Supplement of Biogeosciences, 11, 7179–7192, 2014
http://www.biogeosciences.net/11/7179/2014/
doi:10.5194/bg-11-7179-2014-supplement
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Biogeosciences
Open Access

Supplement of

Inorganic carbon fluxes across the vadose zone of planted and unplanted soil mesocosms

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Supplementary Information

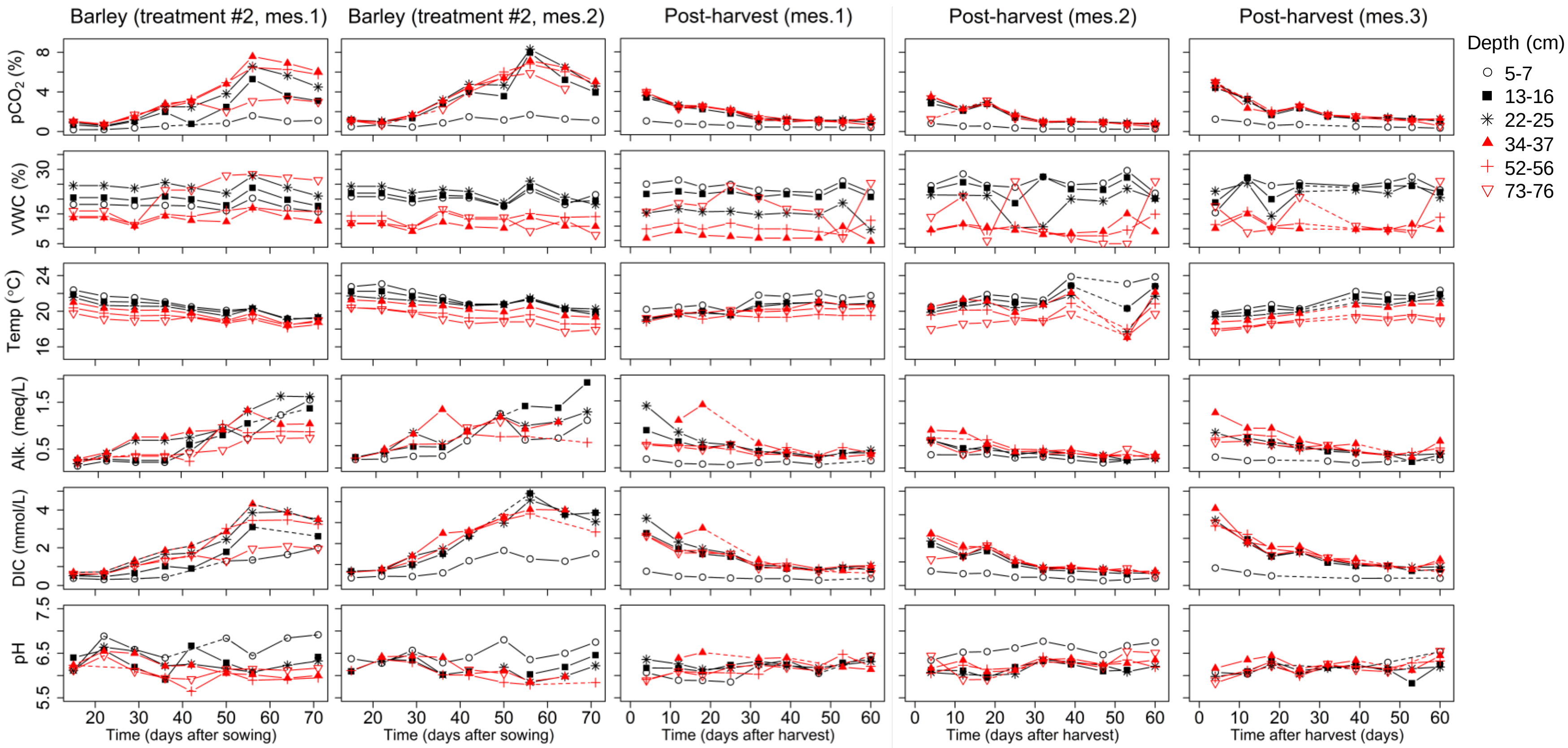

Fig. S1. Time course of pCO_2, volumetric water content (VWC), temperature, alkalinity (Alk.), DIC and pH on measurement days throughout depth during barley growth (treatment #2) and after harvest. Measurements at 45 and 63 cm depth were excluded for clarification of the figure but followed the same trends as measurements at 13–56 cm. Note the different x axis scale for the subfigures.

