Tropical peat – just another data-source from hotter and wetter conditions?

SOMPA

Peatlands: Greenhouse Gas Budgets and Hydrology
Workshop in Helsinki, 25-27 April 2018
Organizer: SOMPA project

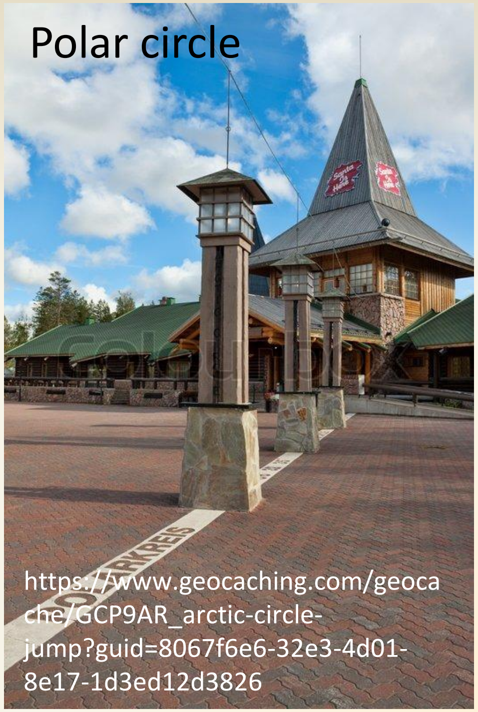
Jyrki Jauhiainen
Natural Resources Institute Finland

Tropical peat – just another data-source from hotter and wetter conditions?

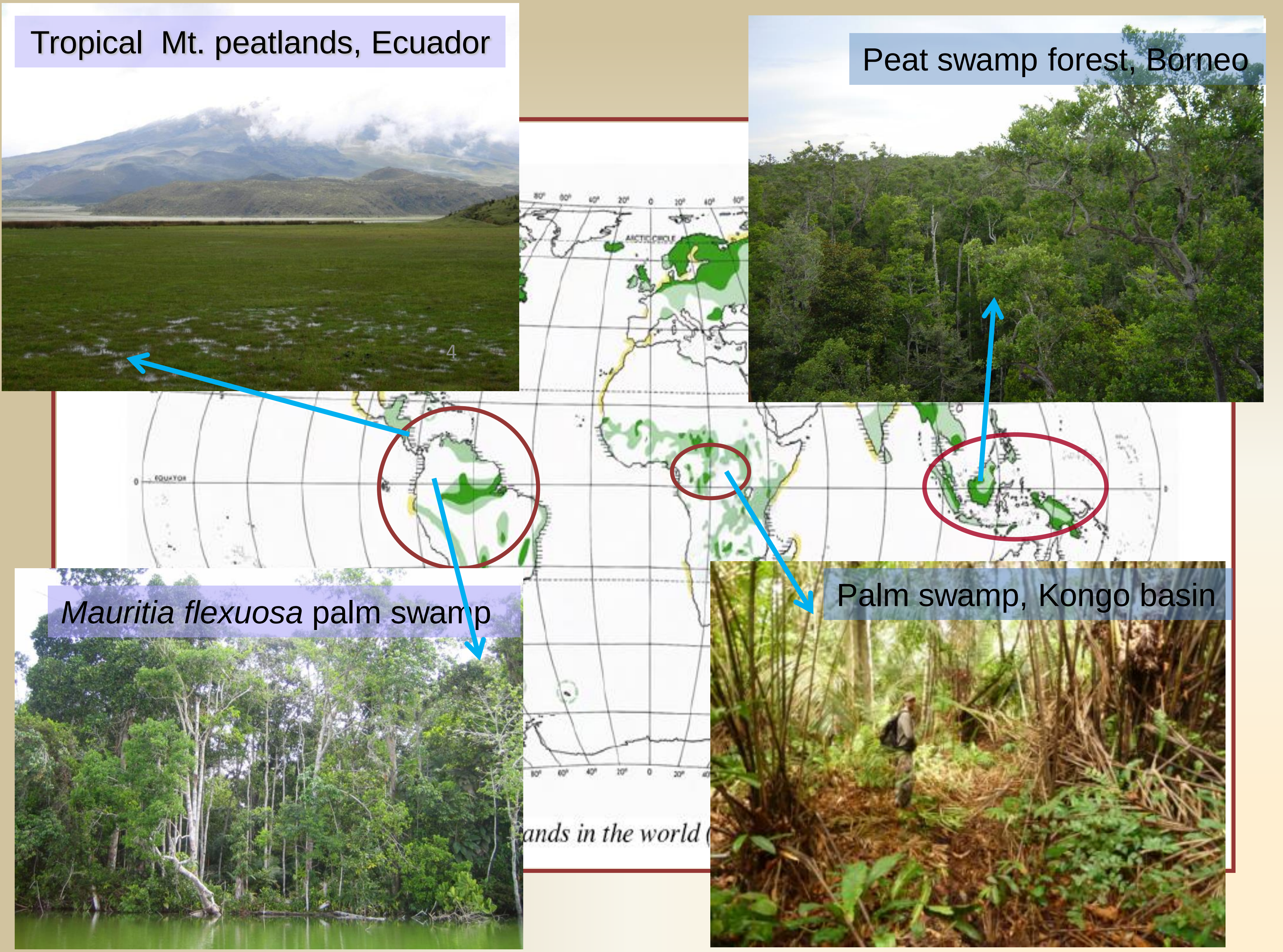
Rhetorical question, and thus no answer will be provided

Content

- Similarities and differences, tropical vs. more northern peatlands
  - Peatland types
  - Peatland features
- Tropical peat decomposition process
- Conclusions



Most peatlands look the same from high above


Tropical Mt. peatlands, Ecuador
Peat swamp forest, Borneo
Mauritia flexuosa palm swamp
Palm swamp, Kongo basin
ands in the world

