APFNet Forest Carbon Accounting Zoom Webinar: **Holding Forests Accountable**

December 8th 2021

# Improving Capacities Towards Reducing Greenhouse Gas Emissions from Peat Swamp Forest Fires in Indonesia:

## Forest carbon accounting and emission estimation from peatland fires


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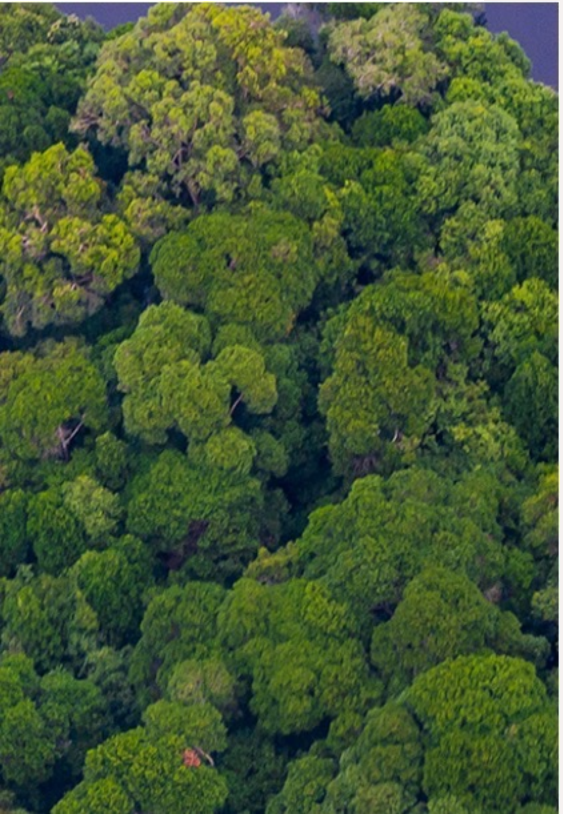
# Outlines

1. Rationale & Background
2. Objectives
3. Methods
4. Results
5. Conclusion

# Rationale



Tropical peatlands are areas of high carbon density and play an important role in providing numerous ecosystem services.

Clearing and drainage of tropical peatlands have resulted in an unprecedented increase in peat fires, which not only produce deadly toxic haze and pollution, but also endanger the critical ecological services of the ecosystem.

Drainage and burning of tropical peatlands release about 5% of the global GHG emissions.

However, there is a great uncertainty in GHG emissions estimates from peat swamp forest fires.

Therefore, need to fill the knowledge gap to improve emission estimates, including emission parameters, effect of frequent fires, importance of pyrogenic carbon, peat combustion factor.

# Background

**Currently, emissions from peat fires is estimated as:**

$$E = A \times h \times BD \times CF \times C_{org} \times 3.67$$

Where:

*A* = area of burnt peat (ha)

*h* = the depth of burnt peat (m) → ***Peat depth = 0.33 m***

*BD* = bulk density → ***Peat Bulk Density = 0.153 t/m³***

*CF* = combustion factor → ***Peat Combustion Factor = 1***

$C_{org}$ = peat C content → *Resulting in a single* ***Emission Factor***

**Majority of emission equation parameters are default numbers**

# Background

**Other parameters affect the magnitude of peat fire emissions: e.g. fuels, fire frequency, season**

**Fuel Load**

**Fuel Type (*t*):**
Fine, Coarse, Heavy

**Fire frequency (*f*)**

**Combustion Factor**

**Fuel type (*t*)**

**Fire frequency (*f*)**

**Peat Depth**

**Fire frequency (*f*)**

**Season (dry, normal)**

**Pyrogenic Carbon (PyC)**

$$E_i = FL \text{ x } CF \text{ x } PD \text{ x } EF_i$$

$$\Sigma\ (A \text{ x } P \text{ x } \Sigma((FL_t - \text{PyC}) \text{x } CF \text{ x } PD_f \text{ x } CF_t))$$

# Objectives

**More data are needed for better estimates of emission factors from peat fires**

- **Review the parameters contributing to tropical peat fire emissions estimates, as per IPCC Guideline**
- **Add more empirical data to improve GHG emission estimates**

