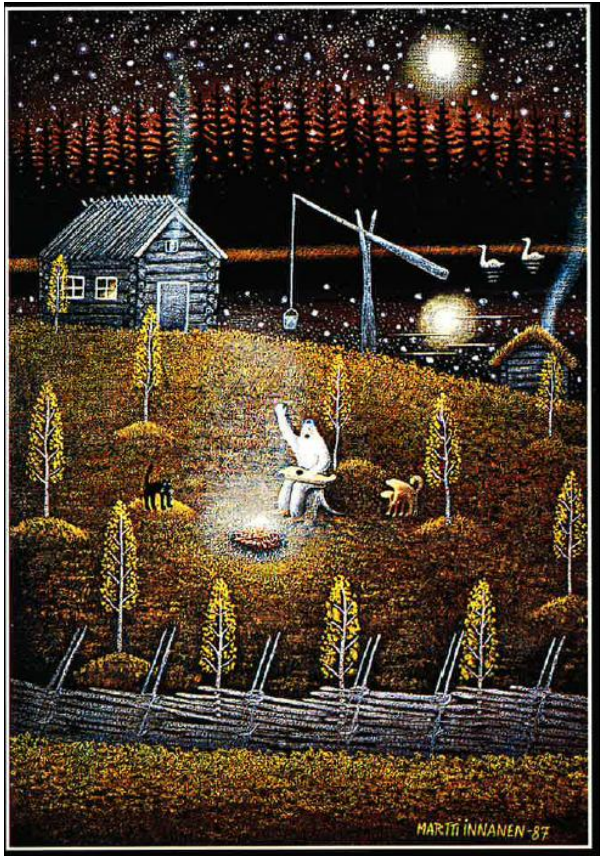
NIBIO

NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

PEATLAND MANAGEMENT AND GHG PRODUCTION

Nibio, Soil quality and Climate Change Section



Turpeisjärven taikayö
The Turpeisjärvi magic night
1987 akryyli kovalevylle 78 x 54

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1. Peatlands and their utilization in Northern Europe
2. GHG production – processes and controls
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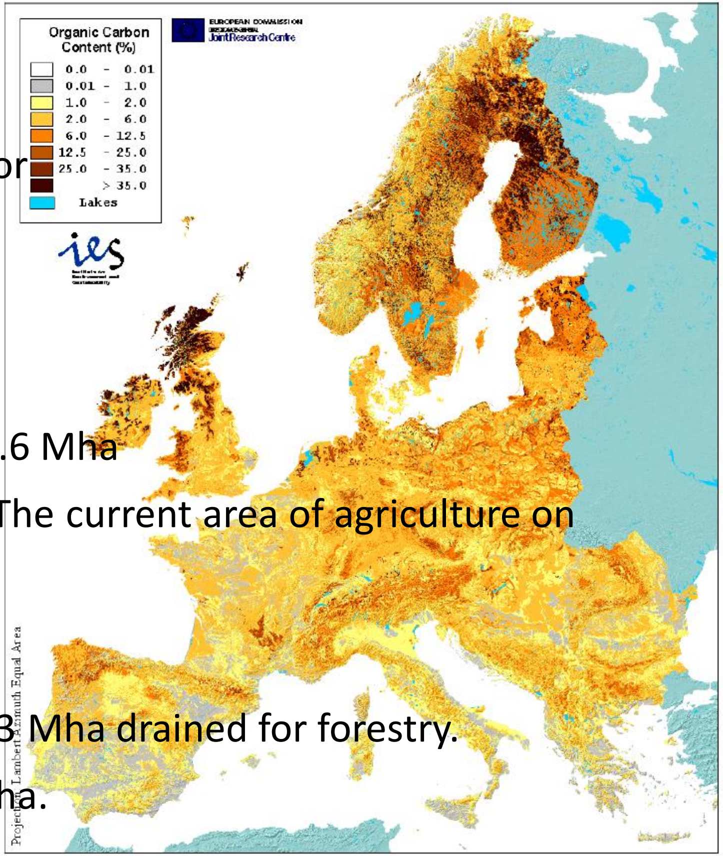
1. PEATLANDS AND THEIR UTILIZATION IN NORTHERN EUROPE

L. Montanarella *et al.* THE DISTRIBUTION OF PEATLAND IN EUROPE



Finland:

Original" mire area 10.4 Mha.FNFI10 gives the total area of mires and peatlands as 8.95 Mha. Totally 5.45 Mha drained for forestry. The current area of agriculture on organic soils totals 0.31 Mha.

Sweden:

Total area of mires and peatlands.around 10 Mha including 3.6 Mha of wet mineral soils. Totally 1.5-2.0 Mha drained for forestry.The current area of agriculture on organic soils totals 0.27 Mha.

Norway:

Total area of mires and peatlands.around 2.2 Mha.Totally 0.43 Mha drained for forestry. The current area of agriculture on organic soils totals 0.08 Mha.

Päivänen & Hånell 2012

2.1 PROCESSES AND CONTROLS – *CARBON DIOXIDE (CO_2)*

Main controlling factors | Process

Photosynthesis

Temperature, vegetation (amount and composition), oxygen availability (i.e. water table level), availability of nutrients, Radiation

CO_2

Process | Main controlling factors

Plant respiration

Temperature vegetation (amount and composition), oxygen availability (i.e. water table level), availability of nutrients

Microbial respiration

- **aerobic** – Temperature, water table level, availability of carbon and other nutrients, pH
- **anaerobic** – Temperature, water table level, availability of electron acceptors (NO_3^-, SO_4^{2-}, Fe_3+, Mn3+), carbon and nutrients

Methane oxidation – Temperature, water table level, NH_4^+

Note! Also anaerobic CH_4 oxidation with SO_4^{2-}, NO^{2-} and Fe^{3+}, less studied, lower ecosystem impact

