Increased nitrate availability in the soil of a mixed mature temperate forest subjected to elevated CO_2 concentration (canopy FACE)

Patrick Schleppi, Inga Bucher-Wallin, Frank Hagedorn (WSL*), Christian Körner (Uni Basel)

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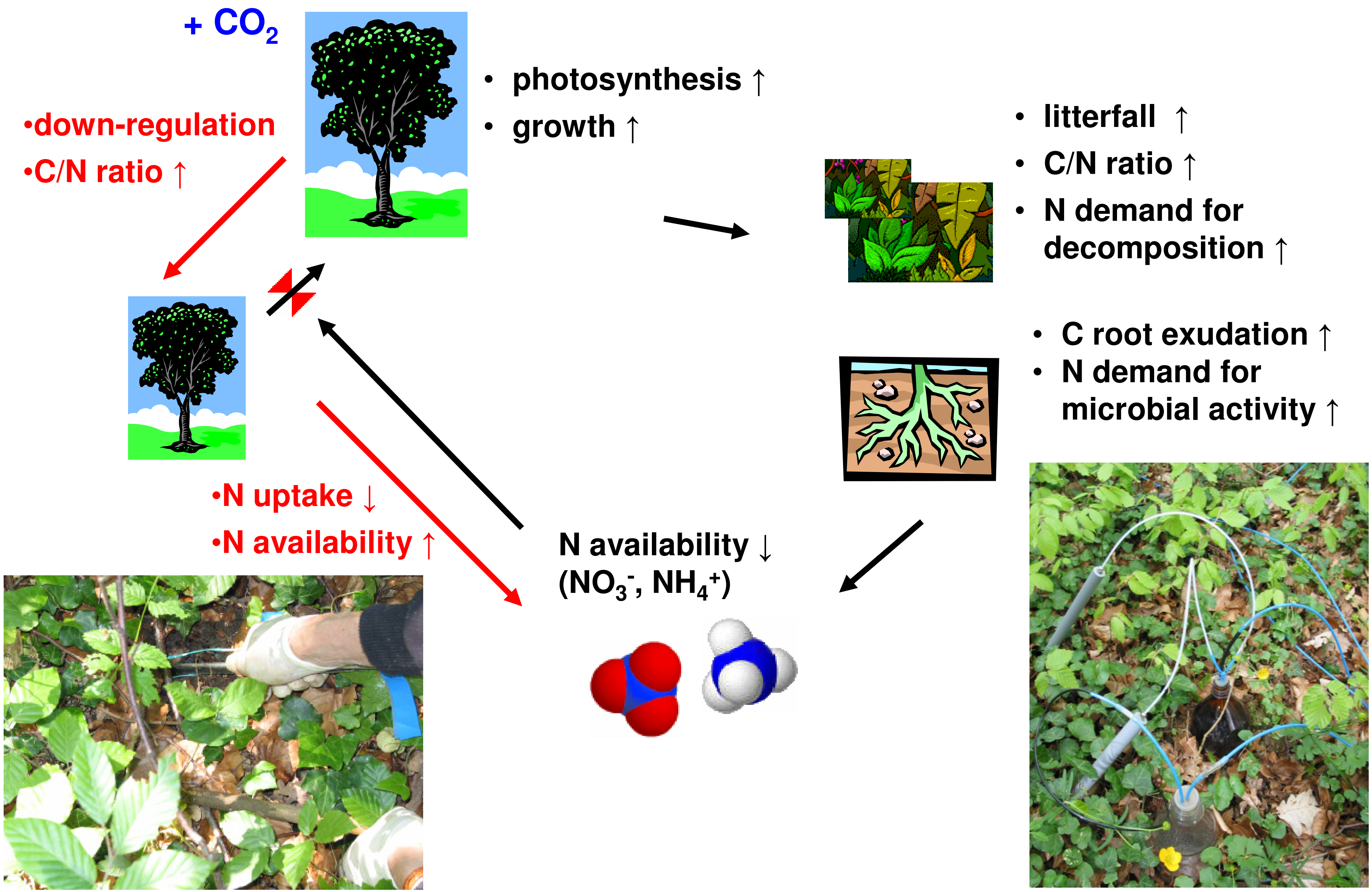
Hypotheses



+ CO_2
• photosynthesis ↑
• growth ↑
•down-regulation
•C/N ratio ↑
• litterfall ↑
• C/N ratio ↑
• N demand for decomposition ↑
• C root exudation ↑
• N demand for microbial activity ↑
•N uptake ↓
•N availability ↑
N availability ↓
(NO_3^-, NH_4^+)

Ecology, 87(1), 2006, pp. 64–75
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PROGRESSIVE N LIMITATION IN FORESTS: REVIEW AND IMPLICATIONS FOR LONG-TERM RESPONSES TO ELEVATED CO_2

DALE W. JOHNSON[1]

?

Soil Biology & Biochemistry 41 (2009) 54–60

Priming depletes soil carbon and releases nitrogen in a scrub-oak ecosystem exposed to elevated CO_2

J. Adam Langley[a], Duncan C. McKinley[a], Amelia A. Wolf[b], Bruce A. Hungate[c], Bert G. Drake[a], J. Patrick Megonigal[a,*]

?

Ecology Letters, (2011) **14**: 187–194

Richard P. Phillips,[1]* Adrien C. Finzi[2] and Emily S. Bernhardt[3]

Enhanced root exudation induces microbial feedbacks to N cycling in a pine forest under long-term CO_2 fumigation

?

