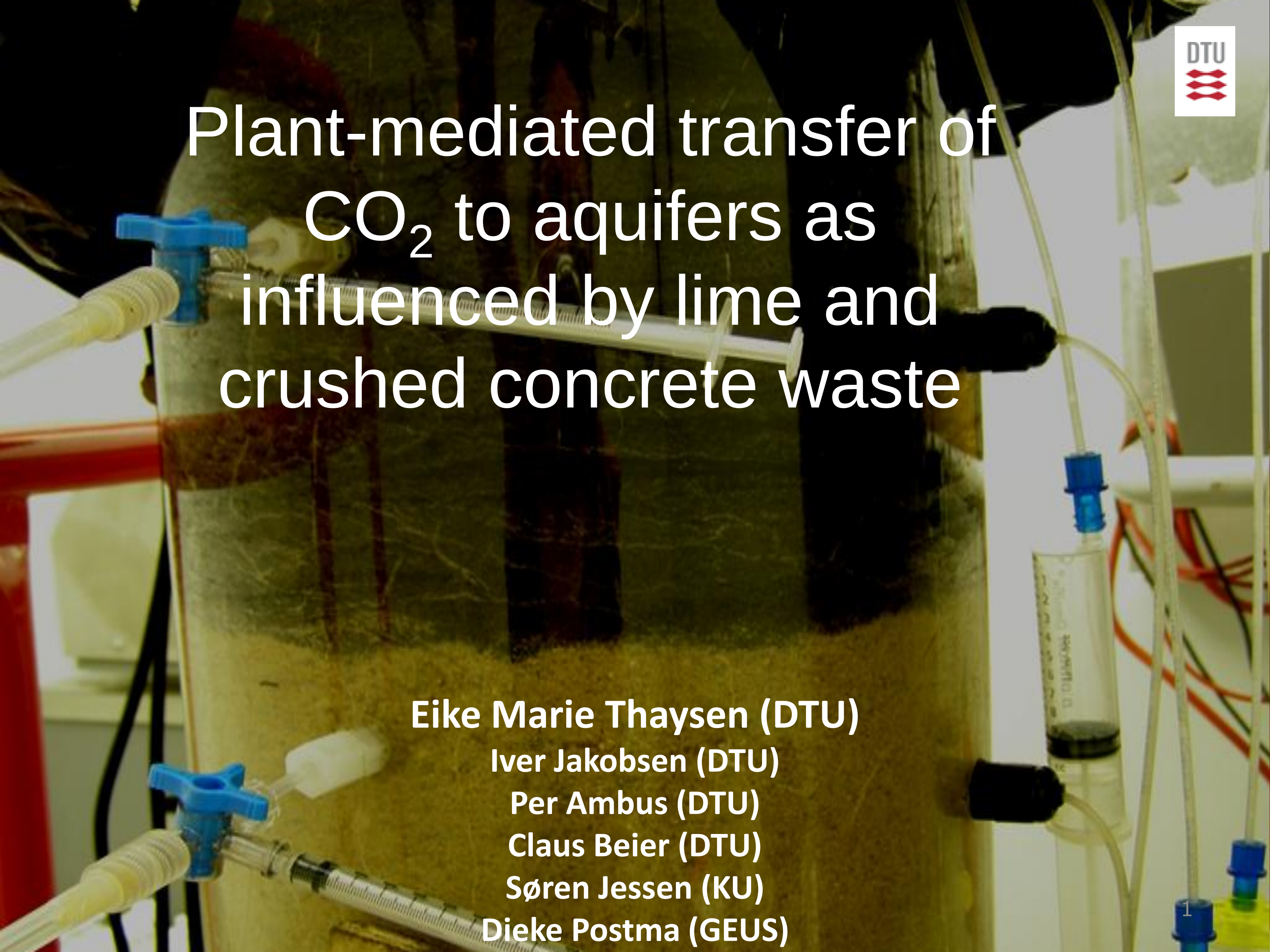
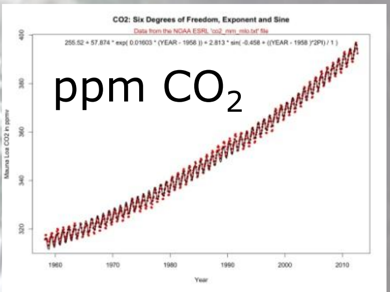


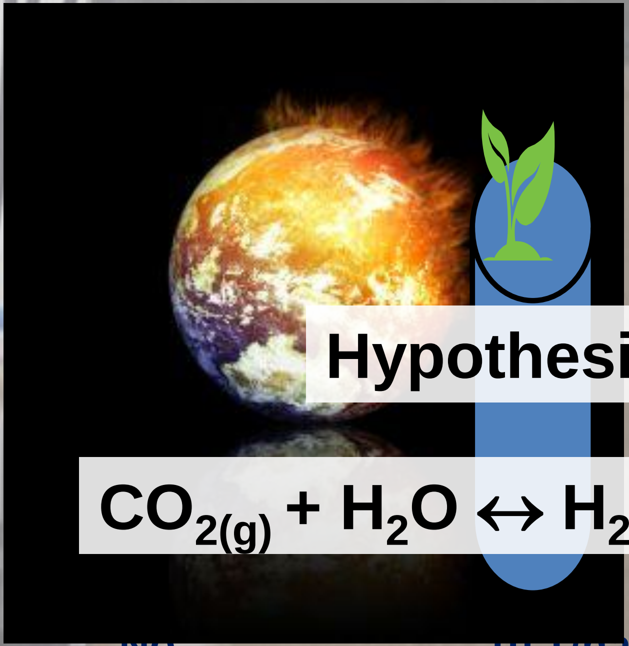
Plant-mediated transfer of CO_2 to aquifers as influenced by lime and crushed concrete waste

Eike Marie Thaysen (DTU)
Iver Jakobsen (DTU)
Per Ambus (DTU)
Claus Beier (DTU)
Søren Jessen (KU)
Dieke Postma (GEUS)



Mesocosms studies

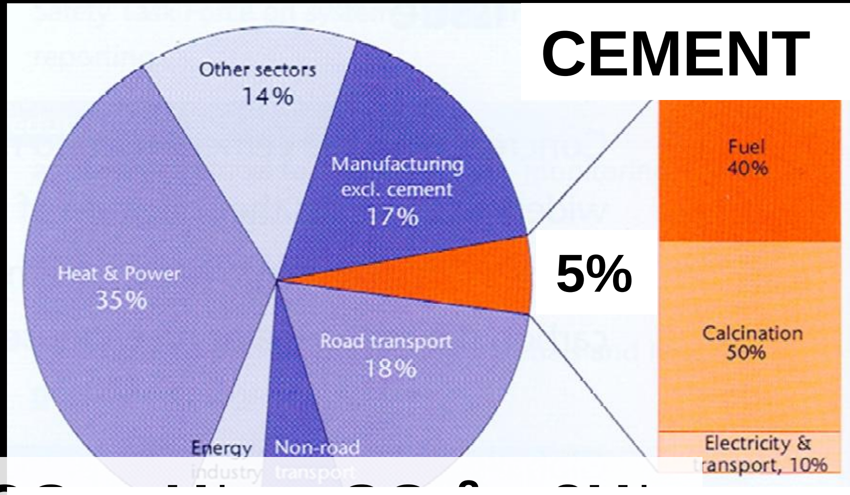
to identify factors controlling CO_2 fluxes in the vadose zone and transport of Dissolved Inorganic Carbon (DIC) to aquifers



$CO_{2(g)}$ + H_2O ↔ H_2

Concrete: cement (7-15%), water, sand, gravel-

Contains base cations (Ca^{2+}, Mg^{2+})



Calcination:

$CaCO_3$ ↔ CaO+ $CO_{2(g)}$↑ ~800°C

Wbscd, 2005

No amendment | 10 T/ha $CaCO_3$ (pH 8) | 78 T/ha crushed concrete (pH 7) | 212 T/ha crushed concrete (pH 8)

pH of topsoil~ 6

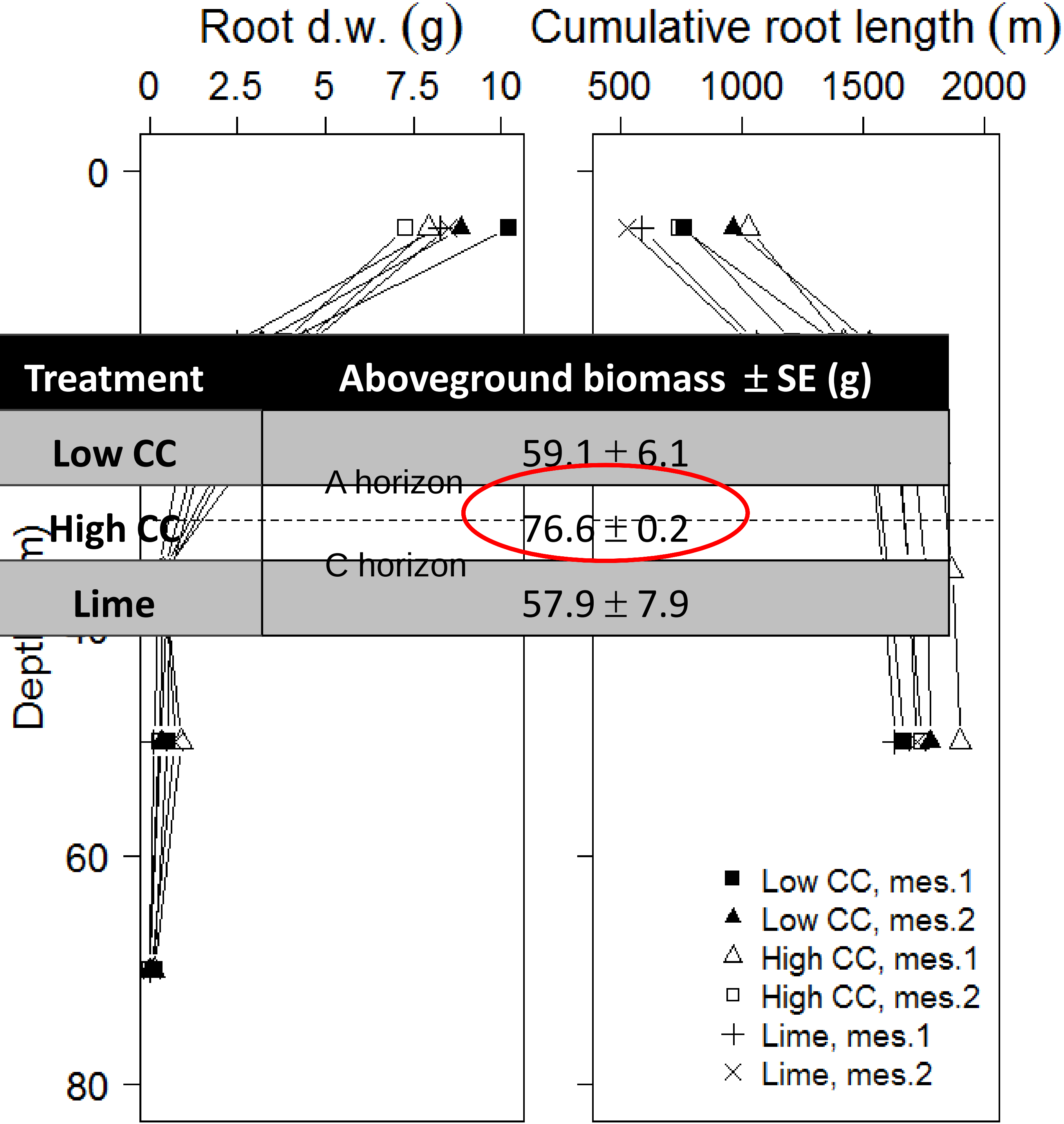
Can we store additional CO_2 in aquifers???

CONTROL | LIME | LOW CC | HIGH CC

Plant Biomass

~90% of root mass in A horizon

2-5 times higher root mass in mesocosms than in the field
(e.g., *Biscoe et al., 1975; Xu et al. 1992; Malhi 2002*)



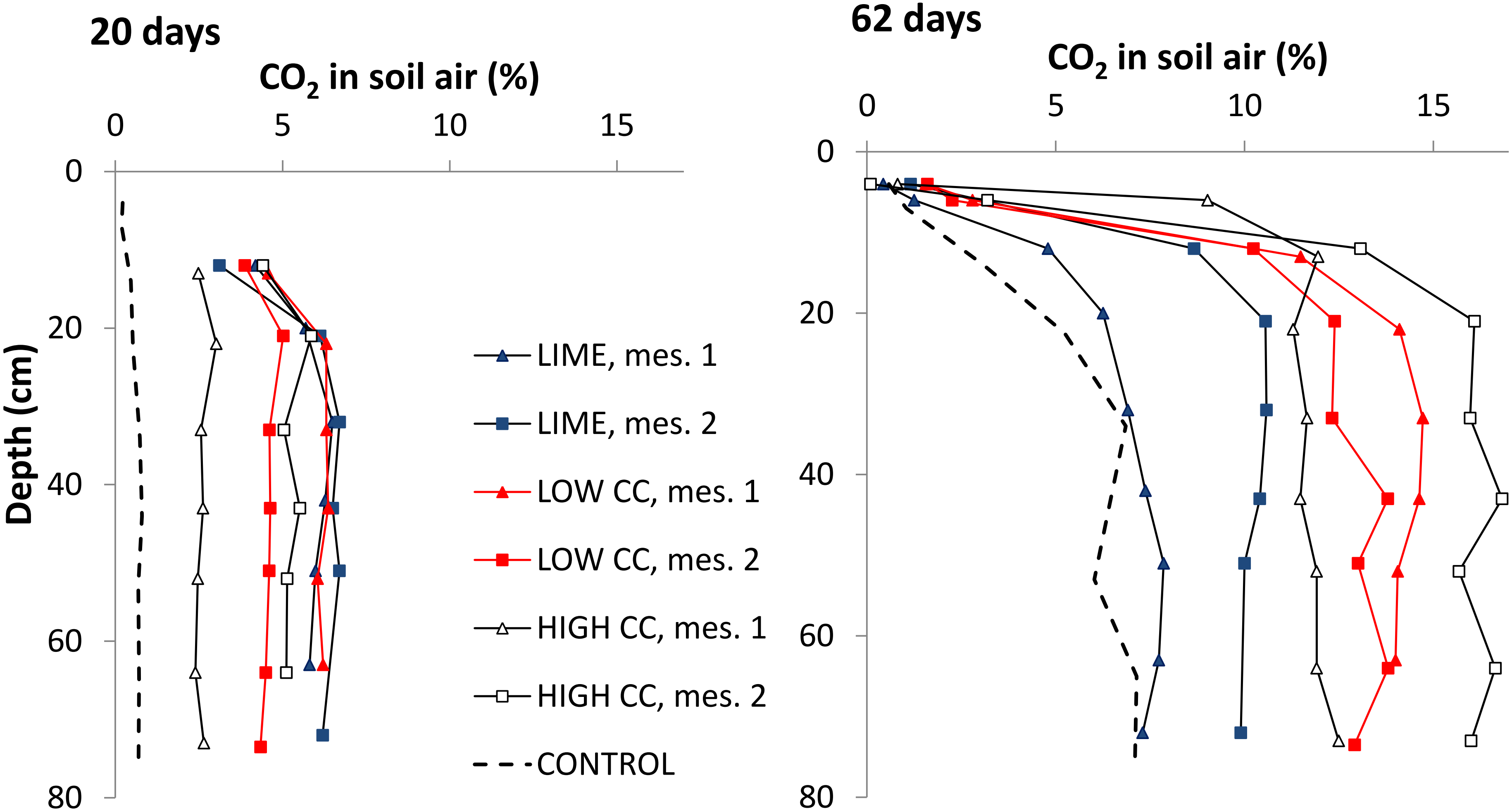
Treatment	Aboveground biomass ± SE (g)
Low CC	59.1 ± 6.1
High CC	76.6 ± 0.2
Lime	57.9 ± 7.9

