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Nitrous oxide emissions from acid sulphate soil at high and low groundwater level in a lysimeter experiment

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Related research presented in 7IASSC

- Virtanen, S., Simojoki, A. & Yli-Halla, M. Aluminium and iron concentrations in pore water of an acid sulfate soil – soil response to waterlogging.
- Epie, K.E., Virtanen, S., Lammi, A., Simojoki, A. & Stoddard, F. Growth of reed canary grass in high moisture acid sulphate soils.
- Šimek, M., Virtanen, S., Simojoki, A., Krištůfek, V. & Yli-Halla, M. Microbial community in boreal acid sulfate soil: vertical distribution, activity assessment, and potential for greenhouse gas emissions.

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Background

1) Various possible reactions for N_2O production in wet conditions in soils rich in organic matter
2) Potential for high microbial denitrifying enzyme acitivity (DEA) in AS soils
3) Large pools of C and N in AS soils

A risk for high N_2O fluxes from AS soils.
The risk may even be increased, if water table is kept high to prevent the oxidation of sulfides.

Reactions producing N_2O emissions from AS soils

In agricultural soils the full range of redox reactions for N fertiliser species are possible. This includes:

nitrification:

$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$ [1]

$NH_4^+ + O_2 \rightarrow 0.5\ N_2O + 1.5H_2O + H^+$ [2]

denitrification:

$NO_3^- + 1.25c + H^+ \rightarrow 0.5N_2(g) + 1.75H_2O + 1.25CO_2\ (g)$ [3]

$NO_3^- + 0.75\{CH_20\} + H^+ \rightarrow NO(g) + 1.25H_2O + 0.75CO_2\ (g)$ [4]

$NO_3^- + \{CH_2O\} + H^+ \rightarrow 0.5\ N_2O\ (g) + 1.5\ H_2O + CO_2\ (g)$ [5]

and reduction:

$2NO_3^- + 2\{CH_2O\} + 8H^+ \rightarrow N_2 + 6H_2O + CO_2(g)$ [6]

From eqns [3] to [6], acidic soils with high organic carbon content, favour denitrification, releasing N_2, NO and N_2O and possibly CO_2, provided soil water conditions are favourable. In acid sulfate soils, nitrate can also oxidise underlying sulfides producing further denitrification:

$NO_3^- + 0.7S^- + .03H^+ \rightarrow 0.5N_2(g) + 0.7SO_4^{2-} + 0.1H_2O$ [7]

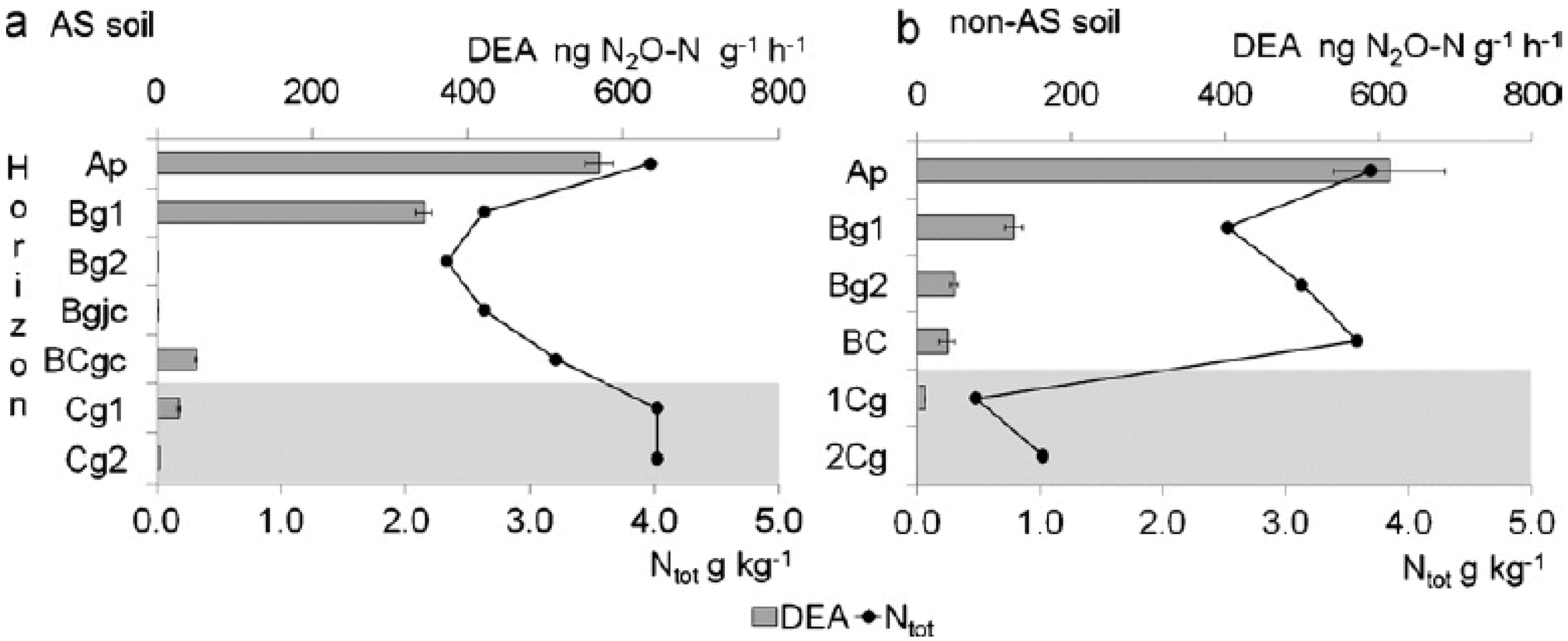
$NO_3^- + 0.4S^- + 0.6H^+ \rightarrow NO(g) + 0.4SO_4^{2-} + 0.3H_2O$ [8]