Peatland

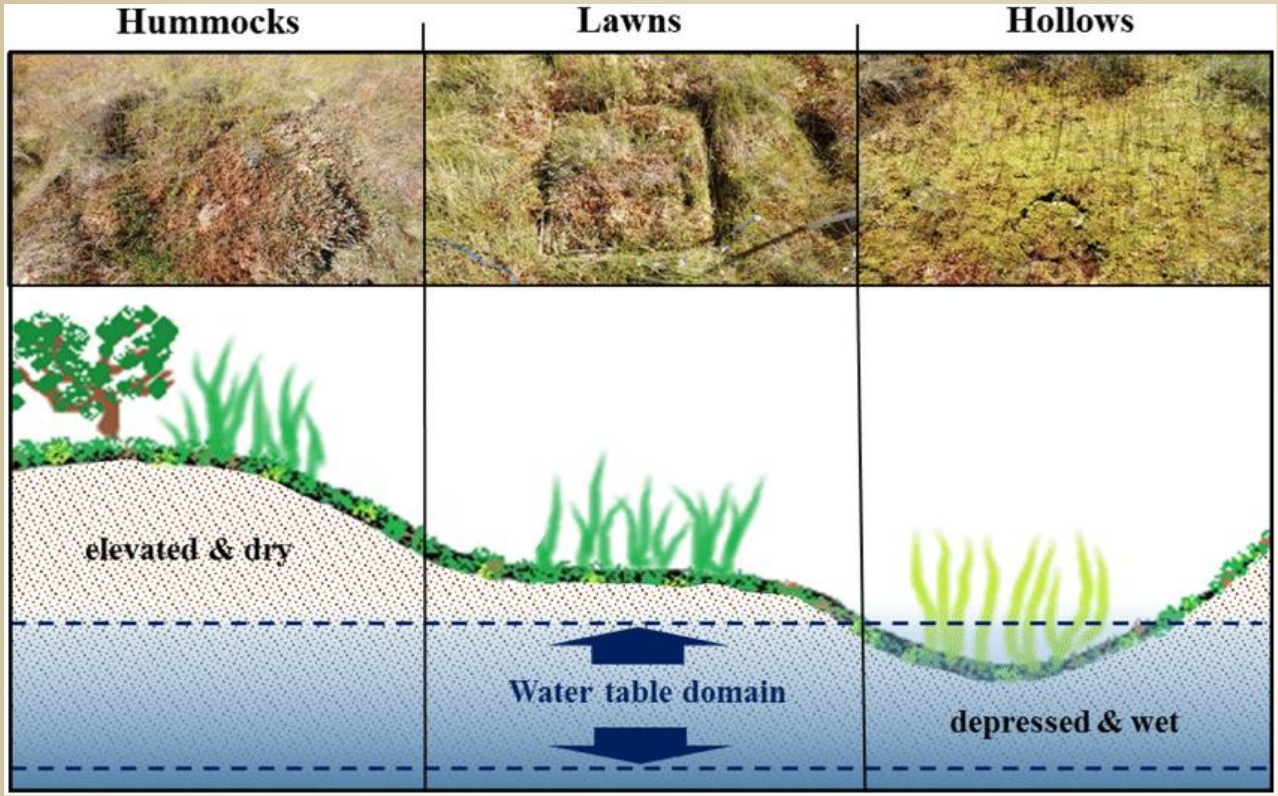
Rain fed (ombrotrophic) peatland

Tropical in Indonesia

Boreal in Finland

Concepts

Hummocks and hollows



https://www.researchgate.net/profile/Maxim_Dorodnikov/publication/313331740

What and where are hummocks lawns and hollows in tropical peatland?

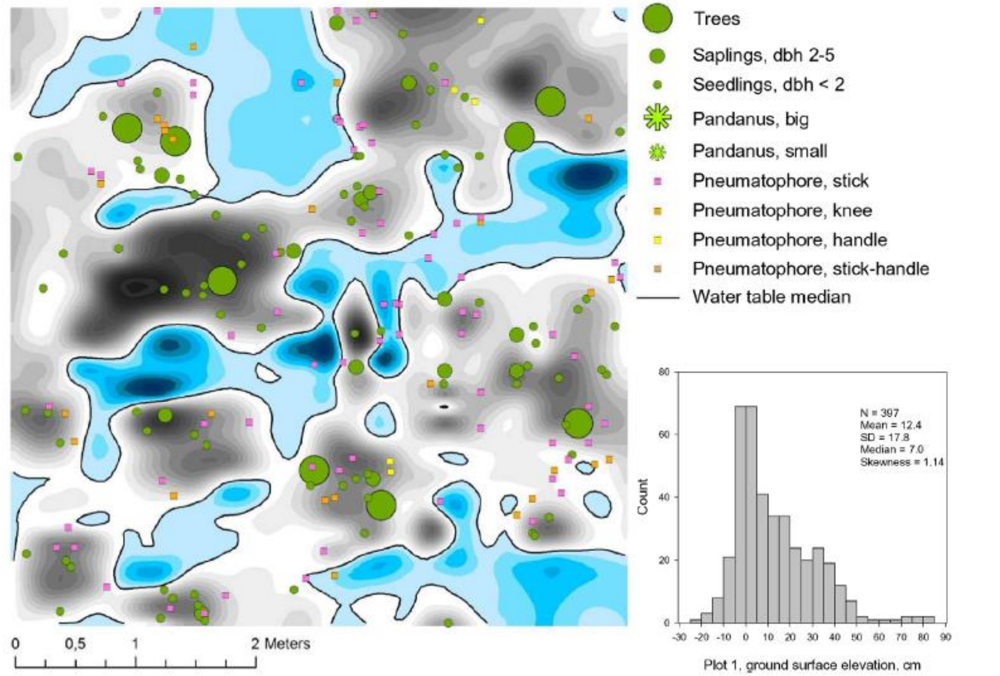


Fig. 6. a) Surface model on forest floor ground surface elevation differences and vegetation features on the ground in plot 1 from site A (illustrations of all plots in Appendix E are above median water table and blue hues are below it; elevation difference between each hue is 5 cm, b) histogram shows measured ground surface elevation frequency dist 5 cm classes.

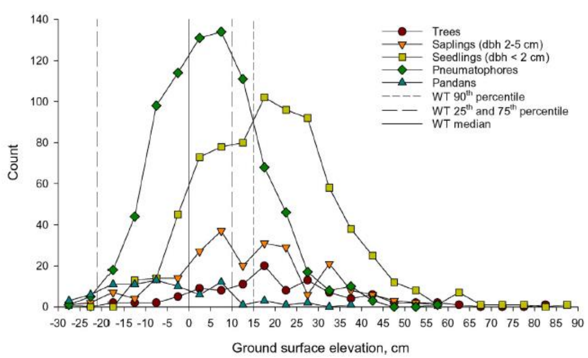


Fig. 8. Frequency of trees, saplings, seedlings, pneumatophores and pandans in relation to the ground surface elevation of forest floor. Vertical lines represent divisions in water table showing 25th (long dashed line), median (solid line), 75th (long dash) and 90th (short dash) percentiles.

