BELOW GROUND EFFECTS OF O_3 IN MEADOWS

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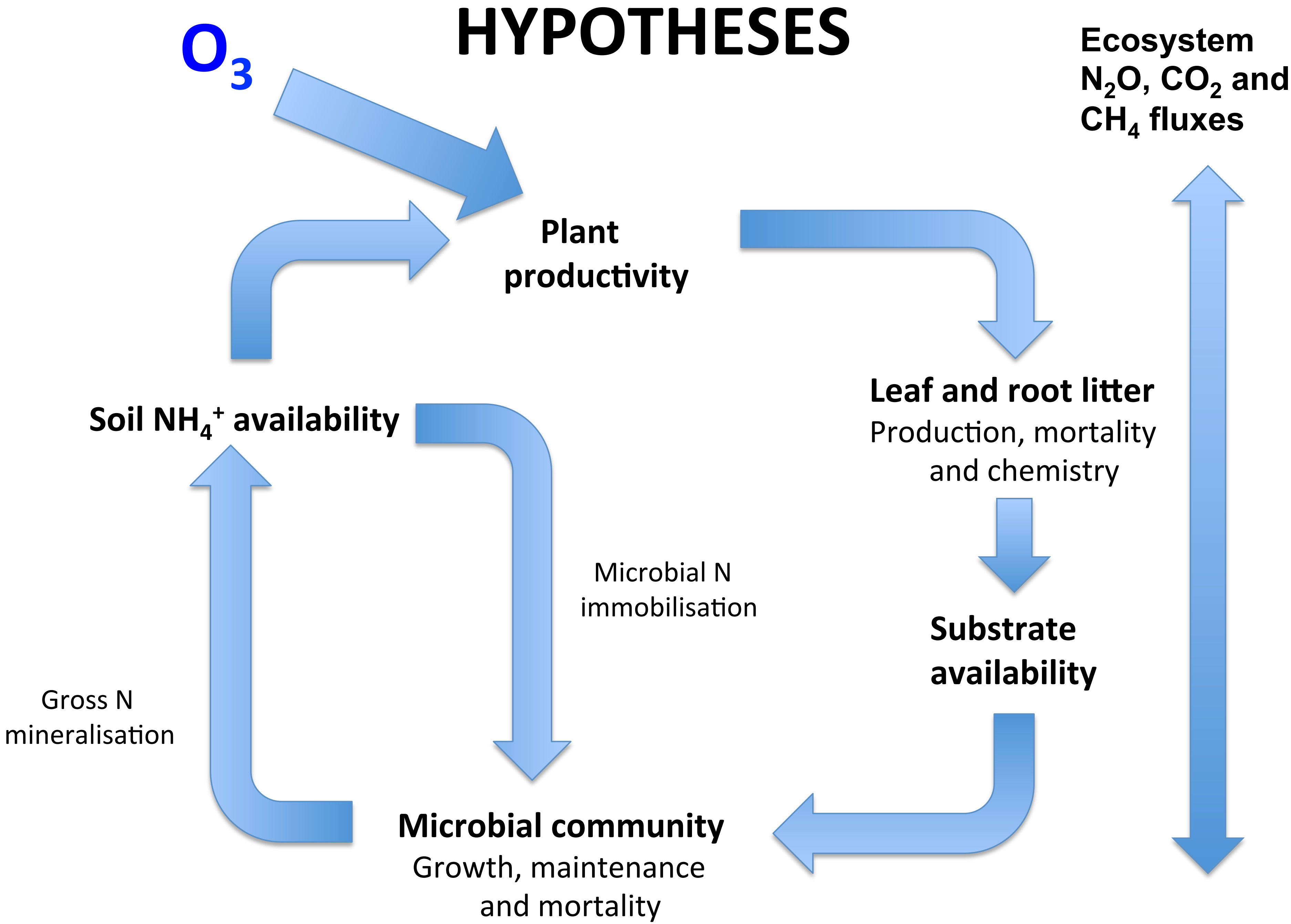
WHY TO STUDY?

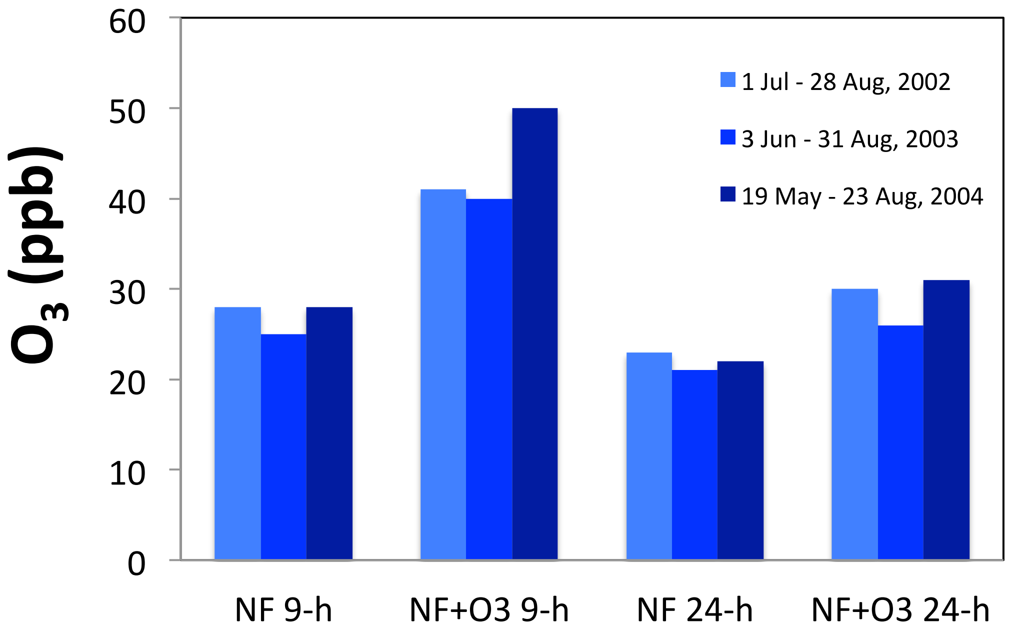
✓ Studies on semi-natural vegetation at community level scarce
  - pot-grown monocultures: legumes most sensitive