$NO_3^- + 0.6S^- + 0.4H^+ \rightarrow 0.5N_2O(g) + 0.6SO_4^{2-} + 0.2H_2O$ [9]

Again reactions [7] to [9] seem favoured by acidic conditions. In acid sulphate soils conditions appear optimum for the conversion of fertiliser N to gaseous N provided there is sufficient soil N, organic matter and water.

MacDonald et al. 2010

High denitrifying enzyme activity in AS soils



Evidence of rich microbial communities in the subsoil of a boreal acid sulphate soil conducive to greenhouse gas emissions

Miloslav Šimek[b,c], Seija Virtanen[a,*], Václav Krištůfek[b], Asko Simojoki[a], Markku Yli-Halla[a]

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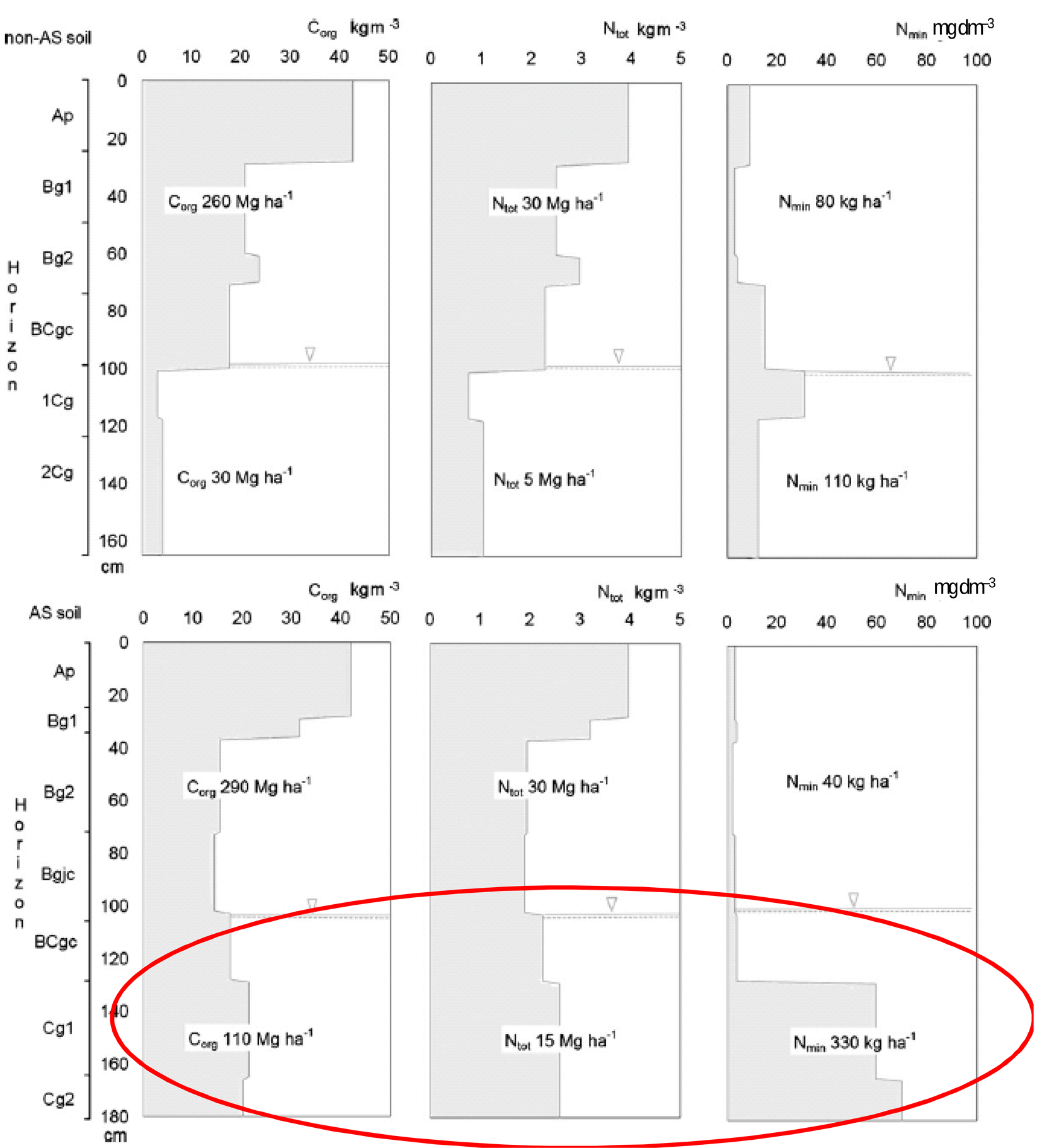
Total C, total N and mineral N stocks in the soil profiles of non-AS and AS soils.