Equation (IPCC GL)

$$E_i = A \cdot [(M_{AG} \cdot C_{AG} \cdot CF_{AG} \cdot Gef_{i\_AG}) + (M_{PEAT} \cdot C_{PEAT} \cdot CF_{PEAT} \cdot Gef_{i\_PEAT})] \cdot 10^{-3}$$

## IPCC Guideline

Chapter 2: Drained Inland Organic Soils

TABLE 2.6
ORGANIC SOIL FUEL CONSUMPTION VALUES
(MASS OF DRY MATTER FOR A RANGE OF ORGANIC SOIL AND FIRE TYPES, TO BE USED IN CONJUNCTION WITH EQUATION 2.8, TO ESTIMATE THE PRODUCT OF QUANTITIES $M_B$ AND $C_f$)

| Climate/vegetation zone | Sub-category | Mean (t d.m. ha$^{-1}$) | 95% confidence interval (t d.m. ha$^{-1}$) | | Citations |
|---|---|---|---|---|---|
| Boreal/temperate | Wildfire (undrained peat) | 66 | 46 | 86 | Amiro *et al.*, 2001; Benscoter & Wieder, 2003; Cahoon *et al.*, 1994; de Groot & Alexander, 1986; Kajii *et al.*, 2002; Kasischke & Bruhwiler, 2003; Kasischke *et al.*, 1995; Kuhry, 1994; Pitkänen *et al.*, 1999; Poulter *et al.*, 2006; Turetsky & Wieder, 2001; Turetsky *et al.*, 2011*a*, *b*; Zoltai *et al.*, 1998 |
| | Wildfire (drained peat) | 336 | 4[a] | | Turetsky *et al.*, 2011*b* |
| | Prescribed fire (land management) | - | - | | No literature found |
| Tropical | Wildfire (undrained peat) | - | - | | No literature found |
| | Wildfire (drained peat) | 353 | 170 | 53[illegible] | Ballhorn *et al.*, 2009; Page *et al.*, 2002; Usup *et al.*, 2004 |
| | Prescribed fire (agricultural land management) | 155 | 82 | [illegible] | [illegible] Nurhayati, 2005 |

[a] Standard [illegible]
[b] The consumption value excludes crop residues.

Note: Where fuel consumption values have been reported as t C ha$^{-1}$, default values for organic soil bulk density (0.1 g cm$^{-3}$)[c] and carbon density (50% mass dry weight)[d] have been applied to derive a value for mass of fuel (t ha$^{-1}$) (following Akagi *et al.*, 2011). At higher tier levels, country- or ecosystem-specific values for both these variables are used.

[c] The value for surface organic soil bulk density is an average derived from Gorham (1991), who provides a default value of 0.112 g cm$^{-3}$ for all northern peatlands and Page *et al.* (2011), who provide a default value of 0.09 g cm$^{-3}$ for all tropical peats.

[d] The value for surface organic soil carbon content is an average derived from the typical average for eutrophic peat of 48% and the typical average for oligotrophic peat of 52% (after Lucas (1982), Immirzi *et al.* (1992) as reported in Charman (2002)).

| | |
|---|---|
| No literature found |
| Ballhorn *et al.*, 2009; Page *et al.*, 2002; Usup *et al.*, 2004 |

Only 3 publications

# Our Studies

- **Review of the parameters contributing to tropical peat fire emissions estimates, as per IPCC GL**

$$E_i = A \cdot [(M_{AG} \cdot C_{AG} \cdot CF_{AG} \cdot Gef_{i\_AG}) + (M_{PEAT} \cdot C_{PEAT} \cdot CF_{PEAT} \cdot Gef_{i\_PEAT})] \cdot 10^{-3}$$

  - There are not many studies which support fire emission parameters of the Equation in a comprehensive way.
  - The majority of studies report field data collected at least ten or more years ago.