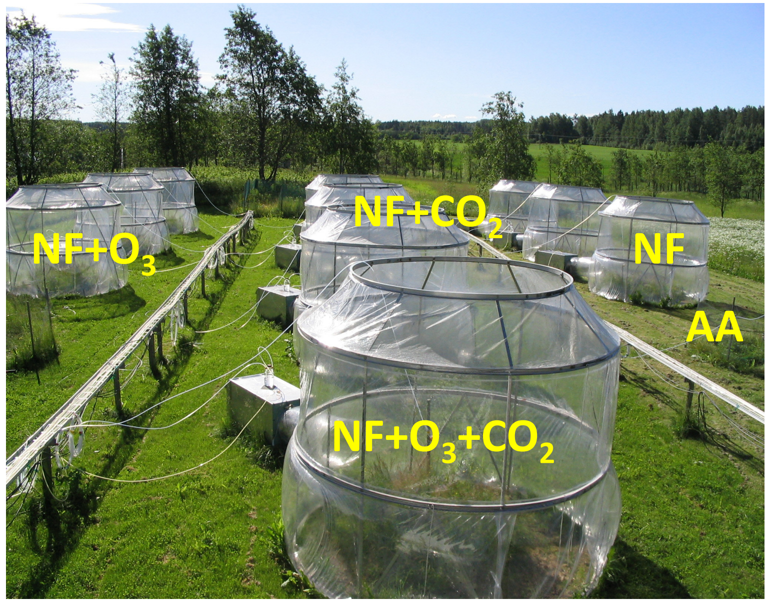
✓ Impact on below-ground processes unstudied

✓ Protected biotopes

✓ Interaction with CO_2

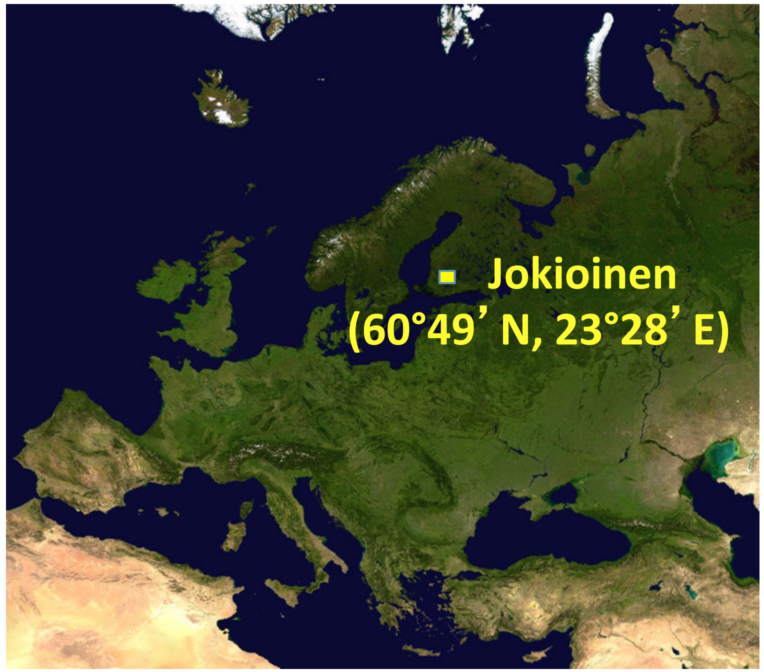

HYPOTHESES
O_3
Plant productivity
Ecosystem N_2O, CO_2 and CH_4 fluxes
Soil NH_4^+ availability
Leaf and root litter
Production, mortality and chemistry
Microbial N immobilisation
Substrate availability
Gross N mineralisation
Microbial community
Growth, maintenance and mortality





	May-August		
	2002	**2003**	**2004**
Precipitation (mm)	207	302	397
Mean temperature (°C)	15,8	14,3	13,3
Temp. OTC - open field (°C)*	0,7	0,8	0,6

*during the fumigations



GROUND-PLANTED MESOCOSMS

MONOCULTURED PLANTS IN POTS

SOIL

- ✓ peat:sand (1:1, v:v)
- ✓ pH_{H2O} 6.8, C 3.3%, N 0.07%, P 8.3 mg/l
- ✓ NPK fertilizer (twice in 2002)
- ✓ *Rhizobium* inoculation (2002)

GROUND-PLANTED MESOCOMS

- ✓ 2.25 m^2, rooting depth 25 cm
- ✓ 2 grasses: *Agrostis capillaris, Anthoxanthum odoratum* (25 seedlings/species)
- ✓ 3 forbs: *Campanula rotundifolia, Fragaria vesca, Ranunculus acris* (25 seedlings/species)
- ✓ 2 legumes: *Trifolium medium* (5), *Vicia cracca* (8)