CO_2 profiles

CC > lime

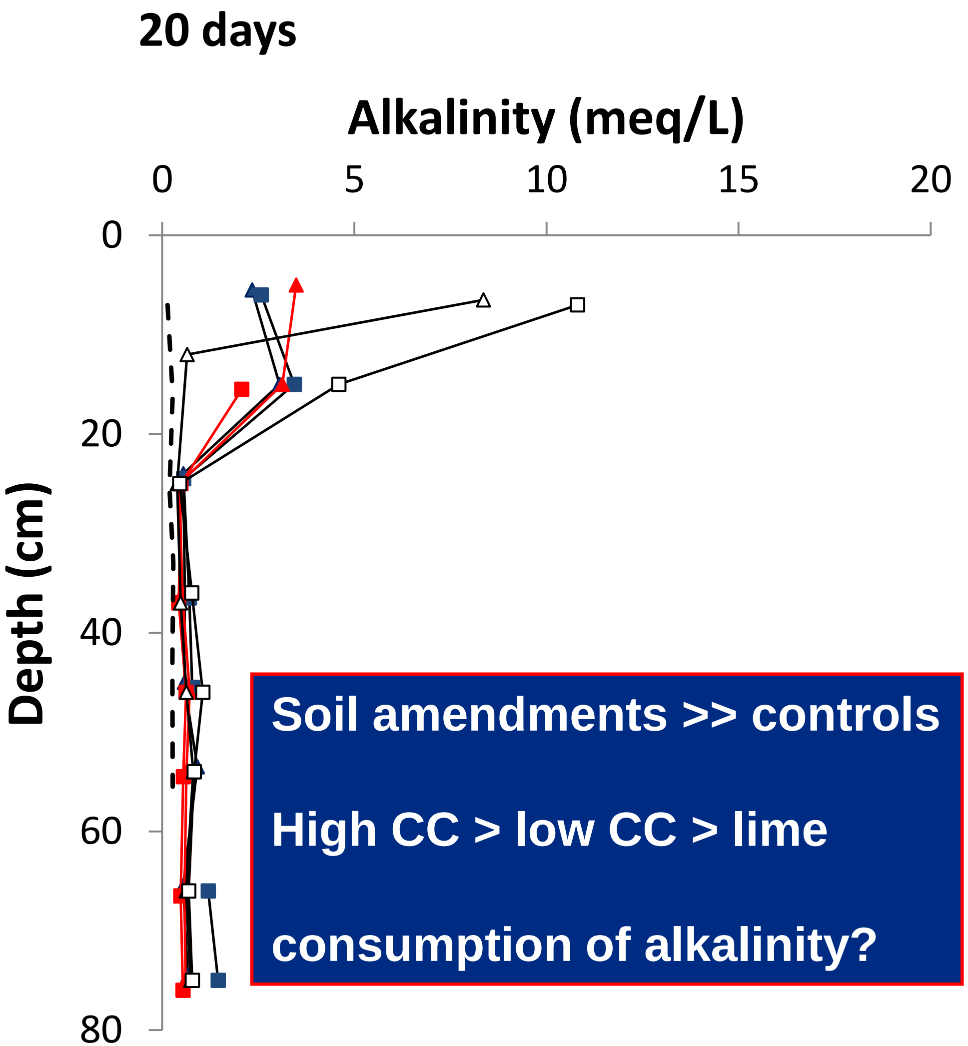
Soil amendments >> controls

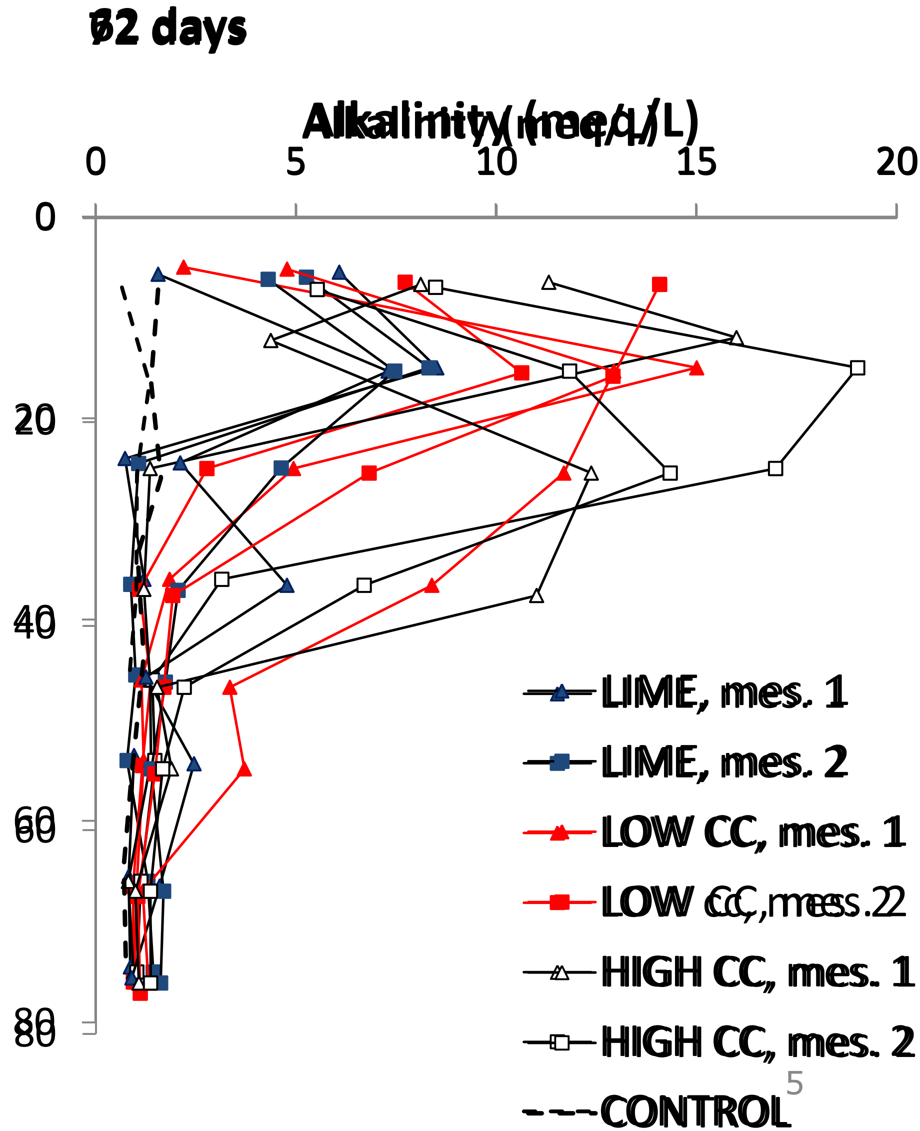
pCO_2 >> pCO_2 in the field



temp of soil ~19-22°C

Alkalinity profiles





Soil amendments >> controls

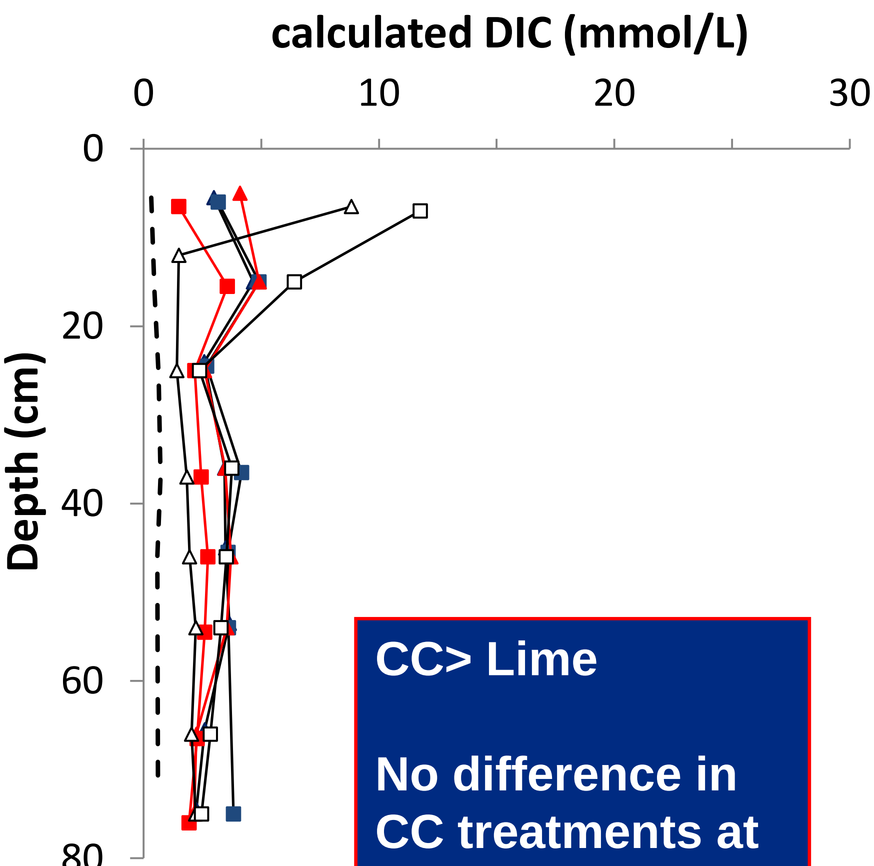
High CC > low CC > lime

consumption of alkalinity?