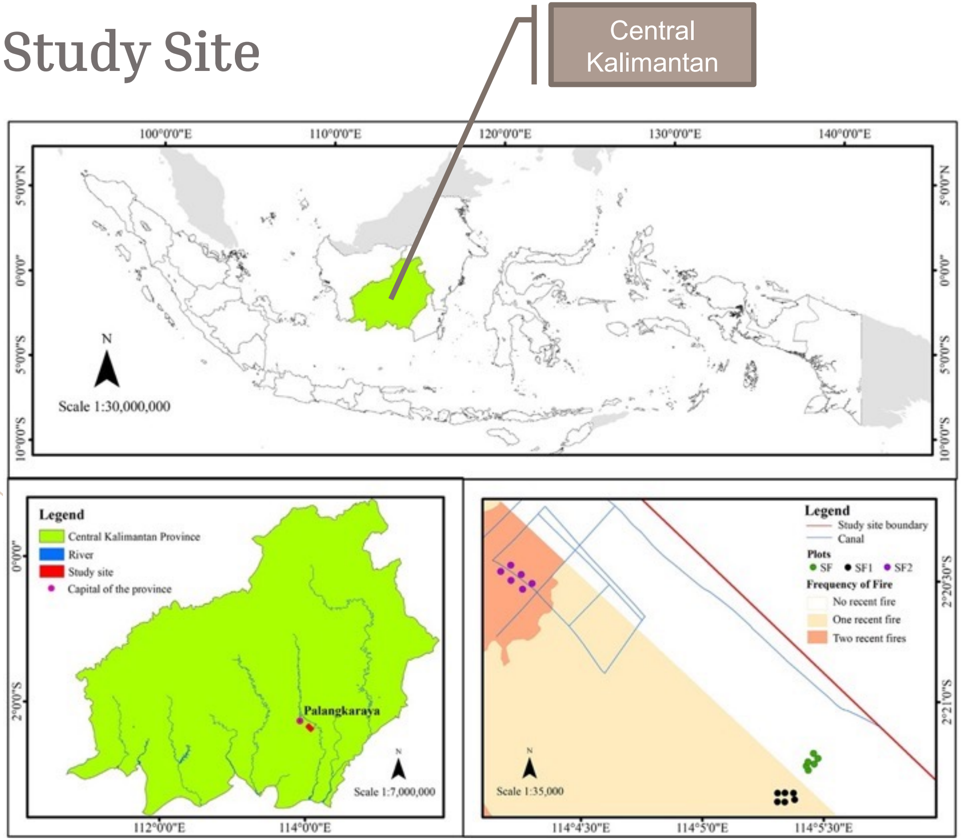
- **Improve emission parameters by conducting field studies to identify differences in emission parameters among a range of peat forests burnt at different fire frequencies**

Source: *Volkova, Krisnawati, Adinugroho et al. (2021)*

| Study | $M_{AG}$ | $CF_{AG}$ | $M_{PEAT}$ | | $C_{PEAT}$ | $CF_{PEAT}$ | $Gef_{i\_PEAT}$ | Date collected |
|---|---|---|---|---|---|---|---|---|
| | | | h | BD | | | | |
| 1 | | | | | x | | | 2013–2014 |
| 2 | | | | x | x | | | 2007–2010 |
| 3 | x | * | x | x | | | | 2014-2015 |
| 4 | | | x | | | | | 2007 |
| 5 | | | x | | | | | 1997 |
| 6 | | | | | | | x | n/g |
| 7 | 1 | * | | | | | | 2014 |
| 8 | 2 | | | | | | | 2011 |
| 9 | | | x | x | | | | 2011 |
| 10 | | | | | | | x | 2009 |
| 11 | | | x | x | x | | | 2010–2013 |
| 12 | | | | | | | x | 2015 |
| 13 | | | | | | | x | 2003 |
| 14 | x | * | | | x | | | 2005 |
| 15 | | | | | | | x | 2015 |
| 16 | | | x | x | x | | | 2010–2011 |
| 17 | | | | x | | | | 2000 |
| 18 | 1 | * | | | | | | 2007-2008 |
| 19 | x | * | | | | | | 2001 |
| 20 | | | | | | | x | 2009 |
| 21 | | | | x | x | | | 1969–2012 |
| 22 | | | x | x | x | | | 1999/2000 |
| 23 | | | | x | x | | | 1995 |
| 24 | x | * | | x | x | | | 2009 |
| 25 | | | | x | x | | x | 2016 |
| 26 | 3 | x | | | | | | 2001–2002 |
| 27 | 1 | | | x | x | | | 2015 |
| 28 | | | | x | x | | | 1997–1999 |
| 29 | x | * | | | | | | 2015 |
| 30 | | | x | | | | | 2015 |
| 31 | | | | x | | | | 2013 |
| 32 | | | | x | x | | x | 2016 |
| 33 | | | | | | | x | n/g |
| 34 | | | x | | | | x | 2015 |
| 35 | x | * | | | | | | 2009 |
| 36 | x | x | x | | | x | | 2002 |
| 37 | | | | x | x | | | n/g |
| 38 | | | | x | x | | x | 2015 |