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Ground surface microtopography and vegetation patterns in a tropical peat swamp forest

Maija Lampela [a,*], Jyrki Jauhiainen [a], Iida Kämäri [a], Markku Koskinen [a], Topi Tanhuanpää [a], Annukka Valkeapää [b], Harri Vasander [a]

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In clear-felled burned sites, development of hollows is not by biological processes

Peat

Peat

Swamp forest peat

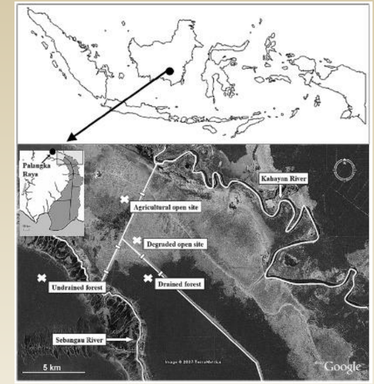
Peat in degraded burned area

Peat

Wetlands Ecol Manage

Table 2 Summary of peat physical structure based on data published in Könönen et al. (2015)

Site	Depth (cm)	BD (g cm^{-3})	Wood (% of the sample)	Fibre (% of the sample)
Forest	10–15	0.13 ± 0.01	22.8 ± 4.0	48.3 ± 8.4
	40–45	0.14 ± 0.01	5.8 ± 1.2	46.1 ± 2.8
	80–85	0.15 ± 0.03	5.8 ± 1.7	15.8 ± 2.5
Drained forest	10–15	0.17 ± 0.03	9.2 ± 1.5	65.1 ± 9.2
	40–45	0.22 ± 0.03	2.0 ± 1.0	49.0 ± 9.1
	80–85	0.15 ± 0.02	7.2 ± 5.1	26.7 ± 1.8
	110–115	0.12 ± 0.01	19.1 ± 7.9	36.5 ± 5.9
Agricultural area	10–15	0.18 ± 0.01	4.3 ± 2.2	37.8 ± 1.1
	40–45	0.17 ± 0.01	9.9 ± 1.0	37.2 ± 4.3
	80–85	0.13 ± 0.01	6.8 ± 2.4	32.0 ± 50
	110–115	0.13 ± 0.00	17.3 ± 12.0	32.1 ± 9.7
Open drained area (degraded)	10–15	0.20 ± 003	2.7 ± 1.8	14.1 ± 0.5
	40–45	0.12 ± 0.03	12.1 ± 1.3	34.1 ± 2.1
	80–85	0.14 ± 0.02	18.2 ± 14.4	30.7 ± 6.3
	110–115	0.15 ± 0.02	15.0 ± 6.4	30.2 ± 3.6



Wetlands Ecol Manage
DOI 10.1007/s11273-016-9498-7
CrossMark
ORIGINAL PAPER

Land use increases the recalcitrance of tropical peat

M. Könönen · J. Jauhiainen · R. Laiho · P. Spetz ·
K. Kusin · S. Limin · H. Vasander

Peat

Table 3 The ash content and C compound composition of non-fractioned samples from every site and depth

Site	Depth (cm)	Ash[a] (mg g^{-1})	Extractive (mg g^{-1})	Total hemicelluloses (mg g^{-1})	Cellulose (mg g^{-1})	ASL (mg g^{-1})	AIL (mg g^{-1})
UF Forest	10–15	0.60 ± 0.04	131.3 ± 4.0	56.7 ± 5.8	39.3 ± 11.8	17.7 ± 0.9	683.6 ± 14.7
	40–45	0.36 ± 0.03	135.0 ± 3.6	37.2 ± 3.9	16.8 ± 1.1	19.1 ± 4.0	708.6 ± 10.8
	80–85	0.63 ± 0.03	290.9 ± 55.9	5.4 ± 1.0	14.8 ± 0.9	4.8 ± 5.2	717.5 ± 35.1
Drained forest	10–15	0.61 ± 0.08	111.6 ± 2.3	59.5 ± 7.3	25.7 ± 1.8	20.0 ± 0.0	674.1 ± 20.3
	40–45	0.39 ± 0.02	380.4 ± 11.8	9.3 ± 0.3	5.7 ± 1.4	4.6 ± 1.8	671.0 ± 18.2
	80–85	0.43 ± 0.04	220.9 ± 9.0	1.0 ± 0.0	12.0 ± 0.2	5.1 ± 3.1	751.0 ± 29.4
	110–115	0.32 ± 0.06	130.8 ± 2.1	2.7 ± 0.6	28.8 ± 11.3	1.1 ± 0.5	811.0 ± 14.8
Agricultural area	10–15	1.10 ± 0.05	207.8 ± 17.0	1.0 ± 0.6	6.7 ± 0.5	12.9 ± 6.0	764.5 ± 29.2
	40–45	0.75 ± 0.04	167.2 ± 17.5	1.9 ± 0.8	17.4 ± 0.9	14.3 ± 0.5	774.1 ± 3.9
	80–85	0.62 ± 0.36	132.1 ± 3.0	1.0 ± 0.1	28.7 ± 12.7	6.2 ± 3.3	808.9 ± 1.2
	110–115	0.60 ± 0.02	129.9 ± 12.8	1.2 ± 0.7	22.9 ± 2.2	5.0 ± 1.7	816.2 ± 4.5
Open drained area (degraded)	10–15	0.88 ± 0.01	118.5 ± 3.5	2.6 ± 0.0	19.7 ± 0.3	2.9 ± 0.0	863.1 ± 10.2
	40–45	0.73 ± 0.03	103.5 ± 5.0	8.4 ± 9.2	18.7 ± 0.9	1.8 ± 0.2	820.4 ± 5.6
	80–85	0.22 ± 0.01	173.7 ± 8.8	5.0 ± 0.5	24.3 ± 0.7	3.8 ± 0.1	815.8 ± 1.0
	110–115	0.23 ± 0.01	129.6 ± 7.6	5.2 ± 1.6	31.2 ± 1.4	6.1 ± 0.8	797.6 ± 6.0

Values are mean ± SD of two laboratory replicates

[a] Proportion of ash published previously in Könönen et al. (2015)

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ORIGINAL PAPER

Land use increases the recalcitrance of tropical peat

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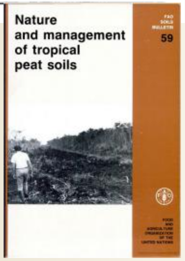
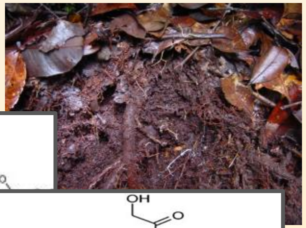
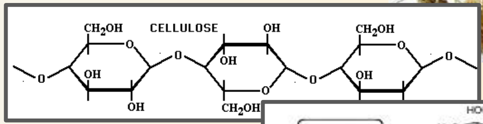
Table 12 CONTENTS OF PRINCIPAL ORGANIC COMPOUNDS OF TROPICAL AND TEMPERATE PEATS (% dry weight)
(sources [1]Lucas 1982; [2]Ravikovitch 1948; [3]Hardon and Polak 1941)

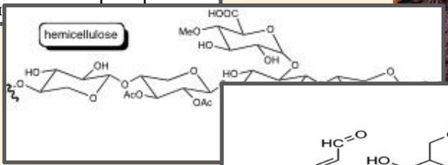
Type of peat	Depth (cm)	Total organic matter	Water soluble compounds	Ether/ alcohol soluble materials	Hemi-cellulose	Cellulose	Lignin and derivates	Nitrogenous compounds
Sphagnum (Main, USA[1])	20–36	95.7	5.2	7.8	24.1	17.1	18.0	0.8
Saw-grass (Florida, USA[1])	80	93.3	2.1	2.3	4.4	2.2	60.1	3.5
Woody sedge (Washington, USA[1])	25–40	93.5	5.9	7.7	7.0	3.2	38.2	3.3
Papyprus (Israel[2])	50–100	77.3	7.9	1.7	8.0	1.7	41.4	17.9
Forest woody (Sumatra, Indonesia[3])	subsurface layer	97.0	1.9	9.4	2.0	10.6	64.0	4.4
Forest woody (Borneo, Indonesia[3])	subsurface layer	98.6	0.9	9.0	2.0	3.6	75.7	3.9
Papyrus vegetation[2]			9.6	4.0	21.5	26.8	18.0	3.6