Hofstetten

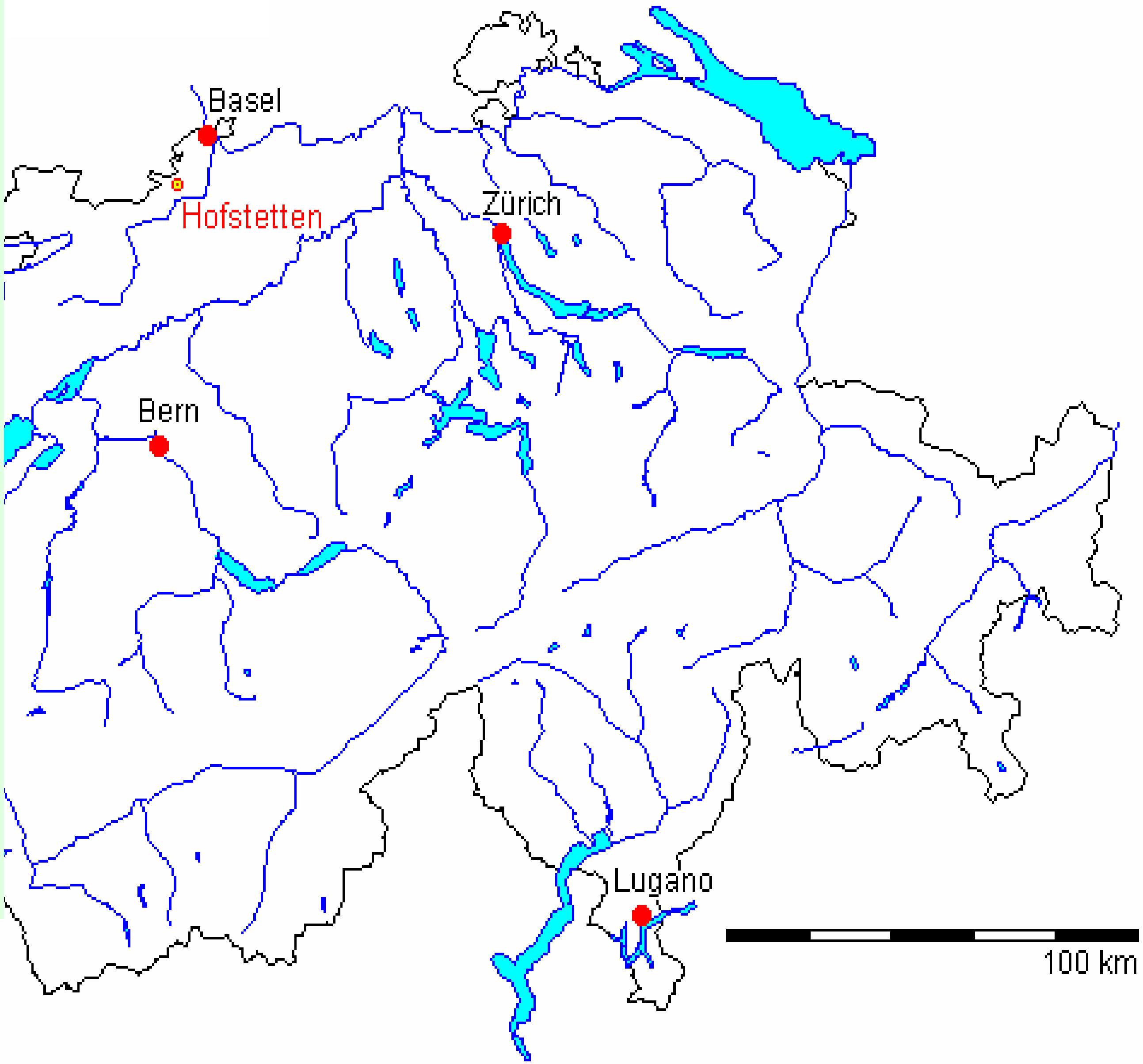
Altitude:
540 m

Geology:
Jura limestone

Vegetation:
mixed forest, 80-120 year old

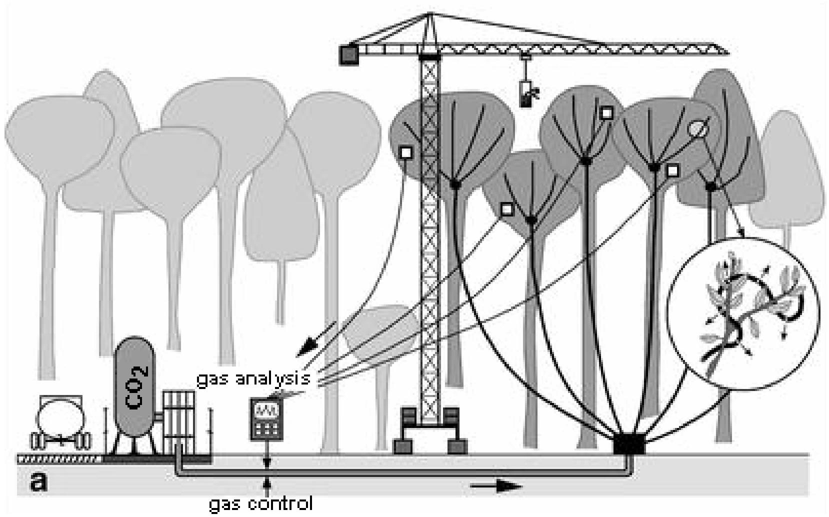
Precipitation:
1000 mm/a

Bulk N deposition:
≅ 20 kg/ha/a



Hofstetten (SO): Swiss Canopy Crane

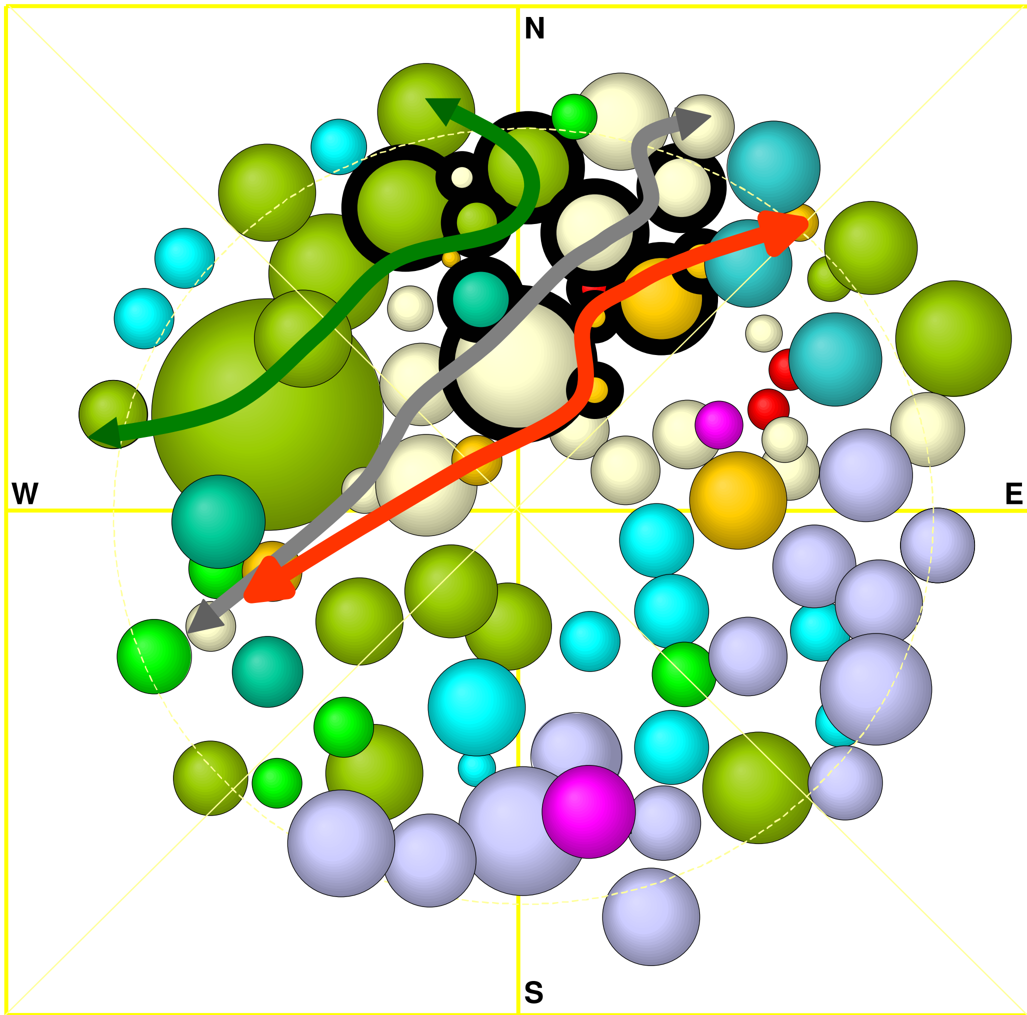
University of Basel



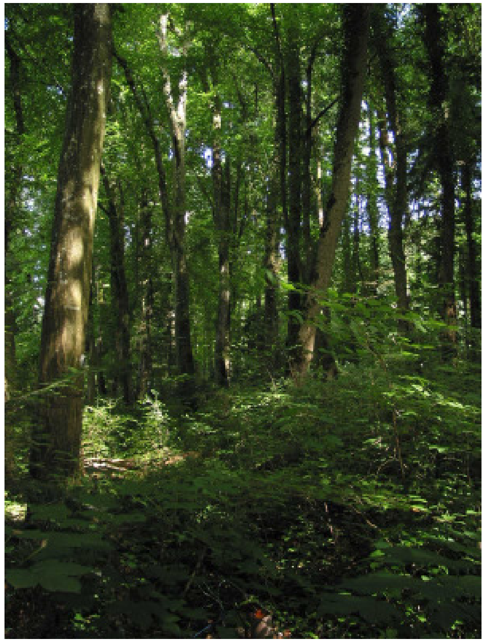
Transects for soil solution sampling
(suction cups and resin bags)