~1 water-filled pore volume flushed

DIC

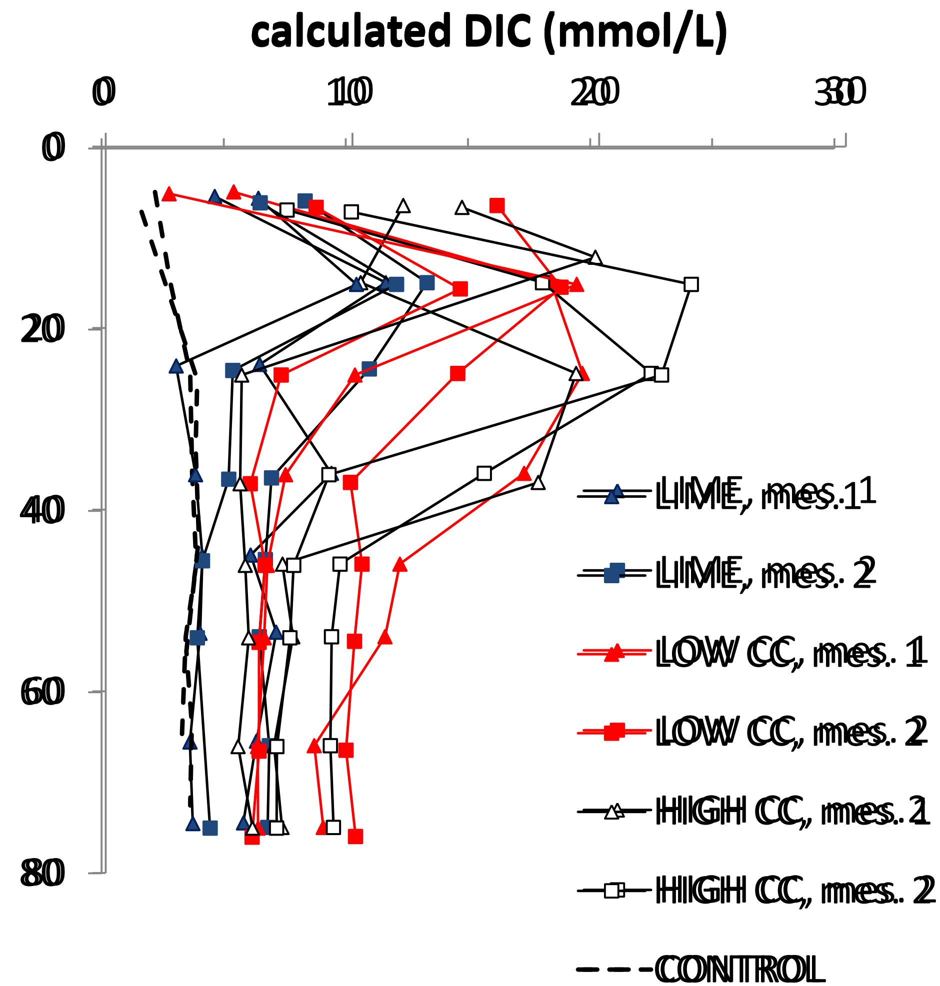
20 days



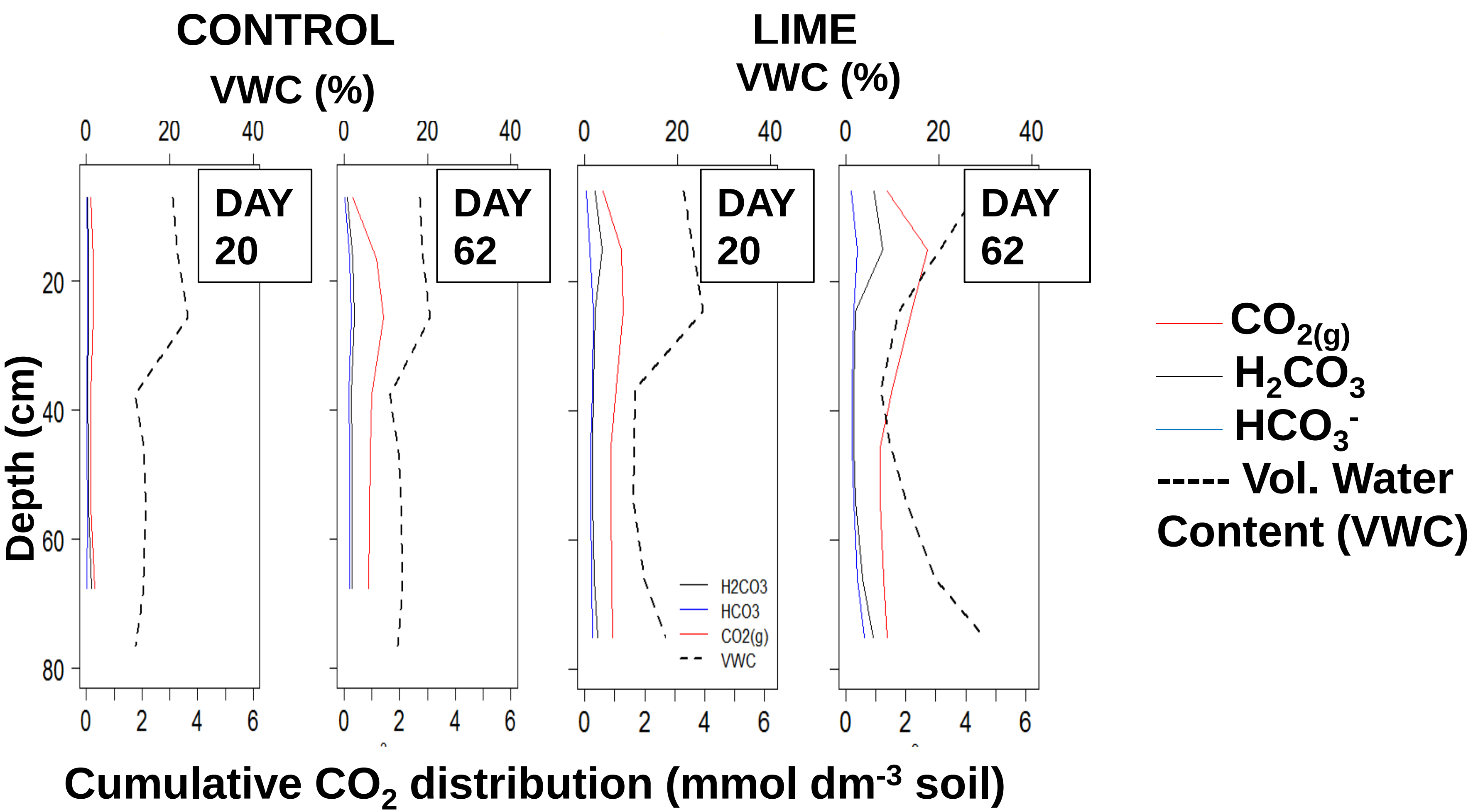
CC> Lime

No difference in CC treatments at the bottom

