Time to think funded by Kone Foundation

Peatland rewetting and climate regulation

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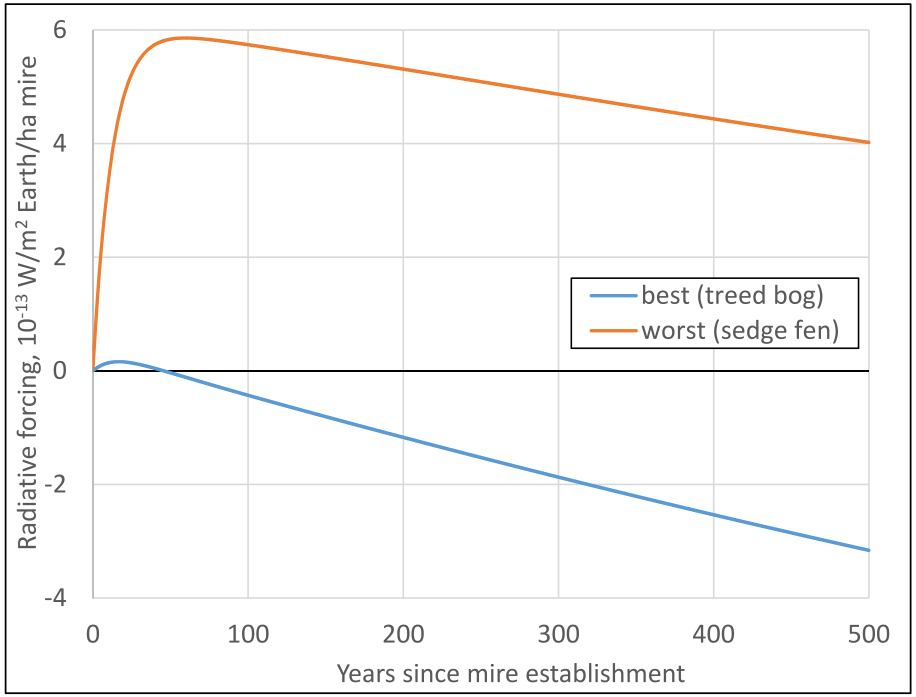
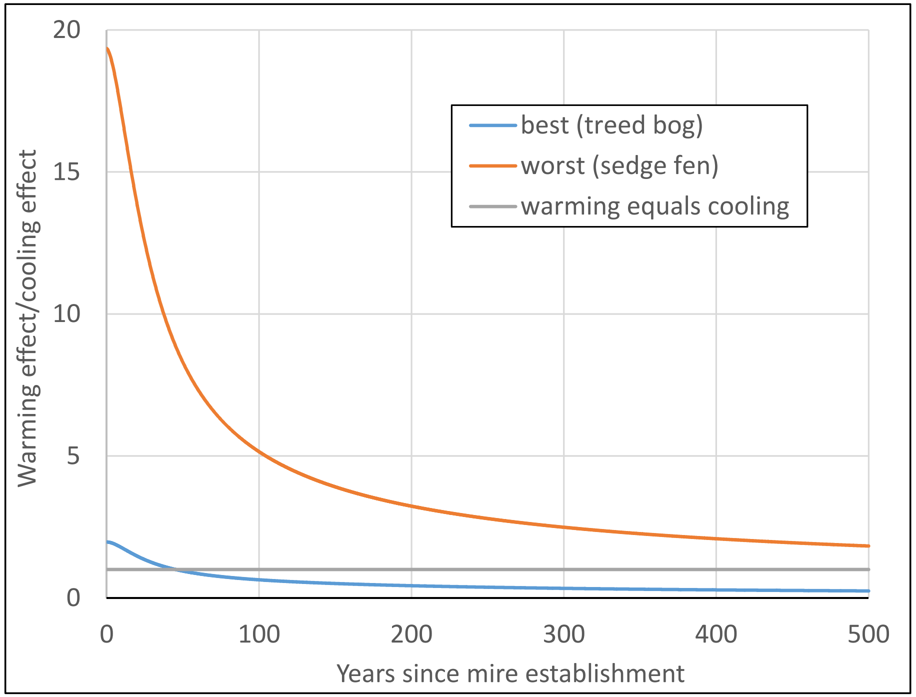
Establishing mires is not an efficient way to prevent the current climate change

Climate effect of new boreal mire soil



Warming effect (CH_4 + N_2O)/cooling effect (CO_2)



Gas emissions (t gas/ha/year)

Treed bog

CO_2 −1.3
CH_4 +0.02
N_2O +0.0008

Sedge fen

CO_2 −1.5
CH_4 +0.24
N_2O +0.0011

This phenomenon has been reported already by Frolking et al. (2006) and Frolking & Roulet (2007).