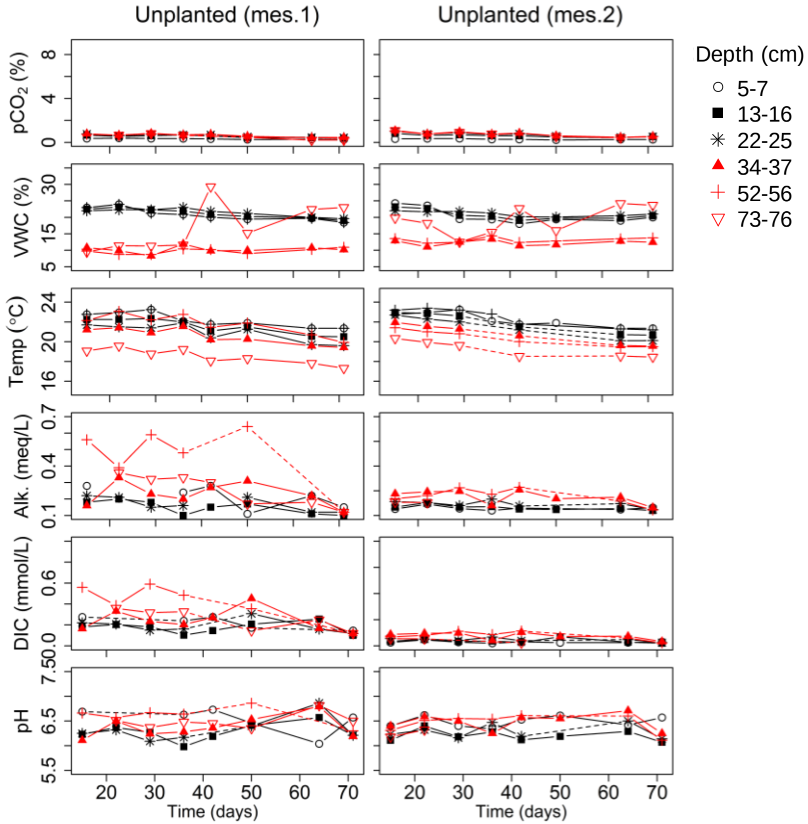

Fig. S1 (continued). Time course of pCO_2, volumetric water content (VWC), temperature, alkalinity (Alk.), DIC and pH on measurement days throughout depth in unplanted soil**.** Measurements at 45 and 63 cm depth were excluded for clarification of the figure but followed the same trends as measurements at 13–56 cm.