61 days
72 days

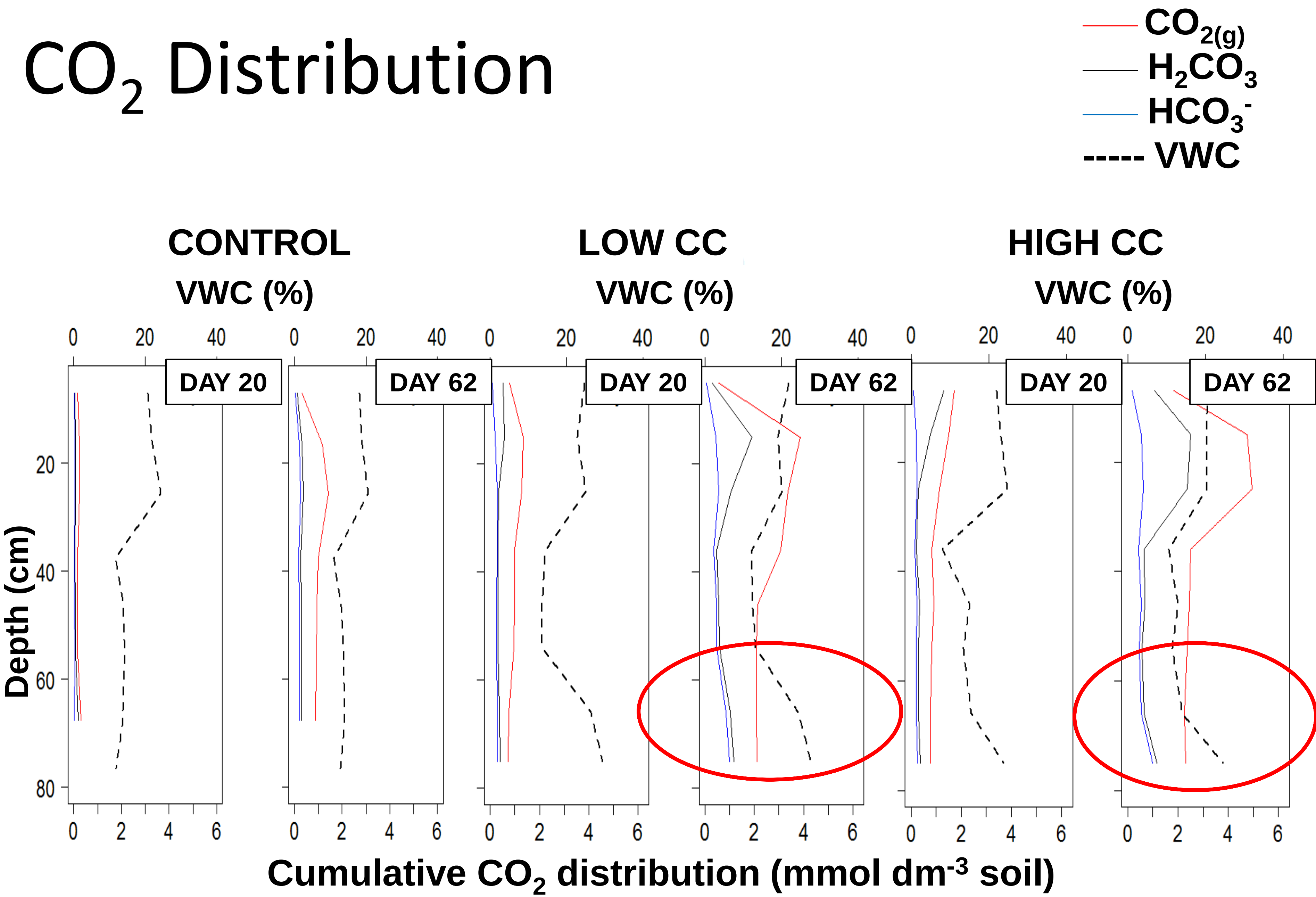


CO_2 Distribution



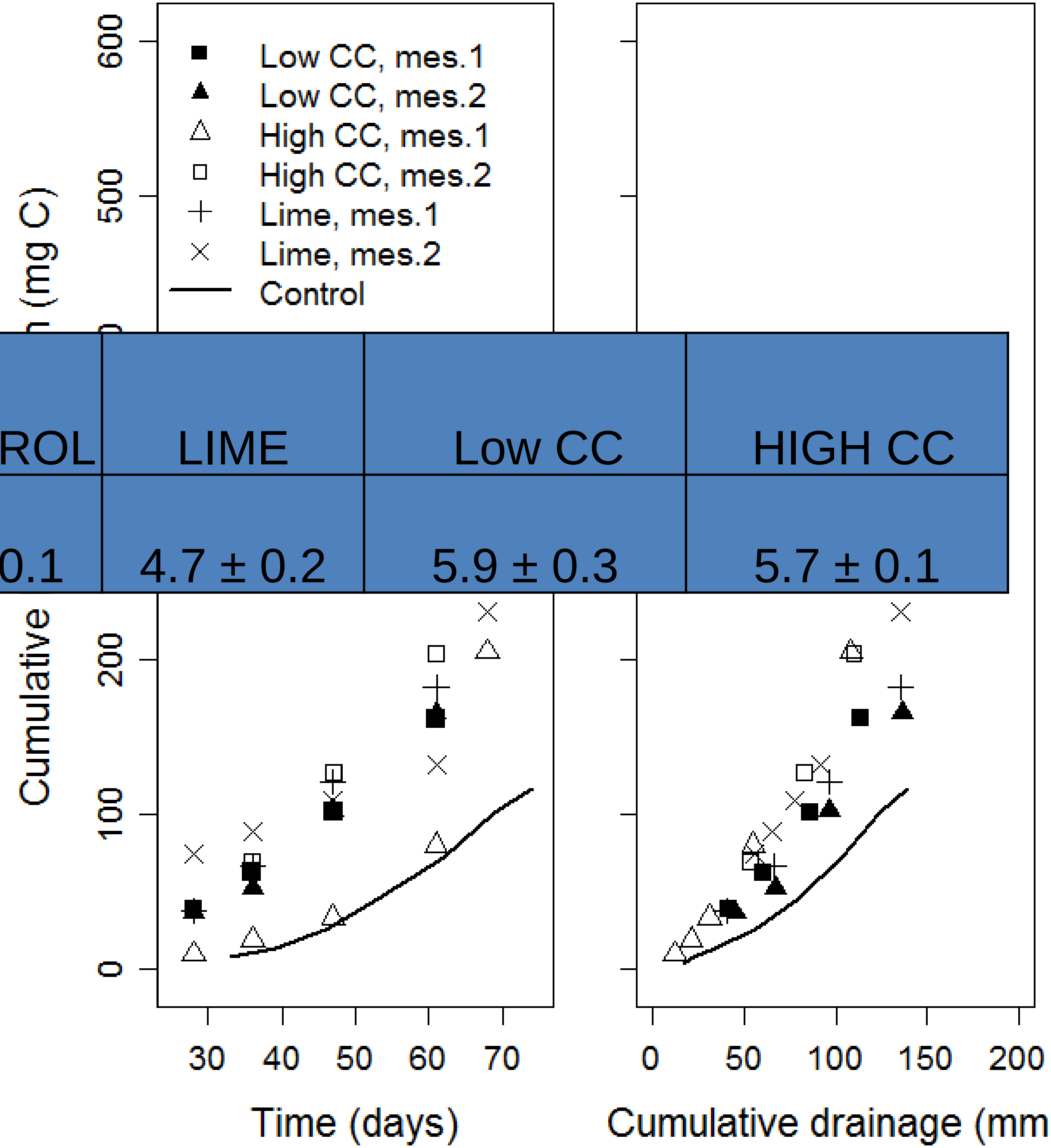
Lime > control. CO_2 mainly present in gas phase