Cellulose



Hemicellulose

Lignin

Concepts

Draining ditches

https://www.vastavalo.net/suo-oja-suooja-rame-puu-ojitettua-suota-383676.html

M. Martikainen

J. Jauhiainen

https://www.vapis.fi/partiotoimikunta-kokoontui-2042013

J. Jauhiainen

https://www.vastavalo.net/suo-ojitettu-oja-suooja-padottu-suooja-617988.html

J. Jauhiainen

Concepts

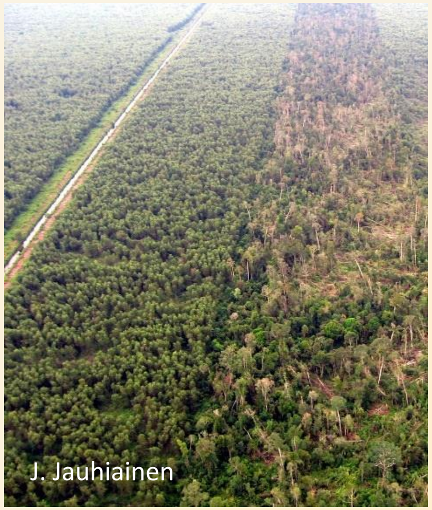
Water table depth

Mean annual water table depth in organic soils drained for forestry in boreal and temperate zone is between -30 - -40 cm

https://www.vastavalo.net/suo-oja-suooja-rame-puu-ojitettua-suota-383676.html

J. Jauhiainen

J. Jauhiainen



J. Jauhiainen

Water table

Sadekausi
Wet season

Kuivakausi
Dry season

Sadek.
Wet seas.

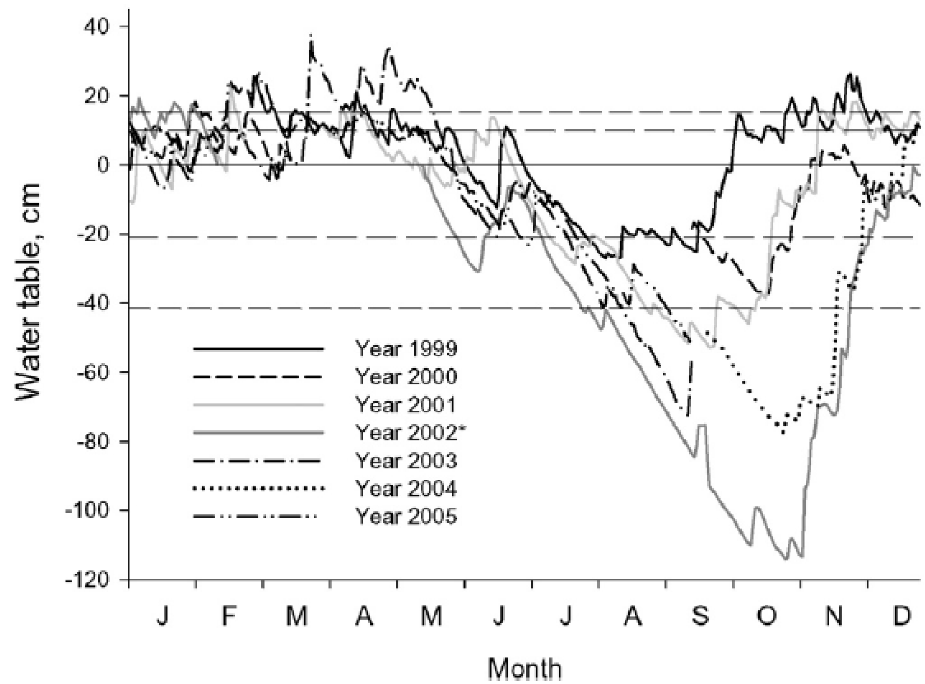


Fig. 4. Forest floor water table levels in a hollow in plot B based on long-term logger measurements (modified from Lampela et al. (2014)). 0-level (solid horizontal line) is the annual median water table calculated from measurements during the period 1999–2005 excluding the exceptionally dry year 2002 (marked with *). Dashed horizontal lines show 10th, 25th, 75th and 90th percentiles. 0-level is 4 cm above the soil surface in the exact location of the logger. Logger-data provided by Dr. Hidenori Takahashi.