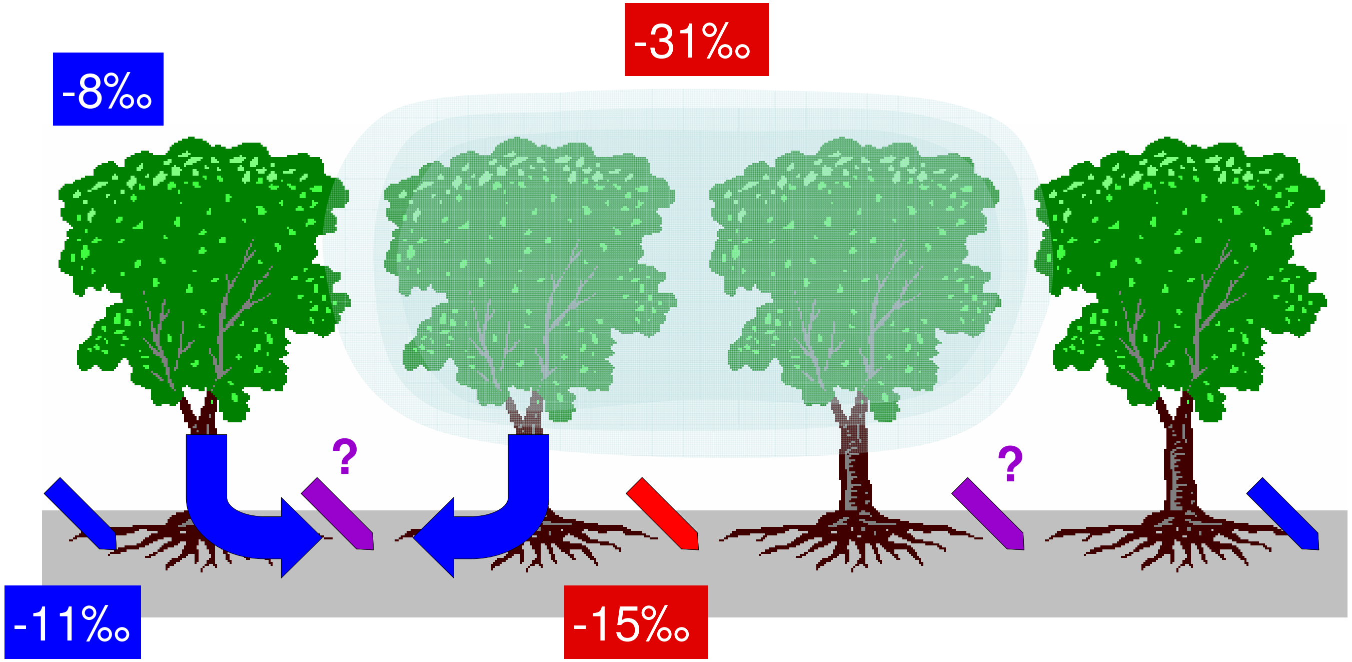
Trees

- 360 µl/l CO_2
- 560 µl/l CO_2
- *Acer campestre*
- *Fagus sylvatica*
- *Quercus* sp.
- *Picea abies*
- *Pinus sylvestris*
- *Carpinus betulus*
- *Prunus avium*
- *Larix decidua*
- *Tilia platyphyllos*
- *Abies alba*



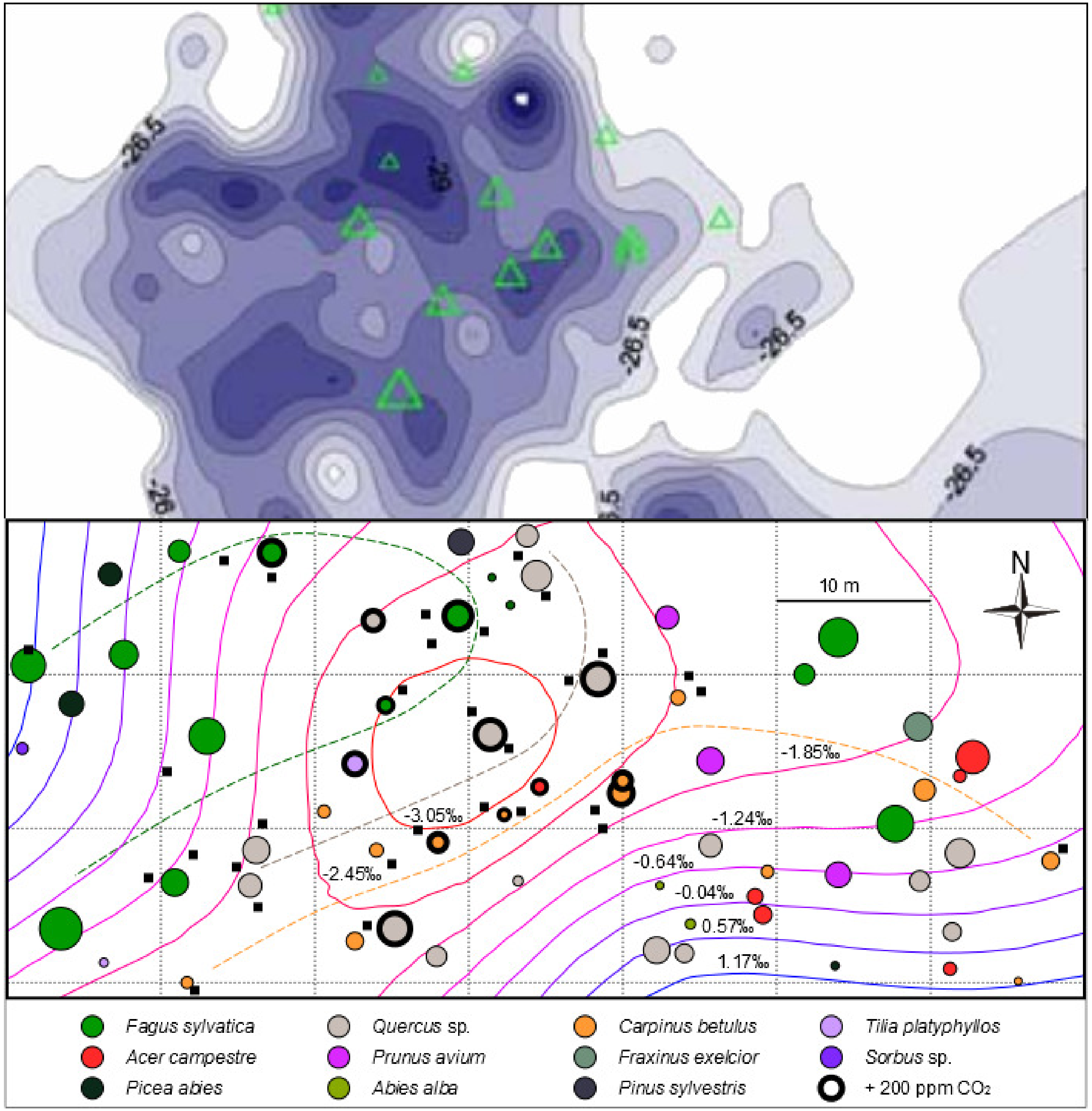
Statistical approach





- Response variables: soil solution chemistry
- Experimental factor: CO_2 ambient *vs.* elevated
- Problem: unknown gradient along transect
- Indicator: $\delta^{13}C$ of inorganic C in soil solution
- Statistics: dose → response relationship
- Graphs: ambient *vs.* intermediate *vs.* elevated

Relative CO_2 effect (based on ^{13}C)