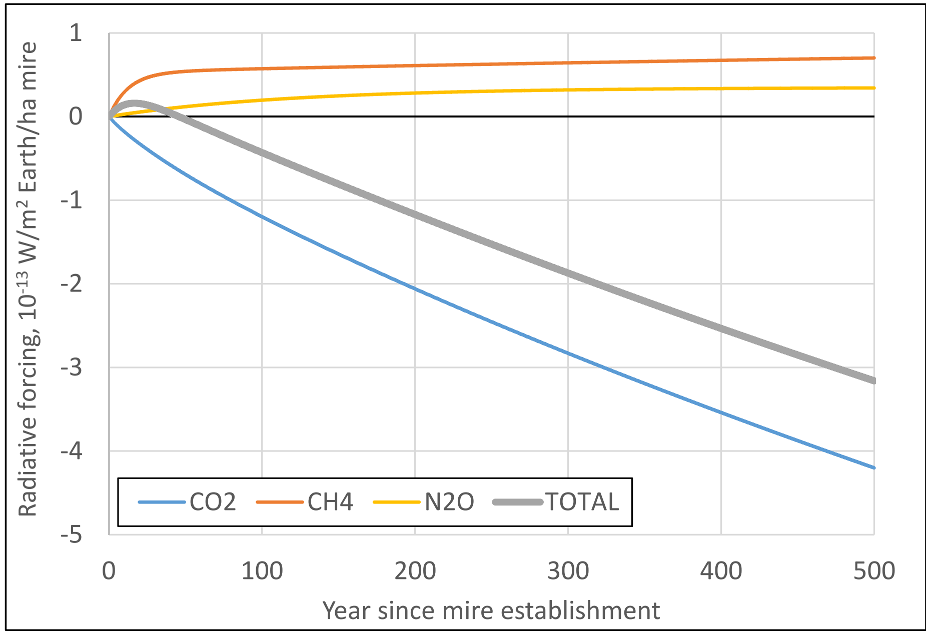
Dynamics of the climate effect of a mire

Different gases have different radiative efficacies and lifetimes (Myhre et al. 2013).

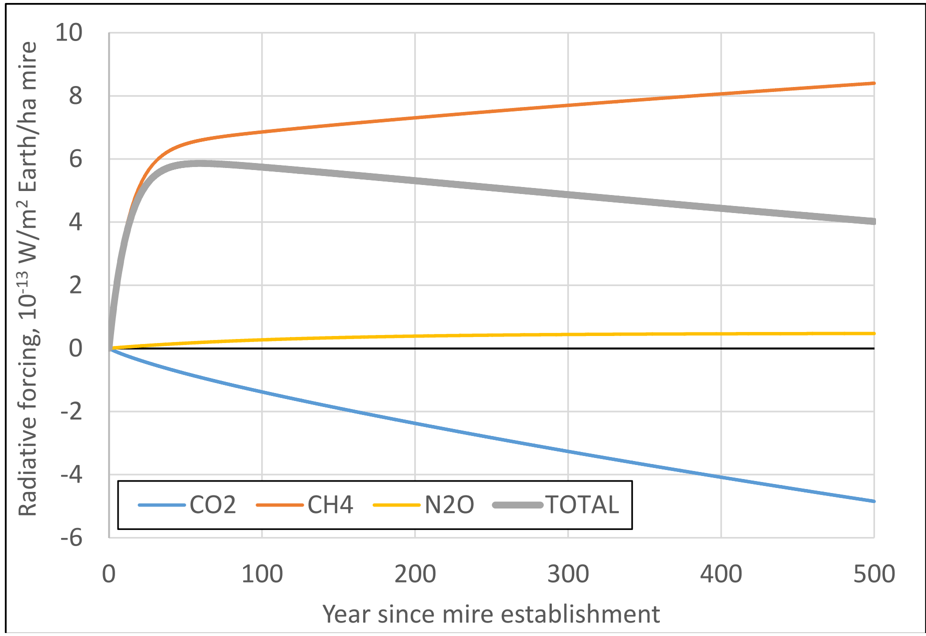
Gas	Total radiative efficacy 10^{-13} W m^{-2} kg^{-1}
CO2	0.0176
CH4	2.11
N2O	3.58

Atmospheric lifetime	
Gas	Half-life (years)
22% of CO2	∞
22% of CO2	273
28% of CO2	25
27% of CO2	3
CH4	9
N2O	84