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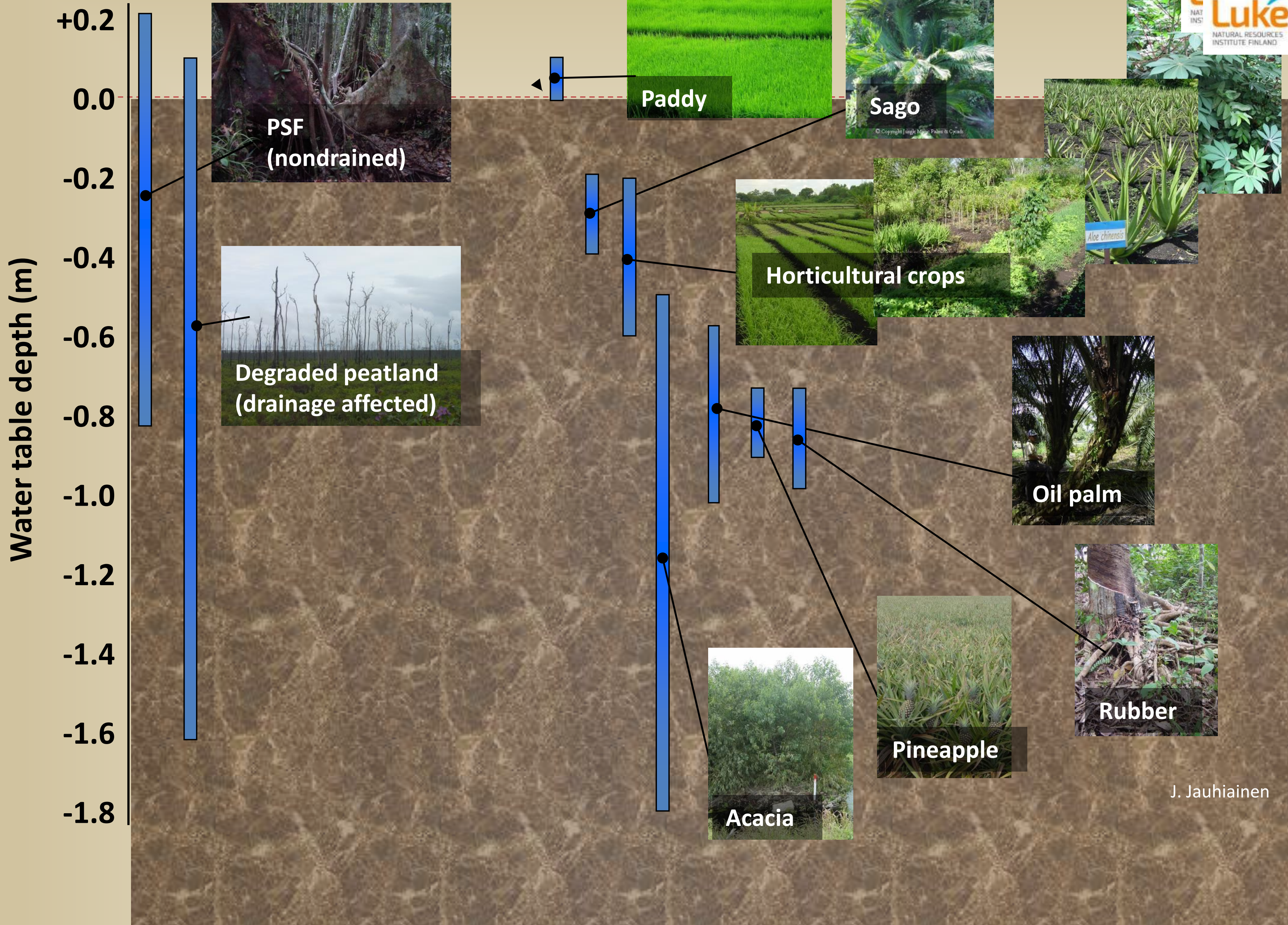
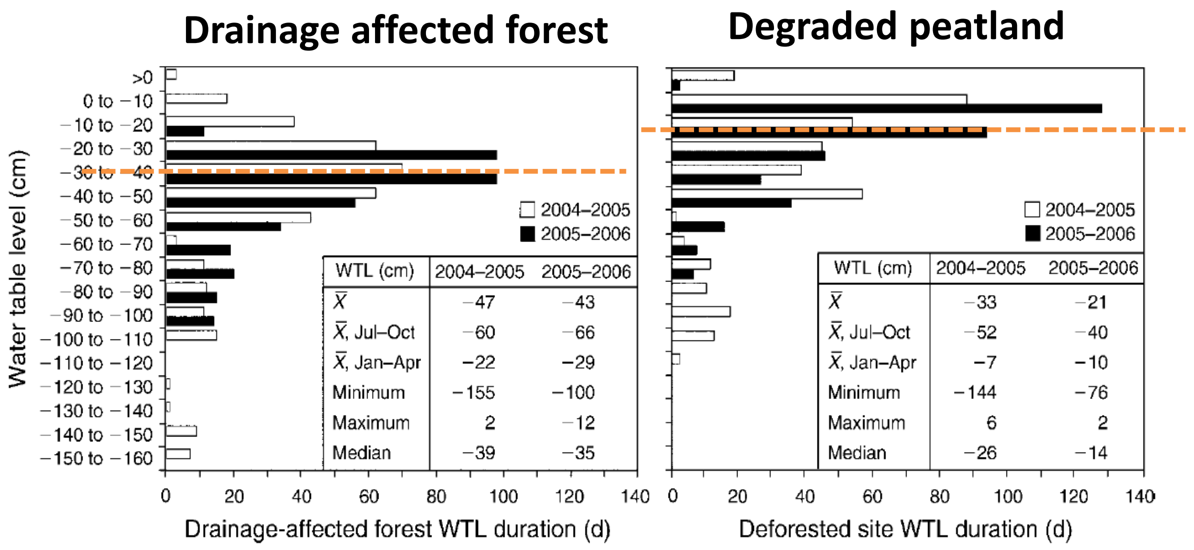
[b] Department of Social Research, University of Helsinki, P.O. Box 54, 00014, Finland

Water table



+0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
Water table depth (m)
PSF (nondrained)
Degraded peatland (drainage affected)
Paddy
Sago
Horticultural crops
Oil palm
Rubber
Pineapple
Acacia
J. Jauhiainen

Water table



Drainage affected forest:

WTL (cm)	2004–2005	2005–2006
$\bar{X}$	−47	−43
$\bar{X}$, Jul–Oct	−60	−66
$\bar{X}$, Jan–Apr	−22	−29
Minimum	−155	−100
Maximum	2	−12
Median	−39	−35

Degraded peatland:

WTL (cm)	2004–2005	2005–2006
$\bar{X}$	−33	−21
$\bar{X}$, Jul–Oct	−52	−40
$\bar{X}$, Jan–Apr	−7	−10
Minimum	−144	−76
Maximum	6	2
Median	−26	−14

FIG. 2. Soil water table level in drainage-affected selectively logged forest (DF) and in deforested (DBP) site depressions before (2004–2005) and after (2005–2006) drainage canal blocking. Duration (days) of soil water table level in 10-cm water table level (WTL) categories is shown, and results are for one-year periods starting from 29 June 2004. Mean ($\bar{X}$), mean dry season (July–October), mean wet season (January–April), minimum, maximum, and median WTL values are presented.

Ecology, 89(12), 2008, pp. 3503–3514

CARBON DIOXIDE AND METHANE FLUXES IN DRAINED TROPICAL PEAT BEFORE AND AFTER HYDROLOGICAL RESTORATION

JYRKI JAUHIAINEN,[1,4] SUWIDO LIMIN,[2] HANNA SILVENNOINEN,[3] AND HARRI VASANDER[1]

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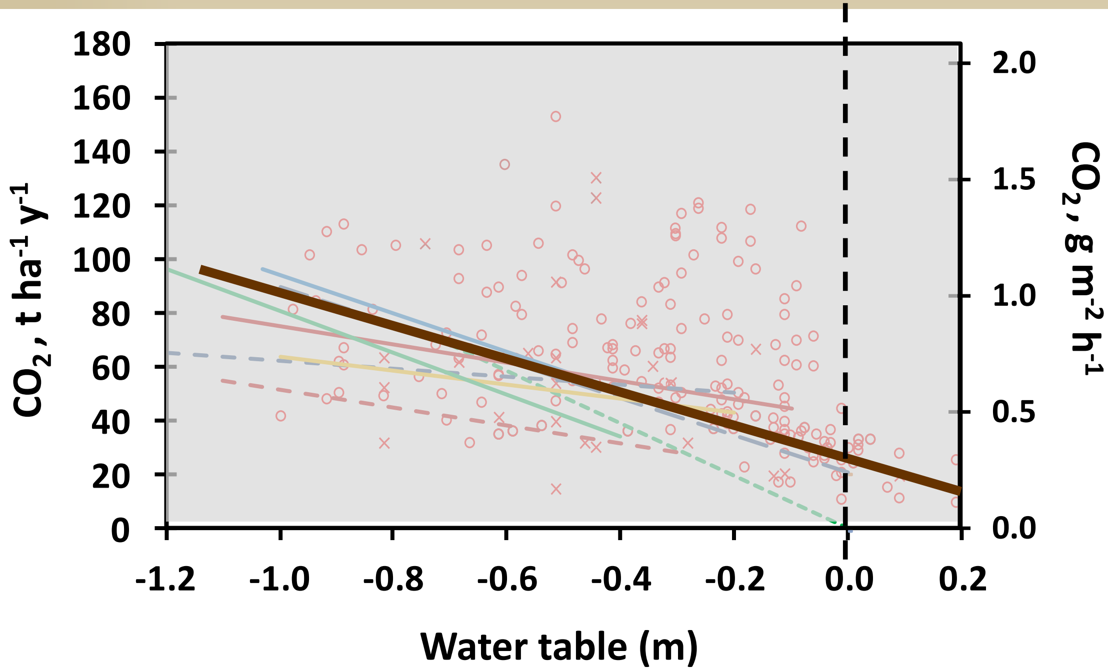
[2]*University of Palangka Raya, CIMTROP, Palangka Raya 73112, Indonesia*
[3]*University of Kuopio, Department of Environmental Sciences, P.O. Box 1627, Kuopio 70211, Finland*

