, 1997-Present
http://www.falw.vu/~gwerf/GFED/GFED3/emissions/

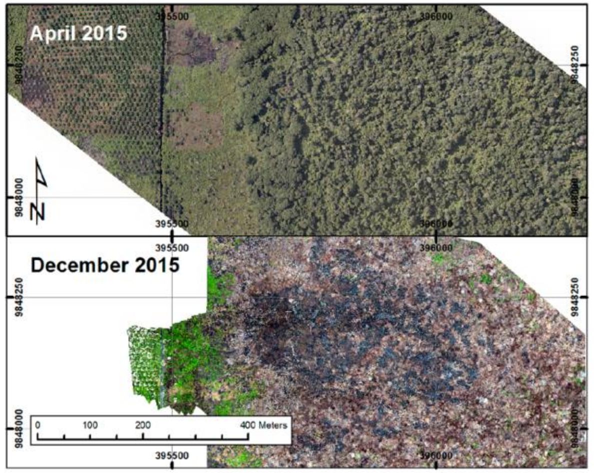


Figure 3. Pre- and post-burn aerial photographs of Site 2, the forest edge site. The pre-burn photo was taken during the aerial LiDAR survey in April 2015 (see Section 2.2.1), whereas the post-burn image is an orthomosaic photo constructed from UAV photos taken in December 2015 (see Section 2.2.2). Coordinates are in UTM 48S WGS84 Datum.

Simpson, Wooster, Smith et al. (2016, Remote Sensing)

Problems in tropical peatlands:
- A: burnt area
- B: peat density
- B: burn depth
- C: burn heterogeneity
- EF: few measurements, esp. PM
- EF: carbon content

How do we calculate total fire emissions?

GFAS1.1 (Global Fire Assimilation System) *(Kaiser et al., 2012)*

FRE-based Combustion Factor (CF) Approach (Wooster et al., 2005))

$$E_i\,[g] = FRE\,[J] * CF\,[kg/J] * EF_i\,[g/kg]$$

Dry matter (DM) combusted

FRE: Fire Radiative Energy [J] (MODIS FRP)
(Time Integrated Fire Radiative Power (FRP) [W])
CF: Combustion Factor (fuel type dependent CF)

Database: daily, 0.5 deg, 2003-NRT
http://www.gmes-atmosphere.eu/fire/

Problems in tropical peatlands:

- FRE: cloud cover
- FRE: low-temperature fires
- FRE: covered by canopy
- FRE: belowground fires
- CF: not known
- EF: few measurements, esp. PM
- EF: carbon content