CO_2 Distribution



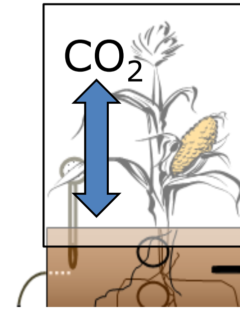
CC> control. High VWC at the bottom- higher DIC

DIC Perco-lation

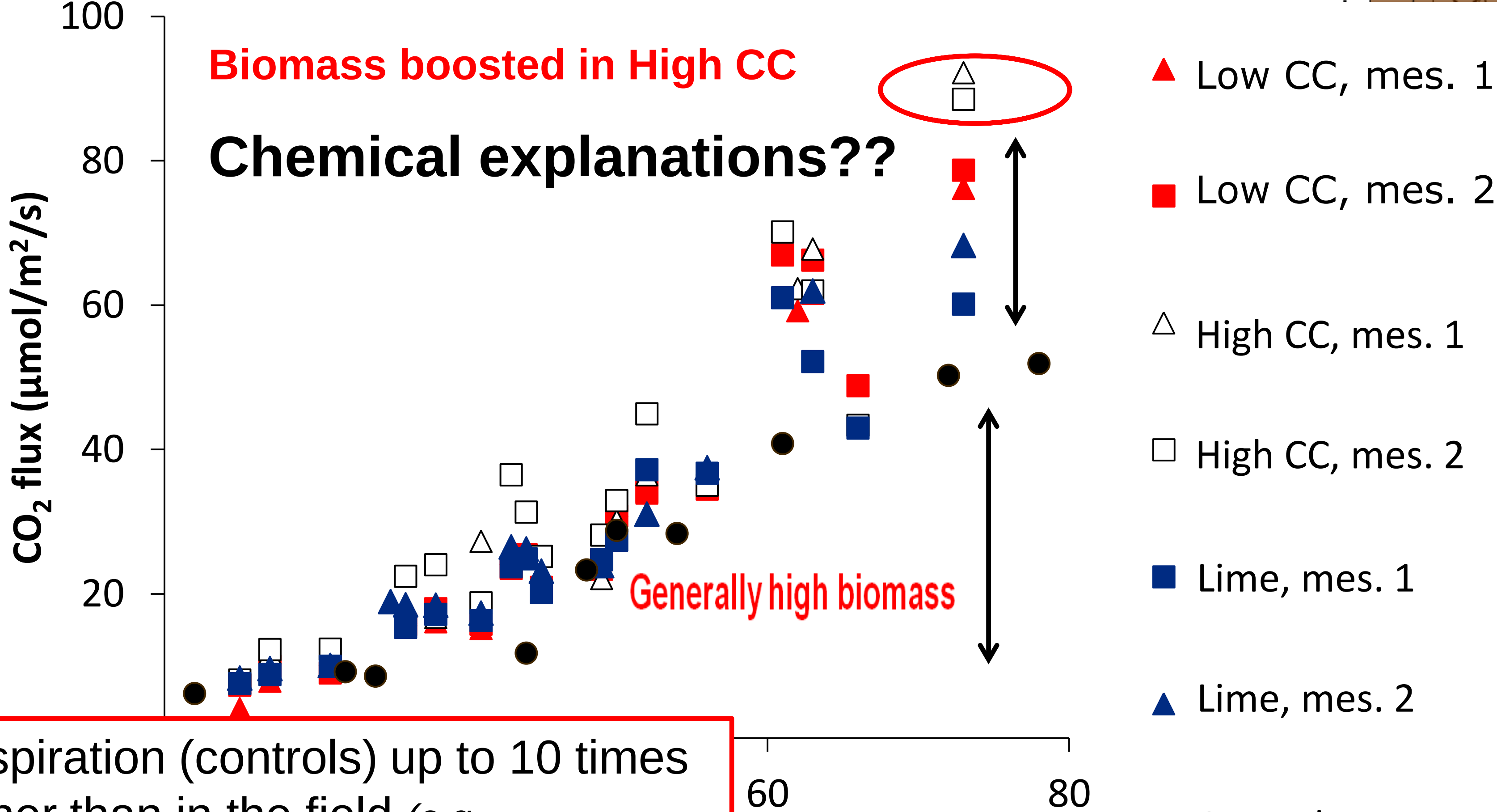


Average DIC (mmol/L)	CONTROL	LIME	Low CC	HIGH CC
	2.5 ± 0.1	4.7 ± 0.2	5.9 ± 0.3	5.7 ± 0.1

Soil-atmosphere CO_2 exchange

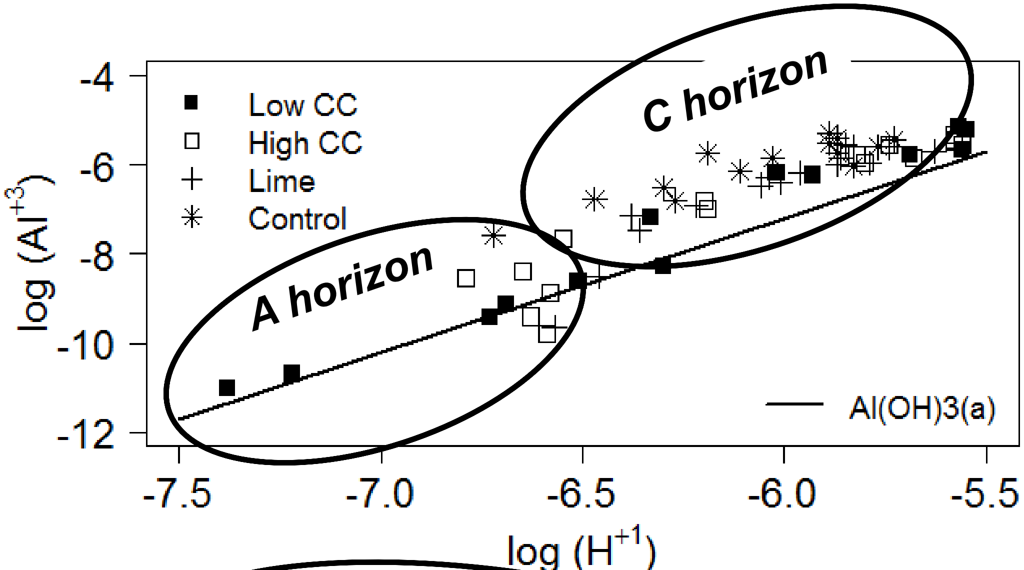


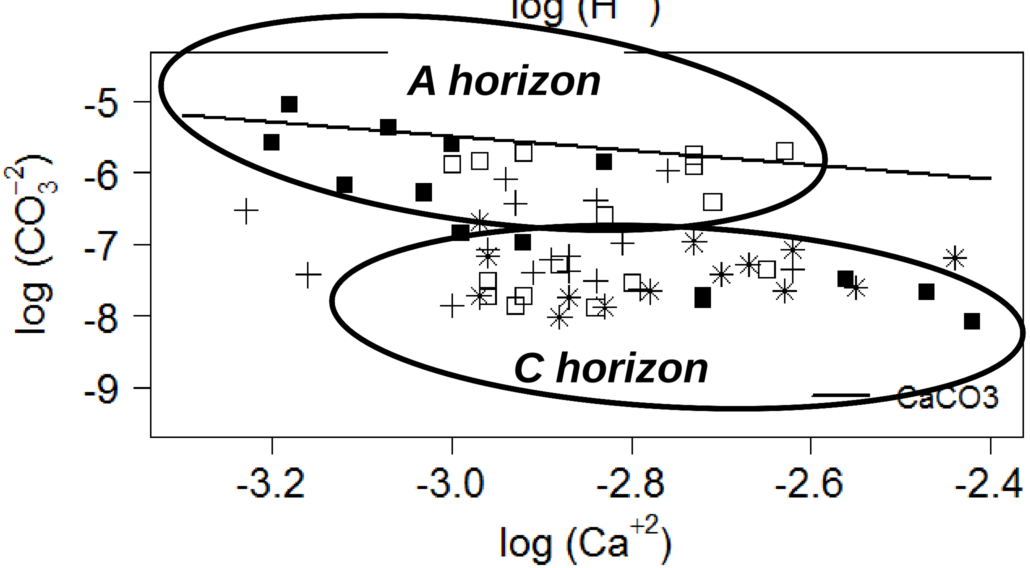
Ecosystem "Respiration"