Water table & decomposition



Tropical peat CO_2 loss (in decomposition) at various water table positions and land uses

× Agroforestry fields and ○ primary, secondary, selectively logged forests hourly total fluxes (Couwenberg *et al*., 2010). *Acacia crassicarpa* plantation annual heterotrophic flux —— (Jauhiainen *et al*., 2012), - - - (Husnain *et al.*, 2014), and annual CO_{2e} loss based on peat subsidence — — (Hooijer *et al*., 2012). Oil palm plantation annual heterotrophic flux – – and —— (Husnain *et al.*, 2014). Rubber plantation annual heterotrophic flux —— (Husnain *et al.*, 2014). Drained natural forest annual CO_{2e} loss based on peat subsidence ----- (Hooijer *et al*., 2012), and secondary forest total CO_2 flux —— (Husnain *et al.*, 2014).

Water tables & Decomposition

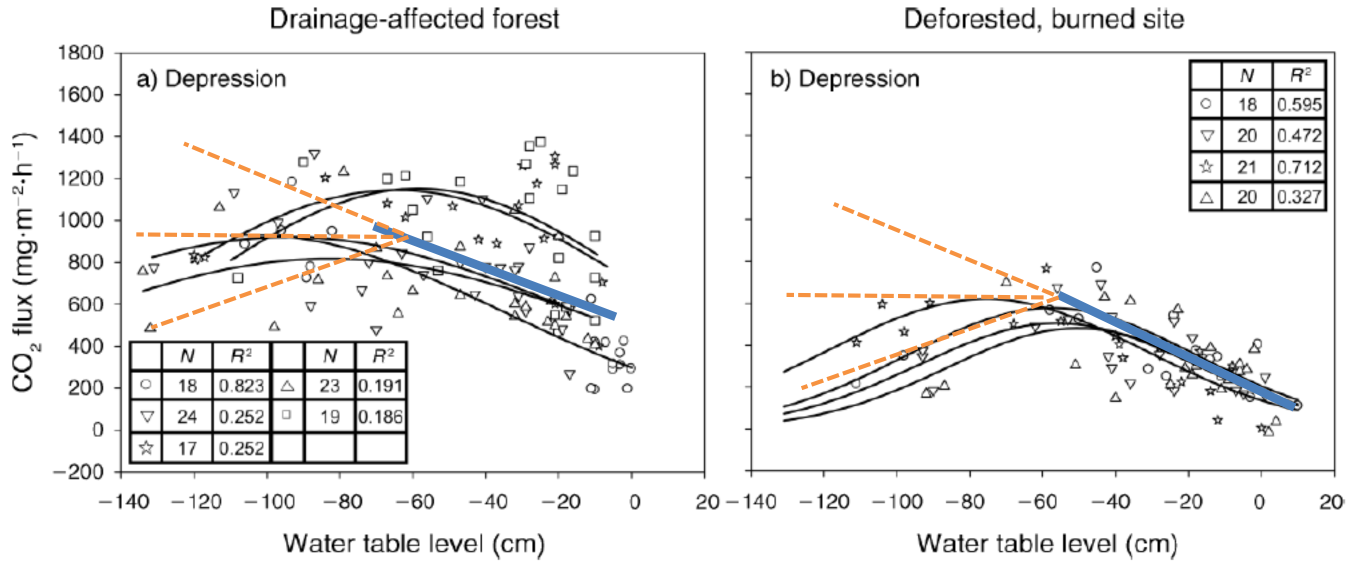
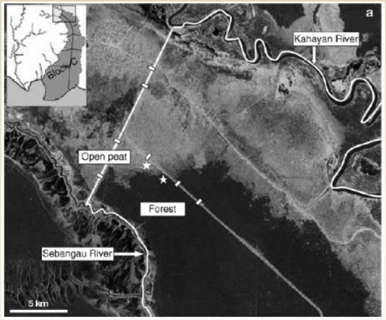


FIG. 3. Tropical peat (a–d) CO_2 and (e, f) CH_4 fluxes at various soil water levels and fitted regression curves for drainage-affected forest (DF) site and for deforested, burned (DBP) site depressions and higher surfaces in the selected subplots. Readings in various subplots are indicated by differing symbols. For the selectively logged forest hummocks, mean CO_2 fluxes are shown in panel (c). The number of measurements and goodness of fit (R^2) are also shown. Five relatively high CH_4 emission rates noted in low WTL conditions were excluded from the regression analysis but are circled on the graphs in panels (e) and (f).