Inter-fire variability

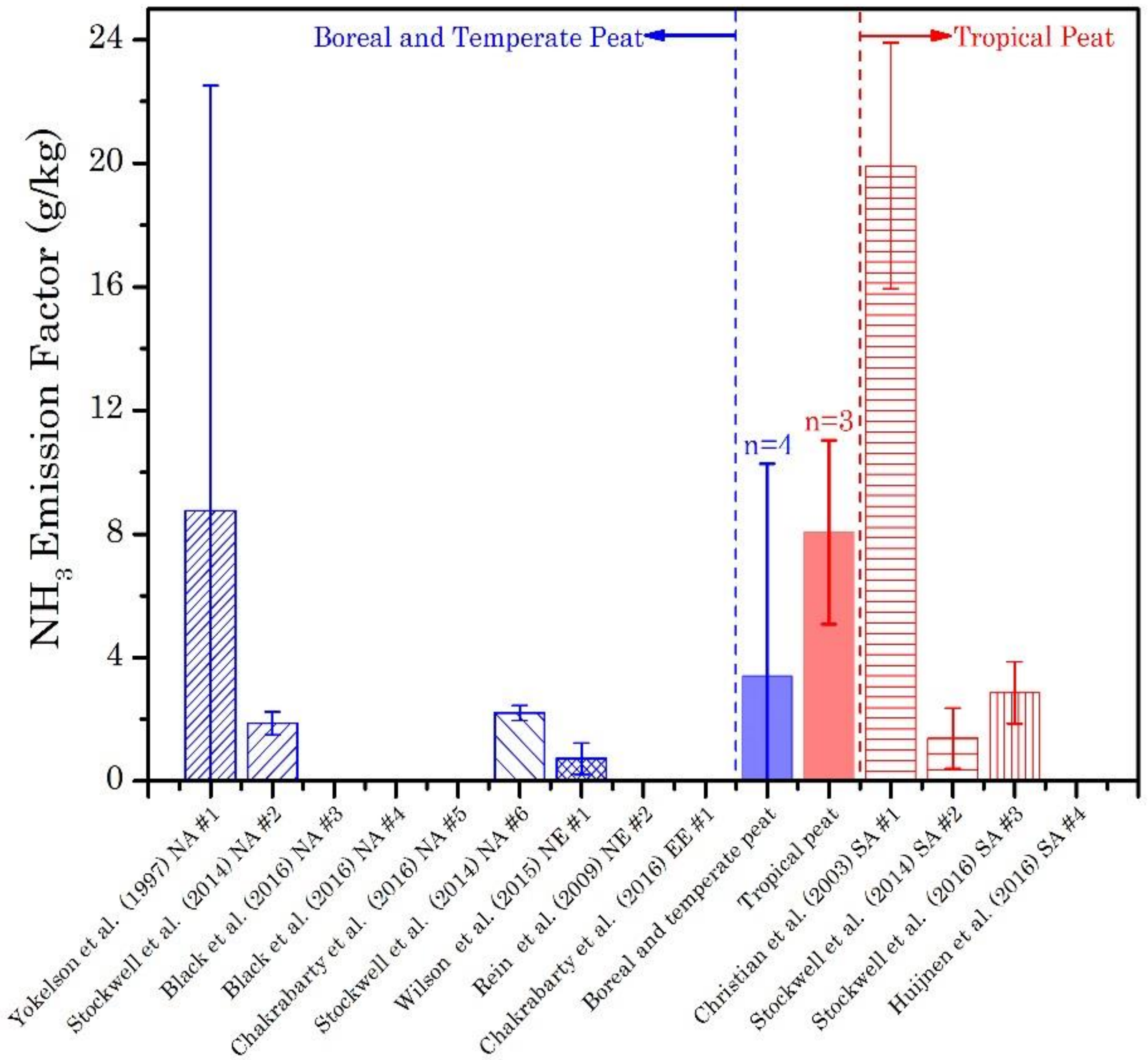
SITE	P1	P2	P3	P4	P5	P6	P7	P8	S1	S2
MCE	0.82	0.77	0.83	0.79	0.79	0.75	0.78	0.79	0.84	0.84
CO_2	1581 ± 158	1577 ± 158	1701 ± 170	1616 ± 162	1612 ± 161	1523 ± 152	1571 ± 157	1599 ± 160	1691 ± 169	1686 ± 169
CO	221 ± 35	293 ± 47	223 ± 36	267 ± 43	267 ± 43	321 ± 51	290 ± 46	272 ± 44	206 ± 33	205 ± 33
CH_4	26.8 ± 4.3	6.83 ± 1.1	5.47 ± 0.9	7.86 ± 1.3	8.57 ± 1.4	9.54 ± 1.5	9.04 ± 1.4	9.04 ± 1.4	15.1 ± 2.4	14.4 ± 2.3
C_2H_2	0.06 ± 0.01	nr	0.05 ± 0.01	nr	nr	nr	nr	nr	nr	nr
C_2H_4	10.4 ± 1.04	1.61 ± 0.16	1.26 ± 0.13	1.43 ± 0.14	1.75 ± 0.17	1.28 ± 0.13	1.69 ± 0.17	1.49 ± 0.15	0.82 ± 0.08	1.72 ± 0.17
C_2H_6	2.38 ± 0.38	0.55 ± 0.09	1.02 ± 0.16	1.37 ± 0.22	1.24 ± 0.20	1.74 ± 0.28	1.27 ± 0.20	1.26 ± 0.20	1.57 ± 0.25	0.88 ± 0.14
H_2CO	nr	1.87 ± 0.19	0.68 ± 0.07	0.47 ± 0.05	0.78 ± 0.08	0.16 ± 0.02	nr	nr	nr	nr
HCOOH	nr	nr	0.29 ± 0.05	nr	0.24 ± 0.04	nr	nr	nr	nr	nr
CH_3OH	2.85 ± 0.46	3.91 ± 0.63	1.66 ± 0.27	1.98 ± 0.32	2.56 ± 0.41	2.43 ± 0.39	2.98 ± 0.48	3.36 ± 0.54	2.74 ± 0.44	4.56 ± 0.73
CH_3COOH	9.12 ± 1.46	3.75 ± 0.60	3.73 ± 0.60	4.24 ± 0.68	3.87 ± 0.62	4.56 ± 0.73	4.24 ± 0.68	5.78 ± 0.92	6.34 ± 1.02	5.74 ± 0.92
HCN	3.51 ± 0.56	3.34 ± 0.53	0.35 ± 0.06	2.01 ± 0.32	6.13 ± 0.98	3.34 ± 0.53	6.39 ± 1.02	6.06 ± 0.97	3.80 ± 0.22	nr
NH_3	14.8 ± 2.39	3.15 ± 0.50	3.83 ± 0.61	5.36 ± 0.86	8.51 ± 1.36	5.88 ± 0.94	9.27 ± 1.49	5.46 ± 0.87	7.23 ± 1.16	16.5 ± 2.66

Why so much variation for these important gas species?
What drives these differences between sites and studies?

- Combustion factors (includes meteorology)
- Peat composition factors
  - Structure
  - Nitrogen-content

Smith et al. (2018, GBC)
Roulston et al. (2018, JGR)

Tropical peat fire emission factors



Why so much variation for these important gas species?

What drives these differences?