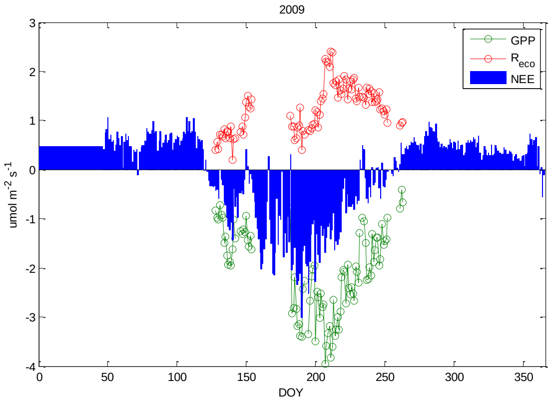
Water table level – Low water table level, more oxic volume, higher CO_2 flux

Nutrients – Increase CO_2 flux

Red ellipse: Lack of O_2 inhibits process

Blue ellipse: Lack of O_2 enhances process

2.1 (2) **PROCESSES AND CONTROLS – CO_2**



- NECB (Net ecosystem carbon balance) = NEE (Net ecosystem exchange) + CH4 flux (production or combustion)

- Net Ecosystem Exchange = GPP (Gross Primary Production) + ER (Ecosystem Respiration)

2.2 PROCESSES AND CONTROLS – *METHANE (CH_4)*

Main controlling factors

Process

Methane oxidation

Temperature, vegetation (amount and composition), oxygen availability (i.e. water table level), availability of nutrients, Radiation

CH_4

GWP 34*

Process

Methanogenesis
(acetoclastic & hydrogenotrophic)

Main controlling factors

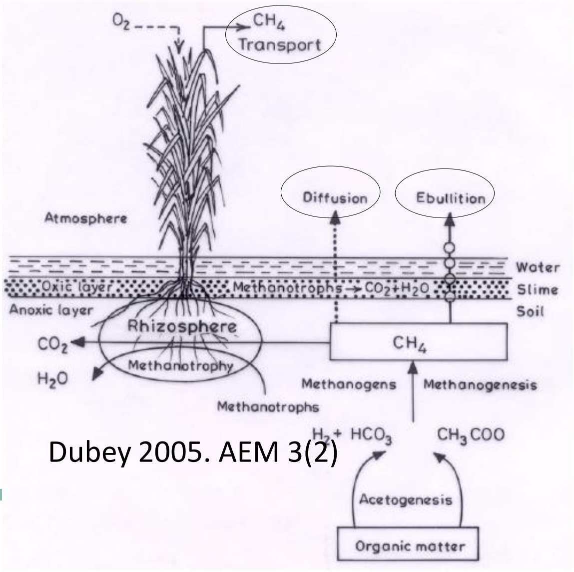
Temperature, vegetation (amount and composition), oxygen availability (i.e. water table level), availability of nutrients

Water table level – Low water table level, more oxic volume, LOWER CH_4 flux

Nutrients – Increase CH_4 flux

Lack of O_2 inhibits process

Lack of O_2 enhances process



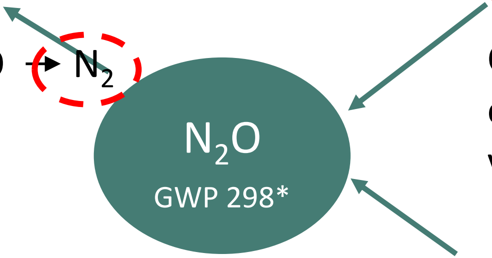
Dubey 2005. AEM 3(2)

2.3 PROCESSES AND CONTROLS – *NITROUS OXIDE (N_2O)*

Process

Denitrification

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$



Process

Nitrification

Chemolitotrophic oxidation of NH_4^+ via NO_2^- to NO_3^-

Denitrification

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

Main controlling factors

Temperature, water table level, availability of nutrients (fertilization), pH

Note! Heterotrophic respiration. Less studied, lower importance on ecosystem level (?)

Temperature, water table level, availability of carbon, availability of NO_3^-, pH

Water table level – Low water table level, more oxic volume, lower denitrification, higher nitrification

Nutrients – Increase in N_2O flux

Lack of O_2 inhibits process (red ellipse)

Lack of O_2 enhances process (blue ellipse)

*IPCC 2013

3. HOW TO MEASURE GHG'S – DIRECT METHODS

EDDY COVARIANCE

Purpose:

Ecosystem scale measurements of gas fluxes

Pro's

Reliable data, with high resolution, (On a long run) easy to manage, no need for every day labour

Con's

Costly (if measurements of all gases), no spatial variability, data processing complex

CHAMBERS

Variations:

Dynamic – static

Transparent (NEE) – dark (ER)

Automatic – manual

Purpose:

Direct measurements of CO_2 (NEE and respiration, N_2O, CH_4)

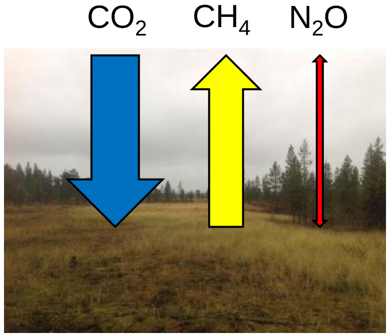
Pro's

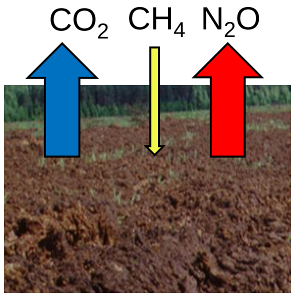
Cheap (manual chambers), all gases easily, enables measuring spatial variation, data processing easy

