Soil based greenhouse gas fluxes at Wallaby Creek – magnitude, spatial and temporal variability

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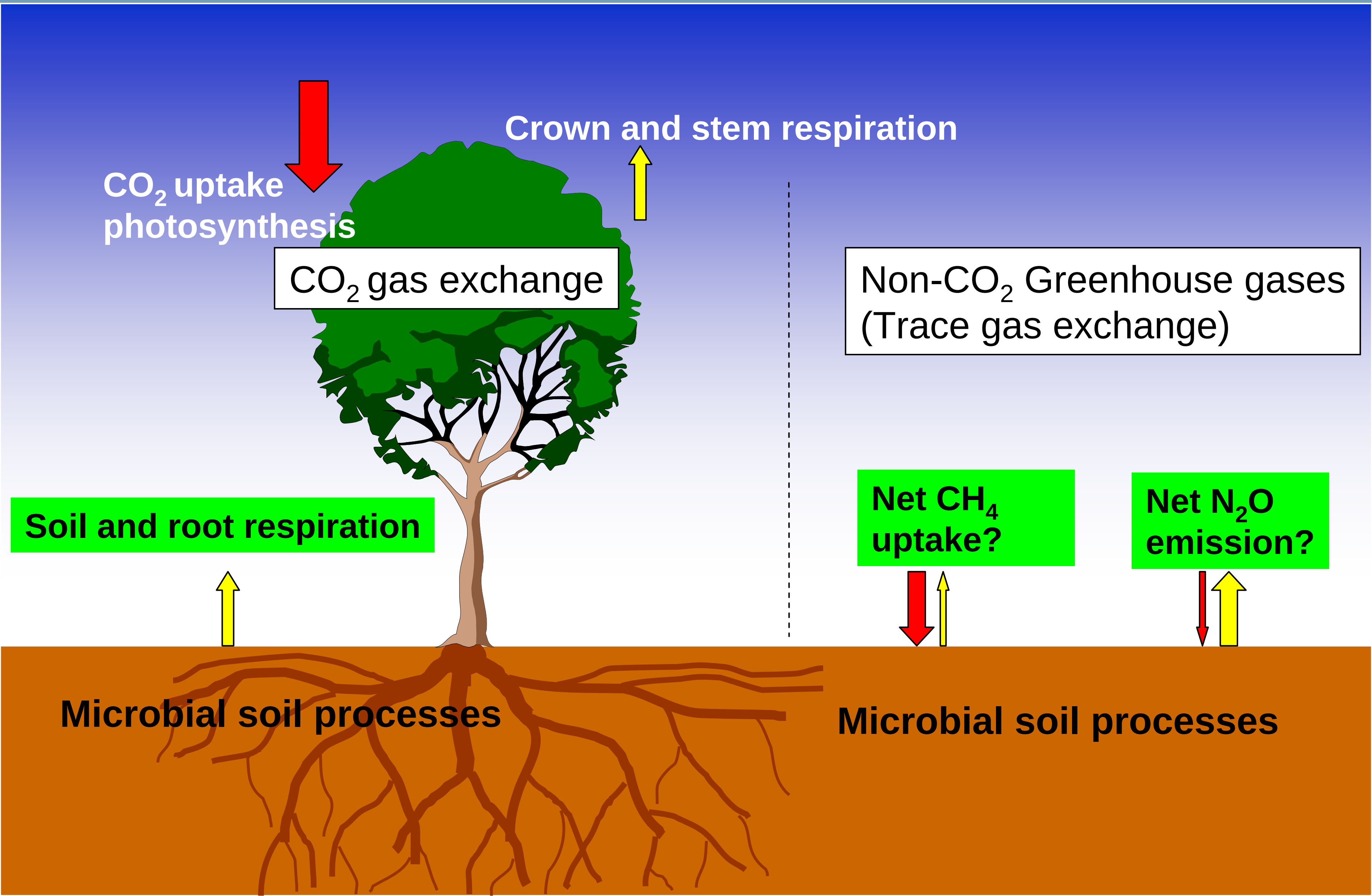
Forest Greenhouse Gas (GHG) balance



Relevant gas species

	Pre-ind.	Current	**Growth**	***GWP***
CO_2	280	375	**1.5 ppm/yr**	**1**
CH_4	0.80	1.78	**7.0 ppb/yr**	**25**
N_2O	0.28	0.31	**0.8 ppb/yr**	**320**

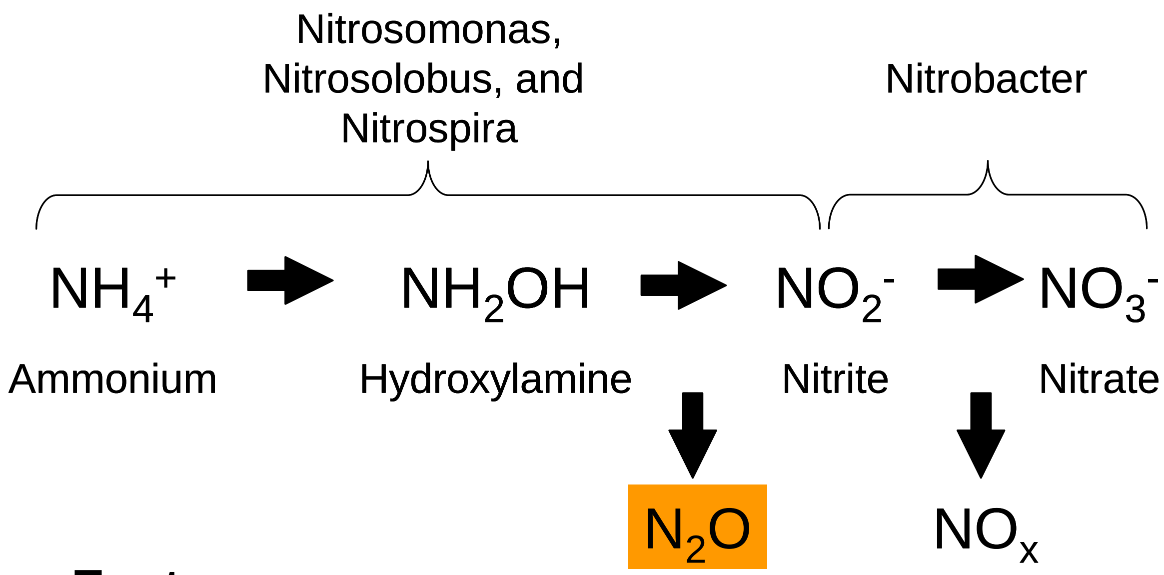
- **Global warming potential** (**GWP**) relates all GHG's to the radiative forcing of CO_2, based on absorption of radiation and persistence in atmosphere
- **Carbon dioxide equivalents** (**CO_2-e**), normalise all gases to that of CO_2 using their GWP

Processes behind soil GHG fluxes

Nitrous oxide (N_2O) can be produced in soils through two biological pathways: nitrification and denitrification

Nitrification – biological oxidation of reduced forms of nitrogen

- **Nitrification**:
  Aerobic, ammonia oxidizing bacteria produce NH_2OH and nitrate (NO_3) from ammonium (NH_4), producing some nitrous oxide (N_2O) as by-product (nitrifier-denitrification). Common in well drained, aerated soils



- **Regulating Factors:**
  NH_4^+ and NO_2^- supply, soil water content, soil aeration, soil pH, temperature

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Denitrification – biological reduction of oxidised forms of inorganic nitrogen

- **Denitrification:**
  Anaerobic bacteria reduce nitrate (NO_3) to gaseous nitrogen (N_2). Nitrous oxide (N_2O) is an **integral step** in this process. Common in wet or compacted soils.