”Best”
Treed bog
decades



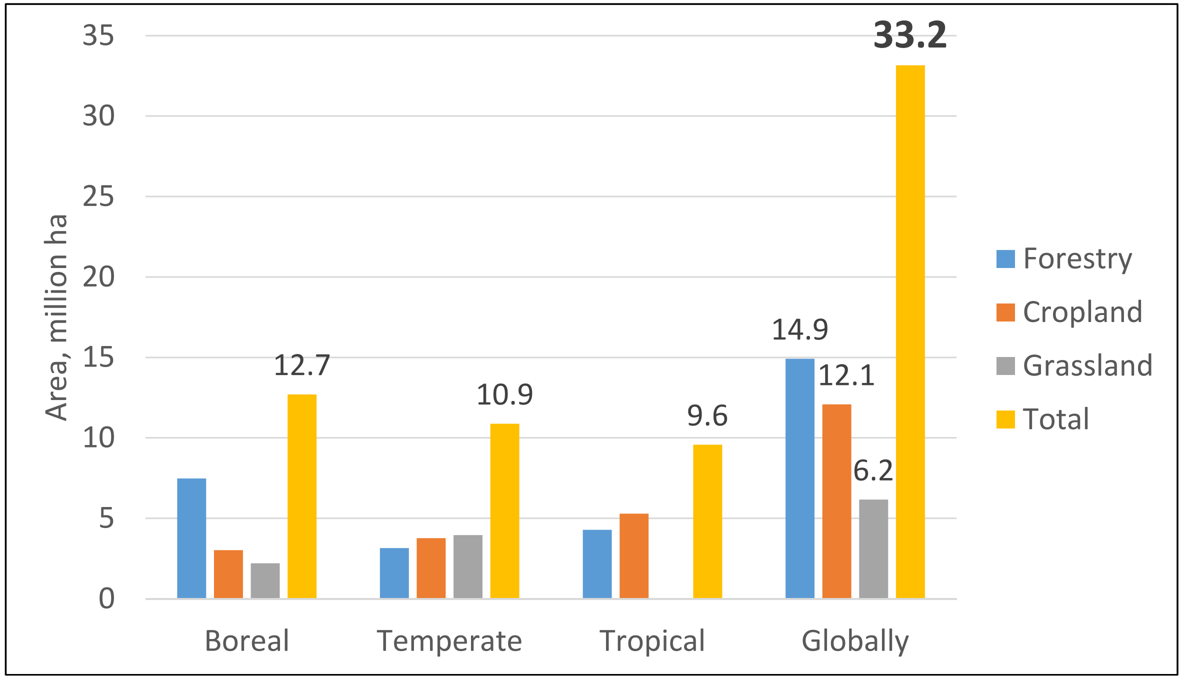
”Worst”
Sedge fen
millennia



So why talk about peatland rewetting?

- Peatlands have accumulated a huge carbon (C) storage as peat
  - ca. 500–600 Pg C (vs. 800 Pg C in the atmosphere)
- Peat C storage is vulnerable
  - high water table (WT) protects the C storage
  - land-use typically means lowering of WT by drainage (ditching)
    => gradual loss of peat C
- **1.** Peat C storage needs to be actively protected
  - careless land-use can lead to a big increase in the atmospheric C content
    => long-term (centennial) climate goals require peatland protection
- **2.** Greenhouse gas emissions need to be reduced
  - peatlands have been drained for agriculture and forestry
  - drainage causes CO_2 and N_2O emissions from soil to the atmosphere
    => short-term (decadal) climate goals require emissions reductions

Area **estimate** of drained peatlands



Equals to

- 2‰ of the Earths land area
- ca. 7% of the Earths peatland area

Rather conservative estimates based mainly on National Inventory Submissions 2017 for boreal (6 countries) and temperate (29 countries) climate zones.

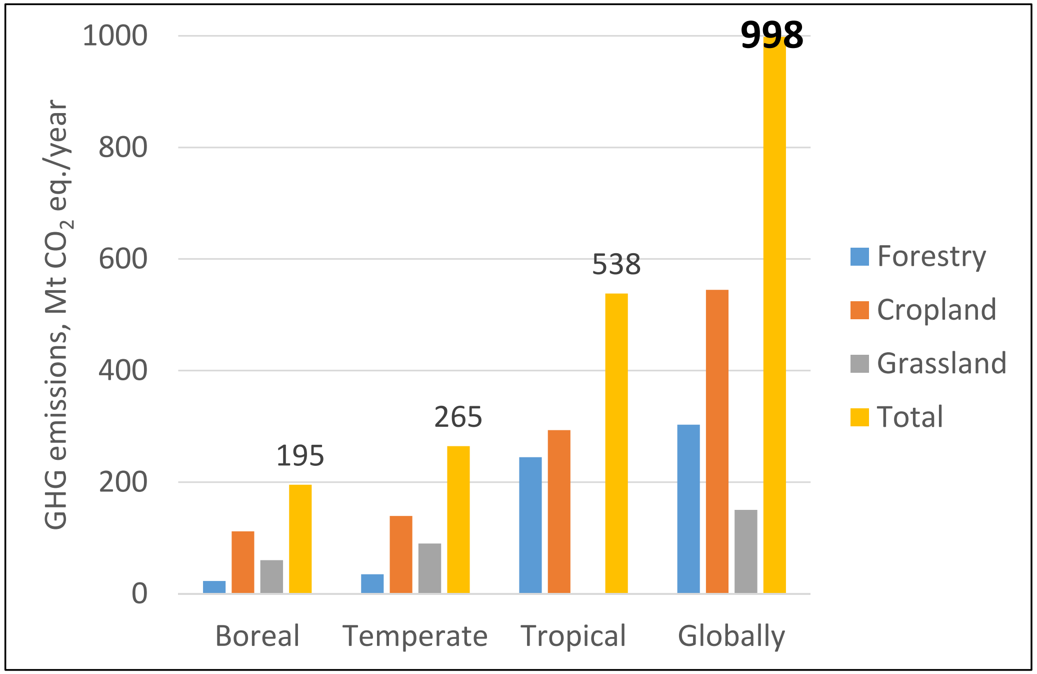
Other sources: Renou-Wilson et al. 2018 & David Wilson (Ireland), Chris Evans & Rebekka Artz (Great Britain), Andis Lazdiņš (Latvia), Björn Hånell (Sweden), Lise Dalsgaard (Norway), Kristiina Regina (Finland), Yearbook Forest 2016 (Estonia)

For the tropical zone, Malaysia, Indonesia and China are included, sources: Miettinen et al. (2016), Jyrki Jauhiainen and Strack et al. (2008)