Con's

Labourous, big gaps in data (requires extrapolation

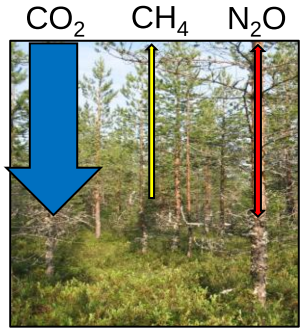
4. Management impacts on GHGs





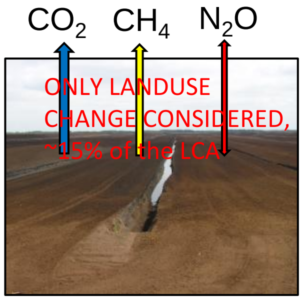
Cultivated

- Abandoning *(no changes in a short run)*
- Slight rise of water table (*decreased CO_2 & N_2O fluxes*)
- Restoration (return to pristine? More research needed!)
- Afforestation (lower N_2O fluxes)



Peatland forestry

- Afforestation (Peat decomposes, despite of CO_2 uptake)
- Restoration (recovery of peat, increased CH_4 emissions)
- Clear cut, cultivation (considered in Norway, increased N_2O and CO_2 flux)

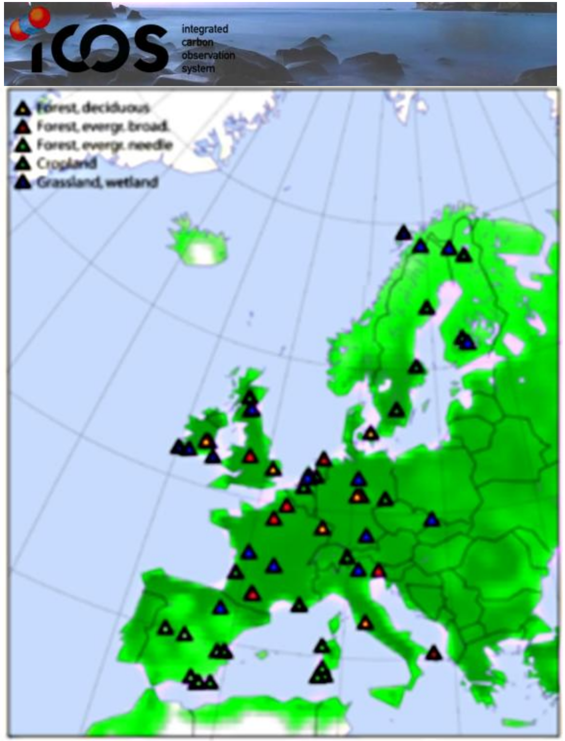


Peat extraction

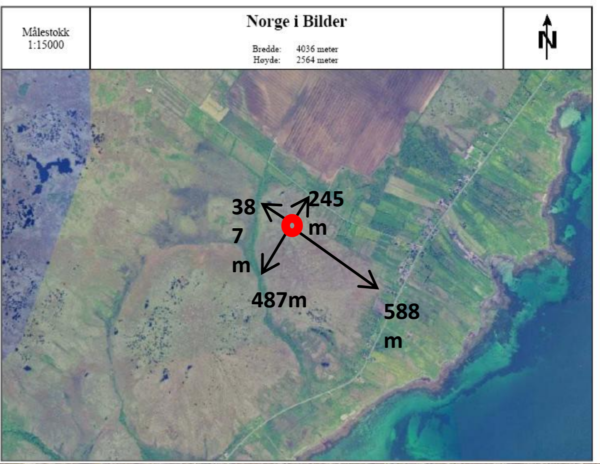
- Restoration (Increased CO_2 uptake, increased CH_4 flux, recovery of peat)
- Cultivation (bioenergy crops without fertilization, increased CO_2 uptake)
- Afforestation (increased CO_2 uptake)

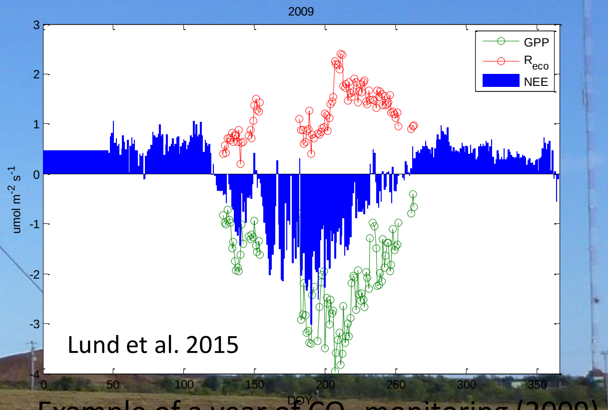
4.1 PRISTINE PEATLANDS

- Decades of research, in general sinks for CO_2, sources of CH_4, minor sources of or even sinks for N_2O
- High water table level, low pH and (in bogs) low nutrient concentrations limit decomposition and lead to peat accumulation
- Many ecosystem sites in Europe, many of them part of ICOS (Integraded Carbon Observation System) and following standardized program for flux measurements (EC)