Soluble materials (found in soil solution): NO_3^- (Nitrate), NO_2^- (Nitrite)

Gaseous products (found in soil solution and gas phase): NO (Nitric oxide), N_2O (Nitrous oxide), N_2 (Di-nitrogen)

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

Nitrate → Nitrite → Nitric oxide → Nitrous oxide → Di-nitrogen

- **Regulating factors:**
  Supply of NO_3- soil pH, temperature, soil water content, soil aeration

Processes behind soil GHG fluxes

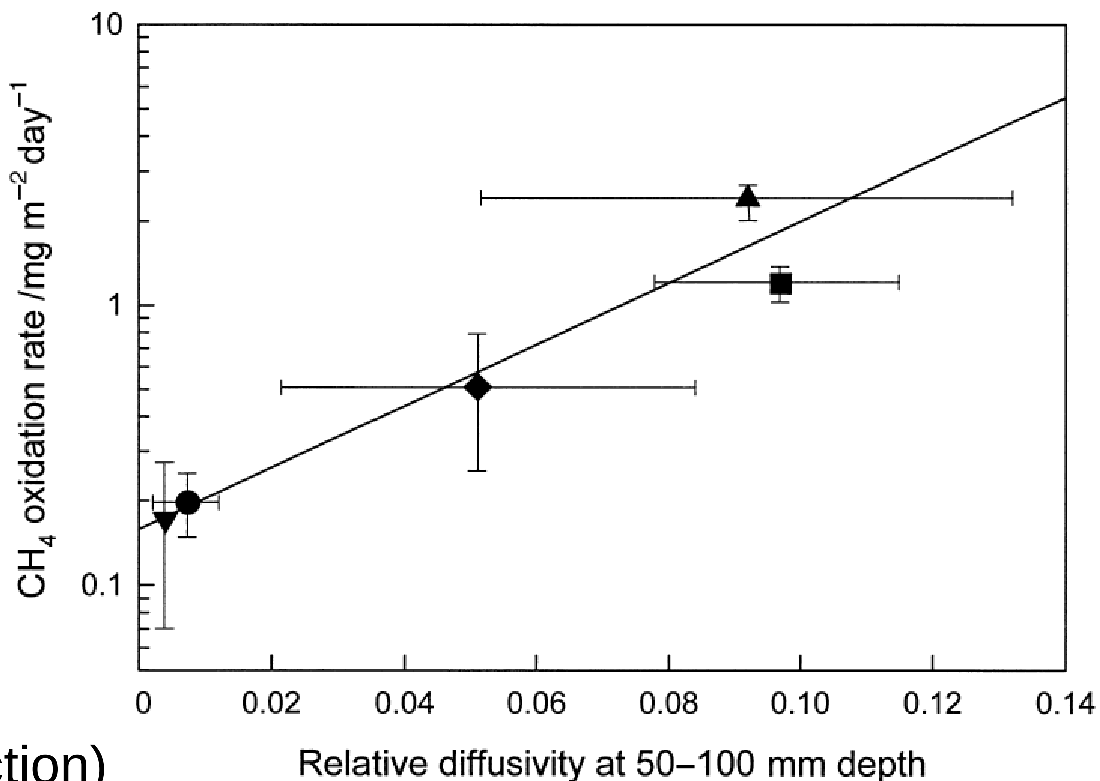
Net soil-atmosphere methane (CH_4) exchange is the balance of co-occurring CH_4 production and CH_4 oxidation processes

Soil methane emission

- Methane is produced by anaerobic methanogenic bacteria, during soil organic matter decomposition and mineralisation
- Methanogenic bacteria require:
  - anoxic conditions
  - C substrates
- Methane emissions increase with:
  - greater temperature
  - increasing soil water status
- However methane production is generally negligible in well drained upland soil systems

Soil methane oxidation

- Methane is consumed in soils by methanotrophic bacteria
- Soils represents 6-8 % of global CH_4 sink
- Soil methanotrophic bacteria require:
  - aerobic (O_2) conditions
  - CH_4 as substrate
- Methanotrophic bacteria:
  - **MMO-enzyme**
  - **can use CH_4 as sole source of energy**
- Diffusion limits oxidation:
  - soil water content
  - soil texture
  - soil bulk density (compaction)



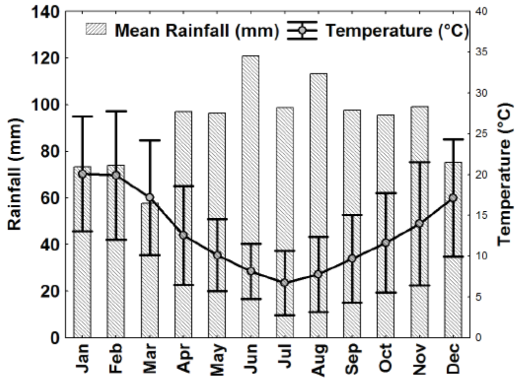
Smith et al. (2003)

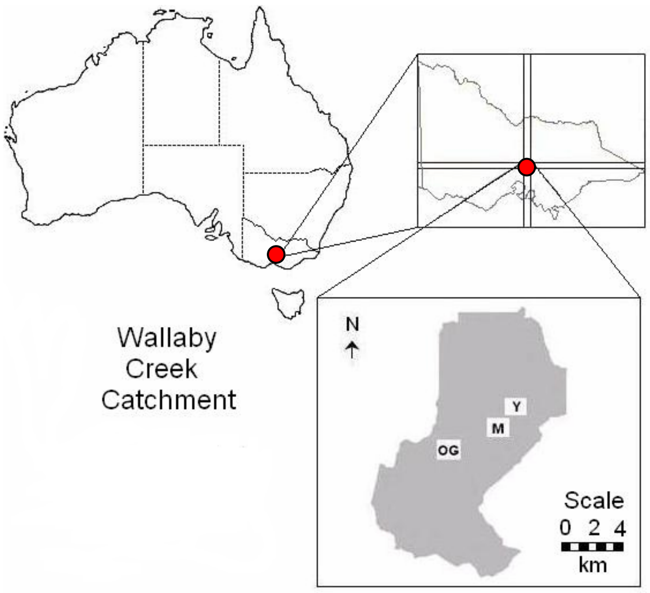
- Soil N status limits oxidation – NH_4+ (thought to inhibit MMO)

Site

Wallaby Creek, King Lake NP

– Comparison of two *Eucalyptus regnans* regrowth stands (30 and 80 years old) with a long term unburnt stand (project started in 2006 and seasonal measurements were taken in 2008)





Over mature

80 years old

30 years old

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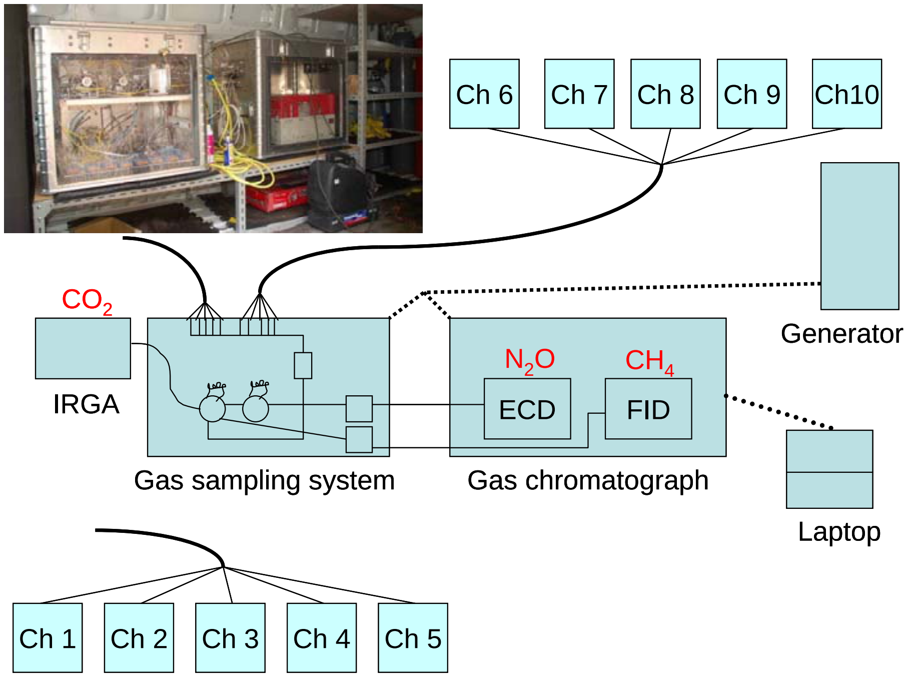
Measuring approach

Soil GHG fluxes were measured with two different measuring systems:

- Manual chamber incubations; to investigate **spatial** variation of soil GHG fluxes **within** and **between** different aged forest stands

- Automated chamber measuring system; to investigate **temporal** variation of soil GHG fluxes next to the CO_2 eddy covariance tower (2 week period in 2006)