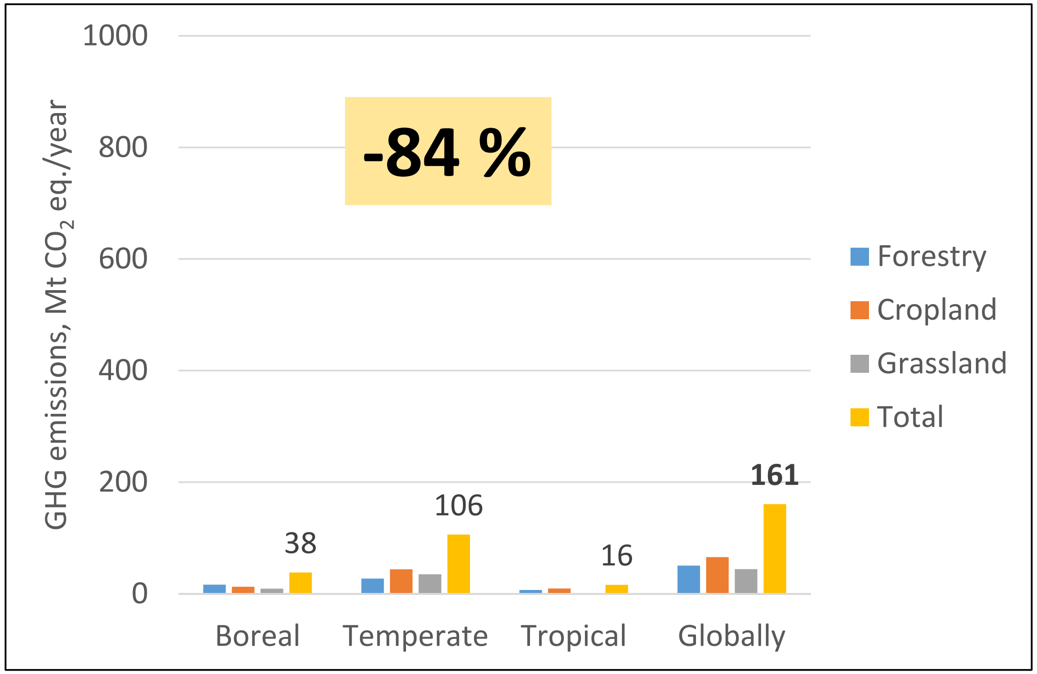
Emissions from **soil** in CO_2 equivalents (GWP_{100})

(based on IPCC (2014) emission factors for CO_2, CH_4 and N_2O updated by Wilson et al. 2016 for rewetted soils)

At the current, drained state



If rewetted



Huge emissions (ca. 25% of LULUCF) that could be greatly reduced!

Rewetting of forestry-drained peatlands – case Finland

Emissions from rewetted peatland soils (1)

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Emissions from forestry-drained peatland soils (2)

=

Effect of rewetting on emissions (3)

(1) Rewetted ≈ pristine peatland soils

	Gas emission, t gas/ha/year			Gas emission, t CO_2 eq./ha/year			
Rewetted (pristine) mire site type	**CO_2**	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**	**TOTAL**
Eu treed (Rhtkg = LhK, RhK)	-1.25	0.02	0.0011	-1.25	0.94	0.30	**0.00**
Eu mixed (Rhtkg = VLK, KoLK, RhSK)	-1.26	0.15	0.0011	-1.26	7.05	0.30	**6.10**
Meso treed (Mtkg = MK, KgK)	-1.25	0.02	0.0011	-1.25	0.94	0.30	**0.00**
Meso mixed (Mtkg = RhSR, VSK, VLR)	-1.26	0.15	0.0011	-1.26	7.05	0.30	**6.10**
Meso open (Mtkg = RhSN, VL)	-1.26	0.15	0.0011	-1.26	7.05	0.30	**6.10**
Oligo treed (Ptkg = PK, KR, KgR, PsR, PsK)	-1.06	0.02	0.0011	-1.06	0.94	0.30	**0.18**
Oligo mixed (Ptkg = VSR, TSR)	-1.28	0.15	0.0011	-1.28	7.05	0.30	**6.07**
Oligo open (Ptkg = VSN)	-1.50	0.24	0.0011	-1.50	11.28	0.30	**10.08**
Oligo-ombro treed (Vatkg = IR, KgR)	-1.29	0.02	0.0008	-1.29	0.94	0.22	**-0.13**
Oligo-ombro mixed (Vatkg = TR, LkR)	-1.37	0.05	0.0008	-1.37	2.35	0.22	**1.20**
Oligo-ombro open (Vatkg = LkKaN)	-1.32	0.15	0.0008	-1.32	7.05	0.22	**5.95**
Ombro treed (Jätkg = RaR)	-1.25	0.05	0.0008	-1.25	2.35	0.22	**1.32**
Ombro mixed (Jätkg = KeR)	-1.25	0.05	0.0008	-1.25	2.35	0.22	**1.32**
Ombro open (Jätkg = RaN, LkN)	-1.32	0.15	0.0008	-1.32	7.05	0.22	**5.95**

TOTAL = sustained annual CO_2 emission that would cause the same radiative forcing during the first 100 years ($SGWP_{100}$: 47 for CH_4, 270 for N_2O).