Šimek et al. 2011.
AEE 140:113-122

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The aim of study

Do high groundwater levels increase N_2O emissions from acid sulphate soils?

Are N_2O emissions similar from cropped and uncropped acid sulphate soil?

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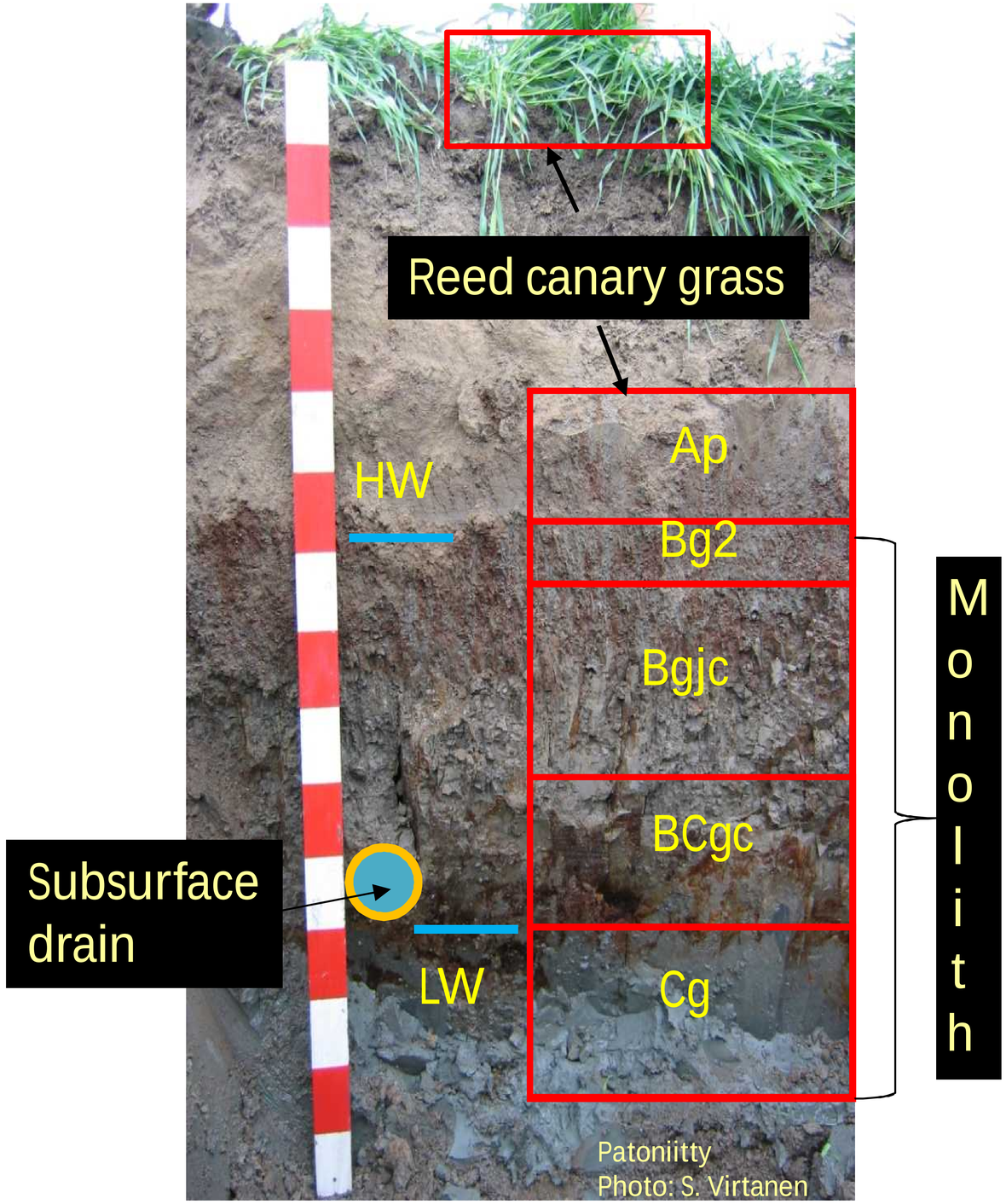
The pedon and the characteristics of soil