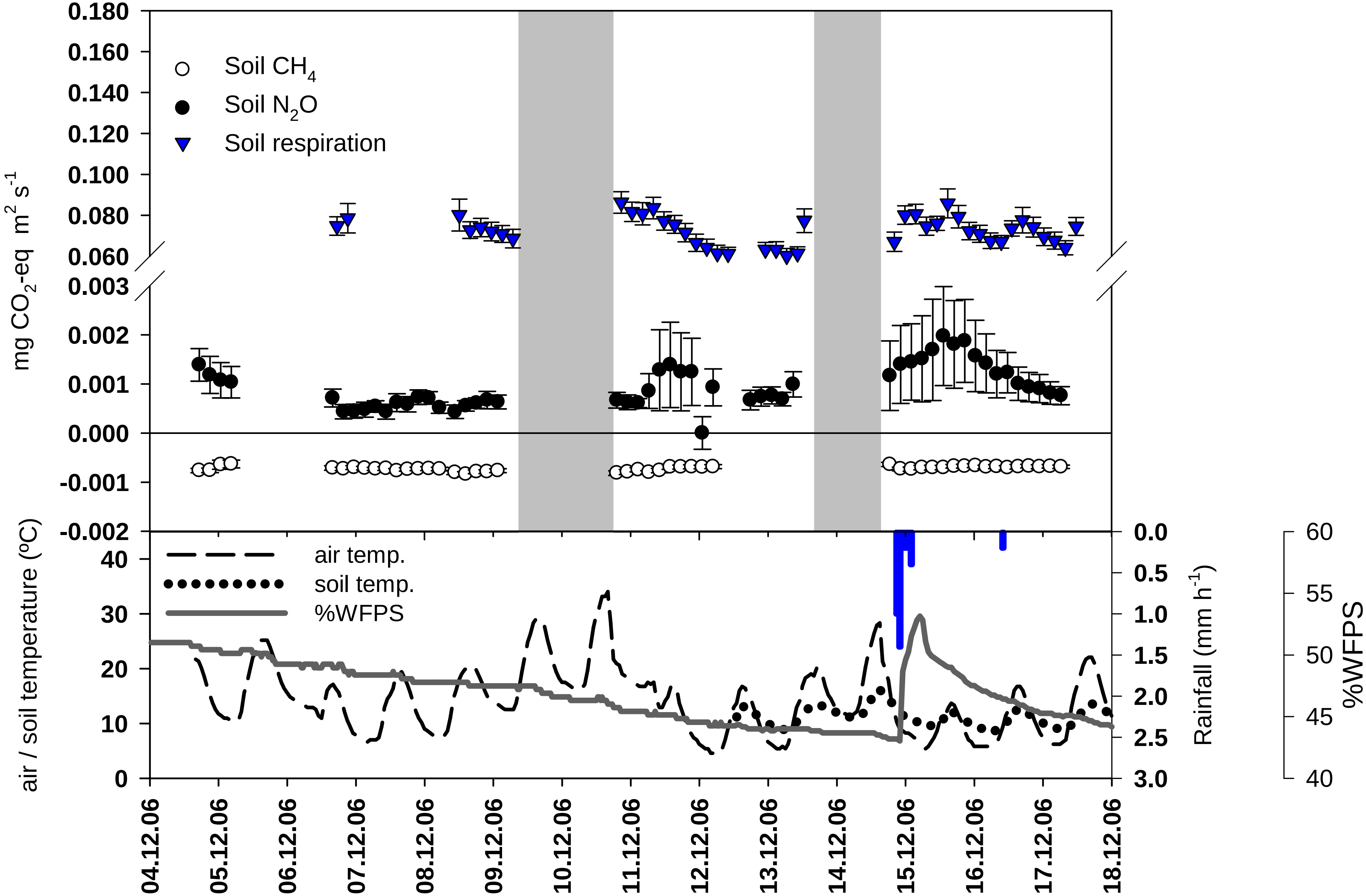
Additional measurements

Established methods were used to determine:

- soil bulk density
- soil gravimetric, volumetric water content
- soil temperature
- soil pH and EC
- particle size analyses
- soil inorganic N status
- soil total N, C, litter quantity
- litter quality (N, C)

Results

Temporal variability of soil GHG fluxes (O)