N_2O (t gas/ha/year): analysis of own measurements (unpublished)

CH_4 (t gas/ha/year): analysis of published measurements (Minkkinen & Ojanen 2013)

CO_2 (t gas/ha/year): = −(LORCA* + DOC emission + CH_4 emission) (*Turunen et al. 2012)

(2) Forestry-drained peatland soils

Forestry-drained peatland site type	Gas emission, t gas/ha/year			Gas emission, t CO_2 eq./ha/year			
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	TOTAL
Eu poorly drained (Rhtkg oj/mu)	0.64	0.016	0.0024	0.64	0.74	0.64	**2.02**
Eu well drained (Rhtkg tkg)	2.57	-0.001	0.0024	2.57	-0.04	0.64	**3.17**
Meso poorly drained (Mtkg oj/mu)	0.64	0.016	0.0024	0.64	0.74	0.64	**2.02**
Meso well drained (Mtkg tkg)	2.57	-0.001	0.0024	2.57	-0.04	0.64	**3.17**
Oligo poorly drained (Ptkg oj/mu)	-0.72	0.016	0.0008	-0.72	0.74	0.21	**0.22**
Oligo well drained (Ptkg tkg)	-0.72	-0.001	0.0008	-0.72	-0.04	0.21	**-0.56**
Oligo-ombro poorly drained (Vatkg oj/mu)	-0.72	0.016	0.0008	-0.72	0.74	0.21	**0.22**
Oligo-ombro well drained (Vatkg tkg)	-0.72	-0.001	0.0008	-0.72	-0.04	0.21	**-0.56**
Ombro poorly drained (Jätkg oj/mu)	-0.72	0.016	0.0008	-0.72	0.74	0.21	**0.22**
Ombro well drained (Jätkg tkg)	-0.72	-0.001	0.0008	-0.72	-0.04	0.21	**-0.56**

analysis of own partly published measurements (Ojanen et al. 2018)

analysis of own partly published measurements (Ojanen et al. 2010)

analysis of own mainly published measurements (Ojanen et al. 2013…)

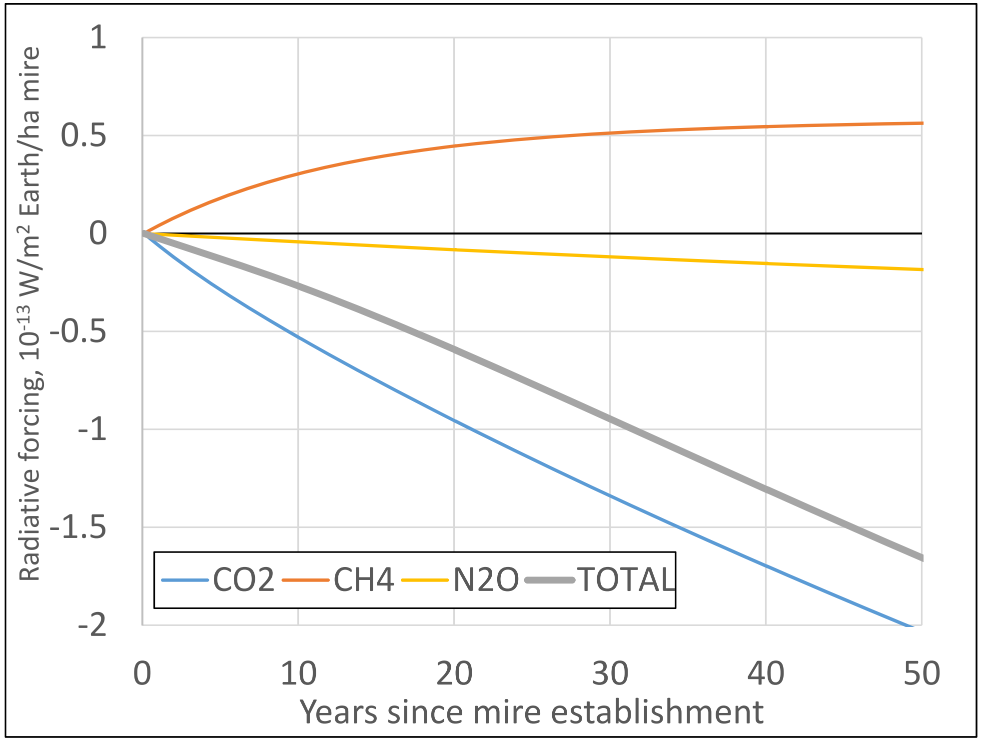
(3) Effect of rewetting on emissions

(= rewetted – forestry-drained)