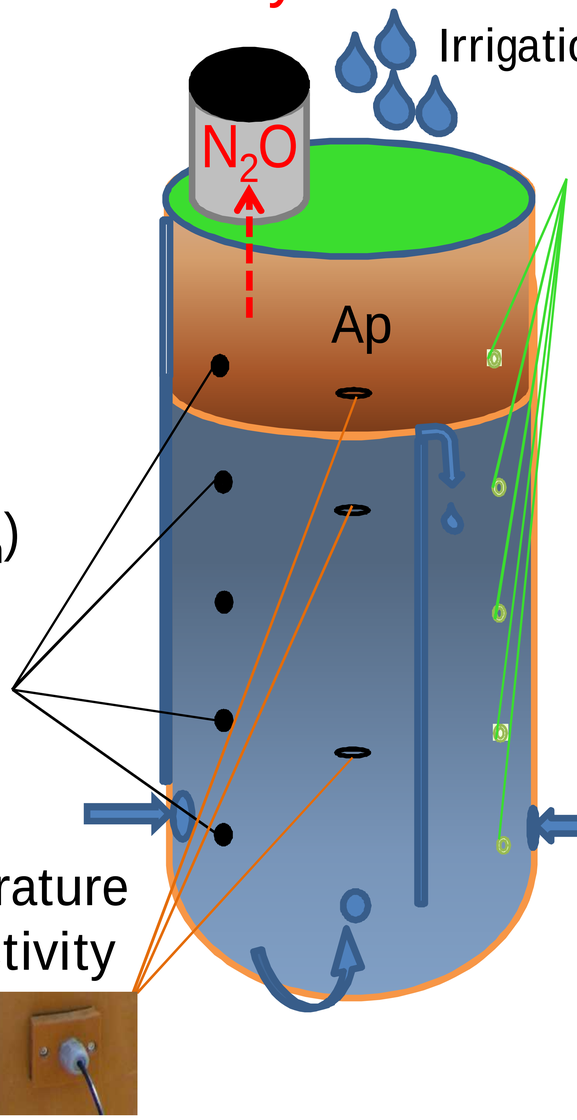
Sulfic Cryaquept

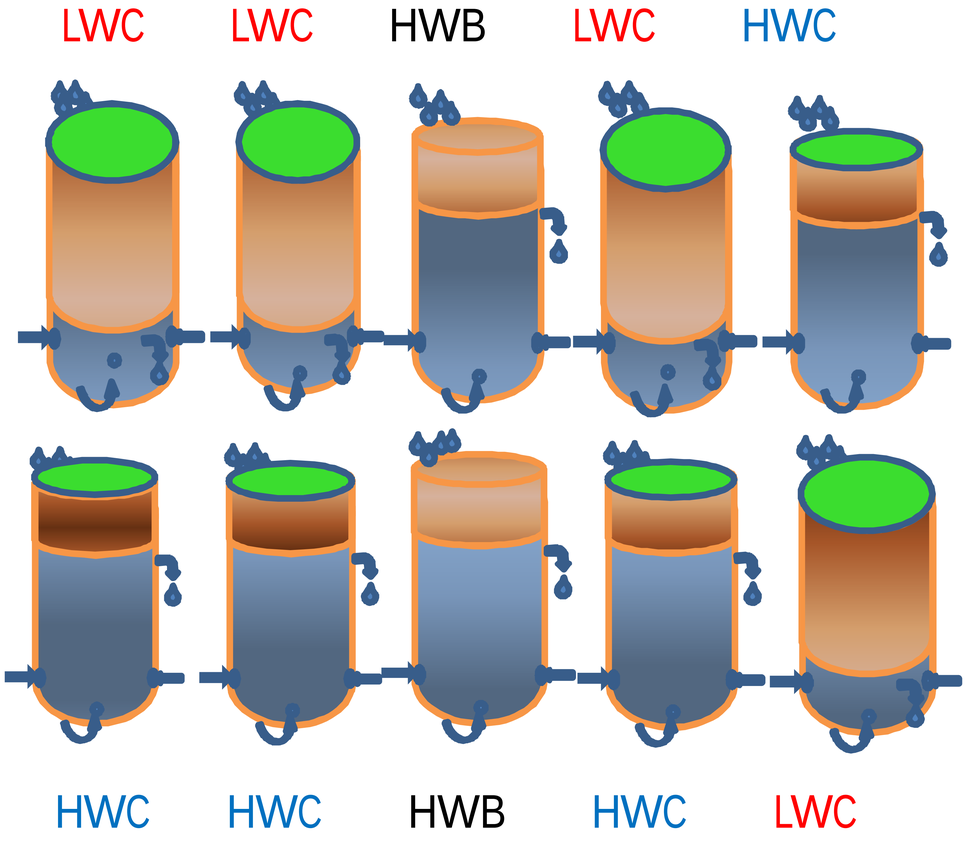
Horizon	Clay	pH Fresh	BS[1]	Total S
	%		%	g kg^{-1}
Ap	33	6.4	73	0.91
Bg2	48	4.4	25	0.94
Bgjc	61	3.8	19	4.21
BCgc	57	4.2	27	4.57
Cg	58	6.5	76	14.87

[1] $(Na^+, K^+, Ca^{2+}, Mg^{2+})/CEC*100$

The setup of experiment and measurements

- Ground water table: high (20 cm depth) or low (70 cm depth).
- Irrigation: according to local long-term precipitation + two 2-day periods with +25 mm/day.
- N_2O emission measured by closed chambers and GC biweekly in 5 May – 13 Oct 2010.





Eh, **θ** ,T and EC were logged continuously.
pH, Al, Fe and DOC in pore water were determined biweekly or monthly.