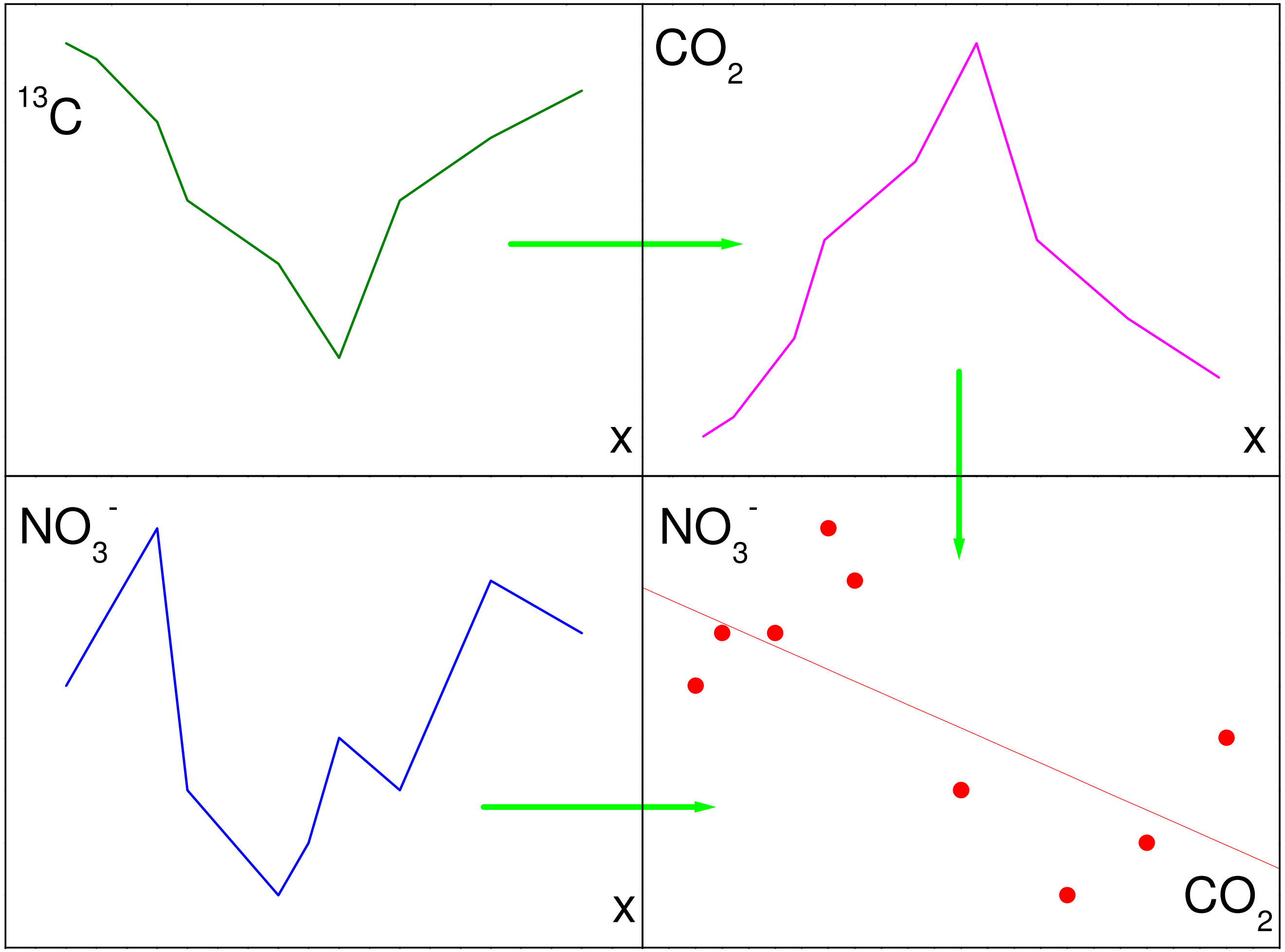


in soil CO_2

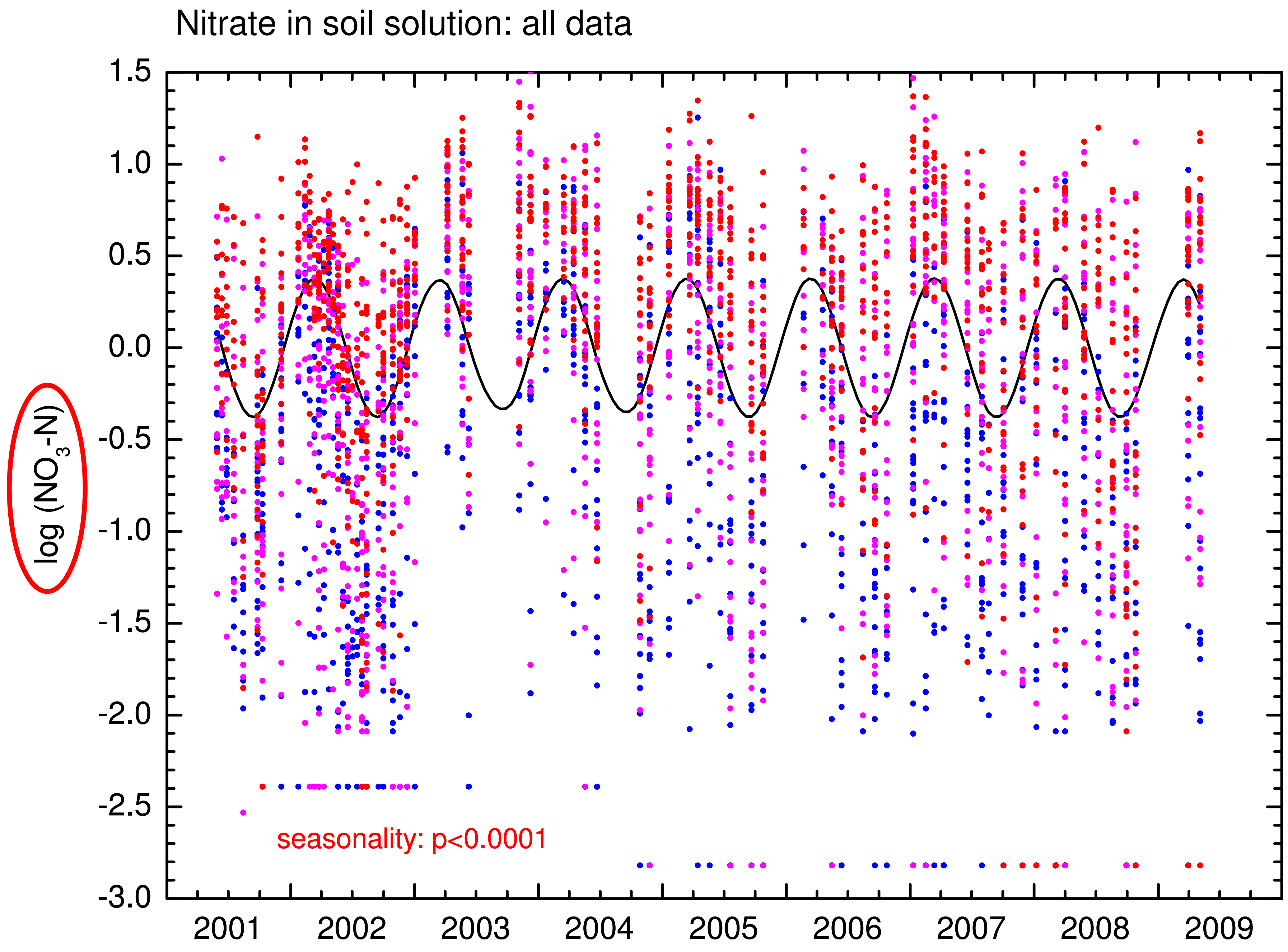
(Steinmann *et al.*, Oecologia, 2004)