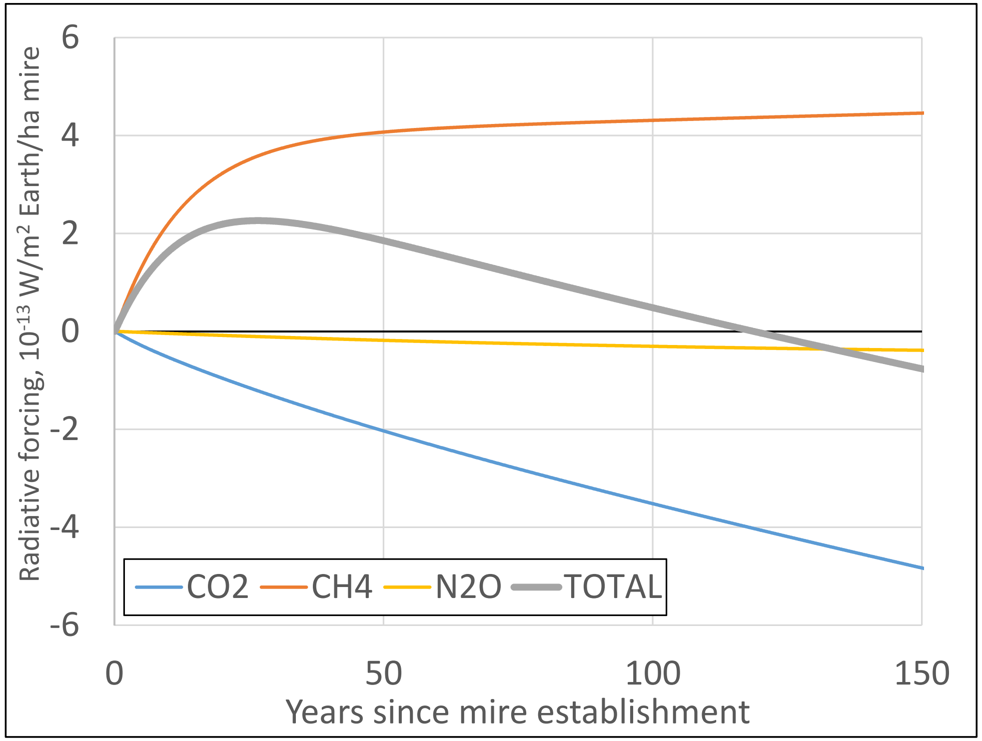
	Rewetted from poorly drained				Rewetted from well drained			
	Effect on emission, t CO_2 eq./ha/year				Effect on emission, t CO_2 eq./ha/year			
Rewetted (pristine) mire site type	**CO_2**	**CH_4**	**N_2O**	**TOTAL**	**CO_2**	**CH_4**	**N_2O**	**TOTAL**
Eu treed (Rhtkg = LhK, RhK)	**-1.89**	0.20	-0.34	**-2.02**	**-3.82**	0.98	-0.34	**-3.17**
Eu mixed (Rhtkg = VLK, KoLK, RhSK)	**-1.90**	6.31	-0.34	**4.08**	**-3.83**	7.09	-0.34	**2.93**
Meso treed (Mtkg = MK, KgK)	**-1.89**	0.20	-0.34	**-2.02**	**-3.82**	0.98	-0.34	**-3.17**
Meso mixed (Mtkg = RhSR, VSK, VLR)	**-1.90**	6.31	-0.34	**4.08**	**-3.83**	7.09	-0.34	**2.93**
Meso open (Mtkg = RhSN, VL)	**-1.90**	6.31	-0.34	**4.08**	**-3.83**	7.09	-0.34	**2.93**
Oligo treed (Ptkg = PK, KR, KgR, PsR, PsK)	-0.34	0.20	0.10	**-0.04**	-0.34	0.98	0.10	**0.74**
Oligo mixed (Ptkg = VSR, TSR)	-0.56	6.31	0.10	**5.85**	-0.56	7.09	0.10	**6.63**
Oligo open (Ptkg = VSN)	-0.78	10.54	0.10	**9.86**	-0.78	11.32	0.10	**10.64**
Oligo-ombro treed (Vatkg = IR, KgR)	-0.57	0.20	0.01	**-0.35**	-0.57	0.98	0.01	**0.43**
Oligo-ombro mixed (Vatkg = TR, LkR)	-0.65	1.61	0.01	**0.98**	-0.65	2.39	0.01	**1.76**
Oligo-ombro open (Vatkg = LkKaN)	-0.60	6.31	0.01	**5.73**	-0.60	7.09	0.01	**6.51**
Ombro treed (Jätkg = RaR)	-0.53	1.61	0.01	**1.10**	-0.53	2.39	0.01	**1.88**
Ombro mixed (Jätkg = KeR)	-0.53	1.61	0.01	**1.10**	-0.53	2.39	0.01	**1.88**
Ombro open (Jätkg = RaN, LkN)	-0.60	6.31	0.01	**5.73**	-0.60	7.09	0.01	**6.51**

Effect of rewetting on radiative forcing

Meso-eutrophic treed mire



Meso-eutrophic mixed/open mire



Let's not forget the trees (work in progress…)

Average tree growth/standing stock at Finnish forestry-drained peatlands
(National Forest Inventory, biomass expansion factor 0.7 Mg dry weight /m^3 stem volume (Lehtonen et al. 2004))

	stem volume		CO_2 sink/storage in(to) tree biomass
Tree growth	2–7.5 m^3/ha/year	=>	**2.6–9.6 t/ha/year**
Standing stock	70–240 m^3/ha	=>	**90–307 t/ha**

	to open mire	to mixed mire	to treed mire
Soil effect	+2.93…+10.64	+0.98…+6.63	−3.17…+1.88
Tree effect, from:			
forestry	↑	↗→	↗→↘
abandoned	↑	↗	↗→

What happens to the tree stand at rewetting has a major effect on the decadal time scale!

Can we rewet a peatland site?

- Typically, a peatland/mire consists of sites with varying fertility and wetness.
- Typically, restoration aims at rewetting a complete mire.
- => Rewetting only the sites optimal for climate change mitigation is often difficult.

Rules of thumb:

- Aim at rewetting meso-eutrophic peatlands
  - Big peat carbon losses if drainage continues
- Let oligotrophic and ombrotrophic peatlands rewet themselves
  - Big peat carbon losses unlikely
  - Tree stand CO_2 sink outcompetes peat carbon loss for a long time

Payment for ecosystem services? Ecological compensation?