4.1 (2)PRISTINE PEATLANDS – *AN EXAMPLE FROM NORWAY*

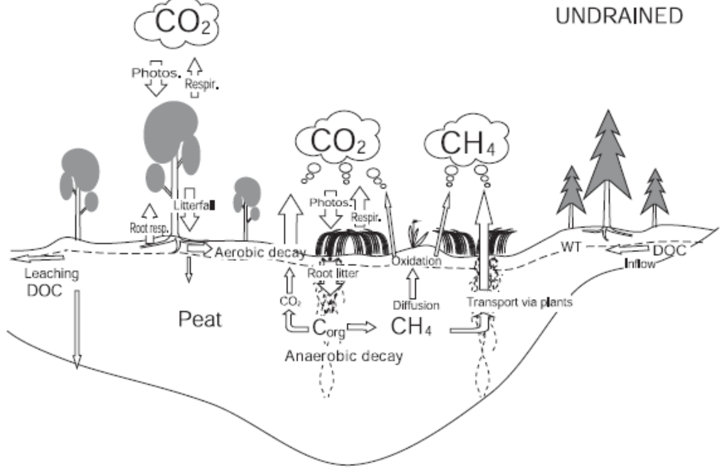


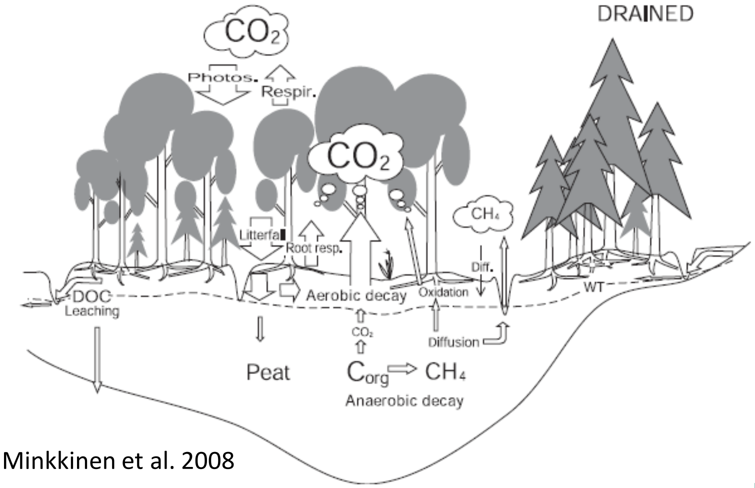


Example of a year of CO_2 monitoring (2009)

4.2 CLIMATE IMPACT OF PEATLAND FORESTRY –

THE LEGACY OF THE SITE MATTERS!





Minkkinen et al. 2008

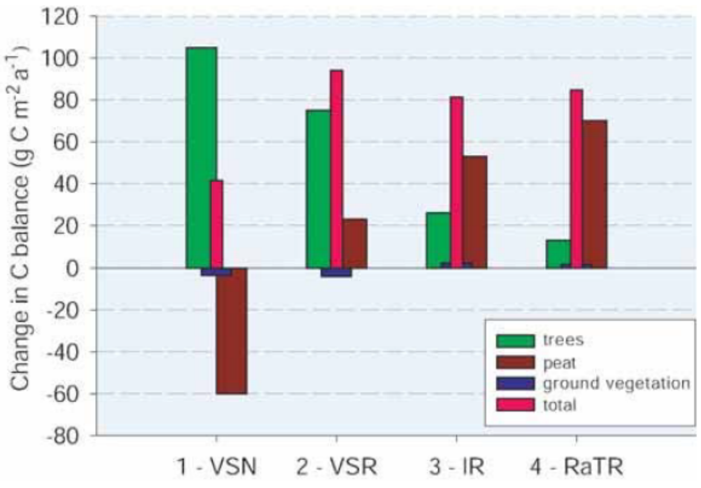


Figure 4.4. *The change in the C balance of the tree stand, ground vegetation and peat soil in four sites on Lakkasuo mire, Central Finland (Minkkinen et al., 1999). C balance of a peatland after drainage for forestry is strongly dependent on the site type and the consequent differences in influx (primary production) and outflux (decomposition) processes. Site 1 - VSN is the most nutrient rich and site 4 - RaTR the most nutrient poor site type.*

 Minkkinen et al. 2008. Climate Impacts of Peatland Forestry. In: Peatlands and Climate Change.International Peatland Society. Maria Strack (Ed.)

4.3 CLIMATE IMPACT OF CULTIVATED PEATLANDS

– *MANAGEMENT MATTERS!*

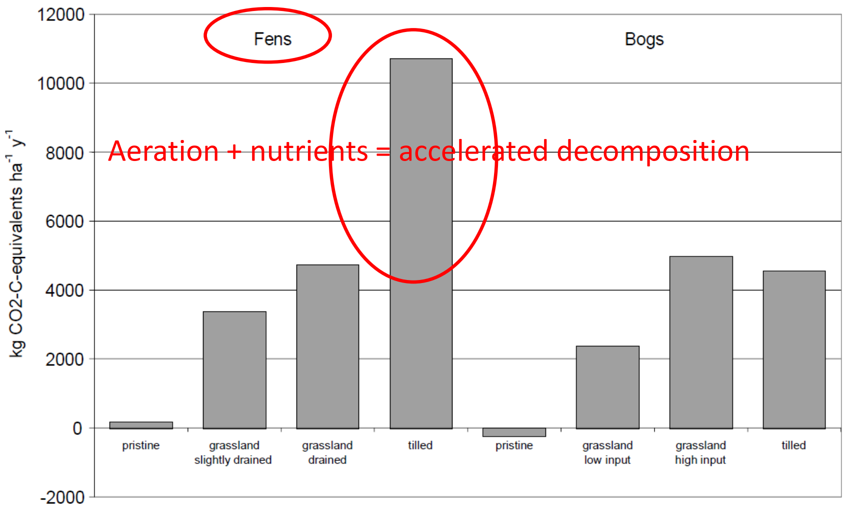
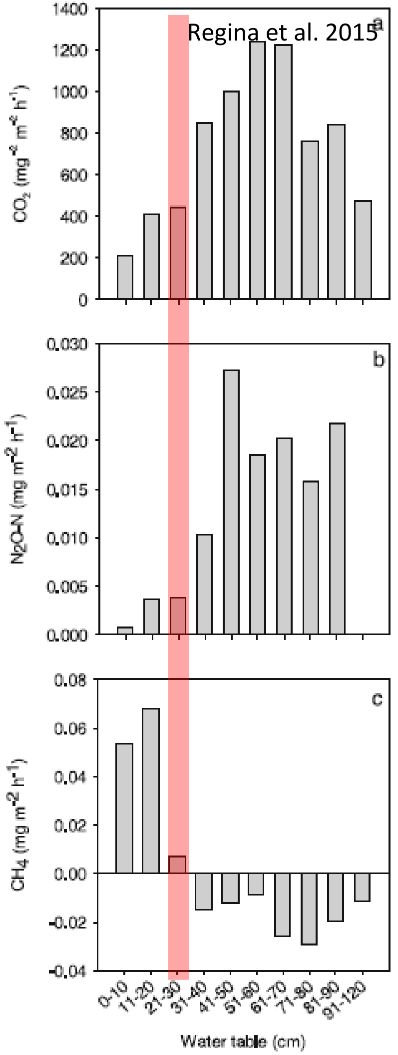