LWC low water table, cropped
HWC high water table, cropped
HWB high water table, bare soil

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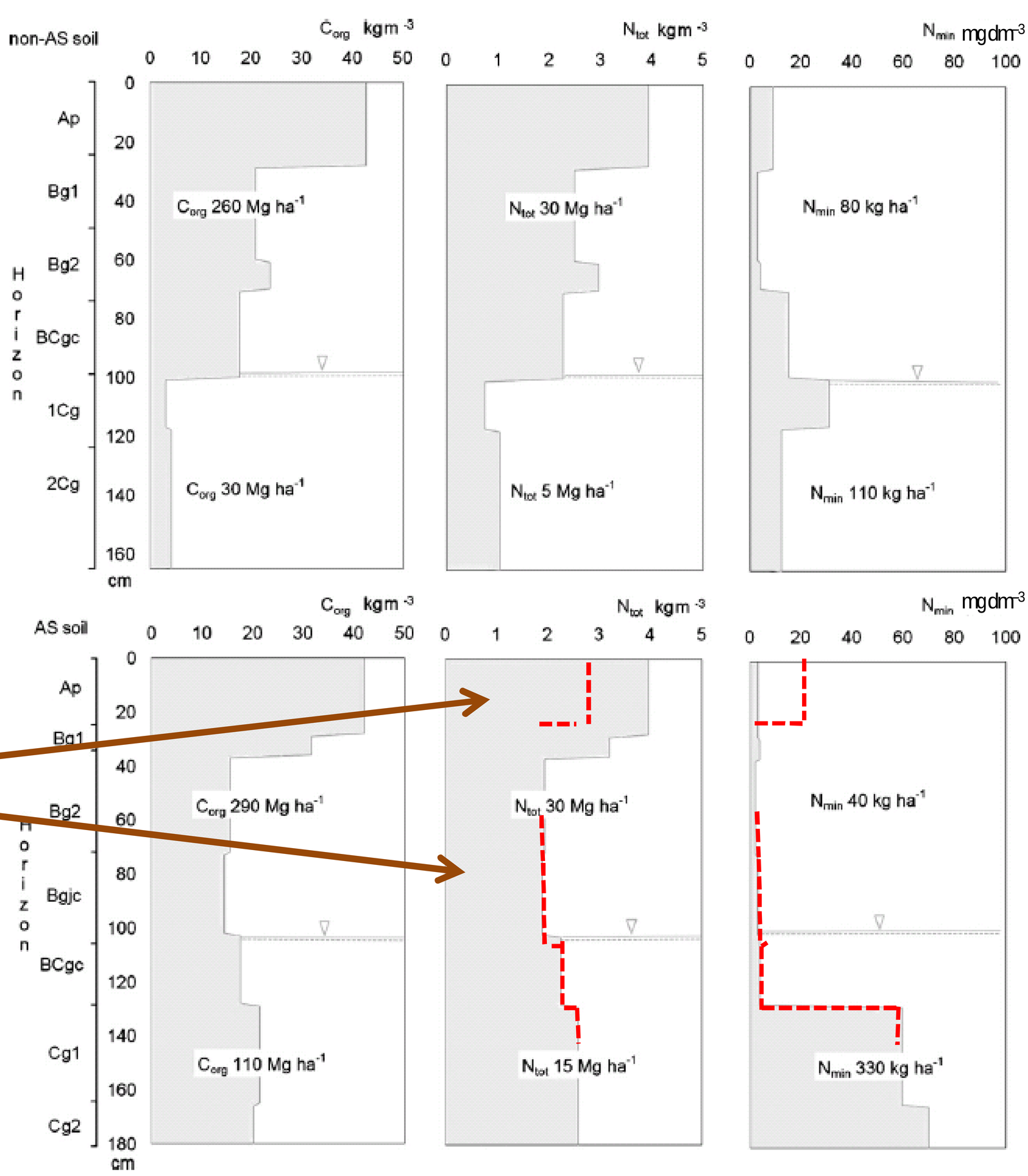
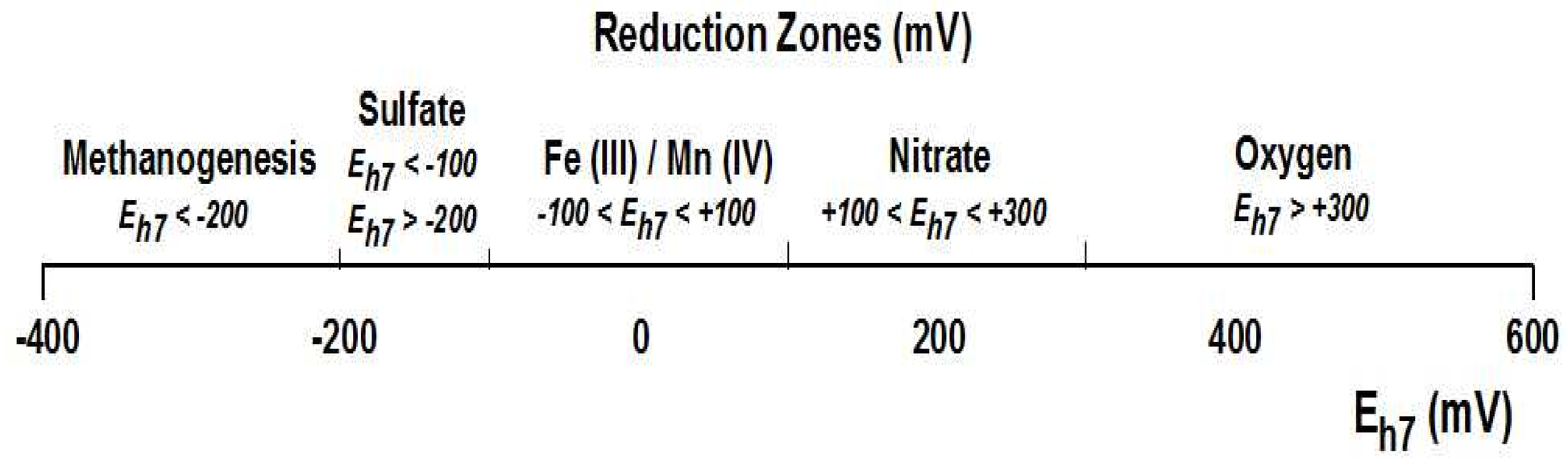
The soil layers taken into the lysimeters.