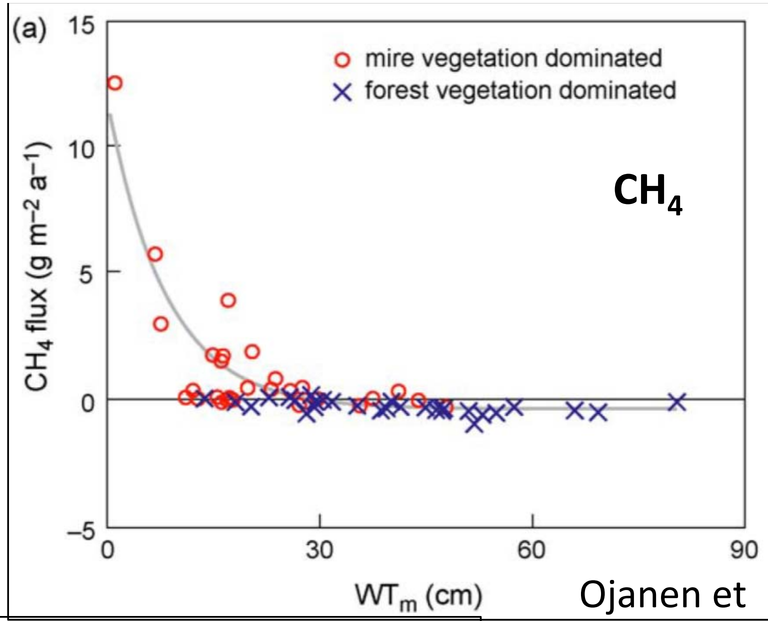
- Protecting peat carbon storage at meso-eutrophic sites a feasible ecosystem service?

- Hard to compensate current greenhouse gas emissions
  - In most cases, the rewetted peatland needs to compensate for itself first.

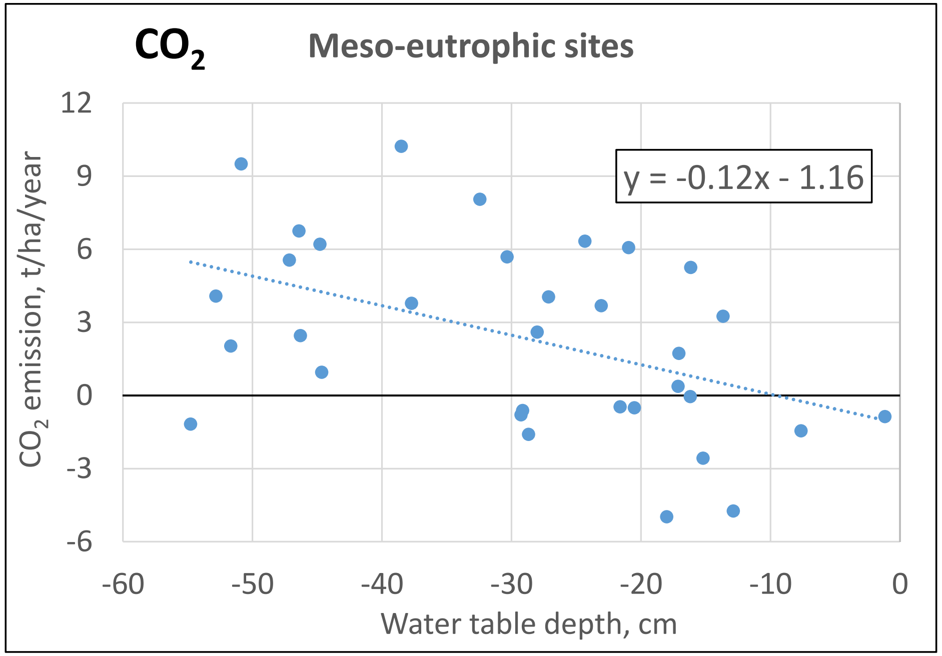
Improving forestry practises?

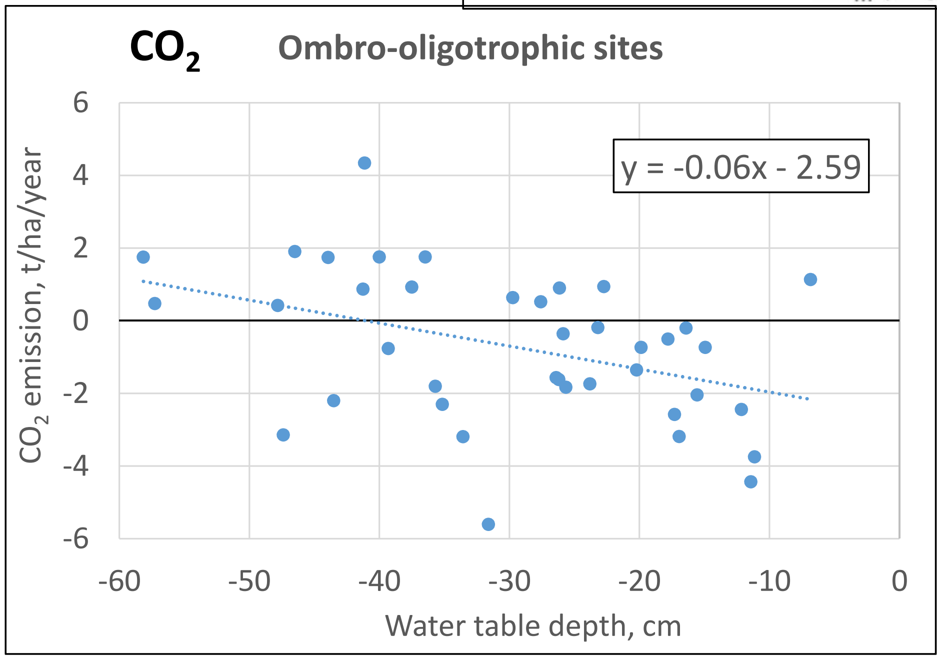
- When considering environment, also other options than rewetting exist.
- Moving from intensive drainage towards paludiculture?
  - Can we decrease the CO_2 and N_2O emissions from soil?
  - How much can we raise the water table without increasing CH_4 emissions?
- Just letting the trees grow?
  - Probably the best option in many cases at the decadal time scale.
  - Our current tree stands are relatively young.
  - Loosing the topmost peat layer but keeping the rest?