# Methods

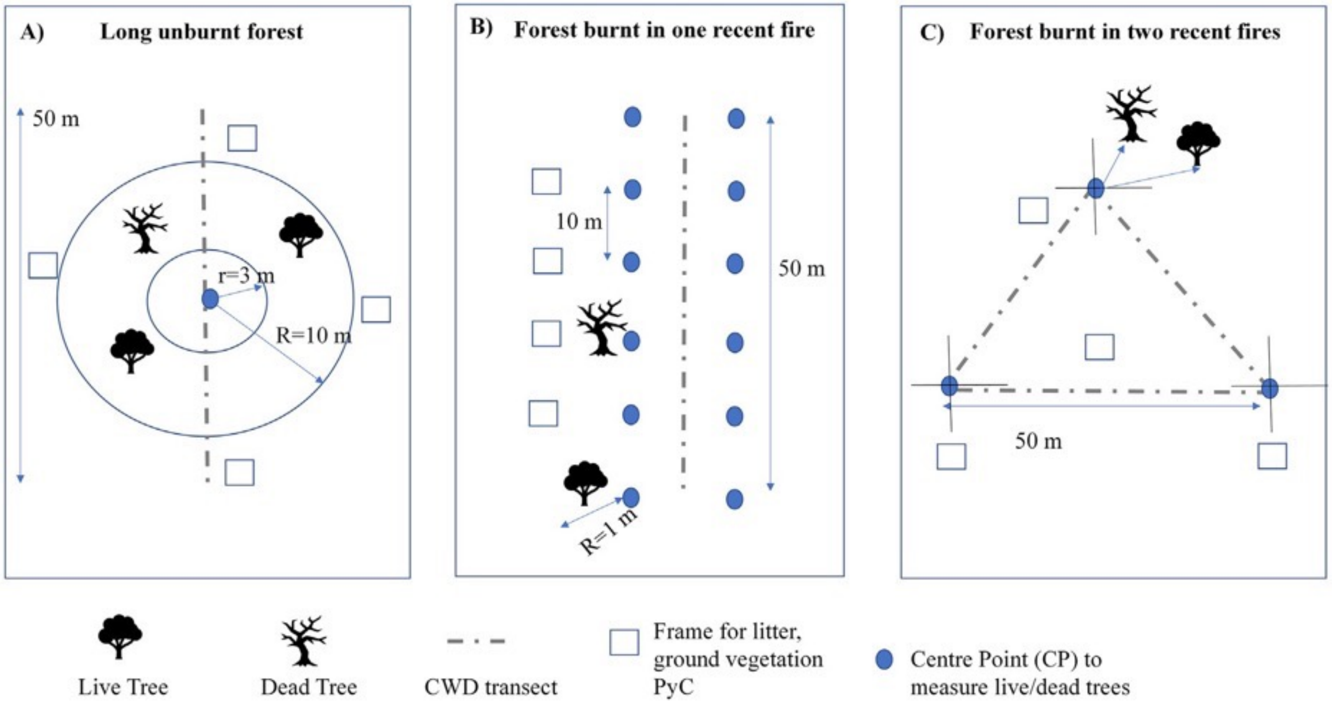
## Study Site




Source: *Volkova, Krisnawati, Adinugroho et al. (2021)*

# Methods

## Sampling Design




*Source: Volkova, Krisnawati, Adinugroho et al. (2021)*

# Methods: Fuels to measure

## accounting for all Carbon pools

Live aboveground biomass
(trees, shrubs, grasses)