Agrostis capillaris AND *Lathyrus pratensis* MONOCULTURES

- ✓ 15 l pots, 33 cm in diameter
- ✓ 113 plants / m^2

O_3 decreased bulk soil NH_4^+ concentration

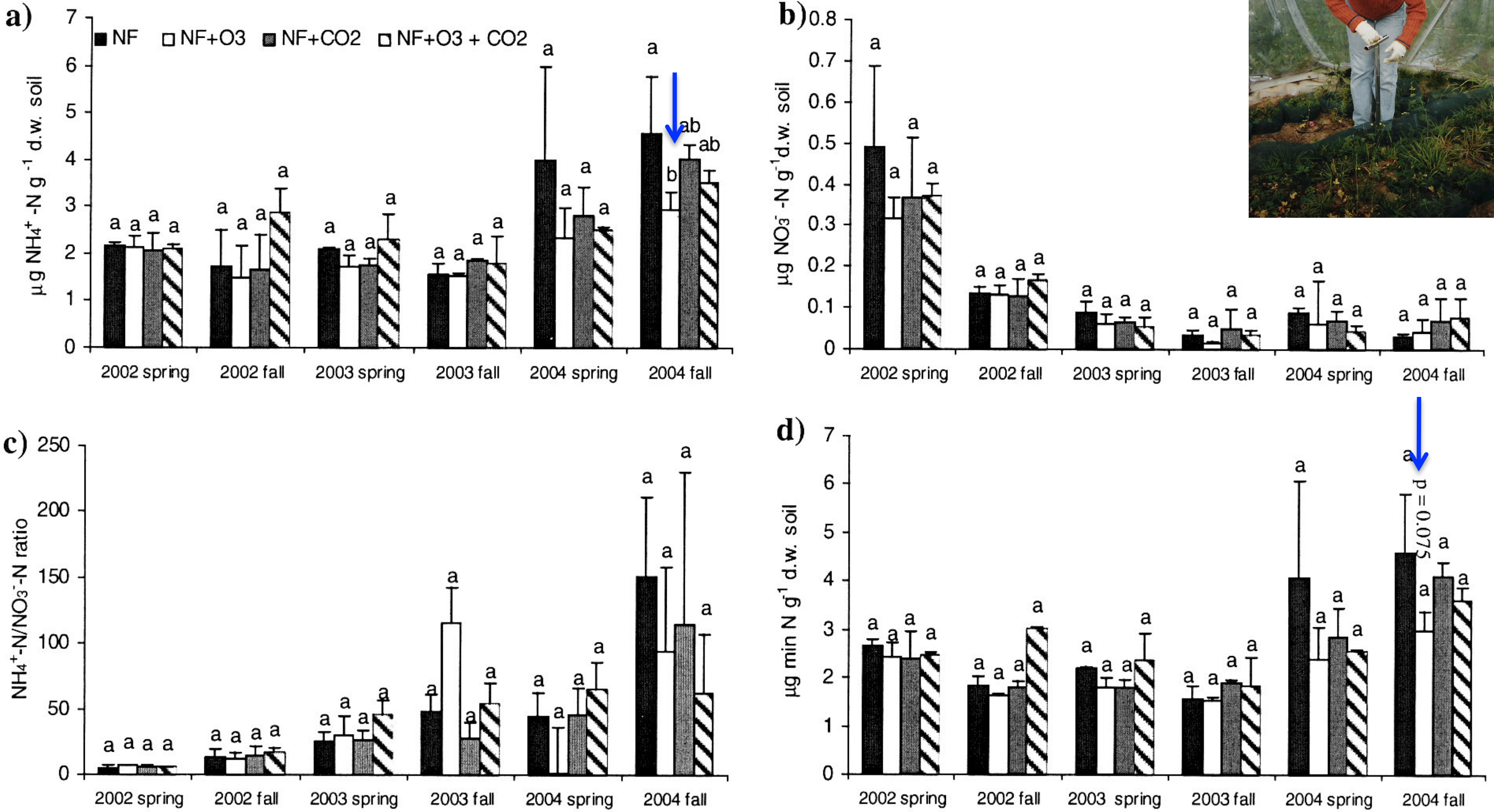


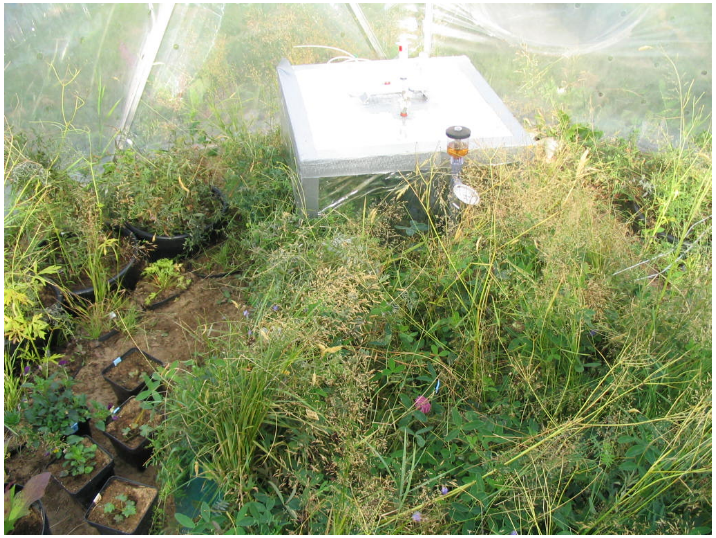
Fig. 1 (**a**) Concentrations of NH_4^+-N (**b**) and NO_3^--N, (**c**) NH_4^+-N/NO_3^--N ratio and (**d**) mineral N concentration. Means marked with different letters within each sampling differ at $P < 0.05$ (measured with one-way ANOVA). A tendency ($P < 0.10$) between the NF control treatment and the other treatments are marked with a P value. Error bars represent positive standard deviation of the means ($n = 3$)