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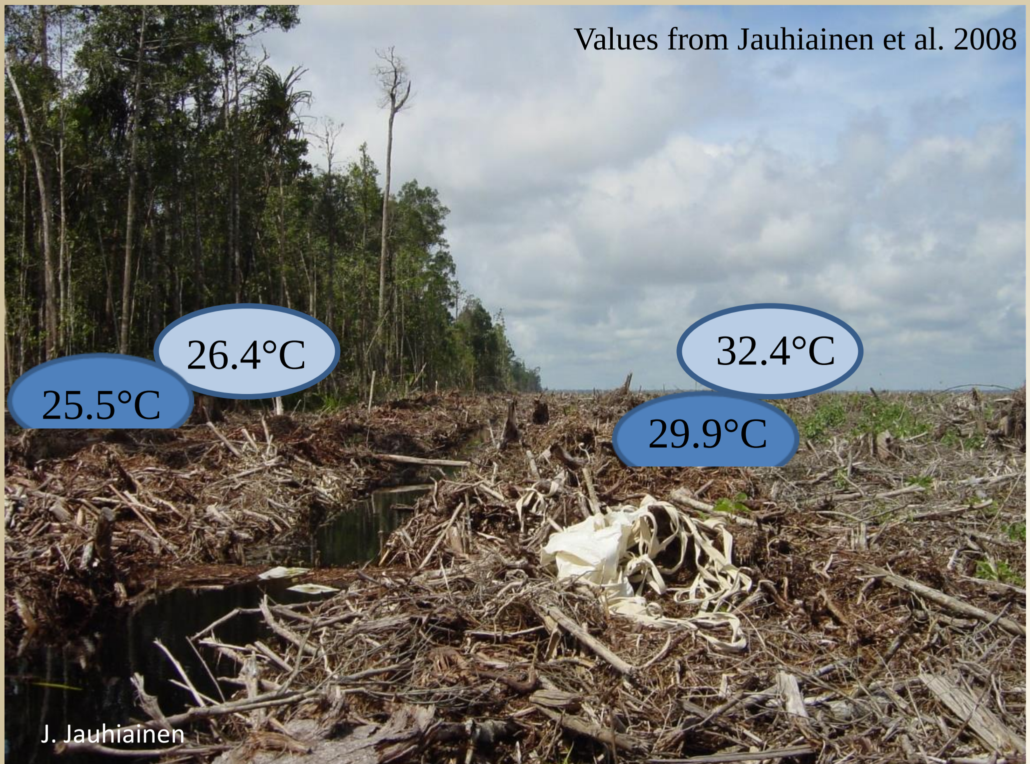
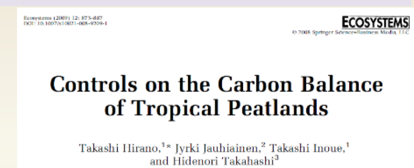
Temperature & decomposition



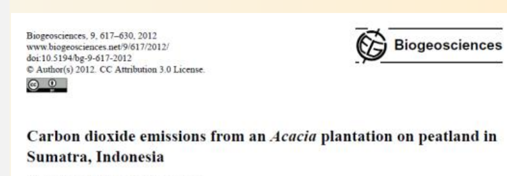
- 4 years of automated hourly monitoring of emission/temperature variables in peat swamp forest
- the rate of instantaneous in-situ peat total CO_2 emission doubled over a temperature range of 5°C (from 24°C to 29°C).


ECOSYSTEMS

Controls on the Carbon Balance of Tropical Peatlands

Takashi Hirano,[1*] Jyrki Jauhiainen,[2] Takashi Inoue,[1] and Hidenori Takahashi[3]

- Daytime mean annual CO_2 emission from peat oxidation alone of 94 t ha^{-1} y^{-1} at a mean water table depth of 0.8
- A minimum emission value of 80 t ha^{-1} y^{-1} after correction for the effect of diurnal temperature fluctuations (1.45°C),
  - result in a 14.5% reduction of the daytime emission.


Biogeosciences, 9, 617–630, 2012
www.biogeosciences.net/9/617/2012/
doi:10.5194/bg-9-617-2012
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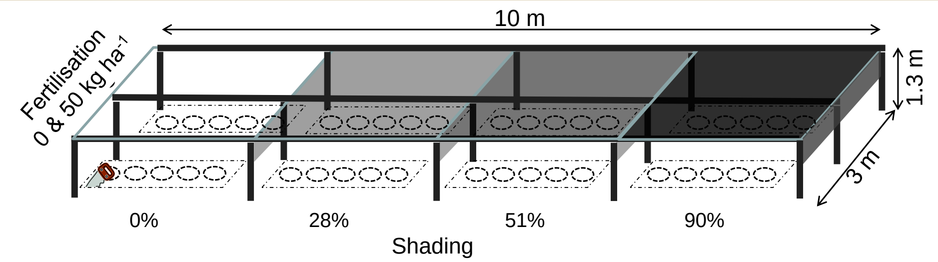
Biogeosciences

Carbon dioxide emissions from an *Acacia* plantation on peatland in Sumatra, Indonesia

J. Jauhiainen[1], A. Hooijer[2], and S. E. Page[3]

Restoration – Temperature



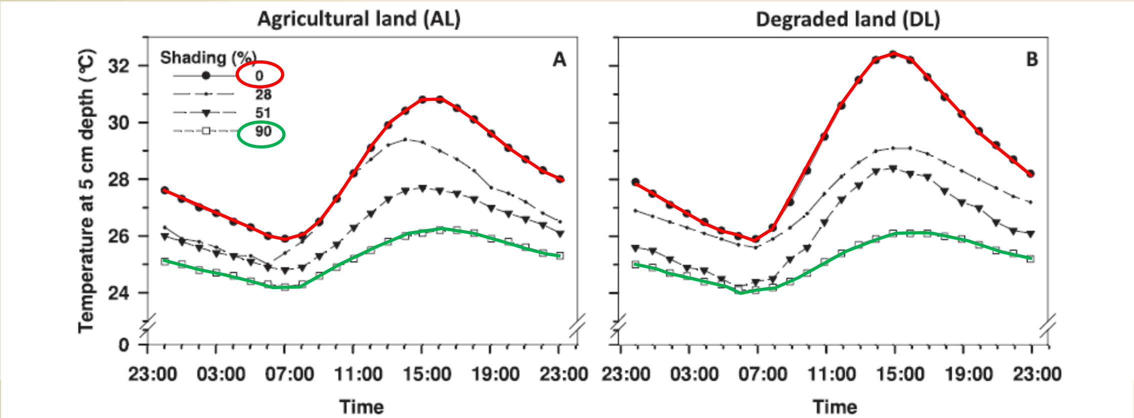


Figure 2. Average diurnal peat temperatures (A) and (B) at various shading levels at 5 cm depth, and at five peat depths under unshaded conditions (C) and (D) based on automated temperature monitoring during the GHG monitoring period 1 May to 31 August 2012. Each presented line presents data from one logger.

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Environmental Research Letters
Environ. Res. Lett. 9 (2014) 105013 (18pp)
doi:10.1088/1748-9326/9/10/105013

Heterotrophic respiration in drained tropical peat is greatly affected by temperature—a passive ecosystem cooling experiment

Jyrki Jauhiainen[1], Otto Kerojoki[1], Hanna Silvennoinen[2,3], Suwido Limin[4] and Harri Vasander[1]

Temperature & Decomposition

Lower temperature and CO_2 loss from decomposition – is there correlation?

c. 8% (unfertilised) and 25% (fertilised) emission change for each 1 °C temperature change at 5 cm depth at the agricultural land