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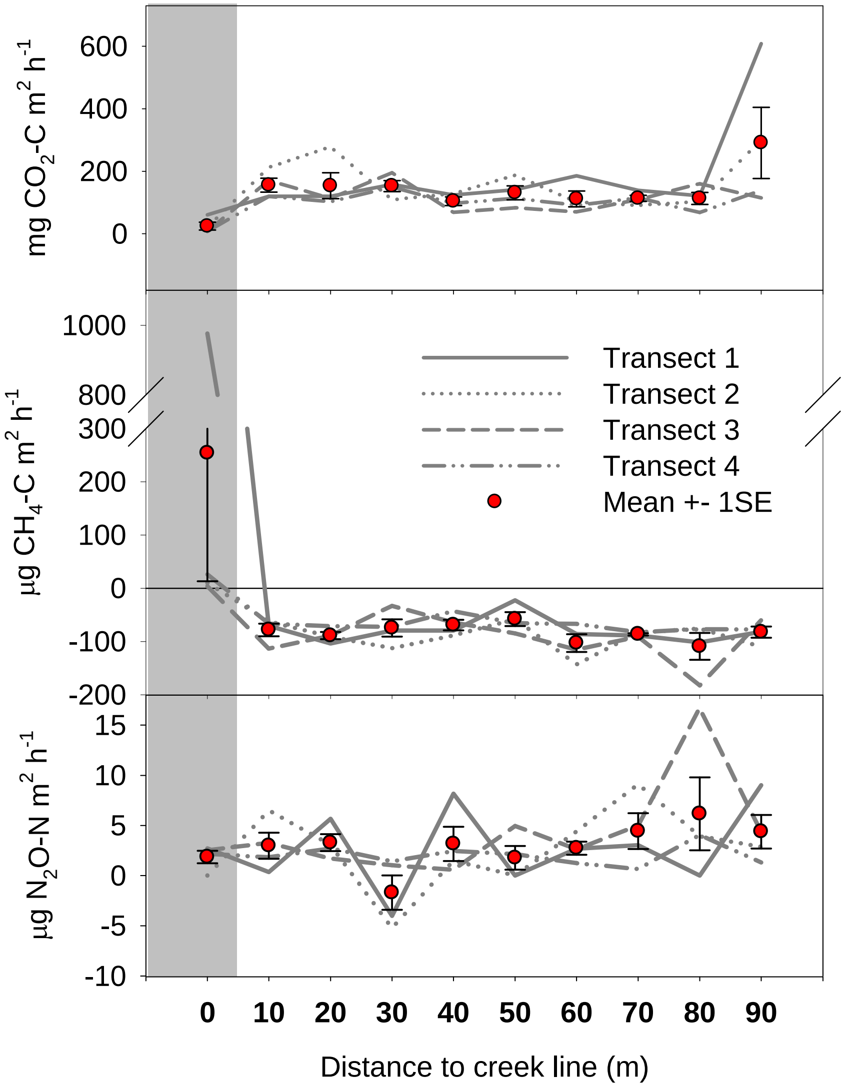
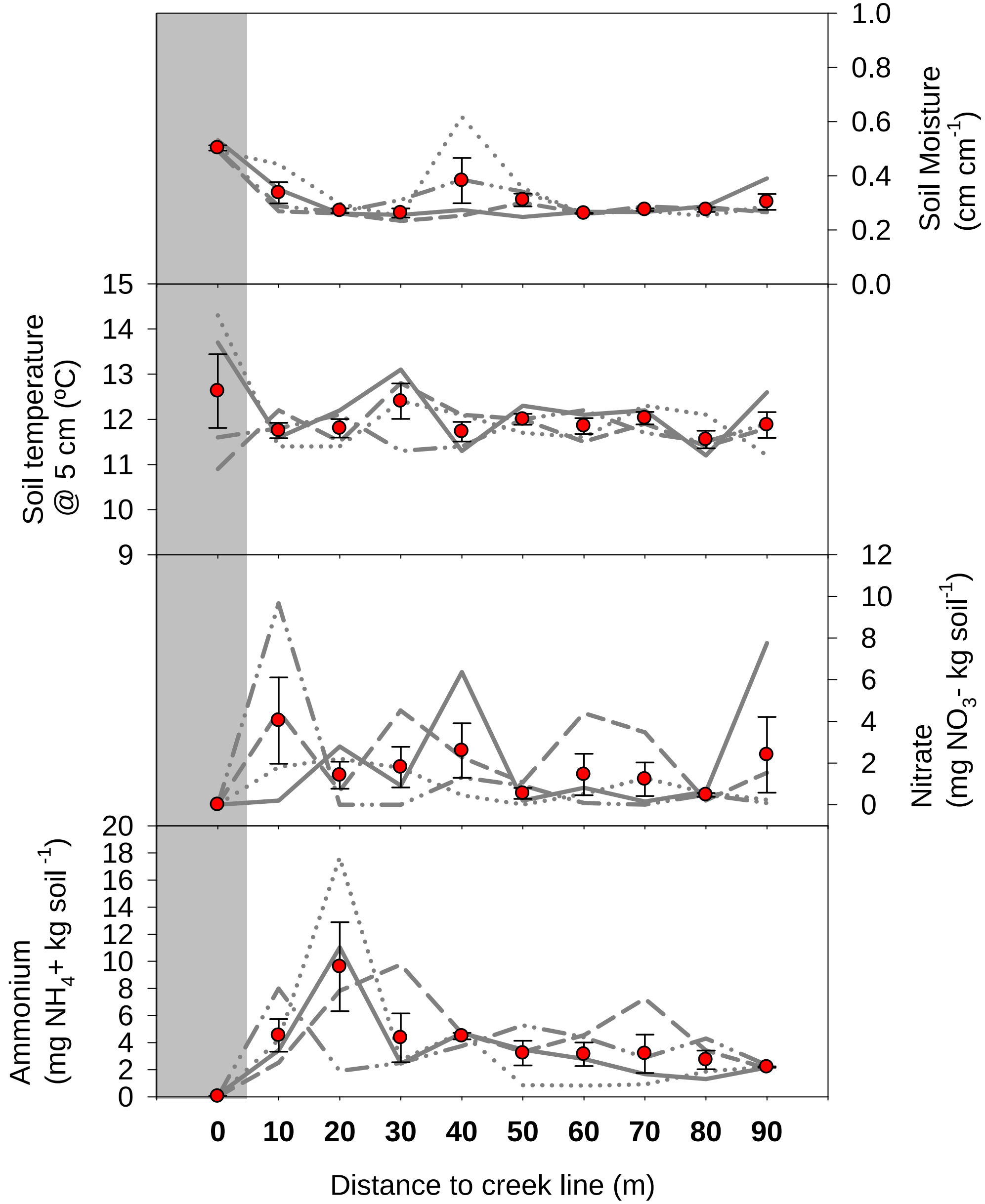
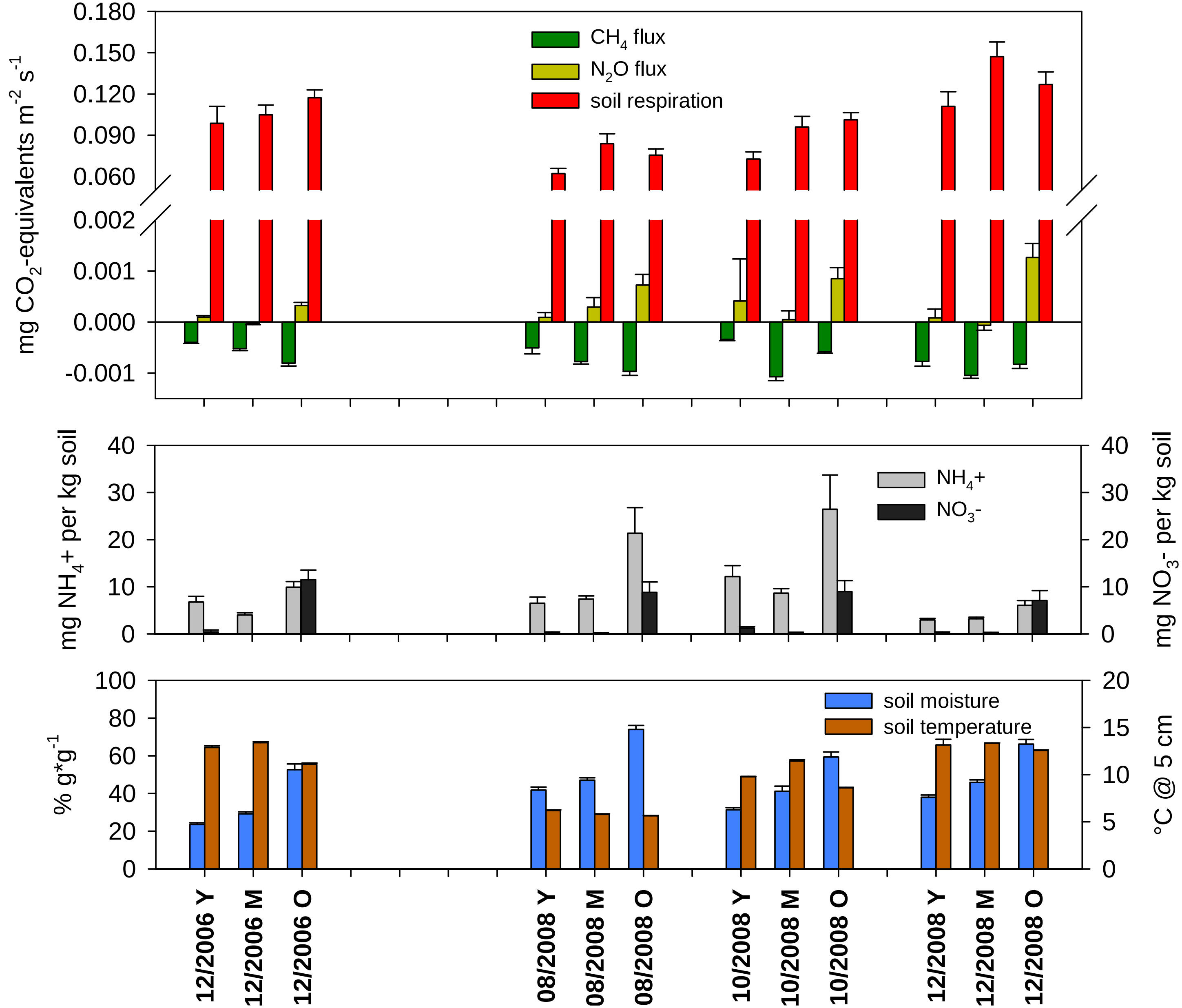
Spatial variability of soil GHG fluxes (O)