Dead organic matter
(litter, coarse woody debris)

Peat
(depth, bulk density, C content)

Pyrogenic carbon

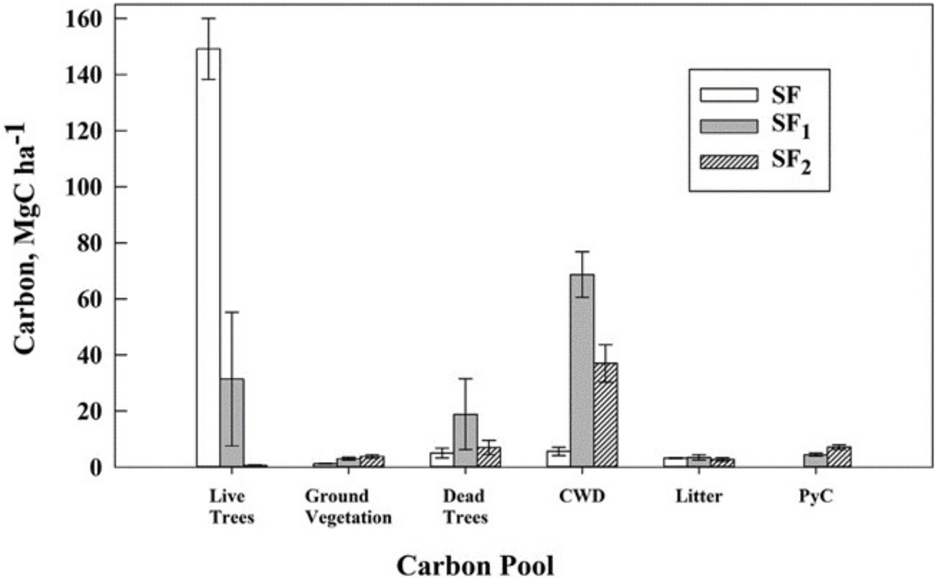
Measuring trees in secondary peat swamp forest

Measuring peat depth

Assessing PyC

# **Result:** Impact of fire frequency on aboveground carbon

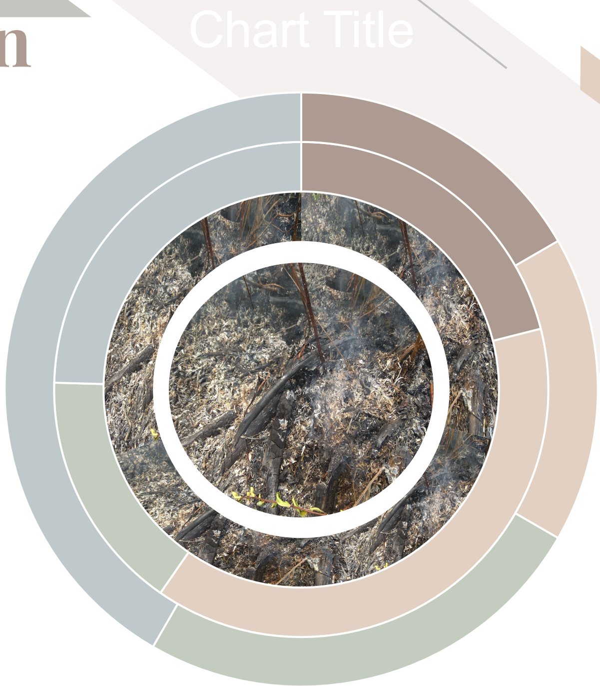
We conducted a comprehensive assessment of the above-ground and peat carbon pools as they are affected by recurring fires




*Source: Volkova, Krisnawati, Adinugroho et al. (2021)*

- Great uncertainty in the estimates of peat fire emissions, especially where peat swamp forest are burnt in more than one fire.
- Our study shows that after one recent fire about 90 Mg C $ha^{-1}$ remains aboveground as the deadwood carbon pool.
- Following a $2^{nd}$ consecutive fire, about a half of the deadwood is retained, mainly as CWD, or converted to pyrogenic carbon.