Improving forestry practises?



Ojanen et al. 2010

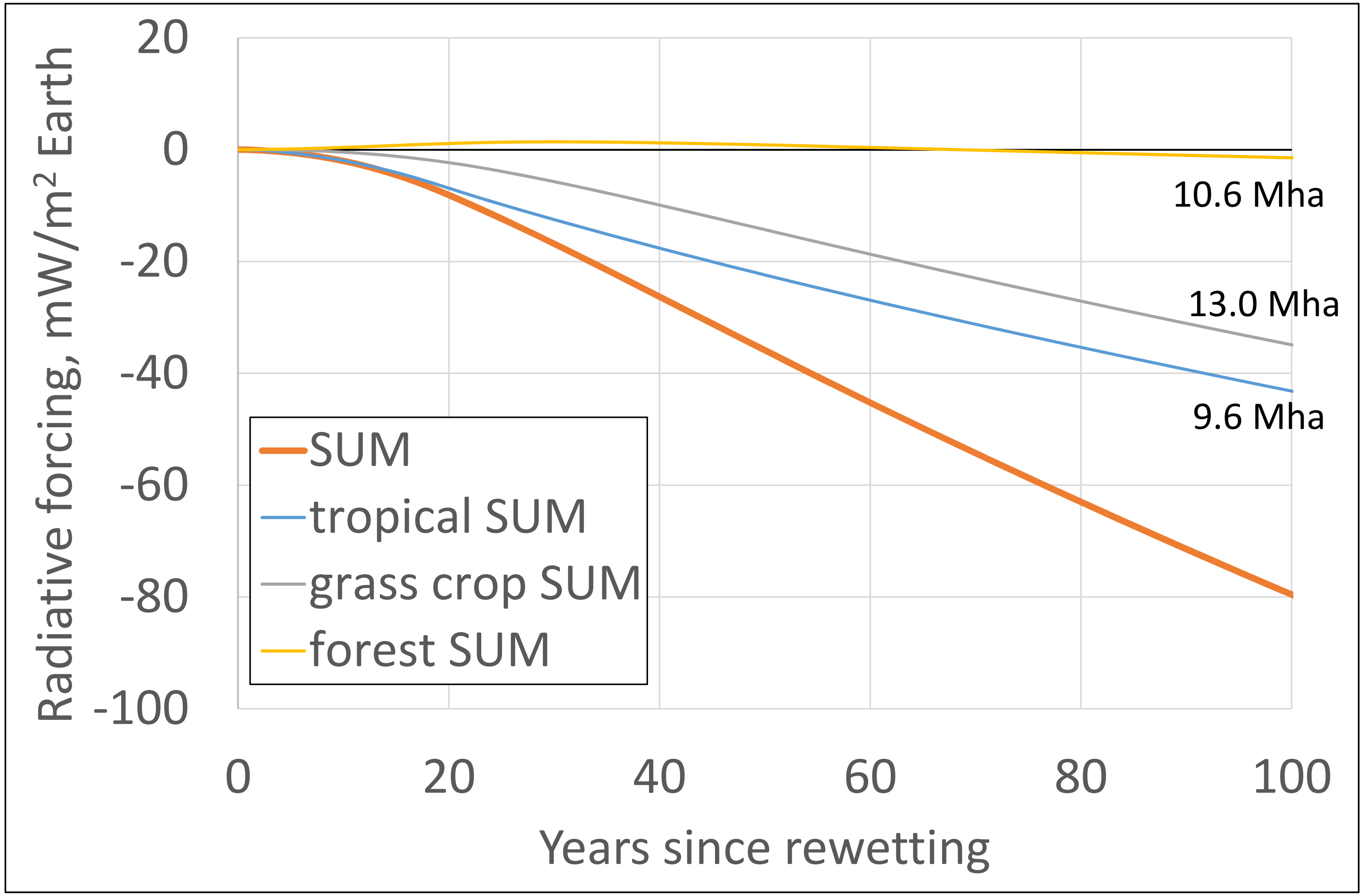




For further details, see: https://tuhat.helsinki.fi/portal/en/person/pjojanen

Some perspective

Global rewetting of all the drained peat soils



Tropical peat soils and cropland and grassland soils important goals for rewetting!
Boreal and temperate forestry-drained peat soils have a small effect.

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