N fertilization in early May corresponded to N 90 kg/ha/yr



Ranges of reduction potentials for various compounds



The reduction zones adapted from Reddy et al. (2000).

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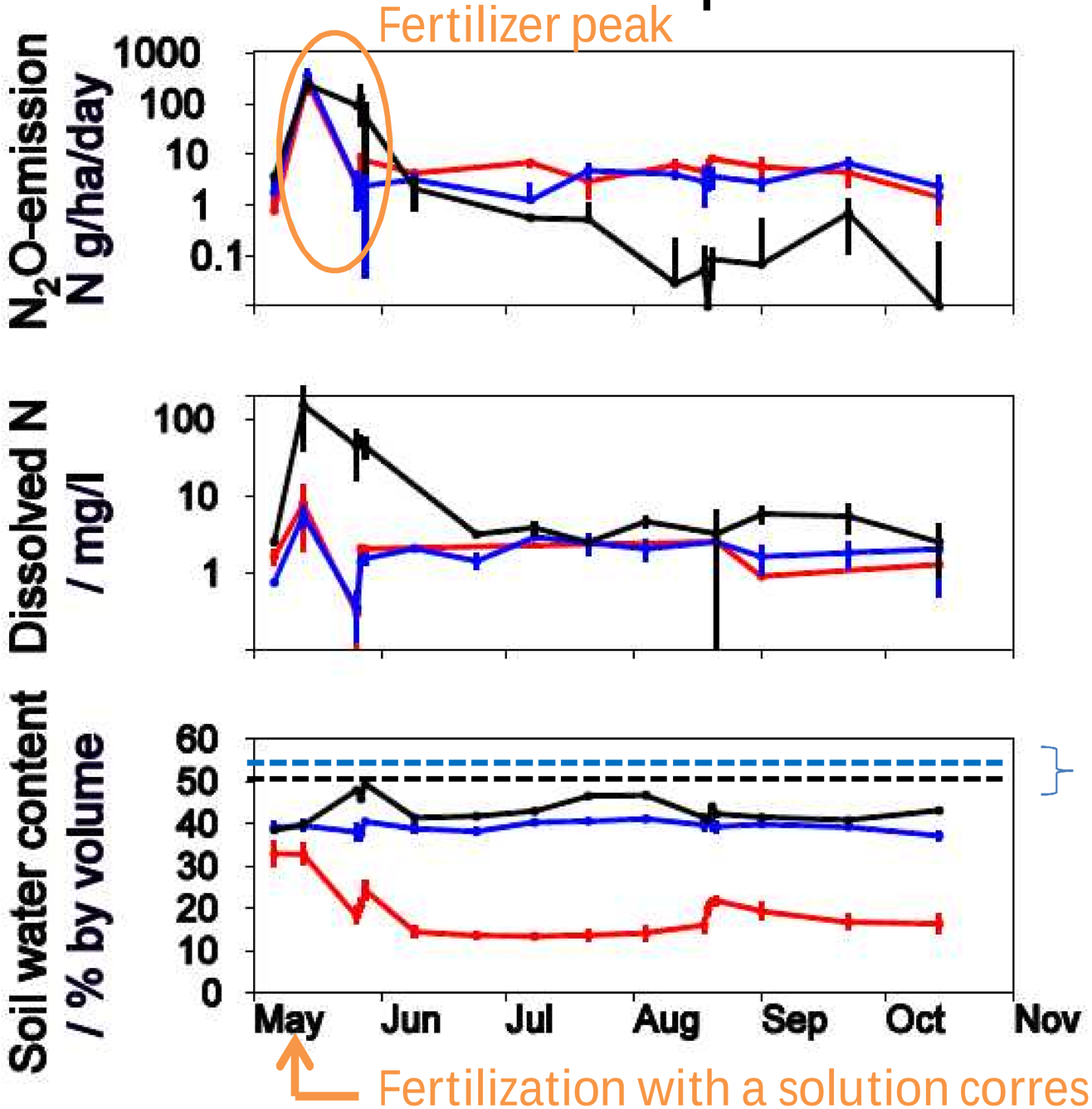
Soil N_2O emissions, dissolved N and water content in different experiment treatments in 2010



High groundwater Bare (**HWB**)

High groundwater Cropped (**HWC**)

Low groundwater Cropped (**LWC**)

Total porosity (water saturation)

Fig 1. The emission of N_2O from soil, the concentration of dissolved N in pore water (10 cm depth), and the water content (15 cm depth) at different experimental treatments (mean ± standard error, n = 2-4).