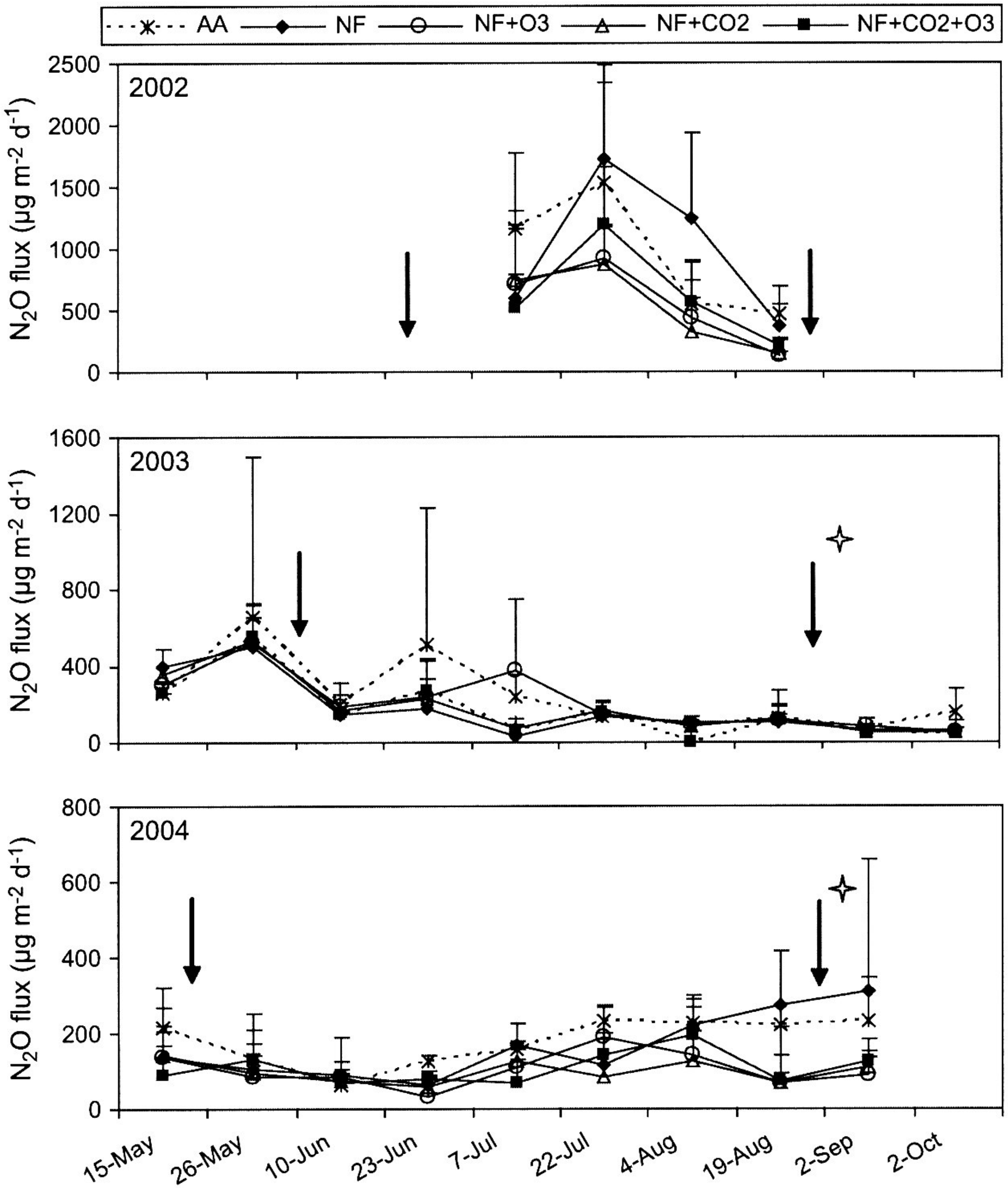
O_3 reduced N_2O, CH_4 and CO_2 fluxes

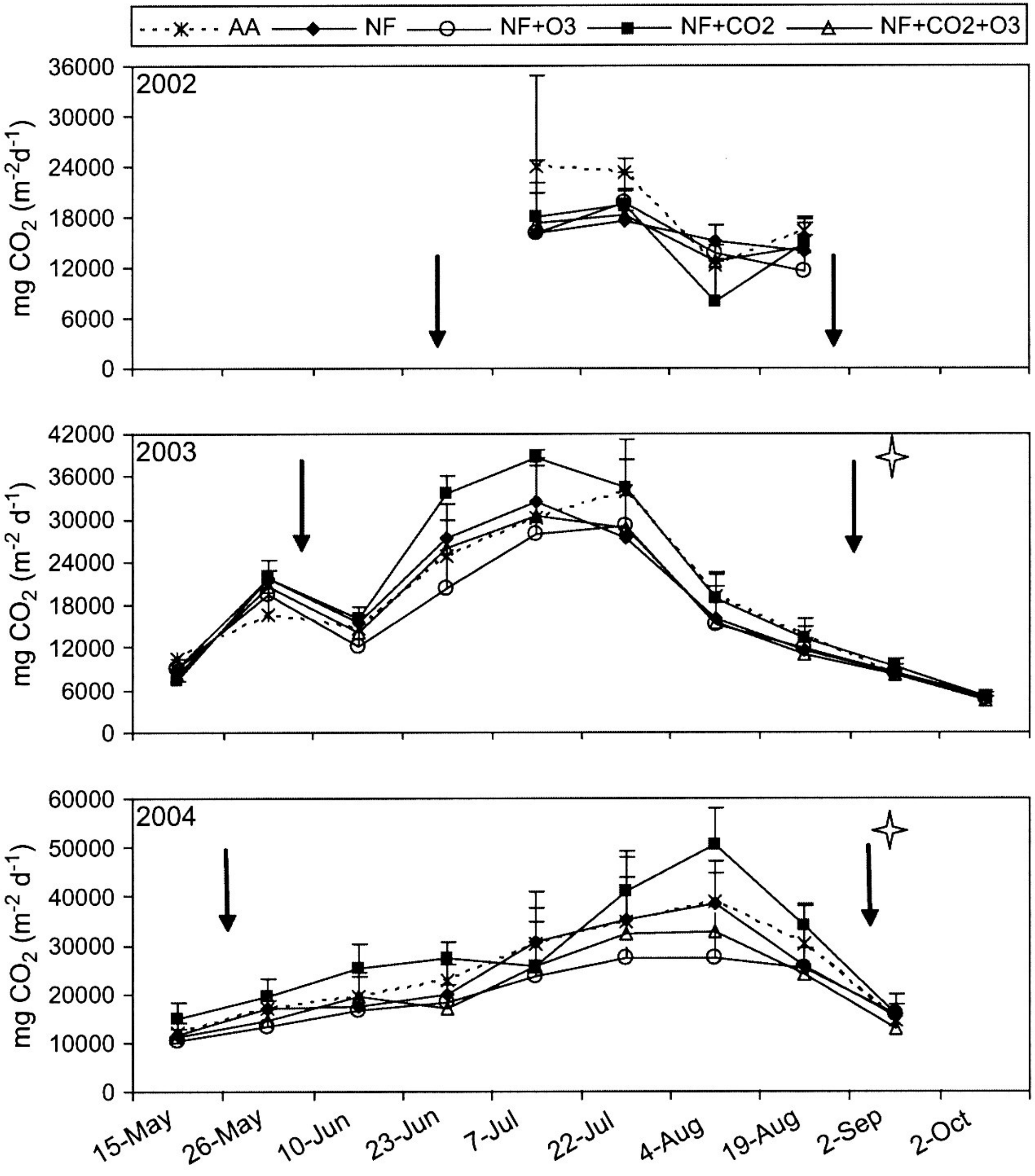
Table 3
Main effects (p-values) of elevated O_3 and/or CO_2 and time and treatment (O_3 and CO_2) interactions on the daily fluxes of N_2O, CH_4 and CO_2 in the growing seasons 2002–2004