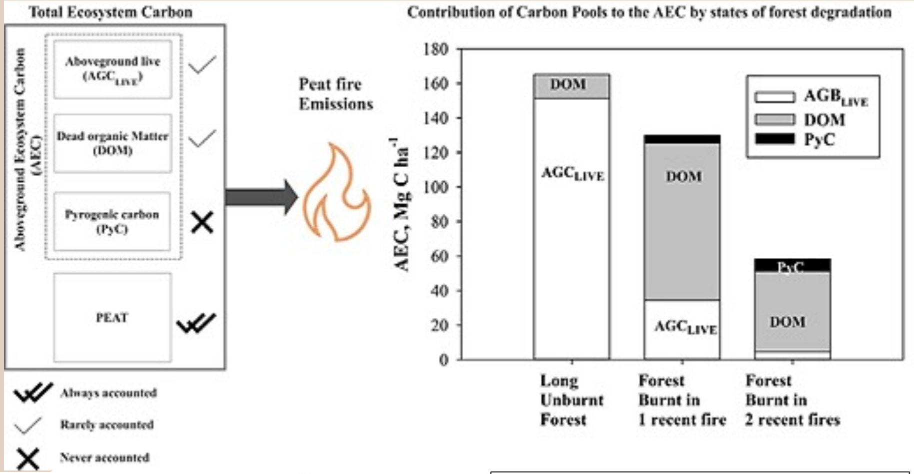
# **Result:** Role of pyrogenic carbon in emission estimates



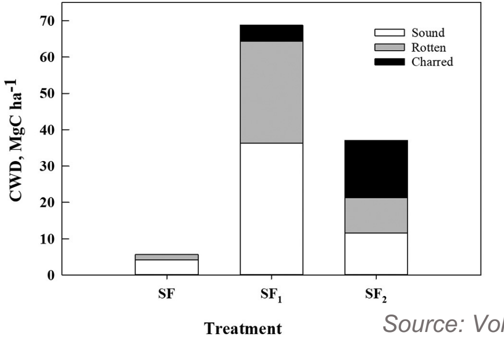

- The role of PyC in forest carbon balance and its contribution to emissions is largely ignored due to a lack of empirical data
- We observed that one fire produced PyC equivalent to about 3% of aboveground biomass and that repeated burning increased this contribution threefold.
- One fire produces 4.5 ± 0.6 Mg C $ha^{-1}$ of PyC, with a second fire increasing this to 7.1 ± 0.8 Mg C $ha^{-1}$.
- PyC becomes an increasingly important carbon pool in repeatedly burnt peat swamp forests. Ignoring fire produced PyC from carbon mass balance will lead to overestimation of atmospheric emissions

*Source: Volkova, Krisnawati, Adinugroho et al. (2021)*

# Improved knowledge on peat fires emissions estimates




| Carbon pool | Treatment | | |
|---|---|---|---|
| | SF | $SF_1$ | $SF_2$ |
| $AGC_{LIVE}$ | 92 (150.4) | 26 (34.4) | 8 (4.5) |
| Live trees | 91 | 24 | 1 |
| Ground cover | 1 | 2 | 7 |
| Deadwood | 6 (10.7) | 68 (87.6) | 75 (44.1) |
| Dead trees | 3 | 15 | 12 |
| CWD | 3 | 53 | 63 |
| Litter | 2 (3.2) | 3 (3.4) | 5 (2.8) |
| PyC | 0 | 3 (4.5) | 12 (7.1) |
| $AGC_{TOTAL}$ | 100 (164.3) | 100 (129.9) | 100 (58.5) |