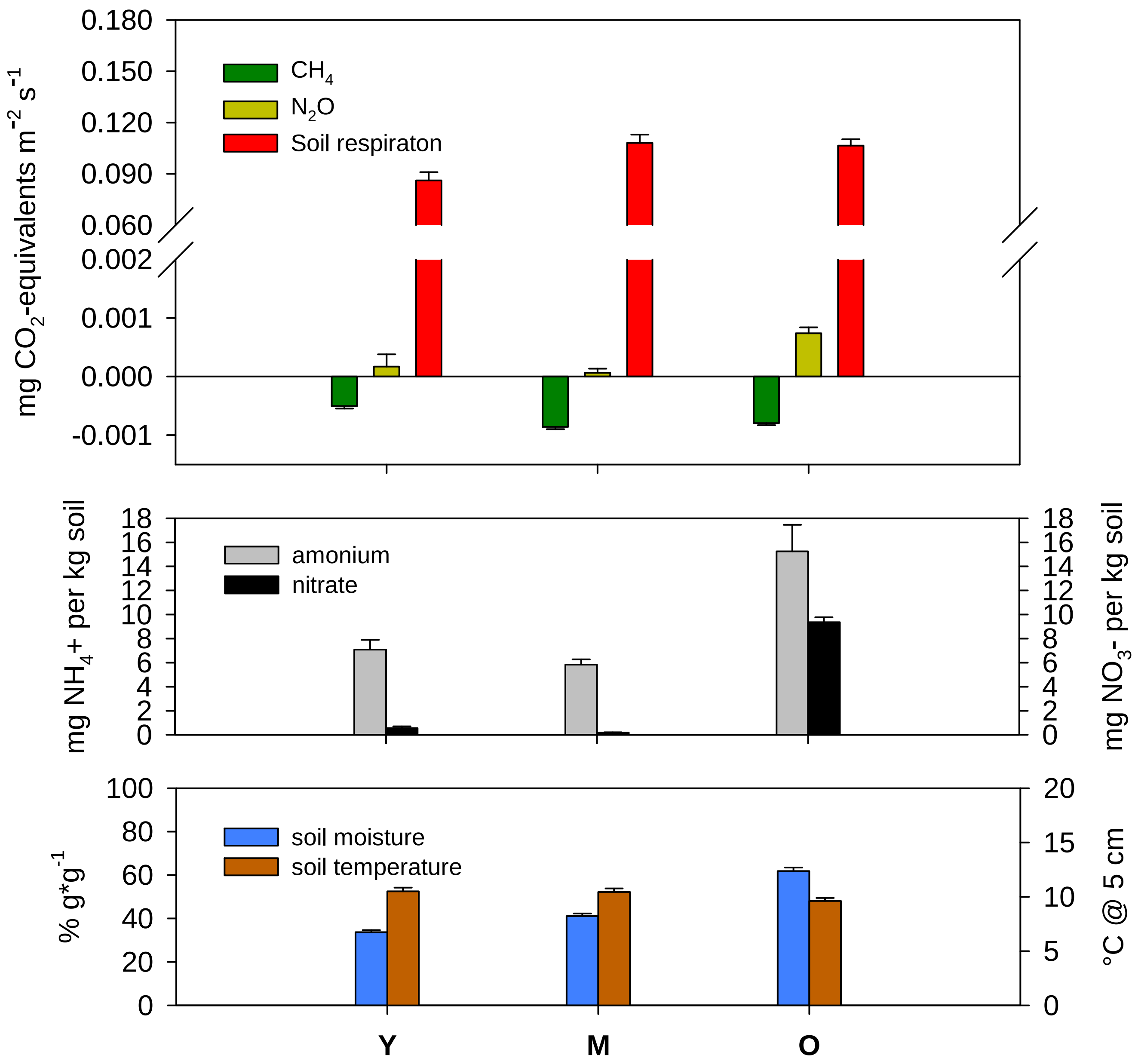




Seasonal variability of soil GHG fluxes in different age classes



Differences between age classes

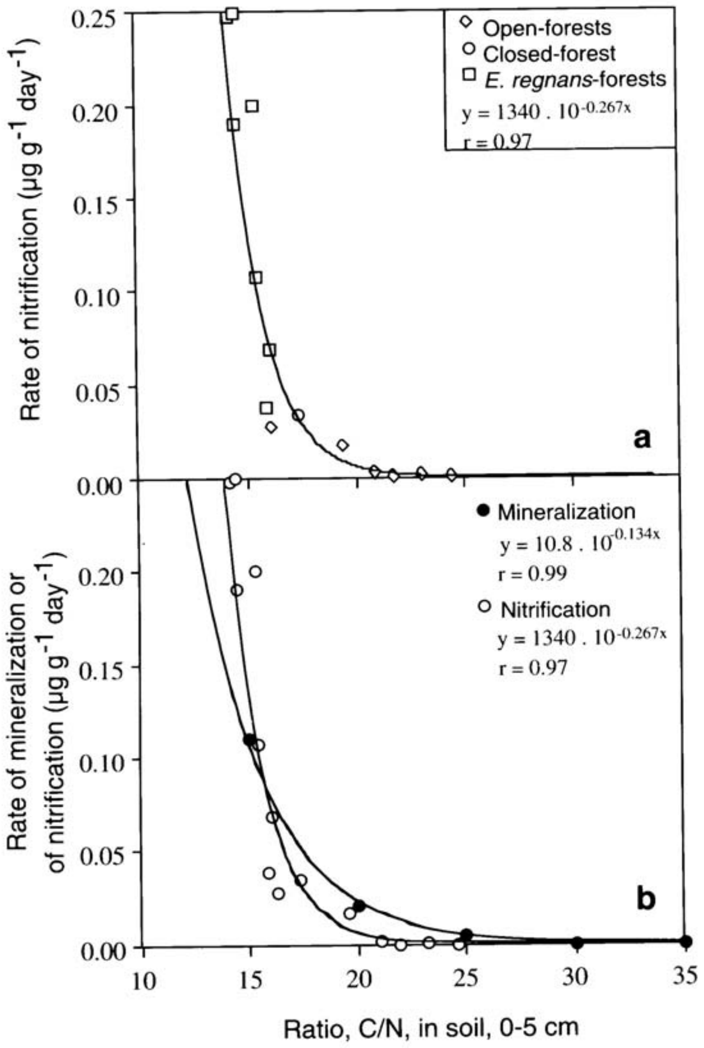


C:N ratio might determine nitrification and mineralisation processes

- Soil C:N ratio determines the rate of nitrification and mineralisation in eucalypt forest soils

- This may indirectly determine N_2O production

- Soil C:N > 20 leads to minimal nitrification, and minimal N_2O production.

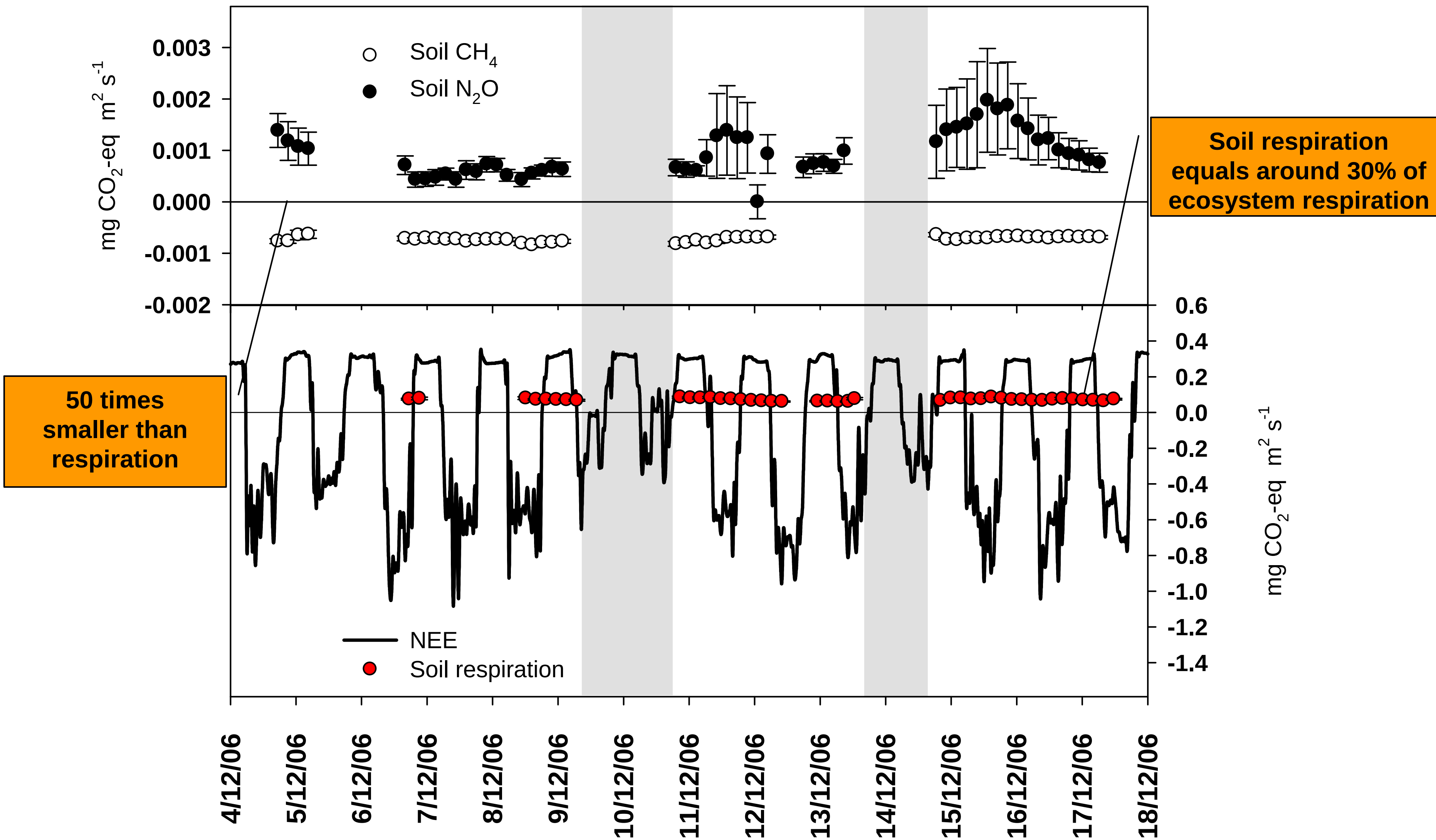


Attiwill & Adams (1996)