Source	N_2O			CH_4			CO_2		
	2002	2003	2004	2002	2003	2004	2002	2003	2004
O_3	n.s.	n.s.	0.076	n.s.	n.s.	0.081	n.s.	0.022	0.016
CO_2	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.076	n.s.
$O_3 + CO_2$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Time	<0.001	0.093	0.034	n.s.	n.s.	n.s.	0.004	<0.001	<0.001
Time*O_3	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.040	0.023
Time*CO_2	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.092
Time*$O_3 + CO_2$	0.070	n.s.	n.s.	n.s.	0.037	n.s.	n.s.	n.s.	n.s.

n.s. not significant ($p > 0.10$).




AA
NF
NF+O3
NF+CO2
NF+CO2+O3
2002
2003
2004
N2O flux (µg m-2 d-1)
2500
2000
1500
1000
500
0
1600
1200
800
400
800
600
200
15-May
26-May
10-Jun
23-Jun
7-Jul
22-Jul
4-Aug
19-Aug
2-Sep
2-Oct



AA
NF
NF+O3
NF+CO2
NF+CO2+O3
2002
2003
2004
mg CO2 (m-2 d-1)
36000
30000
24000
18000
12000
6000
0
42000
36000
30000
24000
18000
12000
6000
0
60000
50000
40000
30000
20000
10000
0
15-May
26-May
10-Jun
23-Jun
7-Jul
22-Jul
4-Aug
19-Aug
2-Sep
2-Oct

Impact of other abiotic factors on GHG fluxes

Table 5
Spearman's correlation coefficients of the fluxes of N_2O, CH_4 and CO_2 with soil and environmental variables

	N_2O		CH_4		CO_2	
	r	N	r	N	r	N
Mineral N spring[a]	−0.12	45	0.15	45	0.45**	45
Mineral N fall[b]	0.29	45	−0.72	45	0.63**	45
Total N[c]	−0.35	30	−0.70	30	0.50**	30
Organic C	0.16	30	−0.13	30	−0.32	30
pH[c]	−0.41*	30	−0.16	30	−0.32	30
Denitrification potential[c]	−0.11	30	−0.20	30	0.21	30
Nitrification potential[c]	−0.16	30	−0.15	30	0.08	30
Total plant biomass[d]	−0.28	30	−0.59	30	0.70**	30
Plant biomass inside the collar[d]	−0.71	15	−0.26	15	0.73**	15
Air temperature	0.27**	237	0.06	237	0.50**	237
Soil temperature	0.34**	210	0.02	210	0.69**	210
Soil water content	0.53**	120	0.14	120	0.18*	120

Asterisks denote two-tailed significances (*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$).

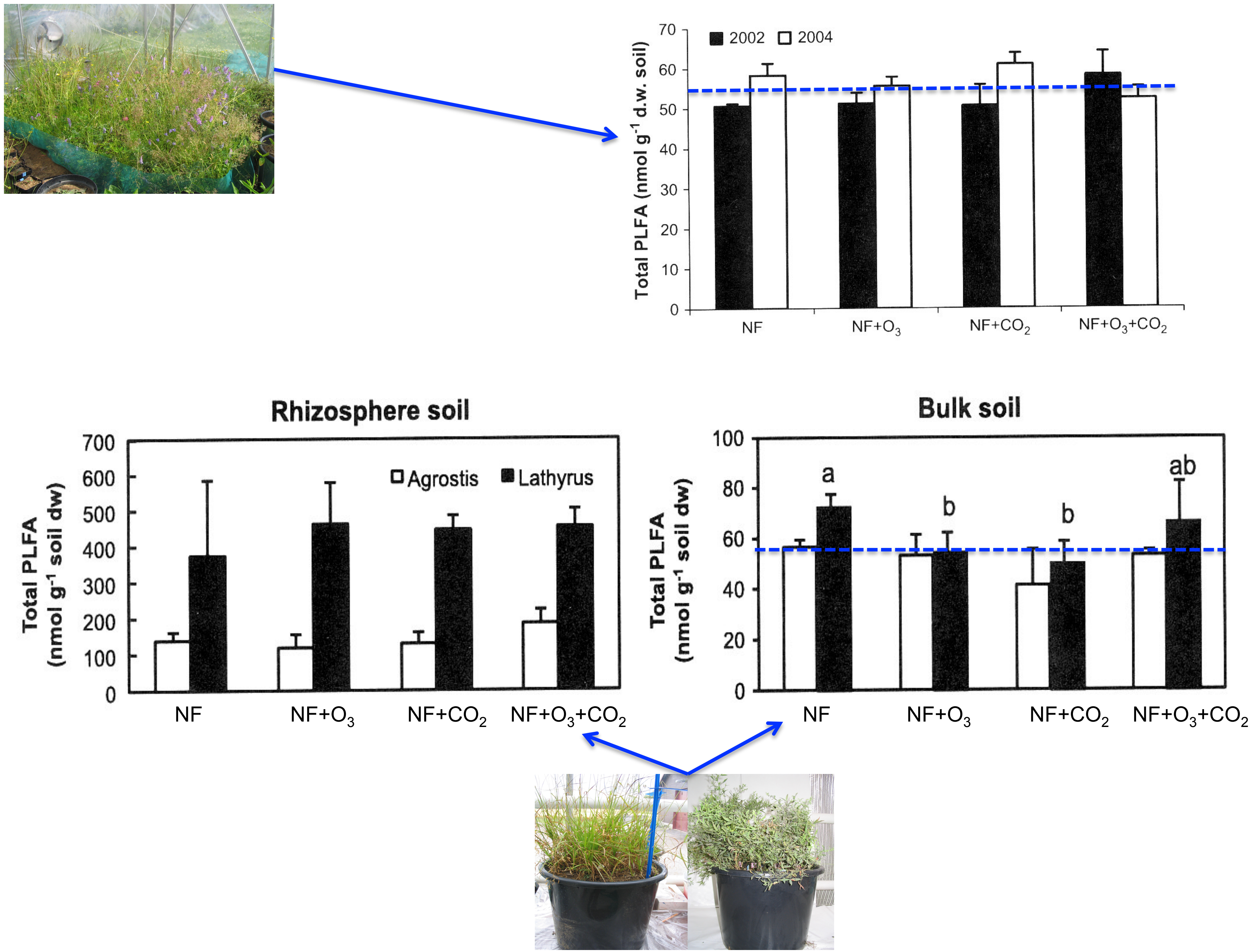
O_3 decreased microbial (PLFA) biomass in bulk soil

