Soil GHG emissions and C pools in afforested arable land

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* Study sites, Soil respiration, CH4, N2O measurements, modelling
* Results: annual fluxes

Mineral soils fields:
* Study sites, carbon pool measurements
* Results: carbon pools

Discussion
Afforestation of agricultural land in Finland

Total 1969-2004: 244 857 ha

- Almost 1 mil. ha of peatlands drained for agricultural purposes
- Afforested peat fields: over 80 000 ha
Soil characteristics 1: Peat fields

Peat characteristics:
- Well humified
- High bulk density
- High nitrogen content
- Increased pH as a result of liming
- Mineral soil often mixed in the peat

Bulk density, g/l

- Drained peatland forest
- Afforested peat field
- Field, mineral soil added
Soil pH, P, Ca amounts even 70 years after afforestation higher than in adjacent forests (Wall & Hytönen 2006)
Aims

Peat fields
Describe the annual soil GHG-fluxes in a typical afforested organic soil croplands

To study the effect of climatic factors and soil properties on the soil CO$_2$ fluxes

Mineral soil fields
Study effects of afforestation age and tree species on carbon pools
Peat soils: Methods

Study sites

- 12 afforested sites
- Species: Birch and pine
- Age: 10 - 37 a
- Peat depth: 30 - >200 cm
- Soil ash content: 7-71%

SITE 5 Kannus
Scots pine
stand age: 33 a
stand volume: 163 m³/ha
peat depth: 50 cm
Peat soils: Measurements

Peat decomposition
(heterotrophic soil respiration)
- Measurements 2003-2005
- 3-5 sample plots/site
- Portable CO\textsubscript{2} measurement system
- Measurements weekly during the growing season and once a month during the winter
- Soil temperature, WT and soil moisture measured simultaneously with chamber measurements
- Continuous soil temperature and soil moisture measurements
• Non-linear regression between measured soil temperature (5 cm depth) and soil respiration for each sample plot separately
  • flux = a* EXP(b*T5)
  • Data from years 2003 and 2004 was combined
  • Temperature at 5 cm depth explained 57-95% of the variation in soil respiration
• Annual soil respiration was calculated using hourly soil temperature data
Gas samples collected in 60 ml plastic syringes in the field with static chamber method (52 chambers) or gas gradient method from snow.

Samples were analysed with a gas chromatograph.
**Peat soils: Average annual soil CO$_2$ effluxes**

Annual soil CO$_2$ effluxes:

207 … 539 g CO$_2$-C m$^{-2}$a$^{-1}$.

Wintertime effluxes:

9% … 25%

average 16%.
Peat soils: Weather-derived long-term variation

30-year weather data.

Simulated annual values ranged 10% above and below the long-term average.

*Simulated annual soil CO$_2$ effluxes and mean summer air and soil temperatures at the depth of 5 cm on afforested cropland site 6.*
Peat soils: Methane

Annual CH₄ flux
kg CH₄-C ha⁻¹

kg CH₄-C ha⁻¹

afforested
afforested
abandoned
abandoned
Grass
Barley
Forest

a) Maljanen et al. 2003, b) Maljanen et al. 2004
c) Nykänen et al. 1998 d) Alm et al. 1999
e) Maljanen et al. 2006
Peat soils: $\text{N}_2\text{O}$

**kg N$_2$O-N ha$^{-1}$**

**Afforested**

- Birch 18
- Birch 18
- Pine 33
- Pine 33
- Birch 35
- Birch 11
- Field a
- Field b
- Field c
- Field d
- Field e
- Cult. a
- Cult. b
- Cult. c
- Cult. d
- Birch b
- Mixed g
- Spruce f
- Spruce f
- Pine e

**Uncultivated**

**Cultivated**

- Afforested
- Abandoned
- Grass
- Barley
- Forest

a) Maljanen et al. 2004
b) Maljanen et al. 2003
c) Regina et al. 2004
d) Regina et al. 2004
e) Regina et al. 1998
f) Huttunen et al. 2003
g) Nykänen et al. 1998
Comparison between C bound annually in tree biomass and annual C fluxes from peat

Site 1: 3280 kg C ha\(^{-1}\)yr\(^{-1}\)  
Site 2: 1860 kg C ha\(^{-1}\)yr\(^{-1}\)  
Site 3: 1600 kg C ha\(^{-1}\)yr\(^{-1}\)  
Site 4: 40 kg C ha\(^{-1}\)yr\(^{-1}\)  
Site 5: 2080 kg C ha\(^{-1}\)yr\(^{-1}\)  
Site 6: 440 kg C ha\(^{-1}\)yr\(^{-1}\)
Mineral soils: Methods

88 afforested mineral soil fields sampled
  27 Scots pine stands
  35 Norway spruce stands
  26 Silver birch stands

Located in South and Central Finland

Chronosequence:
  Stand ages: 10 – 70 years
Mineral soils: Sampling

From each stand 10 samples from
  Ground vegetation
  Litter
  Humus
  Soil to depth of 50 cm

Tree stand and stumps were measured for determination of biomass
Carbon determination

Soil: Carbonate C eliminated with HCl.
C-content with LECO

Litter, C-content with LECO
Humus, C-content with LECO

Vegetation C-content with LECO

Tree stand
*Above-ground (stem, living and dead branches, stump) and below-ground biomass with allometric biomass functions (Marklund 1987, 1988).
*50 % was used as C-content of trees.
*Mass of roots and stumps of trees removed in thinnings calculated based on stump diameter equations.
Mineral soils: C pools

Organic layer

A = Stand age 9-25 a
B = Stand age 26-40 a
C = Stand age > 40 a

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Mineral soils: C pools 2

A=Stand age 9-25 a,  B=Stand age 26-40 a,  C=Stand age > 40 a

Organic layer 0-50 cm 0-100 cm 0-75 cm

Peltoniemi et al. 2004
Liski & Westman 1995
Kauppi et al. 1997

A Pine B Spruce C Birch Vt Mt OMt Forest soils

C, kg/m²
Mineral soils: C in soil, biomass and litter

A=Stand age 9-25 a  
B=Stand age 26-40 a  
C=Stand age > 40 a
Conclusions

Afforested peat fields

- Afforestation decreases heterotrophic soil CO$_2$ emissions of cultivated organic croplands
- When C bound in vegetation is taken account, the CO$_2$ balance of the sites changes considerably
- No change in N$_2$O emissions after afforestation: still rather high
- No change in CH$_4$ fluxes after afforestation: still small sinks
Conclusions

Afforested mineral soil fields

• Soil C pool large compared with continuously forested sites

• Development of organic layer after afforestation is slow process but will result in increase of C pools over time

• Decrease of soil C in plow layer
  - Assumption: differences in properties across sites solely due to differences in time since afforestation
  - Repeated soil sampling needed