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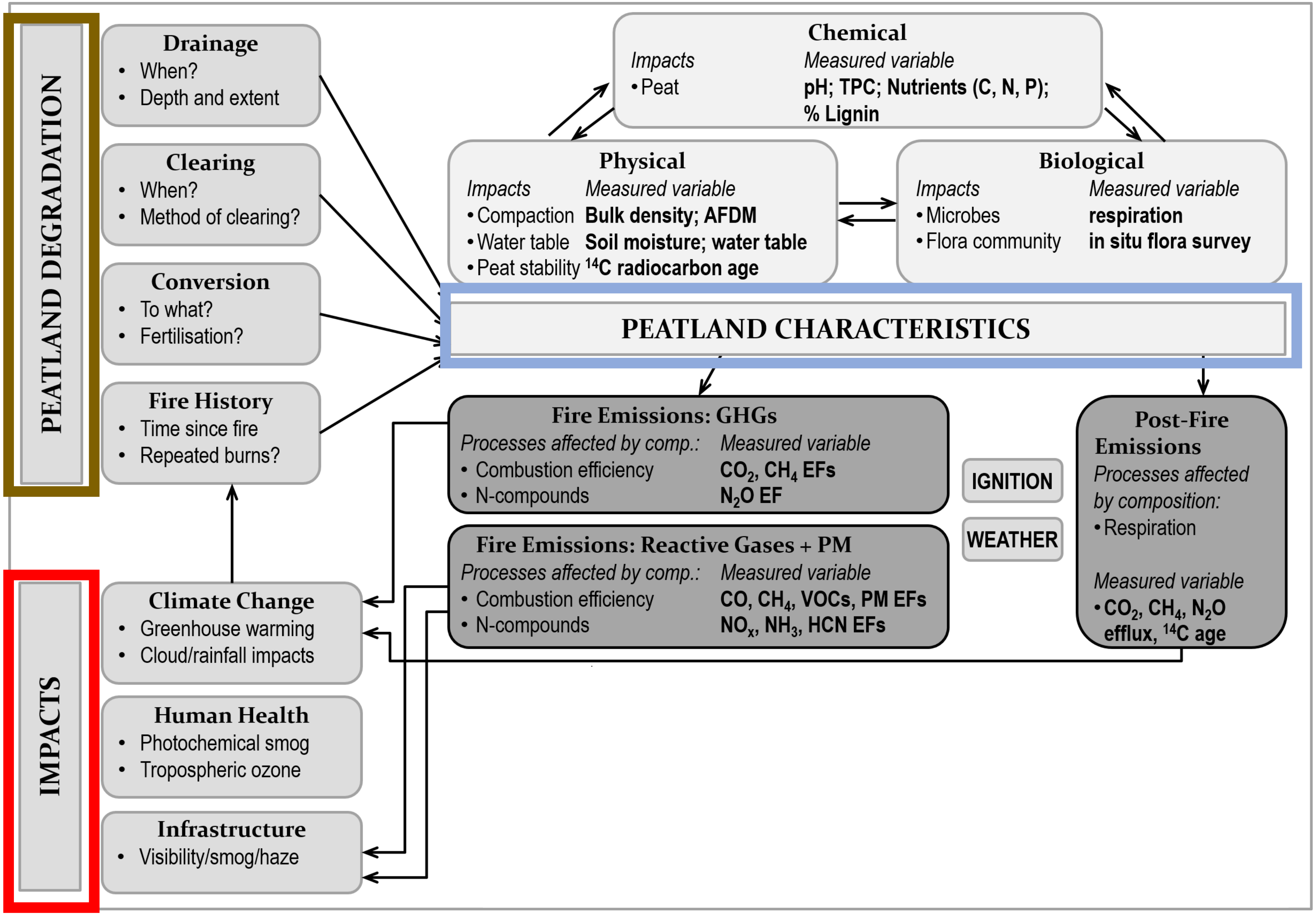
REAL NEED FOR FIELD MEASUREMENT CAMPAIGNS

Hu, Fernandez-Anez, Smith, Rein (2018, IJWF)



PEATLAND DEGRADATION
Drainage
• When?
• Depth and extent
Clearing
• When?
• Method of clearing?
Conversion
• To what?
• Fertilisation?
Fire History
• Time since fire
• Repeated burns?
Chemical
Impacts
• Peat
Measured variable
pH; TPC; Nutrients (C, N, P); % Lignin
Physical
Impacts
• Compaction
• Water table
• Peat stability
Measured variable
Bulk density; AFDM
Soil moisture; water table
^{14}C radiocarbon age
Biological
Impacts
• Microbes
• Flora community
Measured variable
respiration
in situ flora survey
PEATLAND CHARACTERISTICS
Fire Emissions: GHGs
Processes affected by comp.:
• Combustion efficiency
• N-compounds
Measured variable
CO_2, CH_4 EFs
N_2O EF
IGNITION
WEATHER
Fire Emissions: Reactive Gases + PM
Processes affected by comp.:
• Combustion efficiency
• N-compounds
Measured variable
CO, CH_4, VOCs, PM EFs
NO_x, NH_3, HCN EFs
Post-Fire Emissions
Processes affected by composition:
• Respiration
Measured variable
• CO_2, CH_4, N_2O efflux, ^{14}C age
IMPACTS
Climate Change
• Greenhouse warming
• Cloud/rainfall impacts
Human Health
• Photochemical smog
• Tropospheric ozone
Infrastructure
• Visibility/smog/haze

Thank you