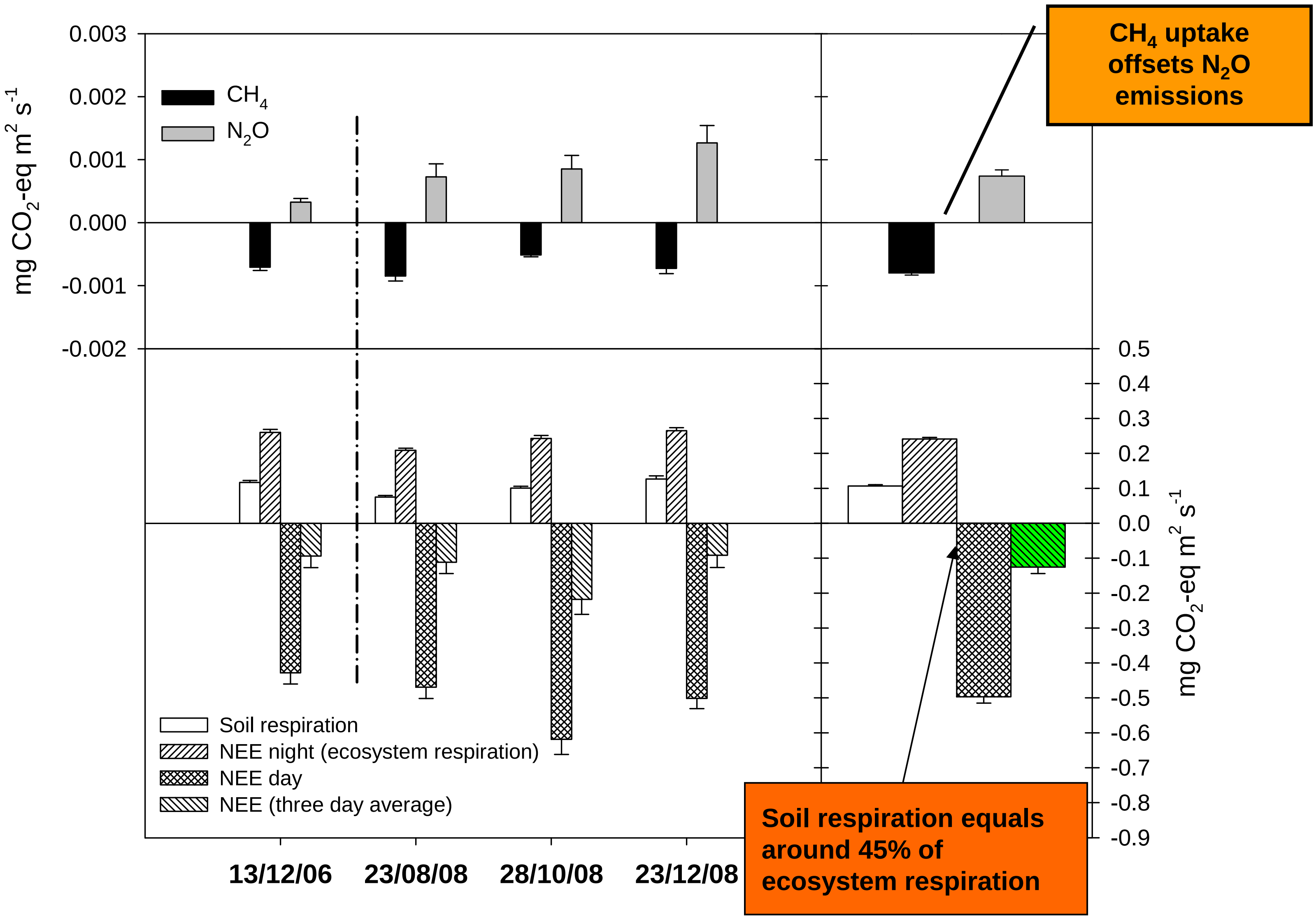
Differences between age classes

	stand age		
	Y (25 years)	M (80 years)	O (350+ years)
GHG fluxes			
CO_2 [mg CO_2-C m^{-2} h^{-1}]	84.5 (4.7)^{A}	106.1 (4.8)^{B}	104.5 (3.6)^{B}
CH_4 [ug CH_4-C m^{-2} h^{-1}]	-54.5 (4.5)^{A}	-92.9 (4.0)^{B}	-85.9 (3.7)^{B}
N_2O [ug N_2O-N m^{-2} h^{-1}]	1.2 (1.5)^{A}	0.48 (0.5)^{A}	5.4 (0.7)^{B}
Soil parameter			
pH	5.1 (0.1)^{A}	5.5 (0.0)^{B}	5.1 (0.0)^{A}
C:N ratio	25.9 (0.6)^{A}	23.0 (0.4)^{B}	20.2 (0.6)^{C}
Bulk density [g cm^{-3}]	0.6 (0.0)^{A}	0.8 (0.0)^{B}	0.6 (0.0)^{A}
Soil moisture [% g g^{-1}]	33.6 (0.0)^{A}	41 (0.1)^{B}	61.8 (0.1)^{C}
Soil NH_4+ [mg kg^{-1}]	7.7 (0.8)^{A}	5.8 (0.4)^{A}	15.2 (2.2)^{B}
Soil NO_3- [mg kg^{-1}]	0.5 (0.1)^{A}	0.1 (0.0)^{A}	9.3 (1.1)^{B}
Clay [%]	27.3 (0.4)	27.8 (0.2)	25.5 (1.5)
Sand [%]	53.5 (0.9)	43.1 (2.7)	48.1 (3.3)
Silt [%]	19.2 (1.4)	29.1 (2.4)	26.5 (2.3)

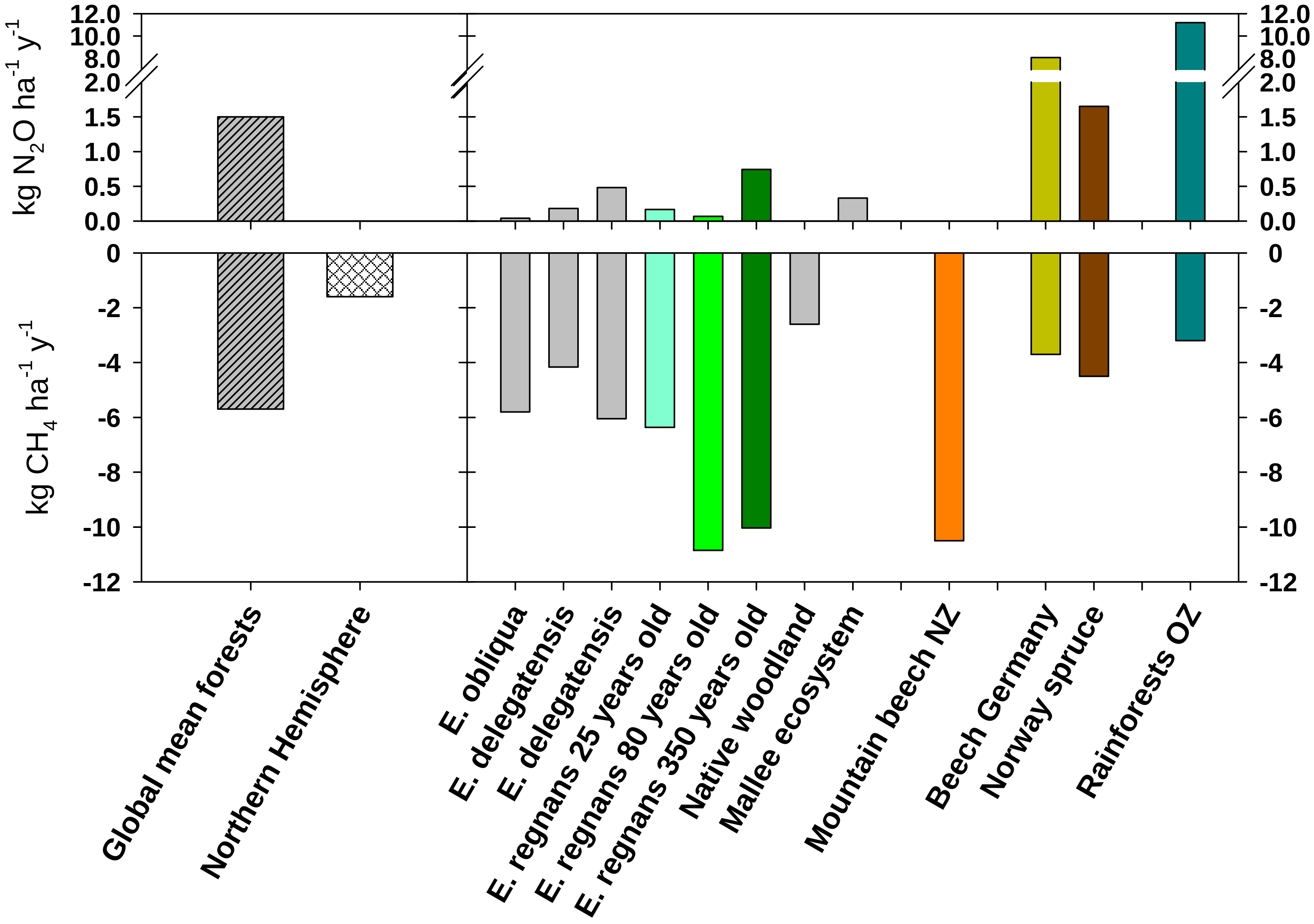
Temporal variability of soil GHG fluxes in relation to NEE (O)



Soil GHG fluxes vs. NEE (O)



Comparison with other forest systems



Conclusion

- Measured mean CH_4 uptake rates at the O and M forest stand are around 5 times higher than the average uptake rates reported for European and N. American forests
- CH_4 uptake rates are the highest reported for Australian forest systems
- N_2O emissions are lower than those in similar European forests because of tight nutrient cycling and high soil C:N ratios
- Soil N_2O and CH_4 fluxes in this forest system are two order of magnitude smaller than soil respiration
- N_2O emissions in this forest soil system offset their CH_4 uptake benefit on a CO_2-equivalent basis

