Lime spreading at the KBS LTER. Photo by Julie Doll.

The missing carbon link: Are ag lime and groundwater irrigation sequestering carbon?

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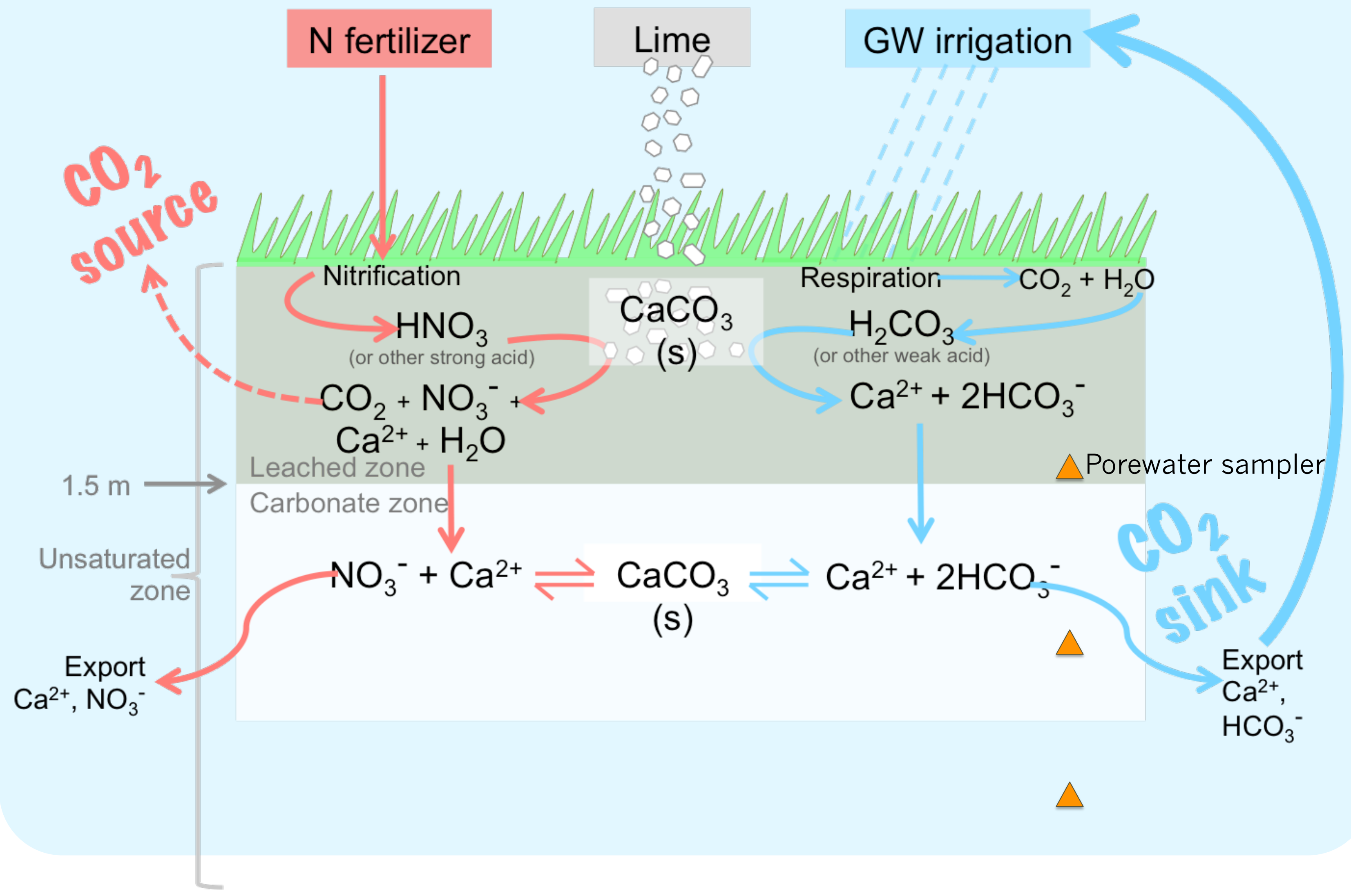
1 Introduction

Farmers routinely add inorganic carbon to row crop soils in the form of crushed lime (e.g. $CaCO_3$ or $CaMg(CO_3)_2$) and/or inadvertently as bicarbonate (HCO_3^-) naturally dissolved in groundwater used for irrigation. In the soil these carbonates can act as either a source of CO_2 to the atmosphere or a sink for keeping additional CO_2 out of the atmosphere.

Both nitrogen fertilizer and crop harvest acidify soils. As global consumption increases and agriculture intensifies, more fertilizer is used and soils are more rapidly acidified. Lime neutralizes soil acidity and its use is expected to grow in step with these trends.

Yet the relationship between nitrogen fertilizer amount, irrigation, and carbonate fate (source or sink for CO_2) is not well understood. This is important for greenhouse gas inventory protocols used by groups such as the IPCC, USDA, and EPA. Current models for calculating C emissions from lime use do not account for N fertilizer amount or irrigation. Hamilton et al. (2007)* found evidence that in certain areas liming may be more of a C sink that source.

