CO₂ fluxes to aquifers beneath cropland: merging measurements and modeling

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Project Aim:
to identify the main factors controlling transport of DIC to aquifers and test for durable strategies to increase DIC transport

Field site
Mesocosm experiments

Mesocosms
Experimental design

Measuring profiles of:
- Alkalinity
- pCO₂
- Soil moisture
- Temperature
- Electrical Conductivity

Mature barley plants

Experimental results. Profiles of pCO₂ and alkalinity
Experimental results. Mineral Equilibrium

Supersaturation (SI>0)
Precipitation

\[ \text{Al}^{3+} \text{+ H}_2\text{O} \leftrightarrow \text{Al(OH)}_{\text{3(s)}} + 3\text{H}^+ \]
\[ \log_k = 10.8 \]

Subsaturation (SI<0)
Dissolution

\[ \text{CaCO}_3(s) \leftrightarrow \text{Ca}^{2+} + \text{CO}_3^{2-} \]
\[ \log_k = -8.48 \]

SOILCO2 HP1

Aim
1. To model major AND minor ions in the system, particularly Al\(^{3+}\) (vs. UNSATCHEM)

Additions:
Linear biomass increase with time (+ root depth increase)
~ 4 times higher root length in pot experiments

Water flow

Model: Mualem/van Genuchten
Upper and lower Boundary: Variable P head
ET from pan evaporation test

Unplanted soil

Modelled with SI Al(OH)\(_{3(a)}\) = 0.6 for A and C horizon. Measured exchanger (low)
Unplanted soil

FLUX FROM TOP

FLUX FROM BOTTOM

Planted soil

Modelled with SI Al(OH)$_3$ = 0.8 and 0.6 for A and C horizon, resp. Estimated exchanger size from org.C and clay content (contained Ca)

Planted soil

Al(OH)$_3(aq)$ equilibrium:

Al$^{3+}$ + 3H$_2$O $\leftrightarrow$ Al(OH)$_3(s)$ + 3H$^+$  \hspace{1cm} (SI>0)

H$^+$ + HCO$_3^-$ $\leftrightarrow$ H$_2$CO$_3$ $\leftrightarrow$ CO$_2$(g)↑ + H$_2$O

Additional alkalinity consuming process??

Soil respiration:

CO$_2$(g) + H$_2$O $\leftrightarrow$ H$_2$CO$_3$ $\leftrightarrow$ H$^+$ + HCO$_3^-$

2H$_2$CO$_3$ + CaCO$_3$ $\leftrightarrow$ Ca$^{2+}$ + 2HCO$_3^-$  \hspace{1cm} (SI<0)
Planted soil

**Conclusions**

- Model mostly confirmed experimental data, aided in their comprehension
- DIC leaching is clearly increased by higher alkalinity and CO₂ in planted mesocosms
- Experiments: CO₂ remains mainly in gas phase due to buffering processed
- Inconsistencies need further investigation