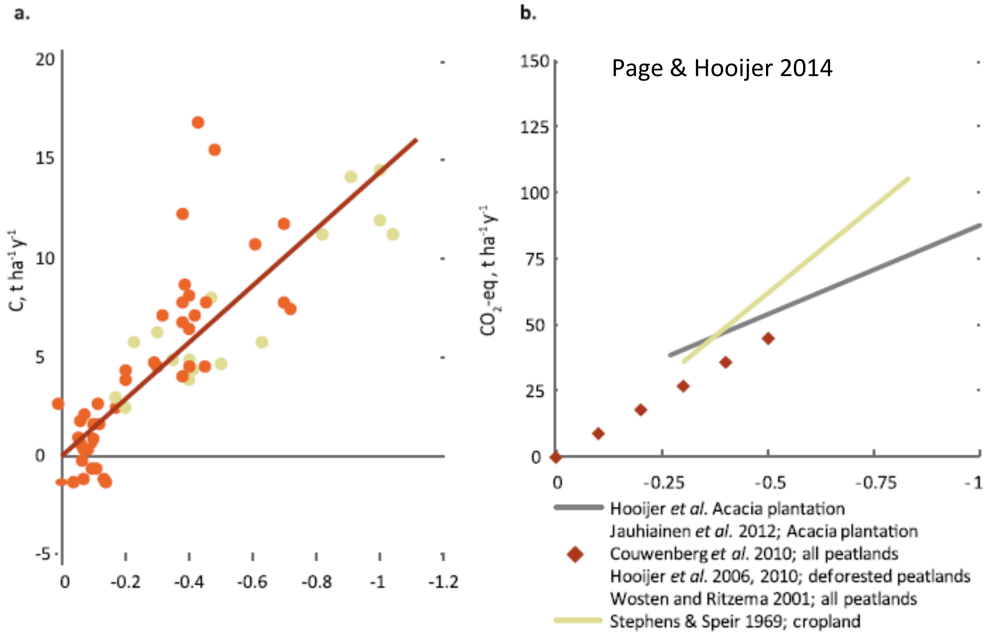
Figure A2/2: Rough estimates of the global warming potential of fens and bogs (in kg CO_2 equivalents ha^{-1} y^{-1}) under different types of land use (compiled by Heinrich Höper 2000).[67]



4.3 (2) CULTIVATED PEATLANDS –

WATER TABLE LEVEL MATTERS

Sufficiently high water table level may lead to lower emissions.



Regina et al. 2015. Mitig Adapt Strateg Glob Change 20: 1529-1544

Page & Hooijer 2014. Environmental impacts and consequences of utilizing peatlands.

In: Towards climate responsible peatlands management, Biancalani & Avagyan (Eds), FAO

4.3 (3) CULTIVATED PEATLANDS – *THE CRUCIAL N_2O*

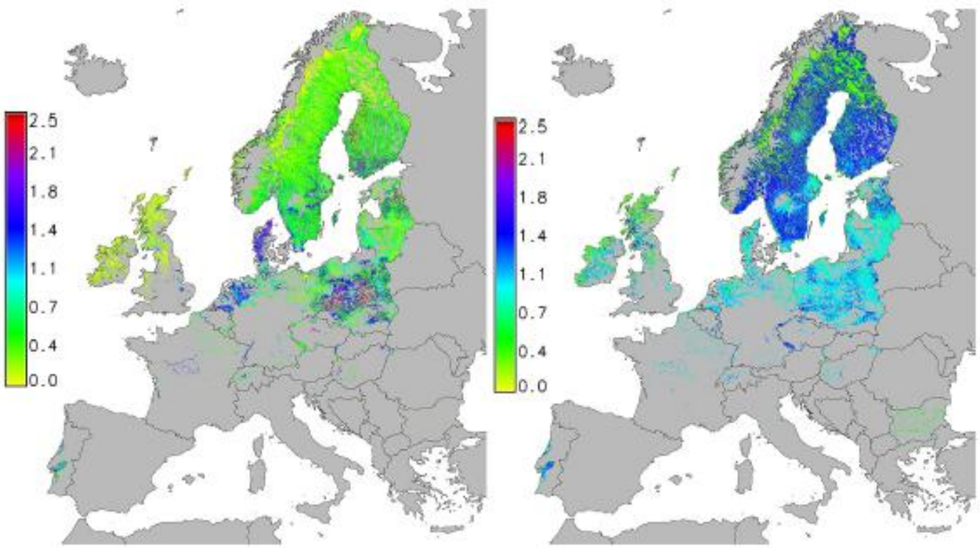


Figure 8. European N_2O fluxes for 1 km × 1 km raster grid cells calculated with the fuzzy logic model approach (left) and the corresponding pixel-wise model uncertainty as standard deviations (right) for organic soils in $g\,N_2O\text{-}N\,m^{-2}\,a^{-1}$. The land use classification is based on CORINE land cover.