Respiration (controls) up to 10 times higher than in the field *(e.g. Buyanokovsky et al., 1983; Feizene et al. 2008)*

Mineral Equilibrium





Supersaturation (SI>0)

Precipitation

$Al^{3+} + H_2O \leftrightarrow Al(OH)_{3(s)} + 3H^+$

log_k= 10.8

Subsaturation (SI<0)

Dissolution

$CaCO_{3(s)} \leftrightarrow Ca^{2+} + CO_3^{2-}$

log_k= -8.48

Soil respiration:

$CO_{2(g)} + H_2O \leftrightarrow H_2CO_3 \overset{\rightarrow}{\leftrightarrow} H^+ + HCO_3^- \uparrow$

Limed:

$CaCO_3 + CO_{2(g)} + H_2O \leftrightarrow Ca^{2+} + 2HCO_3^-$

CC-amended:

$Ca^{2+} + HX \leftrightarrow H^+ + CaX2 \quad \rightarrow pH \uparrow$ X=exchanger

+ ? CC contains other compounds.. e.g. Al_2O_3(~5-10% of cement)

All mesocosms ($CaCO_3$ in A horizon):

$2H_2CO_3 + CaCO_3 \leftrightarrow Ca^{2+} + 2HCO_3^-$ weathering

All mesocosms: $Al(OH)_{3(a)}$ supersaturation

$Al^{3+} + 3H_2O \leftrightarrow Al(OH)_{3(s)} + 3H^+$

$H^+ + HCO_3^- \leftrightarrow H_2CO_3 \leftrightarrow CO_{2(g)}\uparrow + H_2O$

unit: mol cm^{-2} d^{-1}

CONTROL	LIMED	LOW CC	HIGH CC
	+20%	+35%	+45%
CO_2 efflux 2 *10^{-4}	CO_2 efflux 2.4*10^{-4}	CO_2 efflux 2.7*10^{-4}	CO_2 efflux 2.9*10^{-4}

Lime-amended:

0.4*10^{-4} mol cm^{-2} d^{-1} increase in top efflux

>>

0.6*10^{-6} mol cm^{-2} d^{-1} increase in bottom efflux

CC-amended:

0.7-0.9*10^{-4} mol cm^{-2} d^{-1} increase in top efflux

>>

1.1*10^{-6} mol cm^{-2} d^{-1} increase in bottom efflux

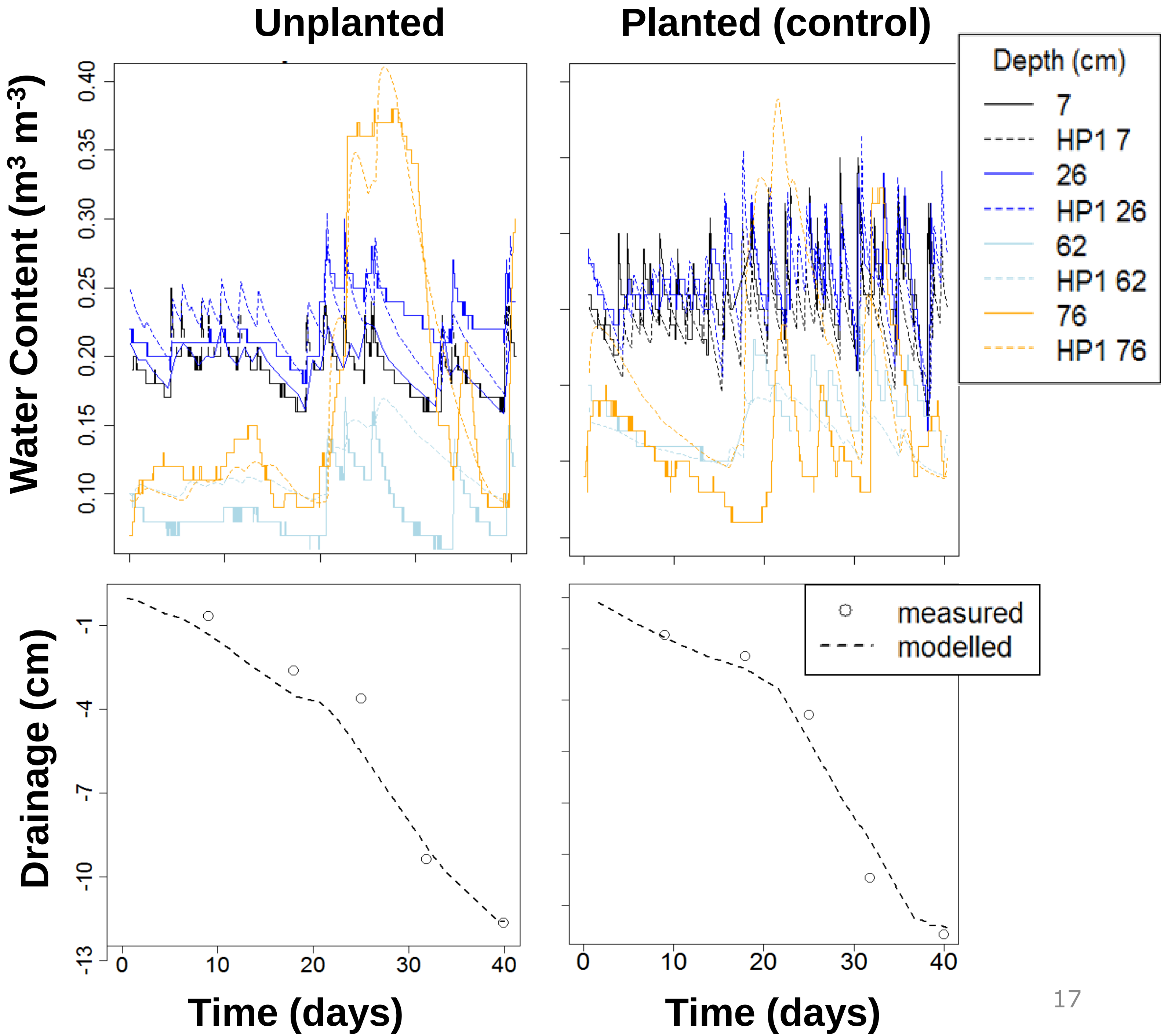
CONTROL	LIMED	LOW CC	HIGH CC
DIC leaching 0.12*10^{-6} L^{-1}	DIC leaching 0.23*10^{-6} L^{-1}	DIC leaching 0.35*10^{-6} L^{-1}	DIC leaching 0.35*10^{-6} L^{-1}
0.26% of top efflux	+190%	+290%	+290%