Table 2

O_3 and CO_2 main and interaction effects (as *P*-values) on the total, bacterial, actinobacterial, fungal, and mycorrhizal PLFAs as well as the fungal:bacterial PLFA ratio in 2002 and 2004 (two-way ANOVA), when the open-field plots (AA) were excluded from the analyses

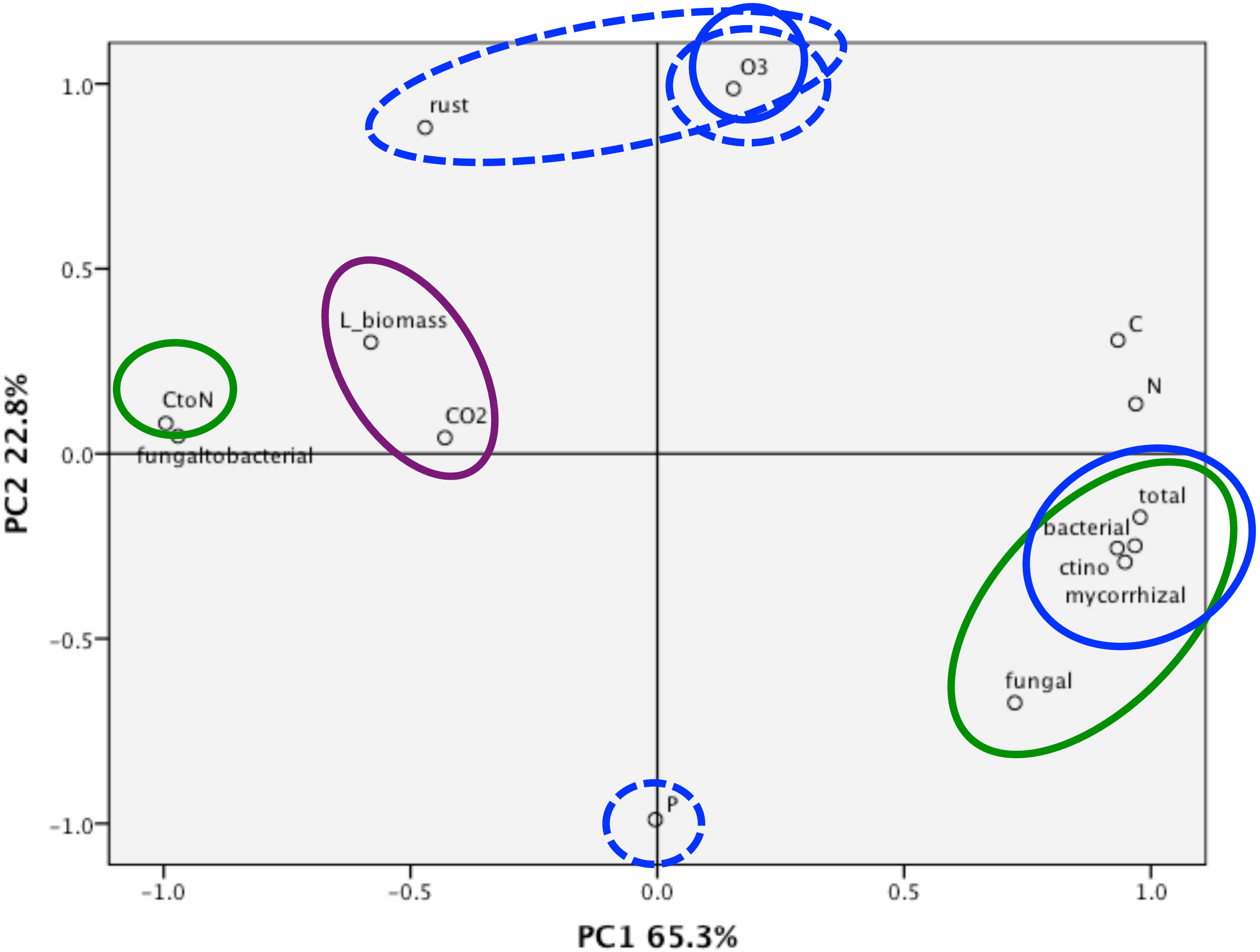
	Total PLFA		Bacterial PLFA		Actinobacterial PLFA		Fungal PLFA		Mycorrhizal PLFA		Fungal: bacterial PLFA ratio	
	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004
O_3	n.s	0.007	n.s	0.034	n.s	0.029	n.s	0.006	n.s	n.s	n.s	0.033
CO_2	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
$O_3 \times CO_2$	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

n.s., Not significant.