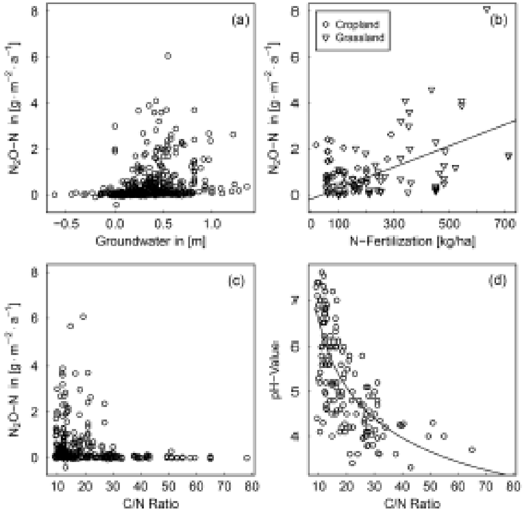


Figure 3. The scatter plots show (a) the N_2O flux relationship to mean annual groundwater table, (b) the relationship between N fertilization and N_2O fluxes for crop- and grassland with significant ($P < 0.001$) linear relationship for grassland ($r^2 = 0.26$), (c) the N_2O fluxes plotted against the C / N ratios, and (d) pH values in relation to these C / N ratios including the fitted non-linear function ($ph = 15\,cn^{-0.36}$) ($r^2 = 0.5$).

4.4 CLIMATE IMPACT OF PEAT EXTRACTION – *THE END USE OF THE PEAT MATTERS!*

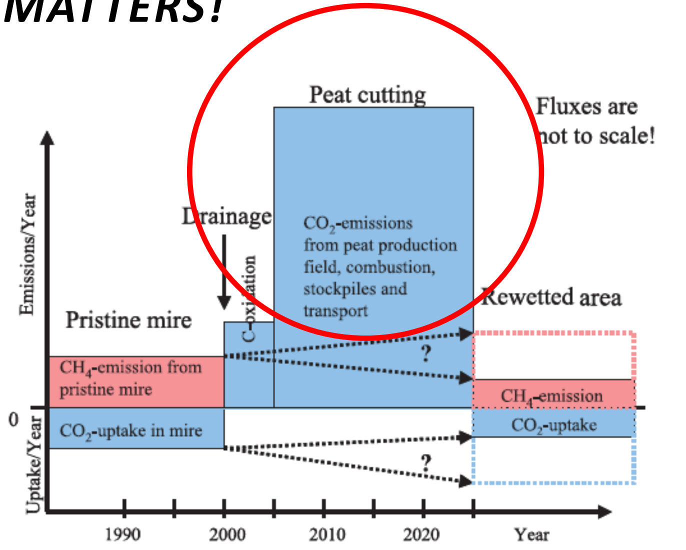
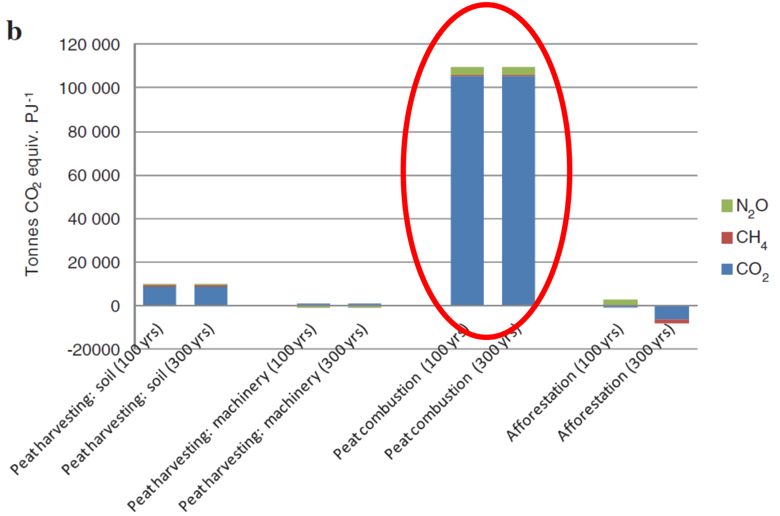


Figure 5.4. *Schematic representation of greenhouse gas emissions during different stages of energy peat production. Also, N_2O emissions can be of importance in peatlands with a low C/N-ratio.*



4.4 (2) THE FATE OF CUT AWAY PEATLANDS?

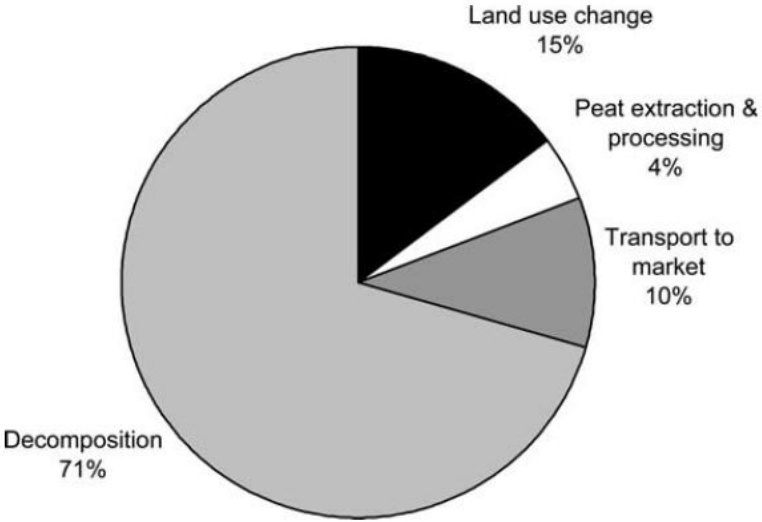
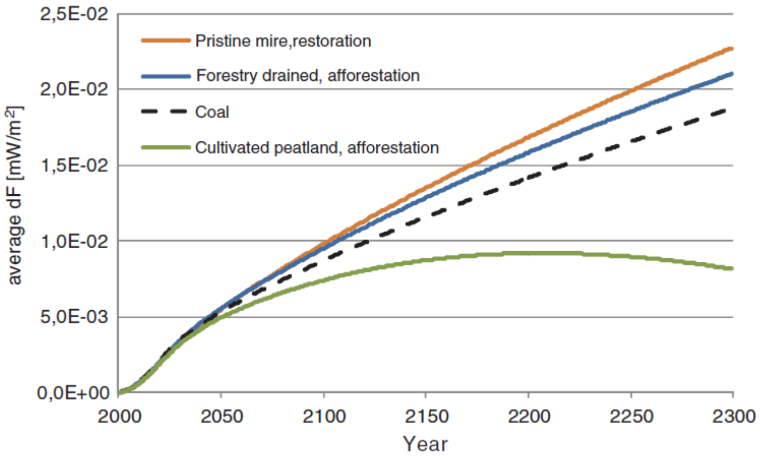