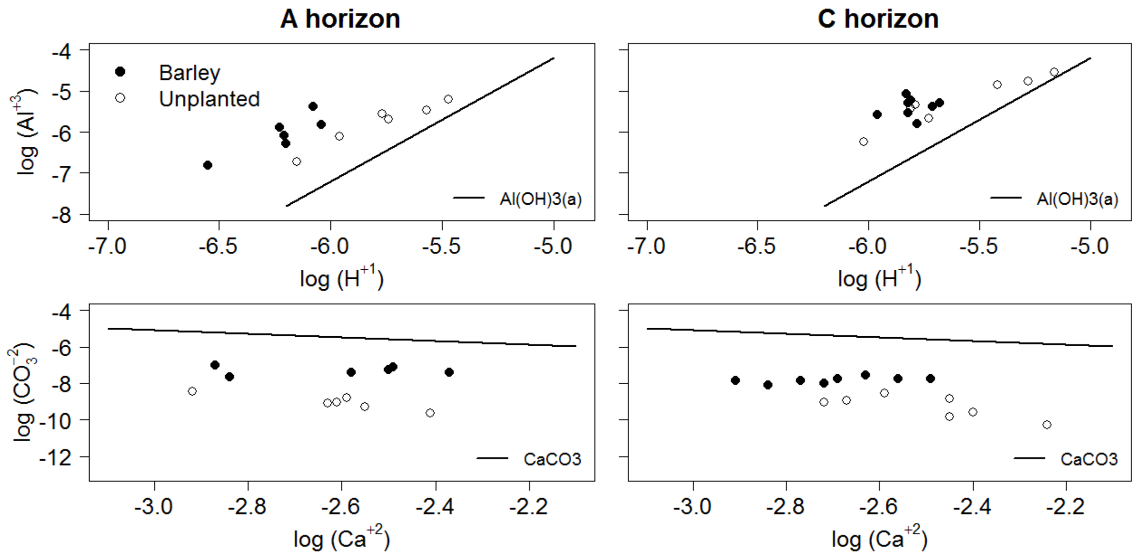

Fig. S2: Log activities of Al^{3+} vs. H^+ as compared to the equilibrium line for $Al(OH)_{3(a)}$ and log activities of CO_3^{2-} vs. Ca^{2+} as compared to the equilibrium line for $CaCO_3$ of pore water in A and C horizons on day 71 (series 2 mesocosms only). Samples were analyzed by ICP-MS (Elan6100DRC, Perkin Elmer, CAN), and concentrations were corrected for dilution by the acid added during a previous alkalinity titration. Saturation indices of different minerals in the mesocosms were calculated with PHREEQC software (Parkhurst and Appelo, 2011). Concentrations of the major anions NO_3^- and SO_4^{2-} were set to 62 and 96 mg L^{-1}, respectively, as given by the Hoagland solution composition (Hoagland and Amon, 1950). Solutions were charged balanced by adding either Li^+ or Cl^- until electro neutrality.

The pore water was supersaturated for amorphous aluminum hydroxide, $Al(OH)_{3(a)}$, and this indicates the possible precipitation of a gibbsite-type mineral. The soil solutions were subsaturated for calcite, $CaCO_3$, indicating the possible dissolution of lime particles added to the field site. The relations between measurement points and the equilibrium lines were less parallel in the C horizon, indicating less control of either aluminum hydroxide or calcite in the subsoil. Activities of H^+ were generally lower in the pore water samples from planted soil than in unplanted soil, while activities of CO_3^{2-} were slightly elevated.