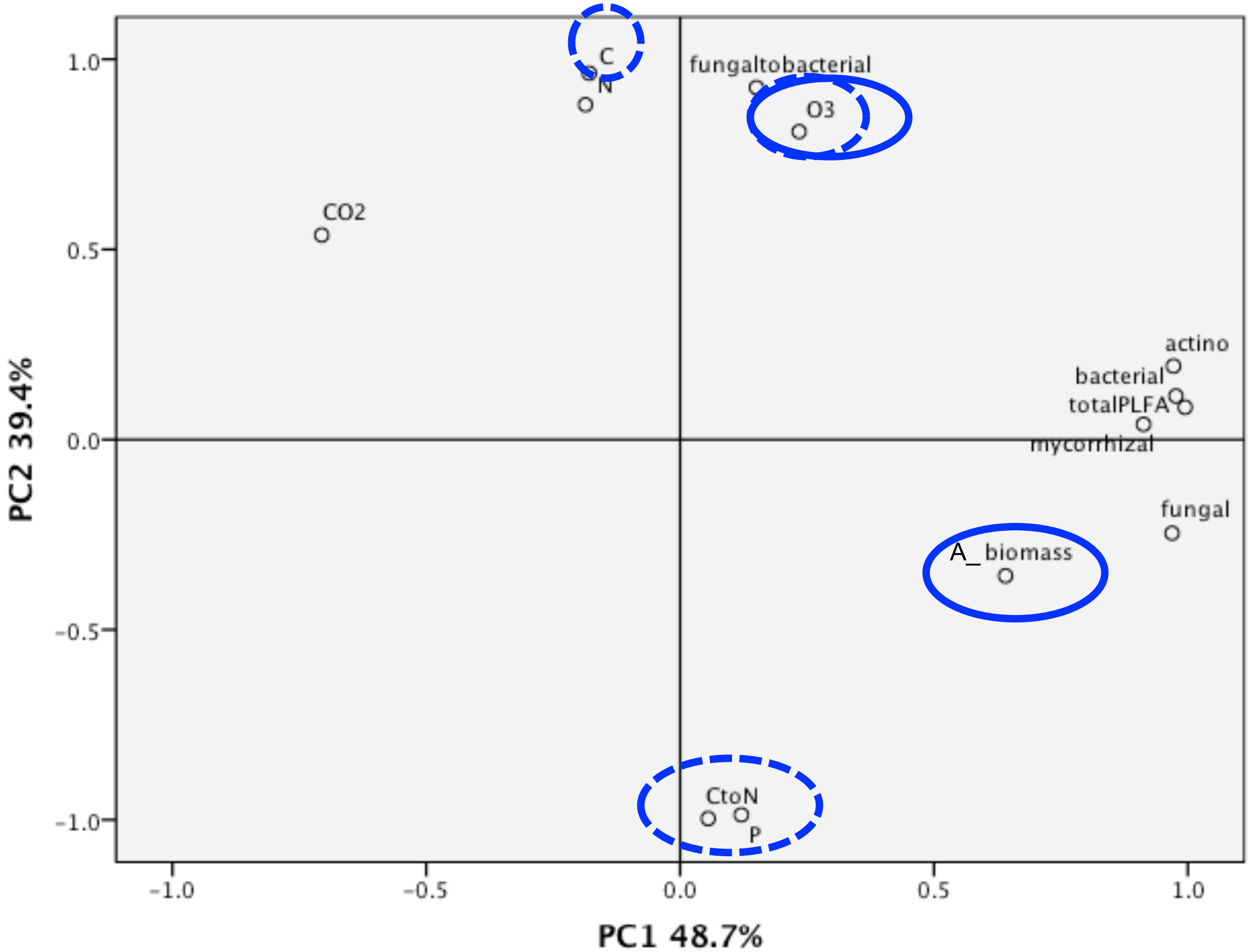


Total PLFA (nmol g-1 d.w. soil)
2002
2004
70
60
50
40
30
20
10
0
NF
NF+O3
NF+CO2
NF+O3+CO2
Rhizosphere soil
Total PLFA (nmol g-1 soil dw)
Agrostis
Lathyrus
700
600
500
400
300
200
100
0
NF
NF+O3
NF+CO2
NF+O3+CO2
Bulk soil
Total PLFA (nmol g-1 soil dw)
100
80
60
40
20
0
a
b
b
ab
NF
NF+O3
NF+CO2
NF+O3+CO2

✓O_3 decreased bulk soil microbial (PLFA) biomass
✓O_3 x rust interaction?
✓O_3 decreased P availability?



- ✓ O_3 positively correlated with bulk soil C and negatively with P and C:N ratio
- ✓ O_3 decreased *Agrostis* (shoot and total) biomass



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Mesocosms mimic natural meadows as regards greenhouse gas fluxes and potential activities of nitrifying and denitrifying bacteria

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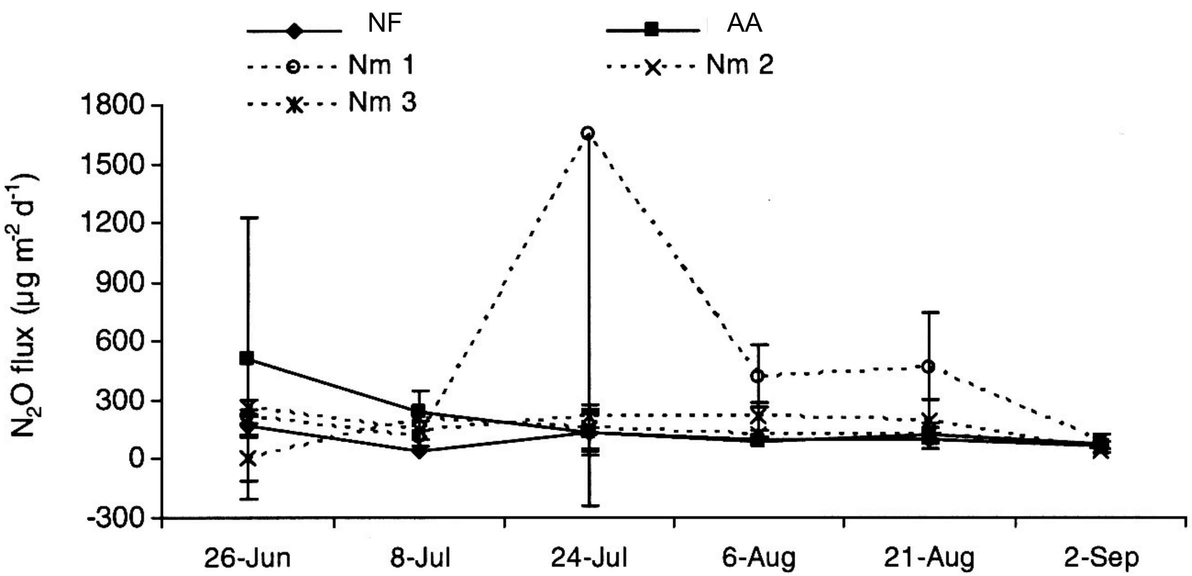