Simojoki et al. (unpublished)

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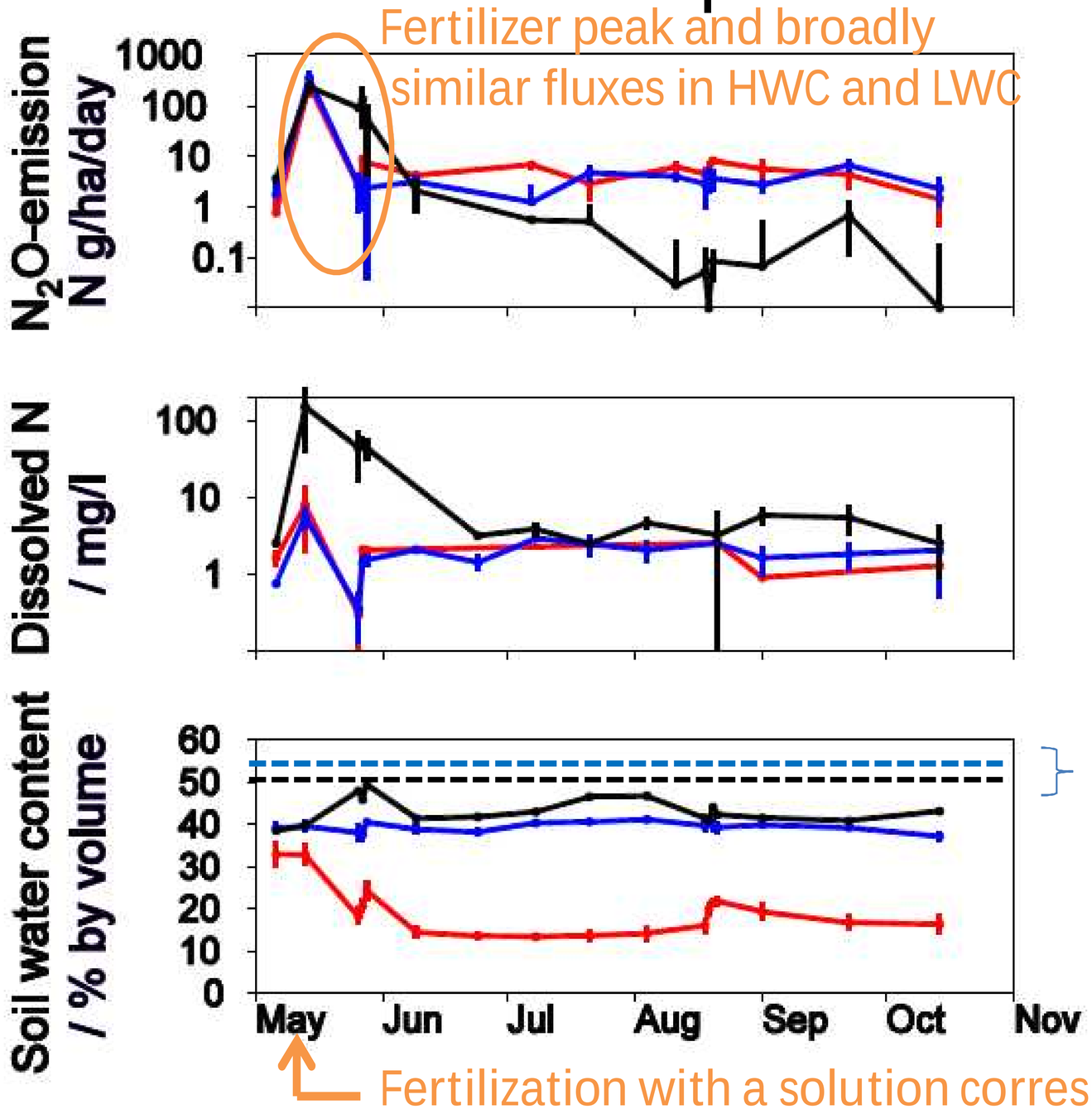