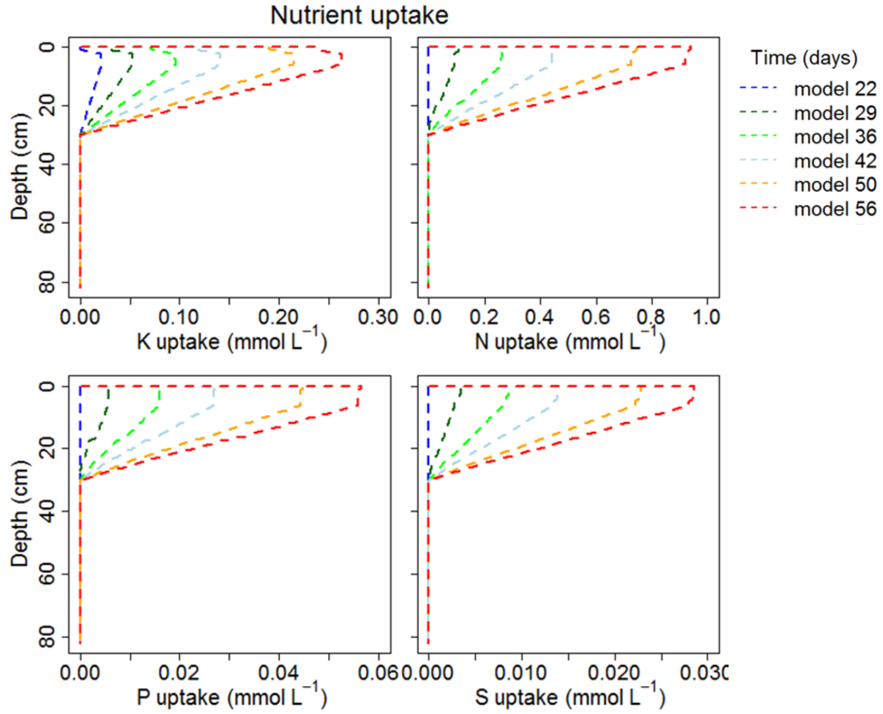

Fig. S3: Simulated nutrient uptake rates of remaining nutrients.

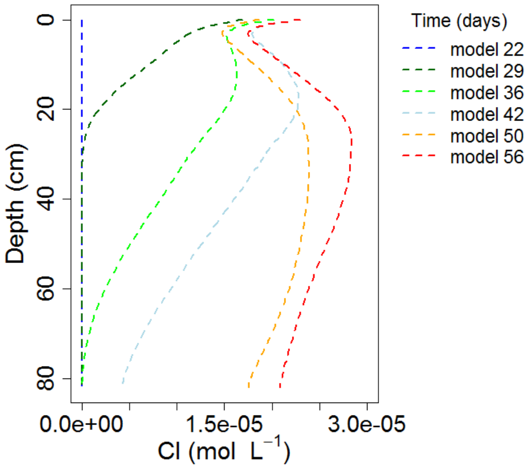

Fig. S4: Simulated movement of chloride tracer applied at a concentration of $0.92*10^{-5}$ moles L^{-1}. Combined action of evaporation and transpiration increased tracer concentration ~3 times. Evapotranspiration caused a peak in the tracer concentration in the C horizon. Evaporation causes steep increases in the tracer concentration at the very top of the mesocosm.