Figure 3. Contribution of land-use change, peat extraction and processing, transport to market, and decomposition of extracted peat to the life cycle of peat extraction from 1990 to 2000.



Cleary et al. 2005 Ambio, 34 (6)

4.5 RESTORATION IMPACT ON GHG’S – *RESEARCH IS NEEDED*

Soini et al. 2010

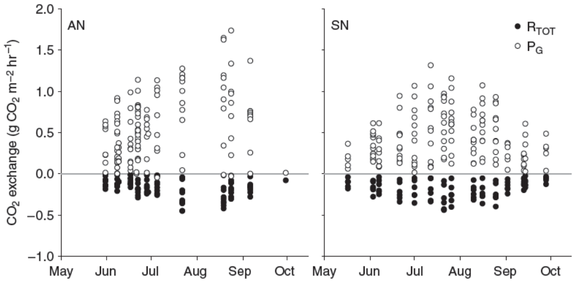


Figure 5. Instantaneous gross photosynthesis (P_G) and total respiration (R_{TOT}) at the study sites. P_G is inferred by subtracting the net CO_2 exchange rate in the light conditions from the exchange rate in the subsequent dark (R_{TOT}) measurement. Positive values indicate a net sink of atmospheric CO_2 to the ecosystem. In each sample plot, multiple measurements in varying light conditions were conducted during each measurement day. AN-Aitoneva (restored site), SN-Siikaneva (pristine site).

Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL

RESEARCH ARTICLE

Rewetting of Cutaway Peatlands: Are We Re-Creating Hot Spots of Methane Emissions?

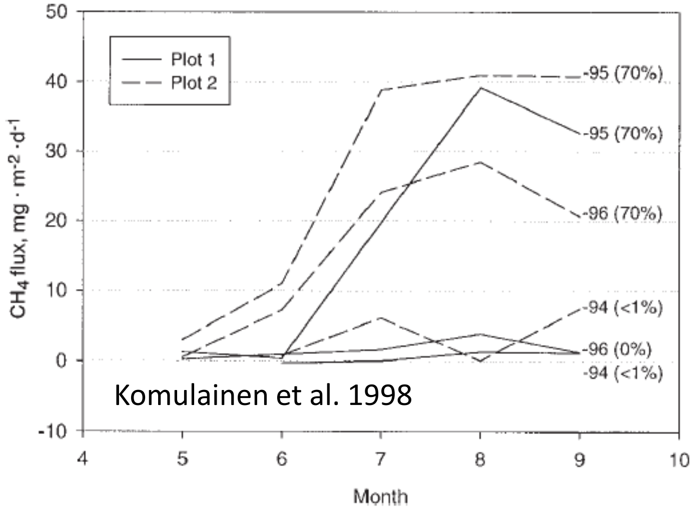
David Wilson,[1,2] Jukka Alm,[3] Jukka Laine,[4] Kenneth A. Byrne,[5] Edward P. Farrell,[1] and Eeva-Stiina Tuittila[6]

Abstract

Hot spots of CH_4 emissions are a typical feature of pristine peatlands at the microsite and landscape scale. To determine whether rewetting and lake construction in a cutaway peatland would result in the re-creation of hot spots, we first measured CH_4 fluxes over a 2-year period with static chambers and estimated annual emissions. Second, to assess whether rewetting and lake creation would

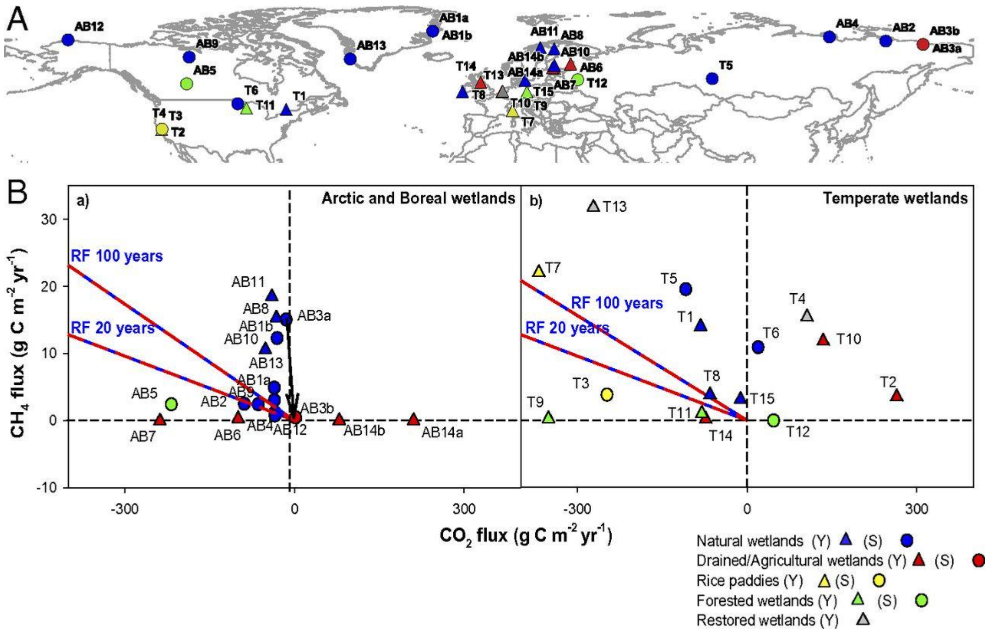
The results showed that hot spots of CH_4 fluxes wer observed as a consequence of microsite-specific differen ces in water table (WT) position and plant productivity CH_4 fluxes were closely related to peat temperature a 10 cm depth and WT position. Annual emissions range from 4.3 to 38.8 g $CH_4\,m^{-2}\,yr^{-1}$ in 2002 and 3.2 to 28.8 $CH_4\,m^{-2}\,yr^{-1}$ in 2003. The scenario results suggest tha lake creation is likely to result in the re-creation of a ho