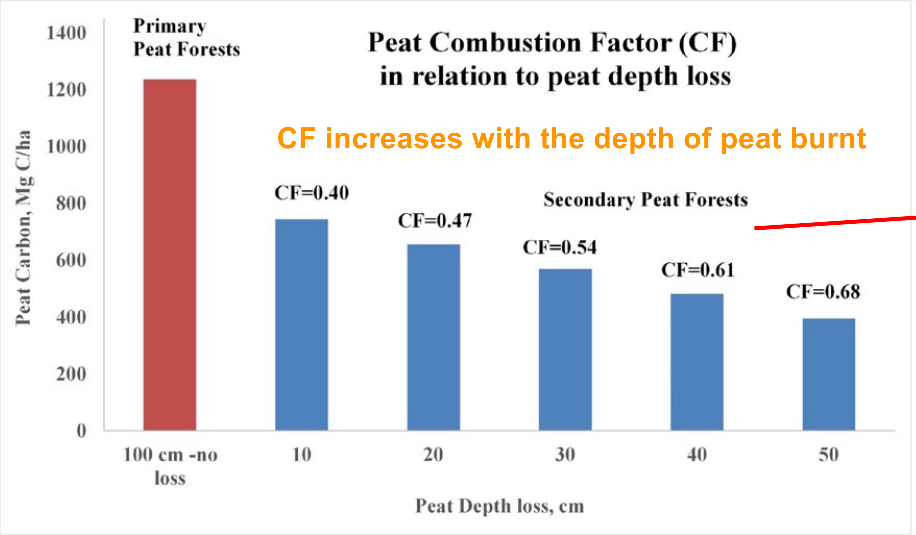



- Contribution of deadwood to peatfire emissions is not properly accounted.
- Deadwood accounts for 50–60% of aboveground carbon in recently burnt peat forests
- PyC accounts for 12% of aboveground carbon in repeatedly burnt peat forests

Source: Volkova, Krisnawati, Adinugroho et al. (2021)

# **Result:** New Combustion Factors for Peat Peat swamp forests

Current assumption of complete combustion of peat (CF = 1) is an oversimplification




*Source: Krisnawati et al. (2021)*

**Table 5**
Combustion factors for aboveground and peat biomass.

| Combustion factor | This study | IPCC default |
|---|---|---|
| $CF_{AGC}$[a] | 0.564 | 0.50 |
| $CF_{PEAT-10cm}$ | 0.399 | 1.0 |
| $CF_{PEAT-20cm}$ | 0.469 | 1.0 |
| $CF_{PEAT-30cm}$ | 0.540 | 1.0 |
| $CF_{PEAT-40cm}$ | 0.610 | 1.0 |
| $CF_{PEAT-50cm}$ | 0.681 | 1.0 |

**Table 6**
Estimated $CO_2$ emissions (Mg $CO_2$-e) from 1 ha of peat burnt down to 10 cm and 30 cm depth using the IPCC default and study derived $CF_{PEAT}$.

| Peat depth burnt | Estimated $CO_2$ emissions using the IPCC default CF | Estimated $CO_2$ emissions using study derived $CF_{PEAT}$ | Emission reduction per hector of peat burnt |
|---|---|---|---|
| 10 cm | 262 | 104 | 2.51 |
| 30 cm | 1275 | 688 | 1.85 |

# Conclusion

Lack of knowledge of the impact of repeated fires on aboveground fuels and on the production of pyrogenic carbon adds to uncertainty in emissions estimates.