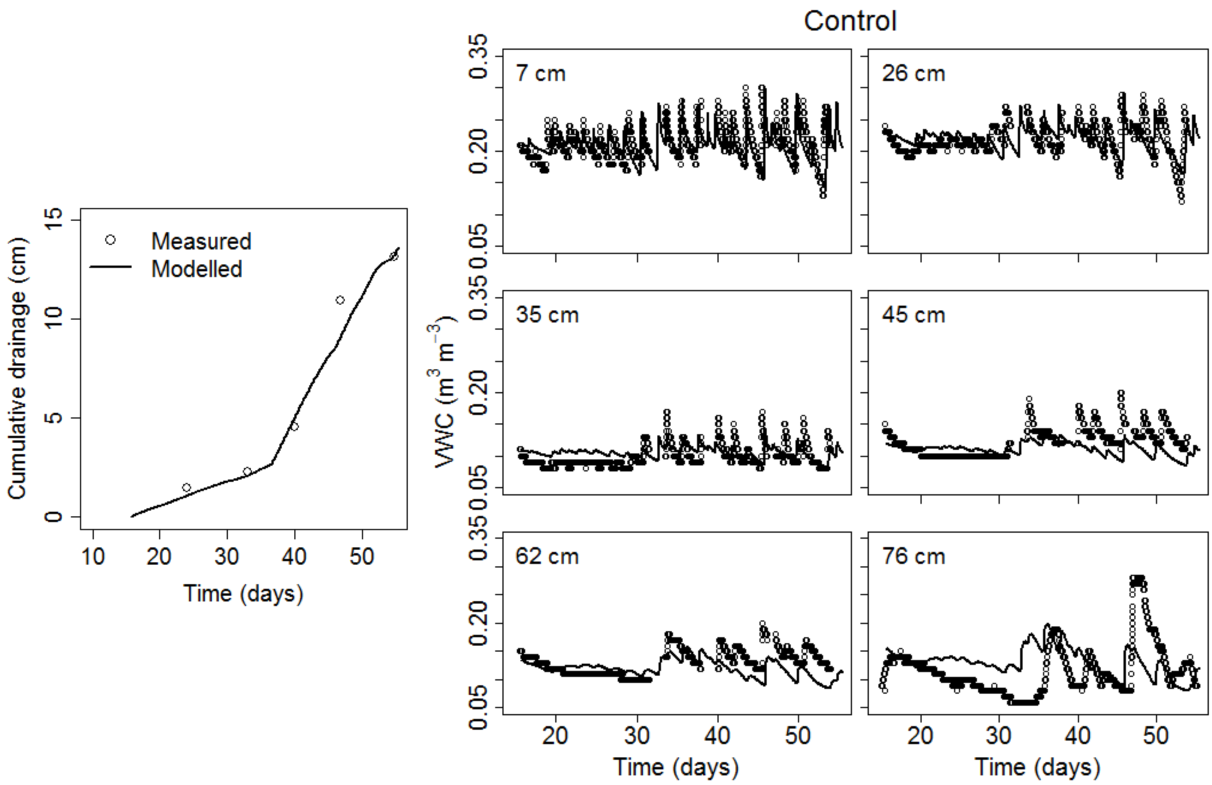

Fig. S5: Measured and modeled cumulative drainage and volumetric water content (VWC) in barley mesocosm 5.

Text S1: Calculation of theoretical diffusion coefficients

Theoretical bulk diffusion diffusivities, D, were calculated using the empiral formulas of Rogers and Nielson (1991) and Andersen (2000) (Eq. 1-3).

$$D = D_e \beta \quad (1)$$

$$D_e = D_0 \varepsilon \exp(-6m\varepsilon - 6m^{14\varepsilon}) \quad (2)$$

$$\beta = \varepsilon_a + L\varepsilon_w + K\rho b \quad (3)$$

where D_e is the effective diffusion coefficient (m^2 s^{-1}), D_0 is the diffusion coefficient in air (m^2 s^{-1}), ε is the total porosity (m^3 m^{-3}), ε_a is the air-filled porosity (m^3 m^{-3}), ε_w is the water-filled porosity (m^3 m^{-3}), m is the water saturation ($\varepsilon_w / \varepsilon$) ($m^3$ m^{-3}), L is the Ostwald coefficient (equals approx. 0.36 at 10°C and 0.23 at 25°C (Clever, 1979)) and K is the radon surface sorption coefficient (kg m^{-3}) (Rogers and Nielson, 1991), and ρb is the soil bulk density (kg m^{-3}).

In the calculations ε_w was set to 0.2 and 0.1 (m^3 m^{-3}) for the A and C horizon, respectively, ρb was 1.45 and 1.53 kg m^{-3} for the A and C horizon, respectively, and K was assumed to be 0. L was set to 0.26. Total porosities of the A and C horizon were 0.45 and 0.43, respectively.

Table S1: Parameters used in the modeling of soil CO_2 fluxes. DW= dry weight.

Symbol	Meaning	Value	Calculation/Source
R_{init}	Initial root mass	2.0 g DW	Calculated from the measured root mass (Table 3) assuming linear root growth
r	Root growth rate	2.4×10^{-6} g s^{-1}	Calculated from the measured root mass 65.5 days after germination (Table 3) and assuming linear root growth
RMI	Root mass index		Calculated by $R_{init}+(r*\text{time})$
γ_{s0}	Optimum microbial respiration	0.8 µmol m^{-2} s^{-1} g_{DWroot}^{-1}	Average "optimum" respiration in planted mesocosms divided by the root mass 65.5 days after germination (Table 3) and by a factor 2 for equal division between root and microbial respiration
γ_{p0}	Optimum root respiration	0.8 µmol m^{-2} s^{-1} g_{DWroot}^{-1}	
a	Scaling factor for depth dependency of microbial respiration	0.0015 m^{-1}	
-	Boundary layer height	0.02 m	

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