OPEN ACCESS
IOP Publishing
Environmental Research Letters
Environ. Res. Lett. 9 (2014) 105013 (18pp)
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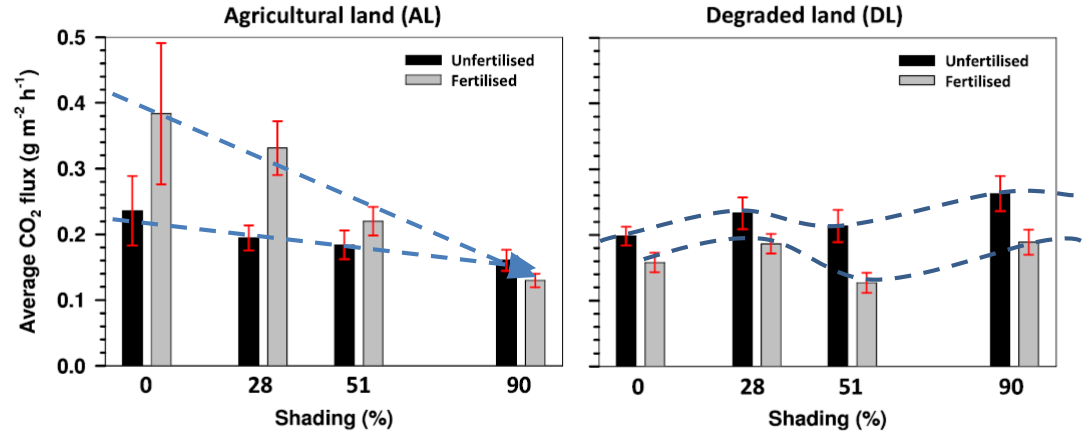


Figure 3. Average heterotrophic CO_2 flux ± 95% CL at four shading levels and two fertilization levels on the AL and DL sites. Non-overlapping CL's represent statistically different average fluxes.

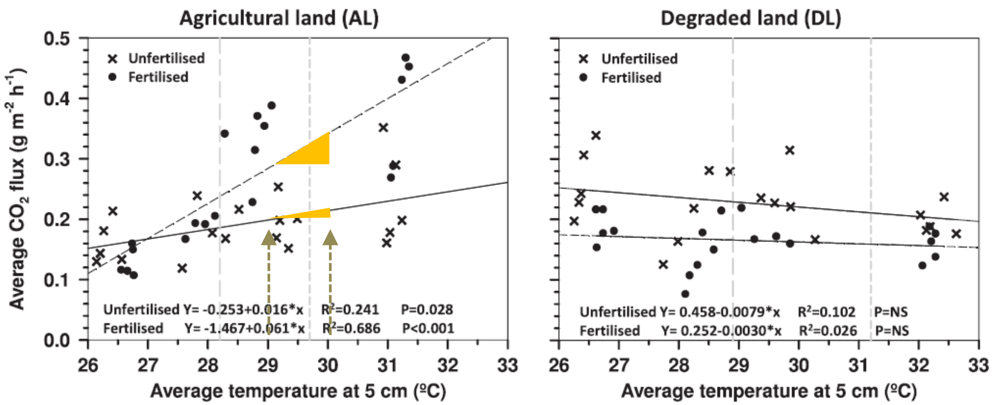
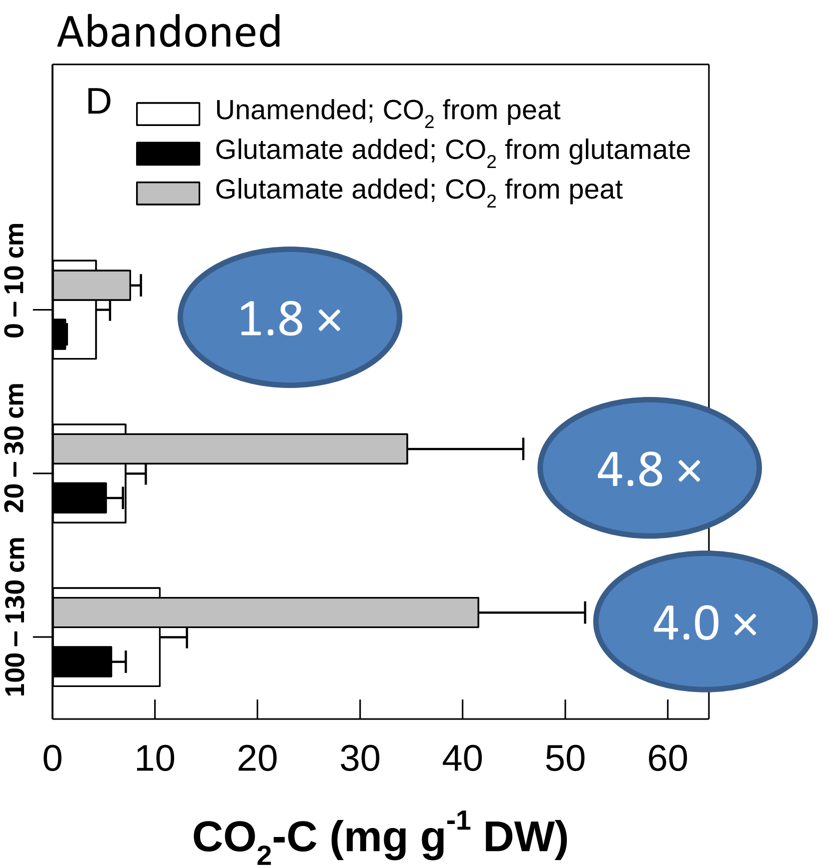


Figure 4. Correlation between plot long-term average CO_2 flux and peat temperature at 5 cm depth and plot long-term average CO_2 flux and groundwater table depth on the AL and DL sites. Each symbol represents an average of 11 flux and groundwater table readouts. Shaded lines represent averages for unshaded peat 24 h temperatures (dashed) and daytime temperatures (dotted) at 5 cm depth, and groundwater table (solid).

Peat resources & decomposition

Effect of root exudation (simulated by added [13]C glutamate) on aerobic decomposition in abandoned peat set in micro-cosmos experiment.

Fig. 2. The total produced CO_2 in the glutamate-added experiment is a sum of CO_2 from glutamate (black bar) and CO_2 from non-labelled sources (grey bar).



- Glutamate addition increased the cumulative CO_2 production 1.8×, 4.8× and 4× in the top, middle and deepest layers, respectively.
- Approximately 98% of the CO_2 production took place within 48 hours of the onset of the experiment.

Biogeochemistry
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Management driven changes in carbon mineralization dynamics of tropical peat

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Peat abiotic environment & decomposition

Top peat (0-10 cm) C mineralization were followed in oxic and anoxic conditions. Slurry experiments, c. 160 hrs, without added substrates.

Table 1. Effect of oxic and anoxic conditions on peat heterotrophic respiration.

	CO_2 production rate (µg g^{-1} DW h^{-1})	
Condition	**Forest peat**	**Abandoned peat**
Oxic	9.345±0.593	1.664±0.248
Anoxic	5.885±1.217	0.898±0.146
	CO_2 production continues in anoxic conditions with **37% rate difference**	CO_2 production continues in anoxic conditions with **46% rate difference**

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Conclusions

- Apparently similar landscapes and landscape features may differ functionally and by content (structure and composition) in different peatland systems
- Conditions in tropical peatland can form equally extreme environment compared to, for example, arctic peatlands
  - Variation in annual water tables and vegetation composition in natural and managed areas are high
  - Temperatures vary relatively little over year, diurnal cycle exists and LU change increase temperature differences - even small differences can matter when it comes to decomposition processes
  - Competition over resources is hard in ombrotrophic peatlands

Thanks for your interest!

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