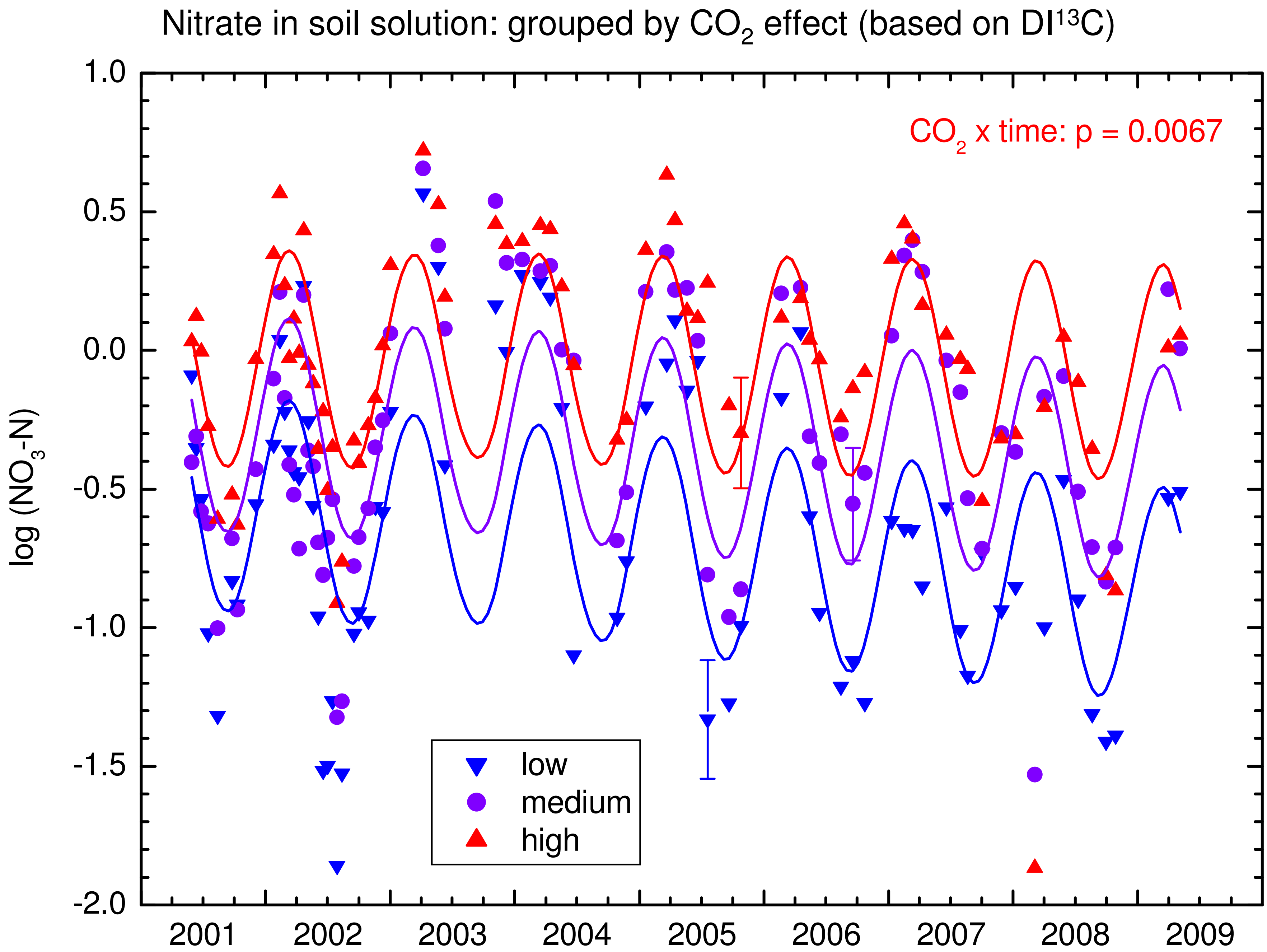
in soil DIC

Dose → response relationship along transect (x): principle



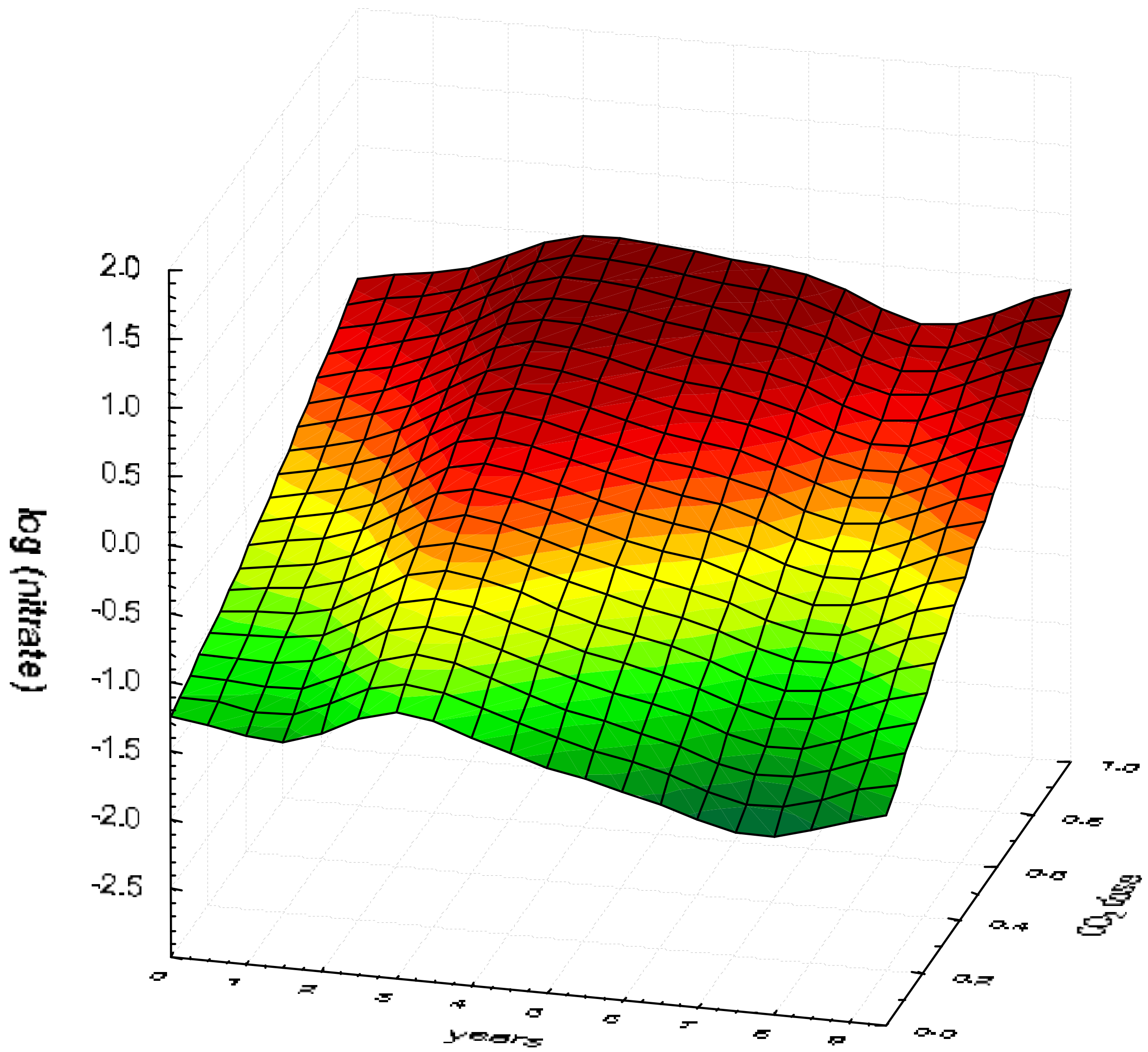
Example only, no real data (graph drawn 9 Mai 2001)


Nitrate in soil solution: all data
log (NO3-N)
seasonality: p<0.0001
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
2001
2002
2003
2004
2005
2006
2007
2008
2009