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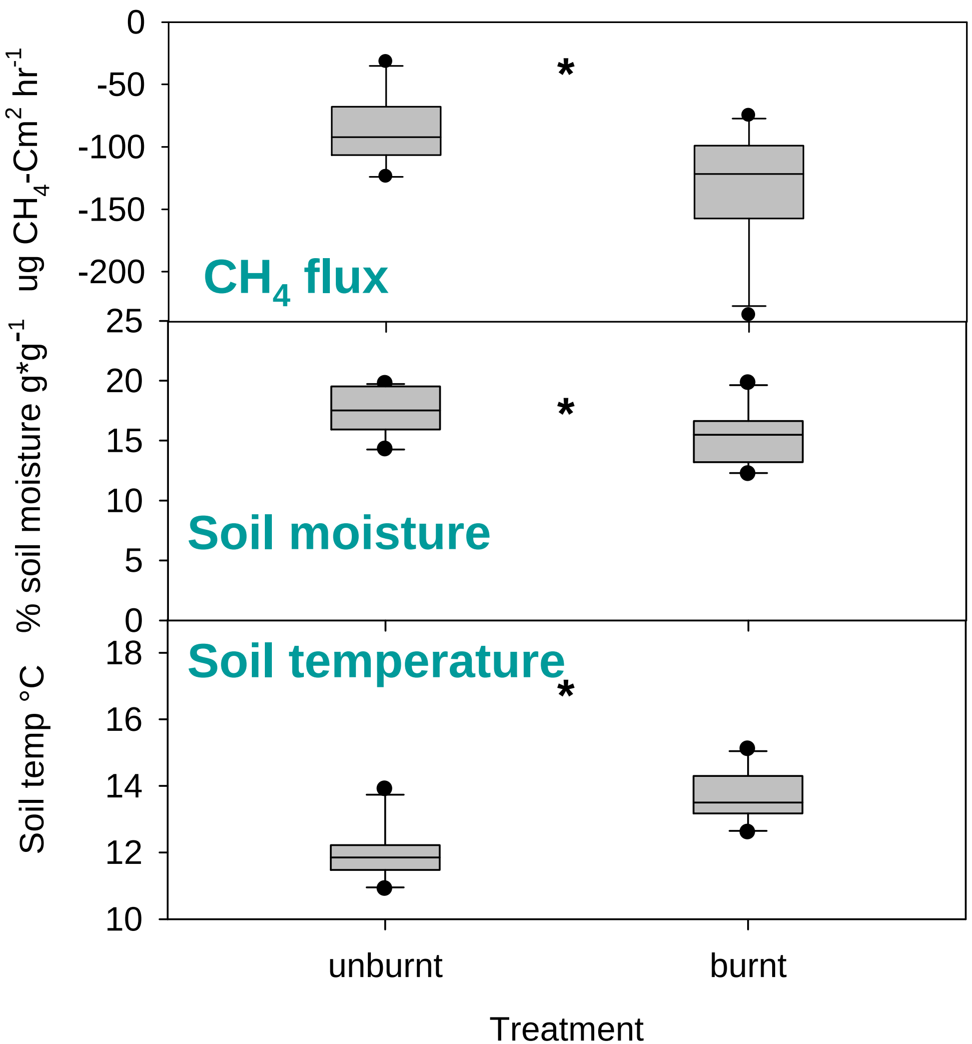
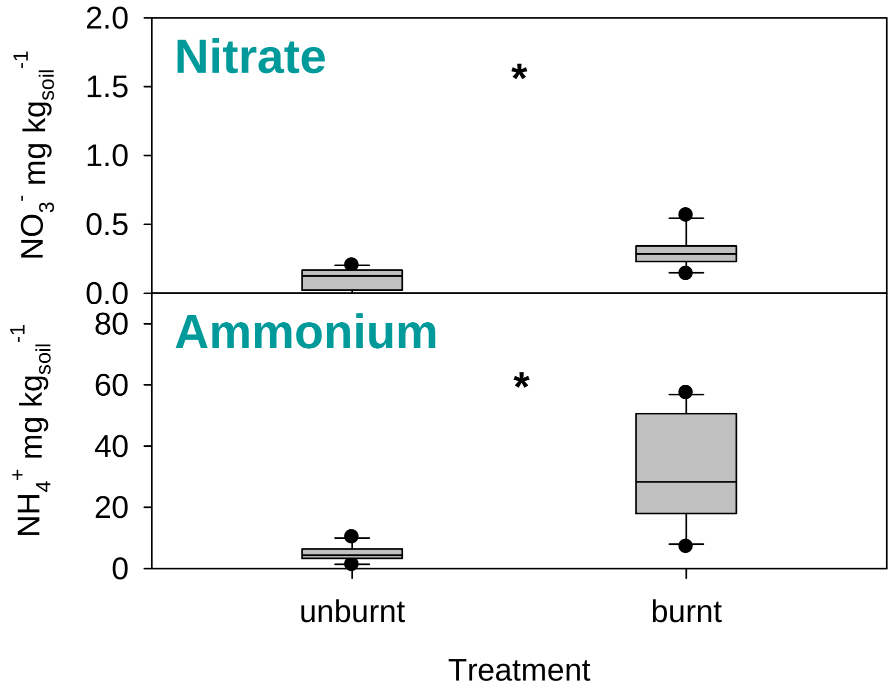
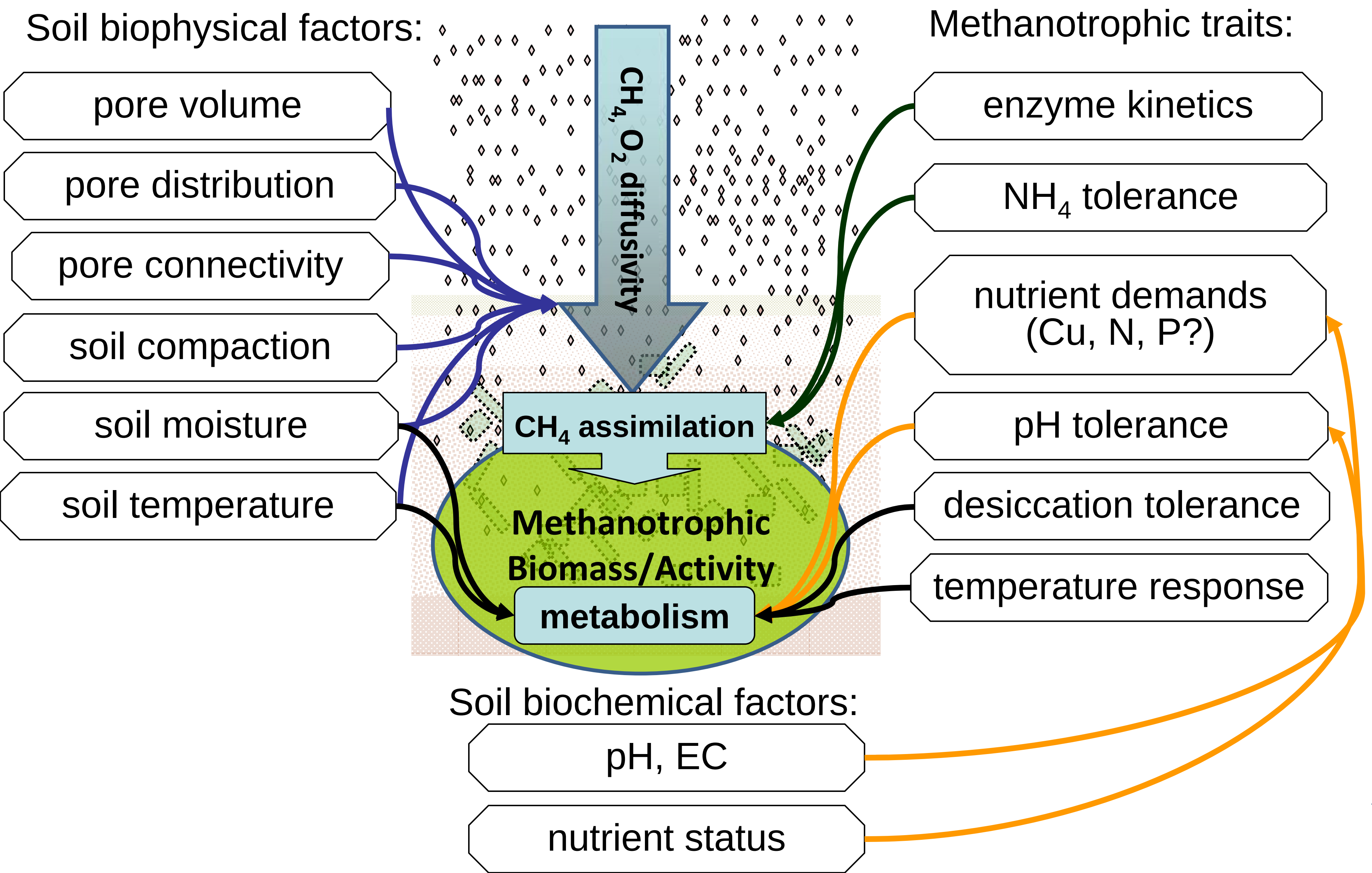
Where to from here?