HP1: Water flow

Model: Mualem/van Genuchten

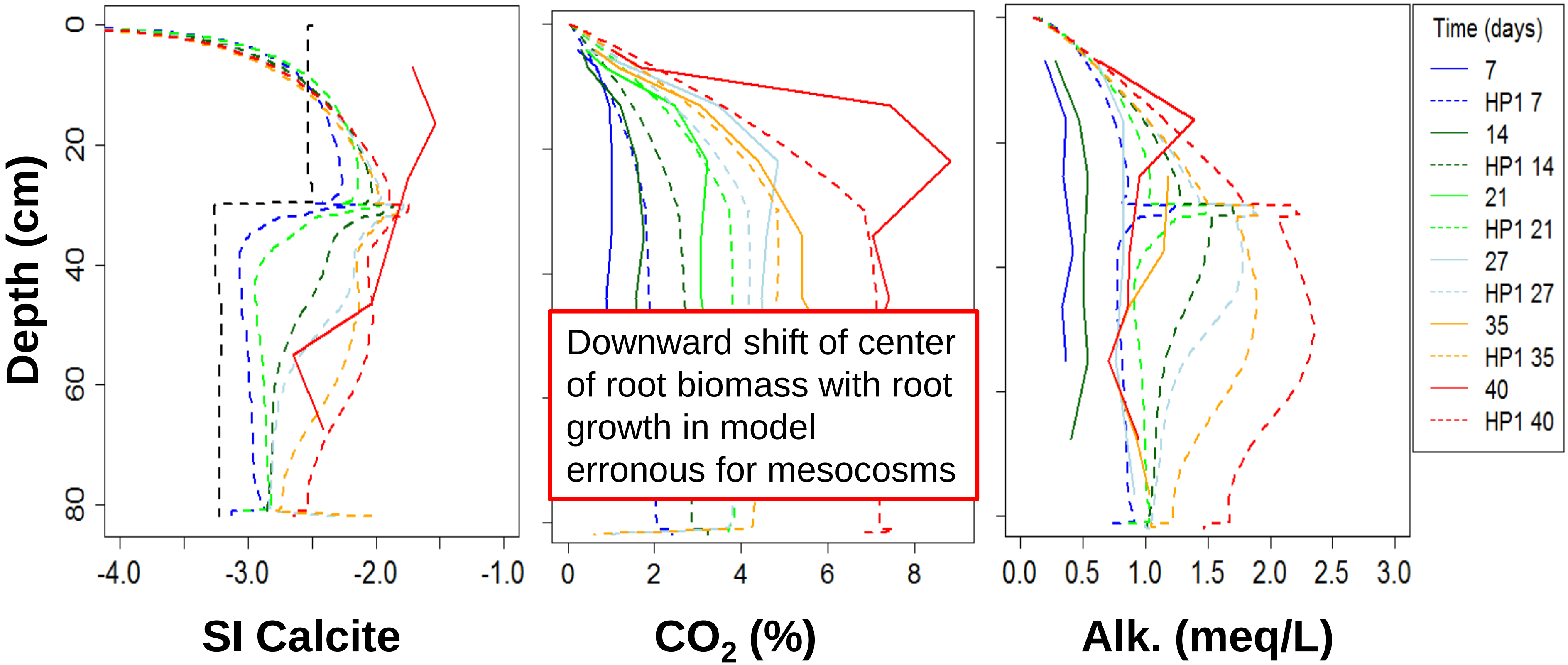
Upper and lower Boundary: Variable P head

ET from pan evaporation test



HP1 (SOILCO2).Profiles (control)

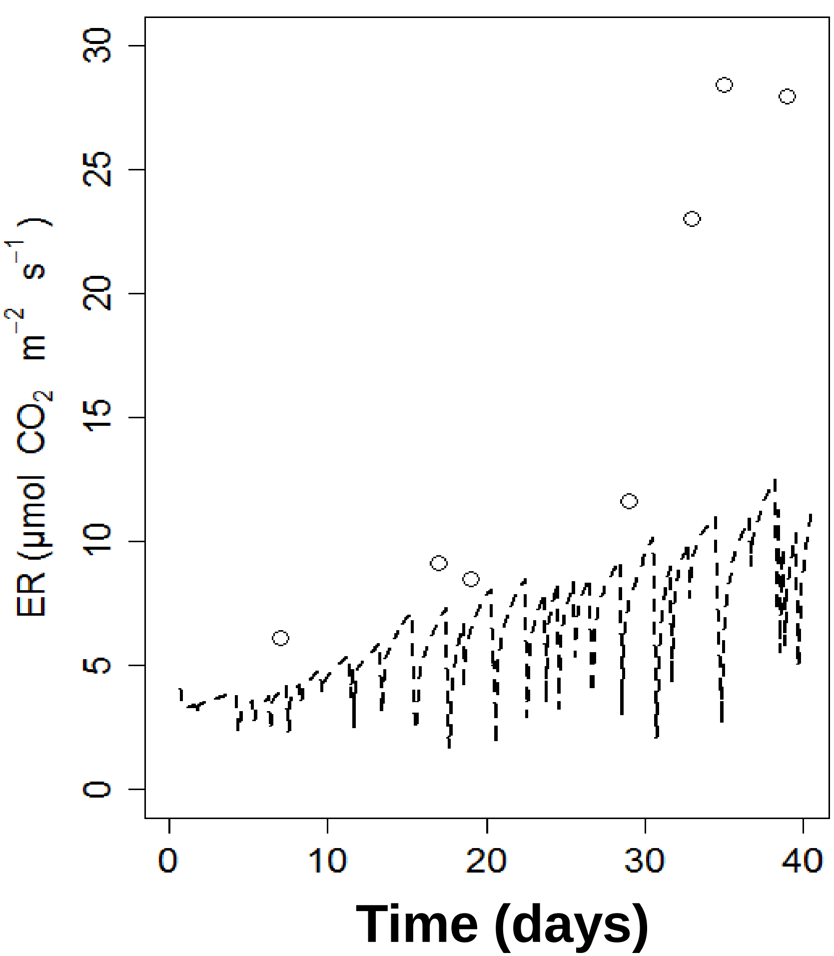
Modelled with SI $Al(OH)_{3(a)}$= 0.8 and 0.6 for A and C horizon, resp.
Estimated exchanger size from org.C and clay content (contained Ca). No nutrients



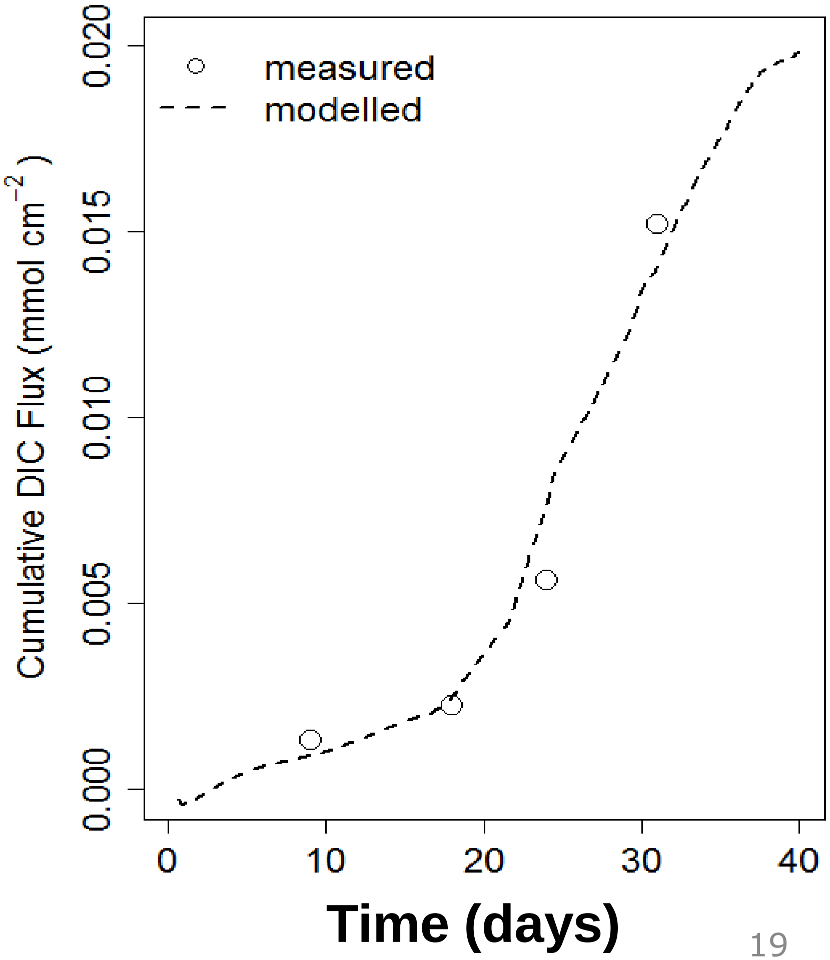
Additional alkalinity-consuming process??

Effluxes (control)

FLUX FROM TOP



FLUX FROM BOTTOM



A new (concrete) wonder?

- Soil amendments increase pCO_2, alkalinity and DIC drastically
- CC & Lime fingerprints in DIC percolation are strong but concurrent increases in efflux follow that are probably caused by $Al(OH)_{3(a)}$ supersaturation
- First modeling proved $Al(OH)_{3(a)}$ -hypothesis
- CC and lime amendments not recommendable in terms of CO_2 storage *in the tested soil*