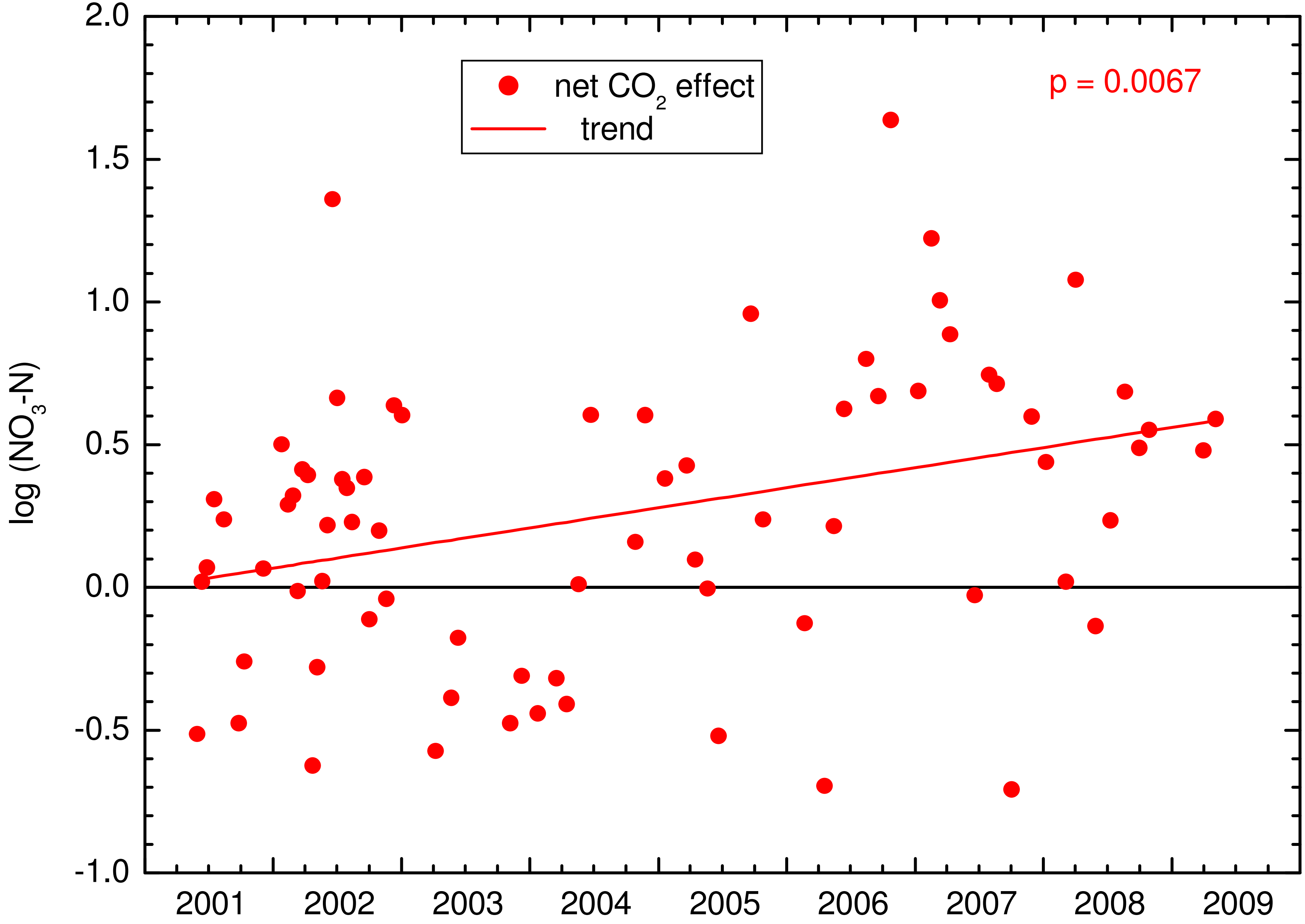


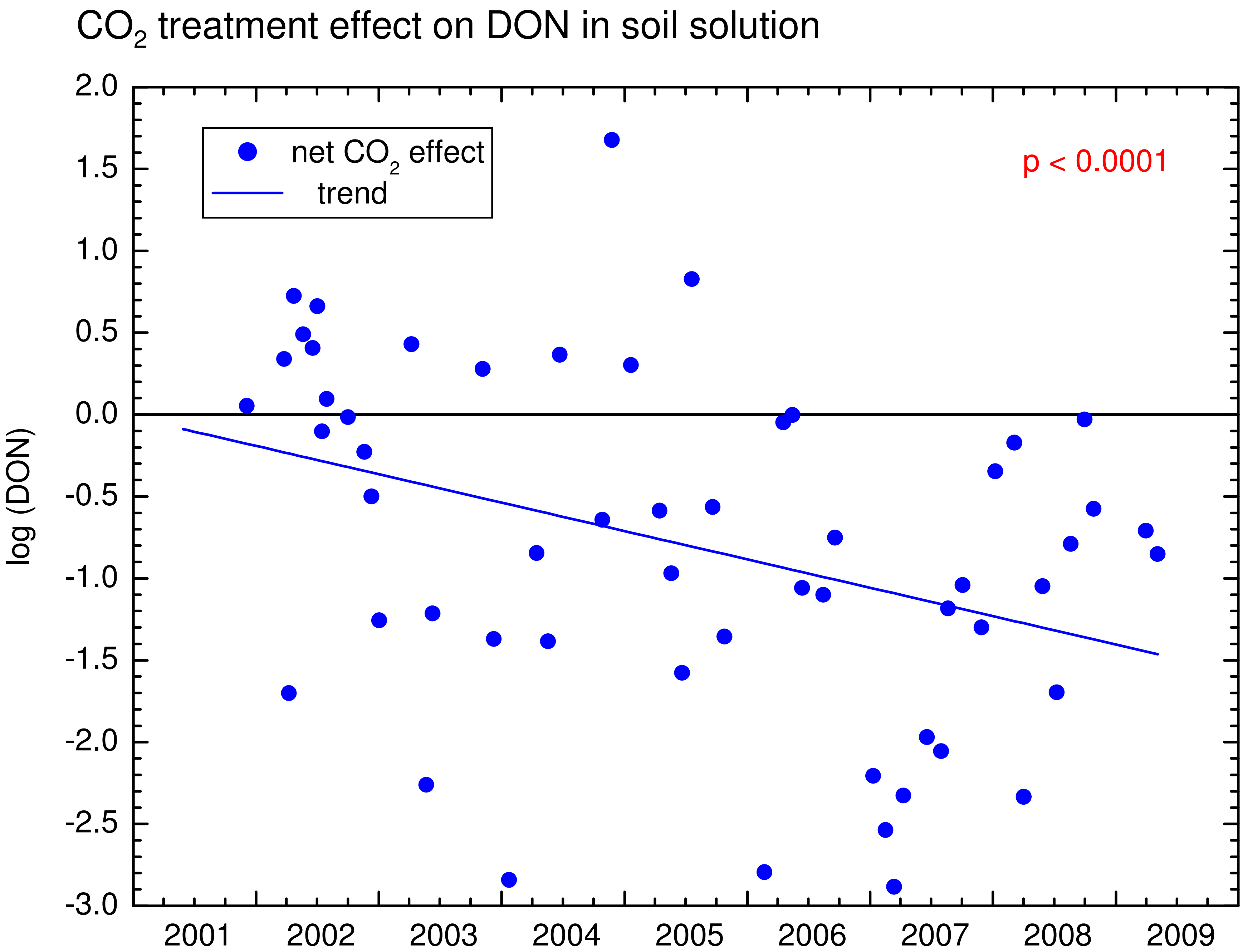
Nitrate in soil solution: grouped by CO_2 effect (based on $DI^{13}C$)
CO_2 x time: p = 0.0067
log (NO_3-N)
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
2001
2002
2003
2004
2005
2006
2007
2008
2009
low
medium
high

Nitrate in soil solution (distance-weighted least squares)