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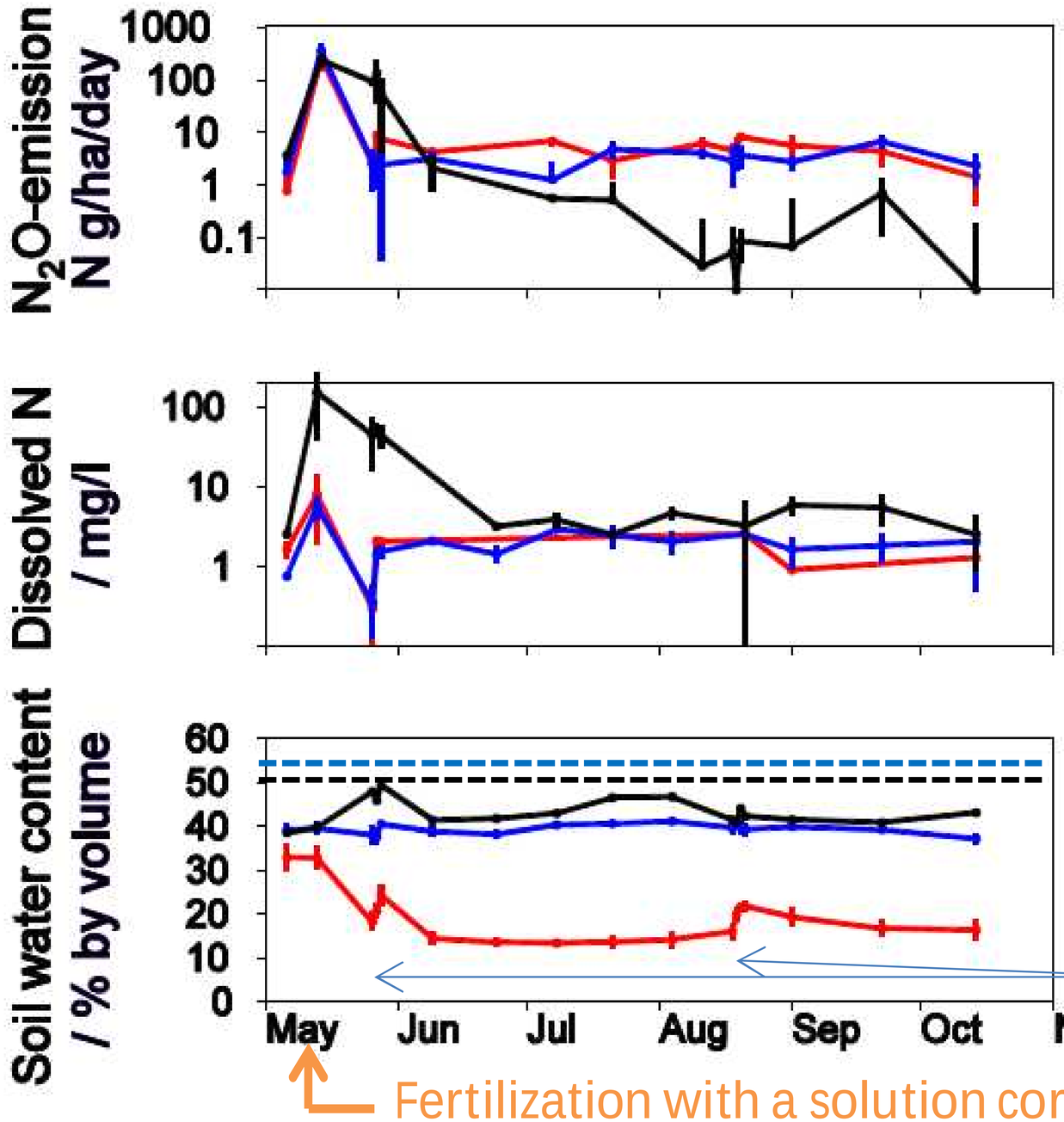

High groundwater Bare (**HWB**)

High groundwater Cropped (**HWC**)

Low groundwater Cropped (**LWC**)

Total porosity (water saturation)

Irrigation with additional 25 mm/day for 2 days caused had little impact

Fertilization with a solution corresponding to N 90 kg/ha

Fig 1. The emission of N_2O from soil, the concentration of dissolved N in pore water (10 cm depth), and the water content (15 cm depth) at different experimental treatments (mean ± standard error, n = 2-4).

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Discussion

In HWC, topsoil water content was always about 40%
⇒ max 10-15% air space, and WFPS (water-filled pore space) >70%.
⇒ at least temporarily deficient aeration in soil
⇒ high N_2O emissions after fertilization

In LWC, topsoil water content was usually about 15% (40% air) and WFPS < 30%
⇒ oxygen deficiency and large denitrification in topsoil unlikely
⇒ production of N_2O in deeper soil horizons?

Immediately after the fertilization, however, topsoil water contents in the LWC were still >30% (WFPS about 60%)
⇒ significant denitrification and large N_2O fluxes possible

In HWB, topsoil water contents were still >40% (<10 % air) and WFPS >80%
⇒ significant denitrification and large N_2O fluxes likely

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Conclusions

Nitrogen fertilization causes large N_2O emissions from AS soils immediately after the fertilization as in other soil types.

Plant nutrient uptake decreases efficiently the dissolved N in pore water and the N_2O emissions from soil to the atmosphere.

Cumulative N_2O emissions (corresponding to about N 4 kg/ha during 161 days) are somewhat higher compared with most mineral soils.

This experiment does not support the view that raising the groundwater level to prevent sulphide oxidation would significantly increase N_2O emissions from AS soils to the atmosphere.

Literature

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