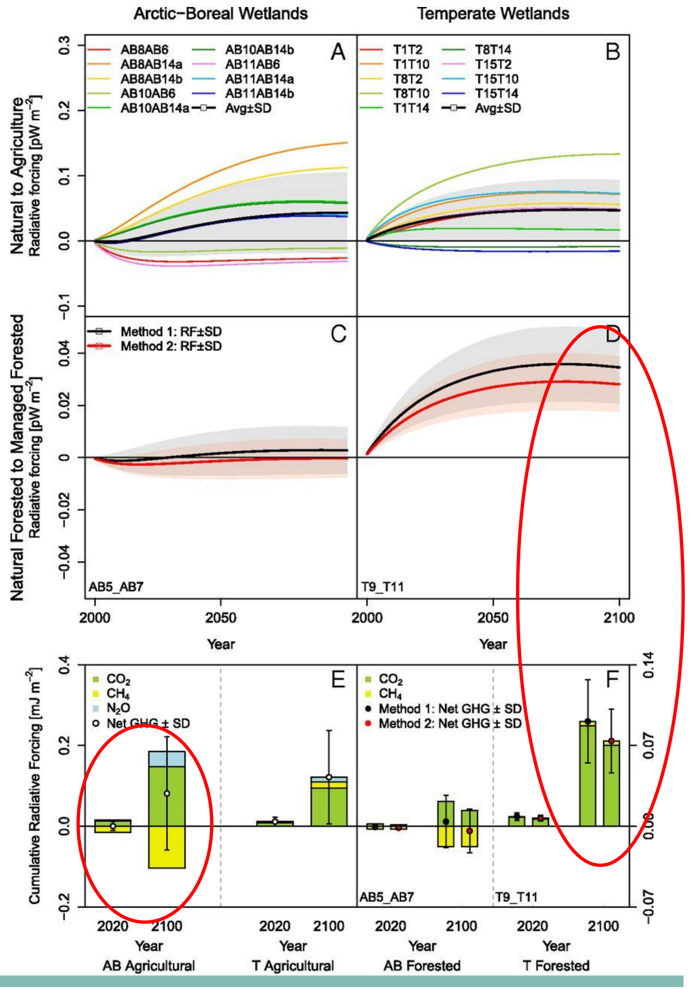
Fig. 4. Monthly CH_4 emissions in 1994 (before rewetting), 1995, and 1996 from sample plots 1 and 2 at the fen site. In May 1996, all vascular plants were removed from sample plot 1. The projection cover of cottongrass is shown for each year.



Komulainen et al. 1998

5. FUTURE PROJECTIONS





Petrescu et al. PNAS 2015;112:4594-4599

6. GAPS IN KNOWLEDGE

Few studies that provide robust comparisons of C and GHG fluxes in relation to management

- The effect of restoration on N_2O emissions
- The effect of fertilization on fluxes of all GHGs
- The specific effects of ploughing/ cultivation
- Studies of any treatment on NEE
- Effect of farming activities on DOC

Intervention/exposure-vs-comparator	CH_4	N_2O	NEE CO_2	$R_{eco}CO_2$	DOC
Cropped-vs-bare	2 (1)	1	0	1 (1)	0
Drained and restored-vs-undrained	0	0	1	1	0
Drained-vs-undrained	9 (4)	5 (5)	3	10 (5)	4
Dry-vs-wet	2	3	1 (1)	1 (1)	0
Extracted and restored-vs-natural	0	0	1	1	0
High intensity farmed-vs-low intensity farmed	5	6	0	2 (1)	1
Fertilised and grazed-vs-unfertilised and mown	0	1	0	0	0
Fertilised-vs-less fertilised	2 (1)	2 (4)	2	2 (1)	0
Grass-vs-forest	1	1	0	1	0
Grazed-vs-mown	3	1	0	0	0
Irrigated-vs-non-irrigated	0	1	0	0	0
Mineral soil dressed-vs-undressed peat	0	1	0	0	0
Old abandoned-vs-recently abandoned	0	0	0	(1)	0
Old afforested-vs-recently afforested	1	1	0	1	0
Poor-vs-rich	1	0	0	1	2 (1)
Restored-vs-unrestored	4	(1)	0	3 (3)	8

Numbers indicate the number of studies presenting meta-analysable data for that outcome and intervention/exposure group. Bracketed numbers indicate the number of additional studies that present *mean only* data (i.e. no measure of variability).

Haddaway et al. 2014

THANK YOU FOR ATTENTION!

More about the gaps and the future in following presentations!