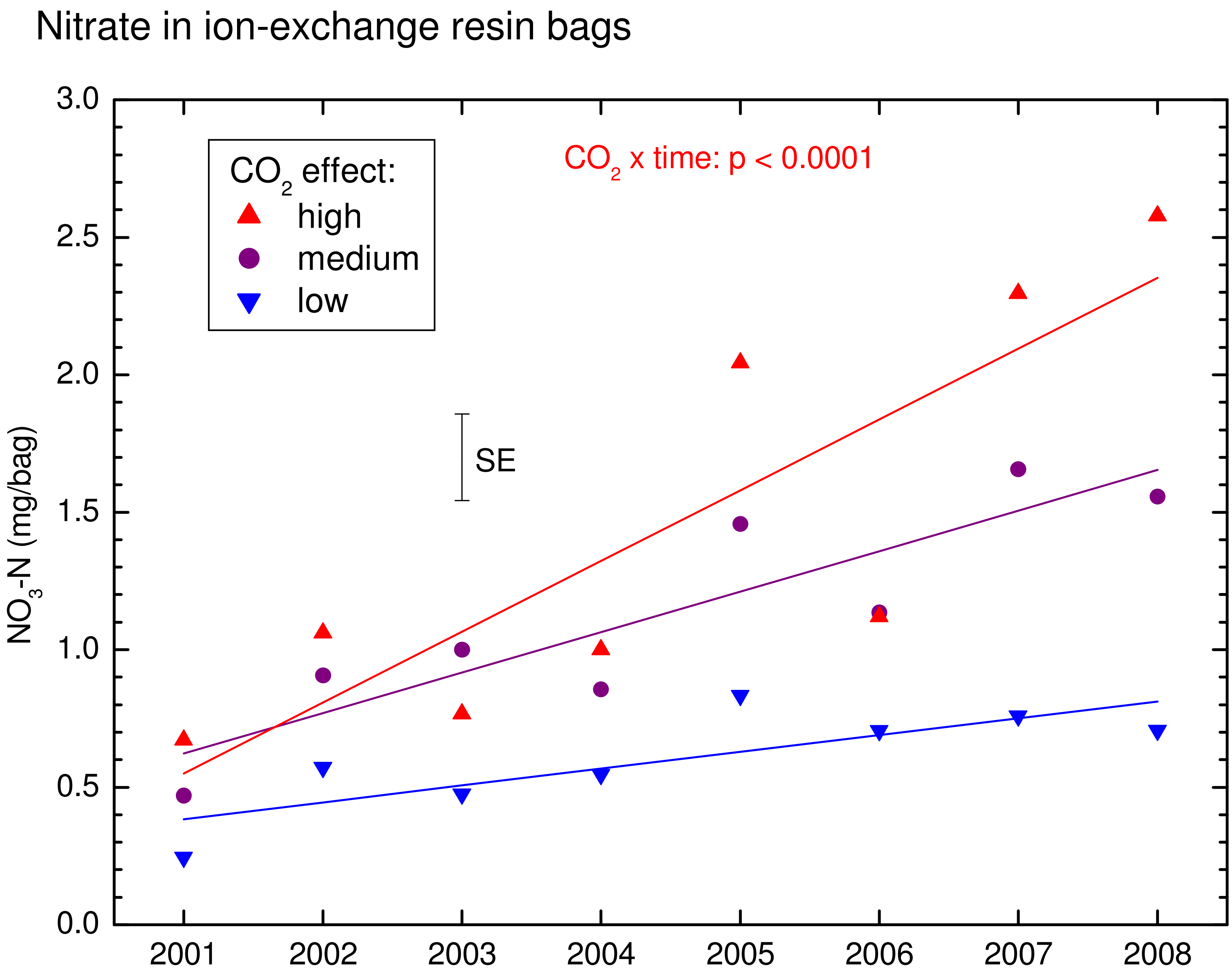


CO_2 treatment effect on nitrate in soil solution

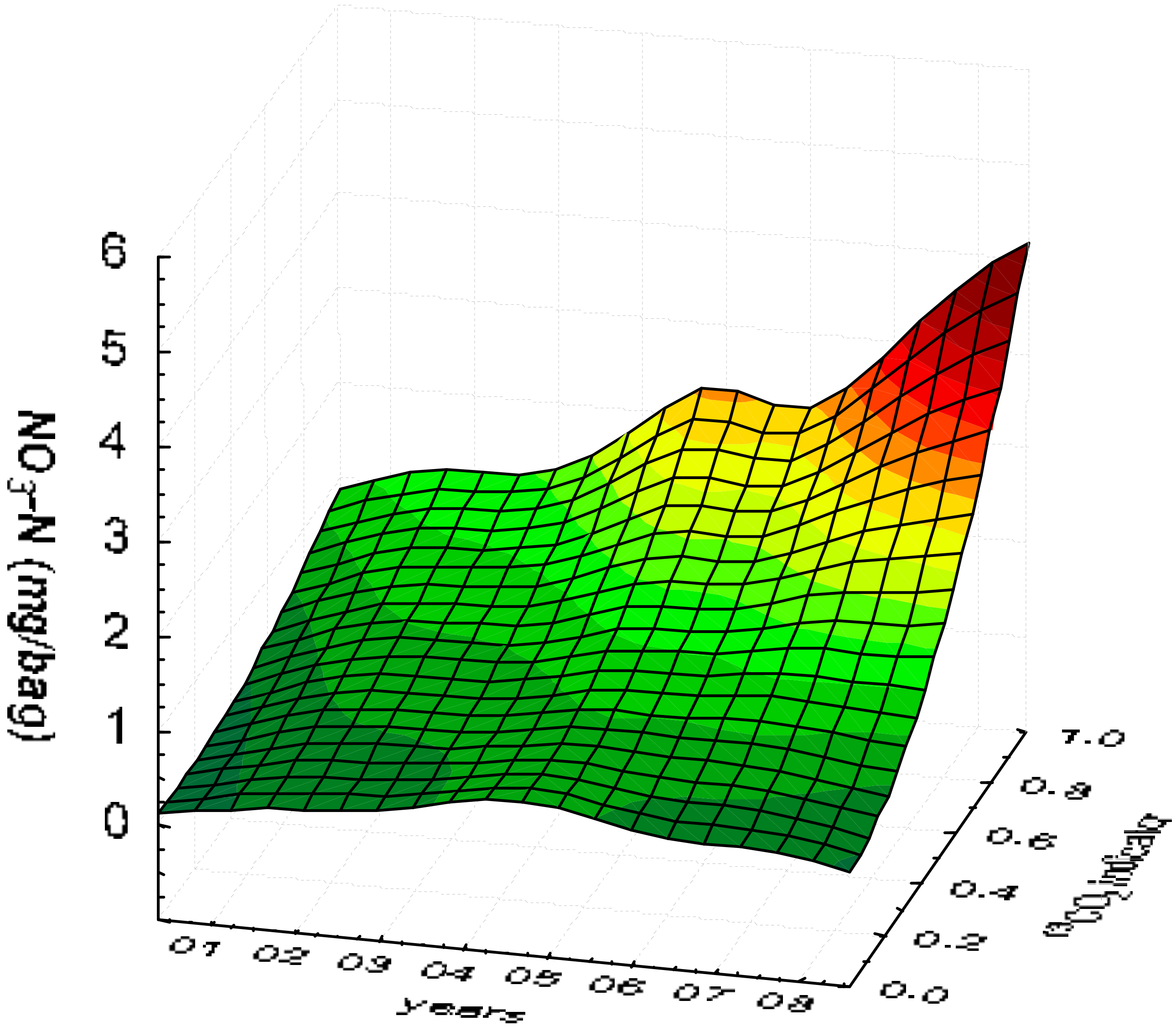


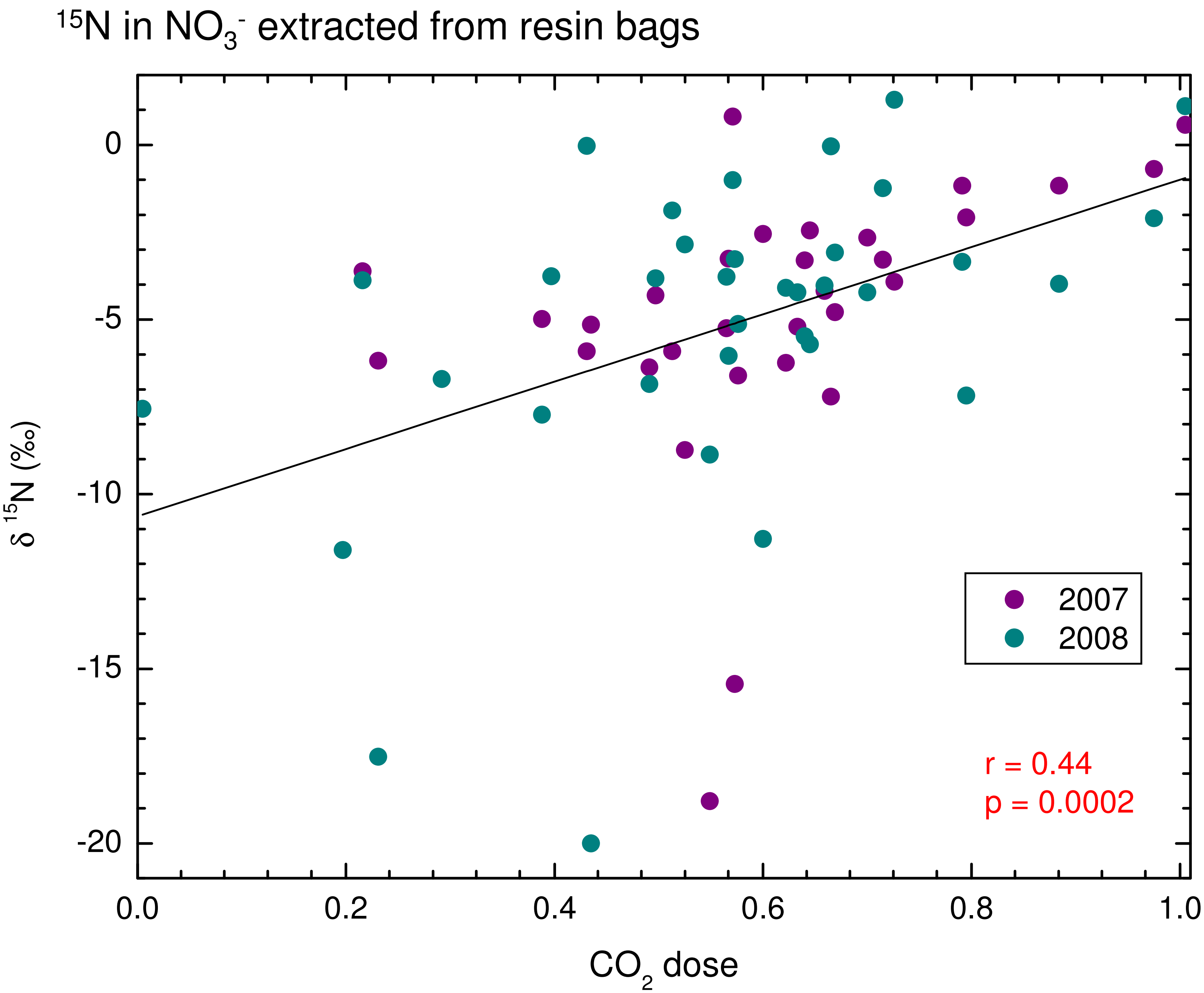


CO2 treatment effect on DON in soil solution
net CO2 effect
trend
p < 0.0001
log (DON)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
2001
2002
2003
2004
2005
2006
2007
2008
2009


Nitrate in ion-exchange resin bags
CO2 effect:
high
medium
low
CO2 x time: p < 0.0001
SE
NO3-N (mg/bag)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2001
2002
2003
2004
2005
2006
2007
2008