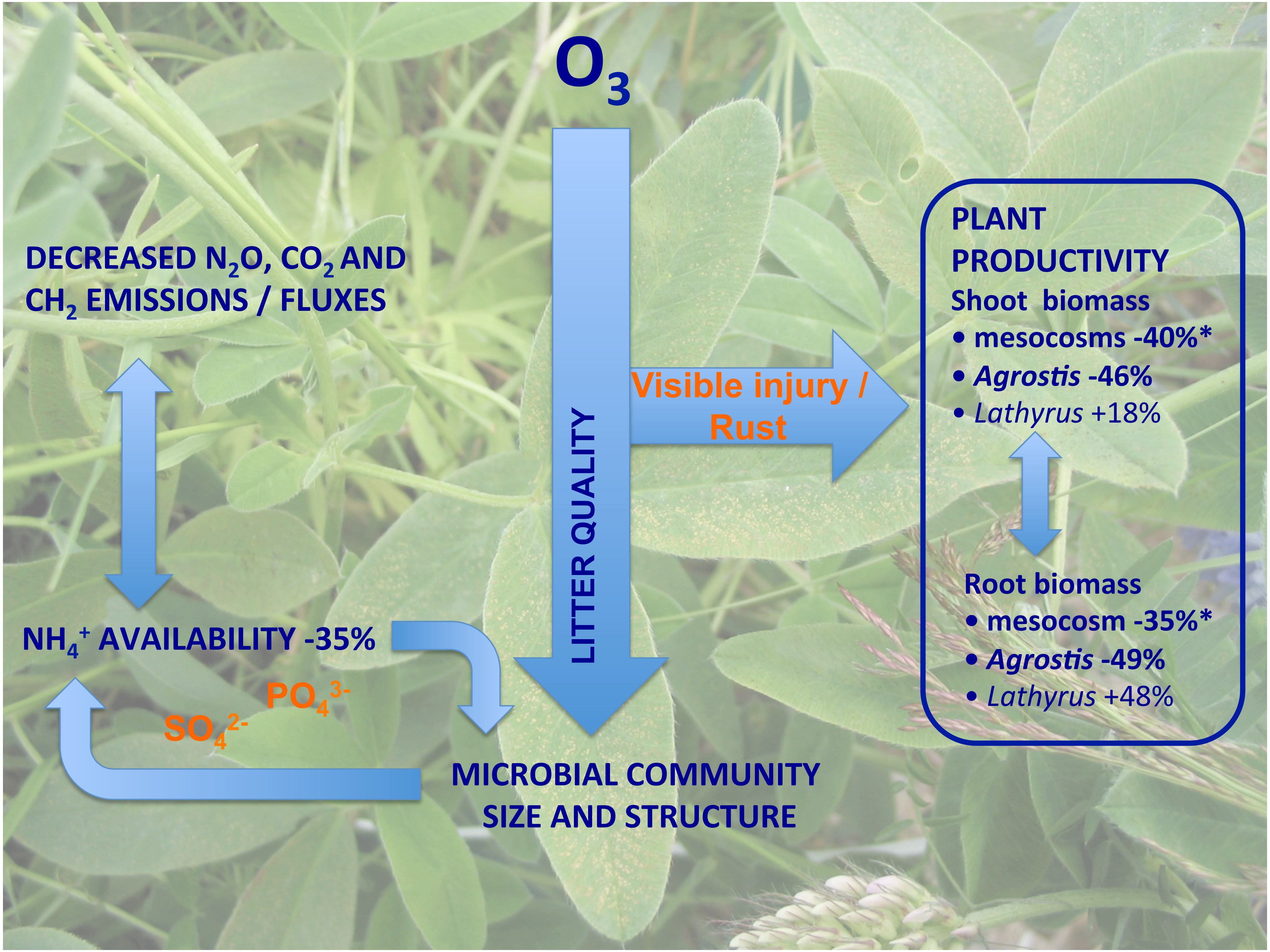
Figure 3. Daily N_2O fluxes from the natural meadows 1, 2 and 3 (Nm 1, 2 and 3) and from the mesocosms of the chambered and unchambered plots in June–September 2003. Error bars represent standard deviation of the means (n = 3).

The soil was low in N. However,

✓**Shoot biomass:**
mesocosms (NF 528 g/m^2) ≈ natural meadows;
3-7 x biomass in monocultures

✓**Root-to-shoot ratio:**
mesocosms 1.03; *Agrostis* 0.25 and *Lathyrus* 0.16

✓**Bulk soil total microbial biomass, C and N:**
mesocosms ≈ monocultures



O_3
DECREASED N_2O, CO_2 AND CH_2 EMISSIONS / FLUXES
LITTER QUALITY
Visible injury / Rust
PLANT PRODUCTIVITY
Shoot biomass
• mesocosms -40%*
• *Agrostis* -46%
• *Lathyrus* +18%
Root biomass
• mesocosm -35%*
• *Agrostis* -49%
• *Lathyrus* +48%
NH_4^+ AVAILABILITY -35%
PO_4^{3-}
SO_4^{2-}
MICROBIAL COMMUNITY SIZE AND STRUCTURE

THANK YOU!

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