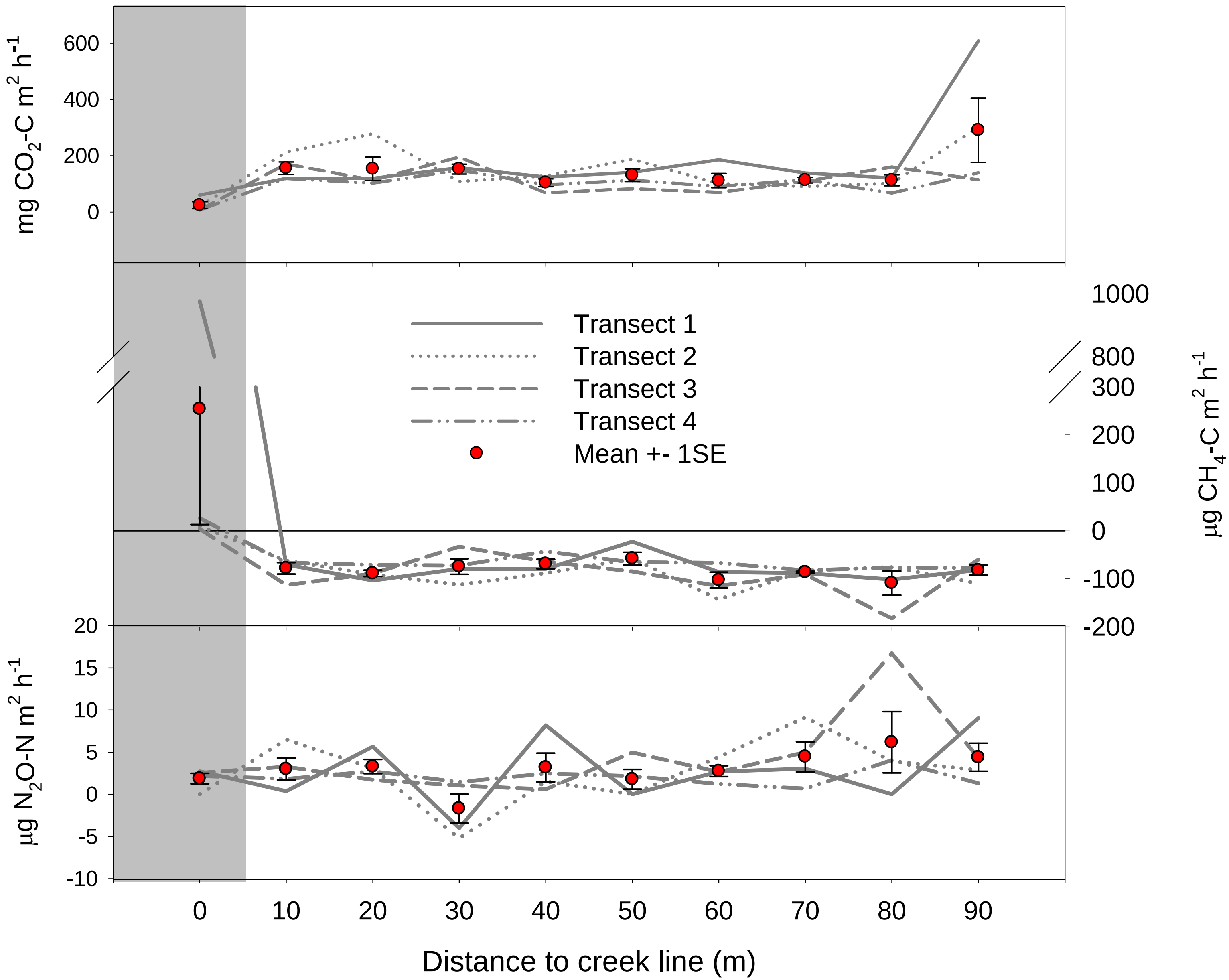




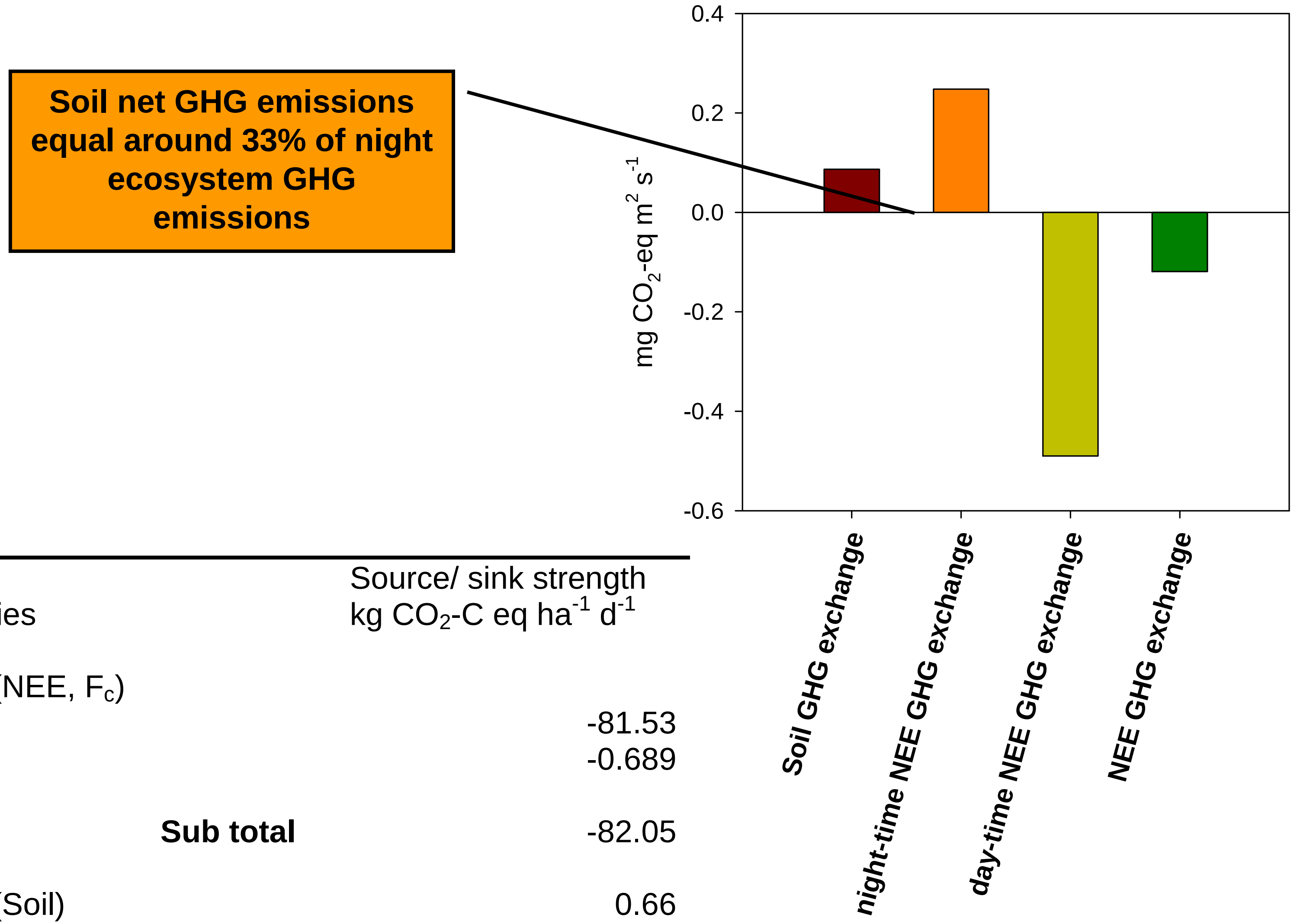
Soil methane oxidation



Spatial variability of soil GHG fluxes (O)



Total ecosystem GHG budget (O) for all measuring dates



	GHG Species		Source/ sink strength kg CO_2-C eq ha^{-1} d^{-1}
Sinks			
	CO_2 (NEE, F_c)		-81.53
	CH_4		-0.689
		Sub total	-82.05
Source			
	N_2O (Soil)		0.66
		Total	**-81.55**

Martin et al. 2007