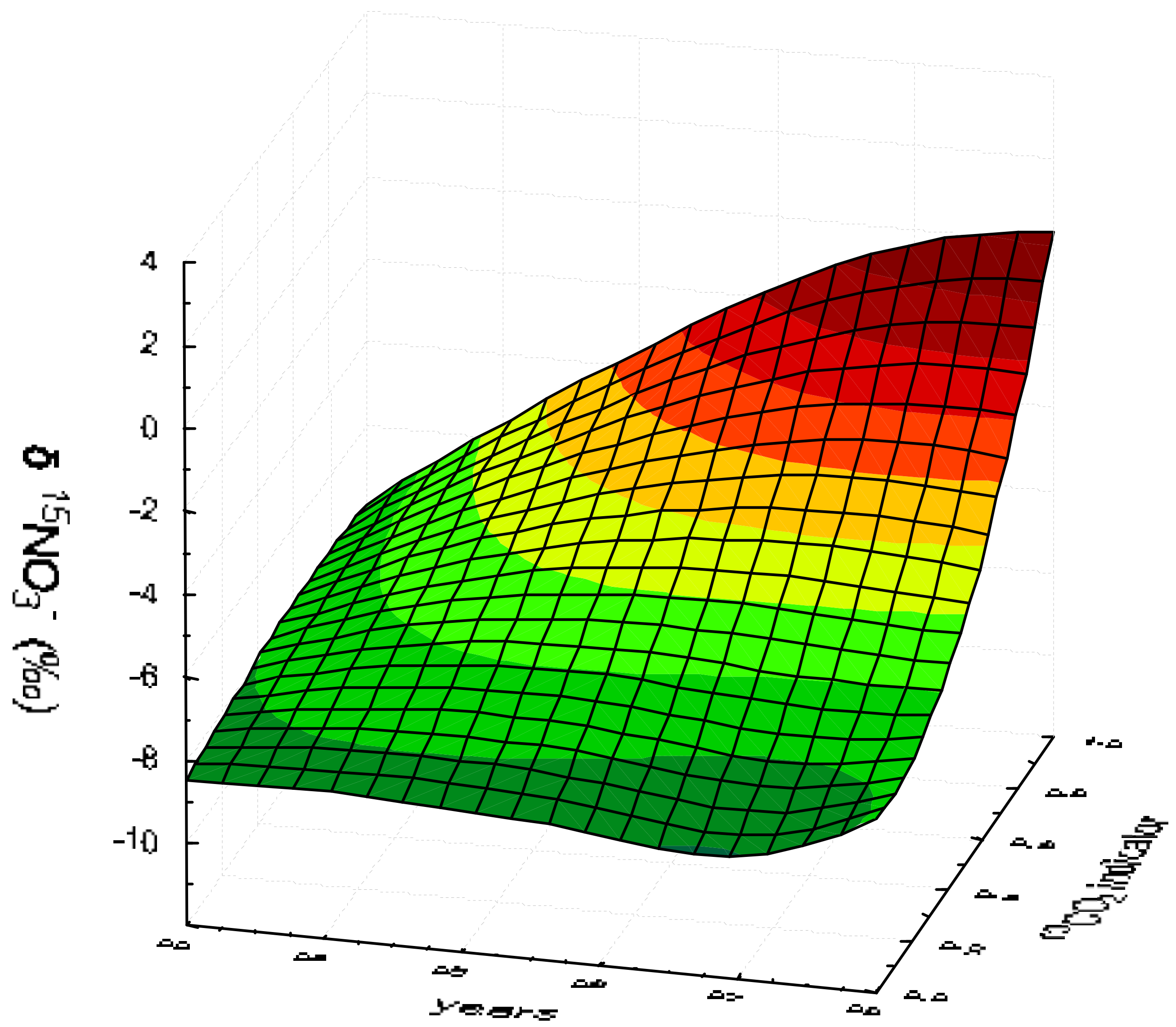
Nitrate in resin bags (distance-weighted least squares)

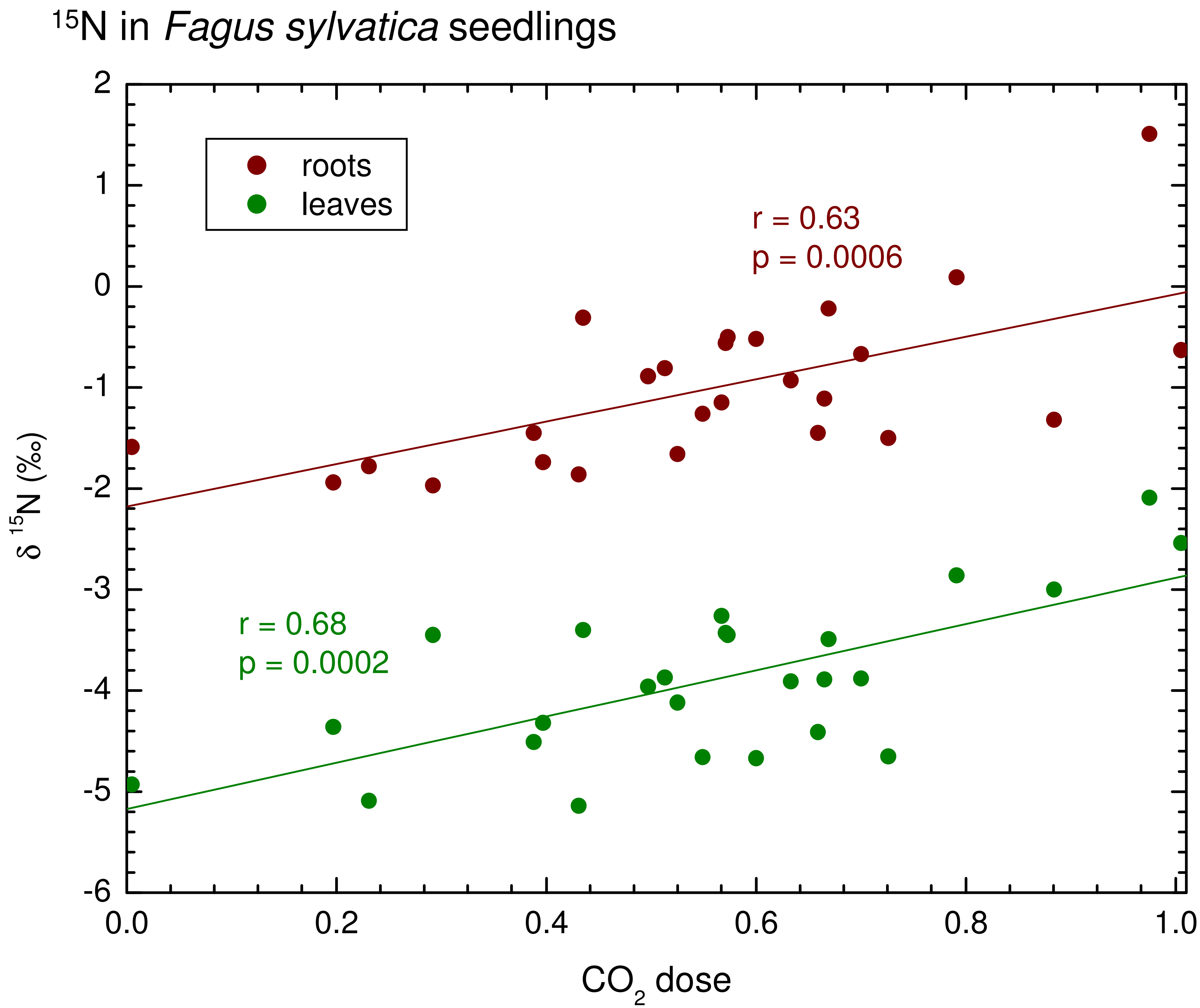




15N in NO3- extracted from resin bags
δ 15N (‰)
0
-5
-10
-15
-20
0.0
0.2
0.4
0.6
0.8
1.0
CO2 dose
2007
2008
r = 0.44
p = 0.0002

^{15}N in nitrate in resin bags (distance-weighted least squares)





15N in Fagus sylvatica seedlings
roots
leaves
r = 0.63
p = 0.0006
r = 0.68
p = 0.0002
δ 15N (‰)
CO2 dose
2
1
0
-1
-2
-3
-4
-5
-6
0.0
0.2
0.4
0.6
0.8
1.0

Global Change Biology (2012) **18**, 757–768, doi: 10.1111/j.1365-2486.2011.02559.x

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Conclusions

- large variability of soil solution
- CO_2 => more nitrate in the soil (no PNL)
- ... but less DON
- more ^{15}N in soil nitrate and in plants
- likely explanation: more mineralisation + nitrification
- either priming effect due to root exudations
- and/or because soil moisture increases due to CO_2


THE END