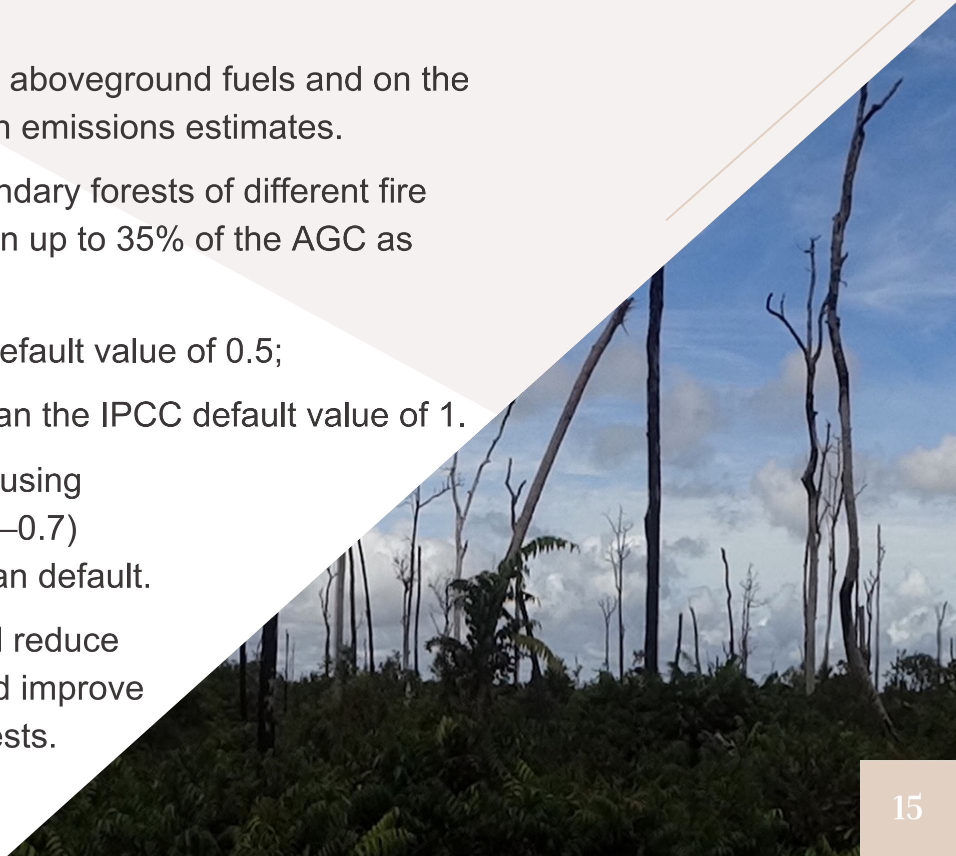
Comparison of primary peat swamp forest with secondary forests of different fire history shows that logged and burnt forests can retain up to 35% of the AGC as standing dead trees, CWD and PyC.

The estimated $CF_{AGC}$ of 0.56 is similar to the IPCC default value of 0.5;

While the $CF_{PEAT}$ is 0.4–0.7, or 30% to 60% lower than the IPCC default value of 1.

A comparison of emissions from peat fire calculated using $CF_{PEAT}$ 1 (default) and our study specific $CF_{PEAT}$ (0.4–0.7) resulted in emission estimates of 2–4 times lower than default.

Findings from our studies provide novel data that will reduce uncertainties in the peat fire emissions estimates and improve the emission reporting from tropical peat swamp forests.



*Source: Volkova et al. (2021); Krisnawati et al. (2021)*

# Our Studies

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Volume 763, 1 April 2021, 142933

### Identifying and addressing knowledge gaps for improving greenhouse gas emissions estimates from tropical peat forest fires

Liubov Volkova [a] ... Christopher J. Weston [a]

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### Carbon balance of tropical peat forests at different fire history and implications for carbon emissions

Haruni Krisnawati [a] ... Liubov Volkova [c]

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### Loss and Recovery of Carbon in Repeatedly Burned Degraded Peatlands of Kalimantan, Indonesia

by Liubov Volkova [1,*], Wahyu Catur Adinugroho [2], Haruni Krisnawati [2], Rinaldi Imanuddin [2] and Christopher John Weston [1]

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*Fire* 2021, 4(4), 64; https://doi.org/10.3390/fire40400

Received: 30 July 2021 / Revised: 3 September 202

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SYMPOSIUM

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# THANK YOU

**Haruni Krisnawati,** Liubov Volkova, Wahyu C. Adinugroho, Rinaldi Imanuddin, Muhammad A. Qirom, Purwanto B. Santosa, Wawan Halwany, Suyoko, Christopher J. Weston, and all field crew

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