Our model for inorganic carbon cycling in a Michigan row crop system:



2 Research Questions

Q1: Is there a relationship between the fate (source or sink) of inorganic C added to soils (lime or groundwater) and N fertilizer amount in the carbonate-leached (upper) zone?

Q2: How does soil porewater chemistry change with transport from the carbonate-leached zone to the native carbonate zone? (i.e. how does chemistry change with depth?)

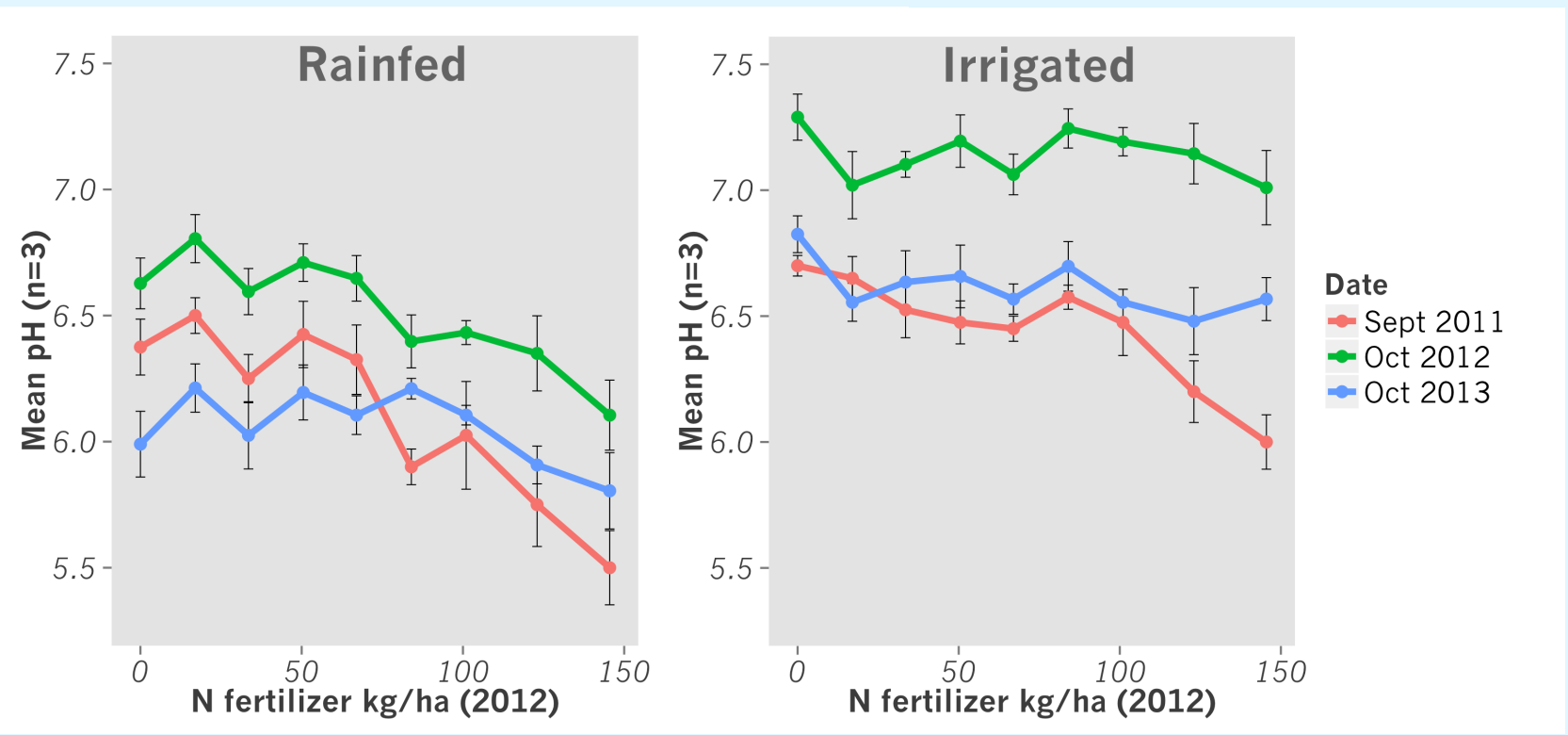
Q3: How do management and climate events affect porewater chemistry over time?

3 Methods

We installed silica carbide porewater samplers (~tension lysimeters) at 1.2, 2.5, and 3.3 m depths (see orange triangles in illustration at left) at a 50° angle from the surface in the KBS LTER Resource Gradient Experiment—"resources" meaning N fertilizer and groundwater irrigation. This is a corn-soy-wheat rotation system with no-till management. The samplers are deployed in two of the replicated blocks: one irrigated block and one rainfed block. We are using eight plots in each block, plots range in N fertilizer level from 0 kg/ha to 246 kg/ha in 2014, which was a corn year.

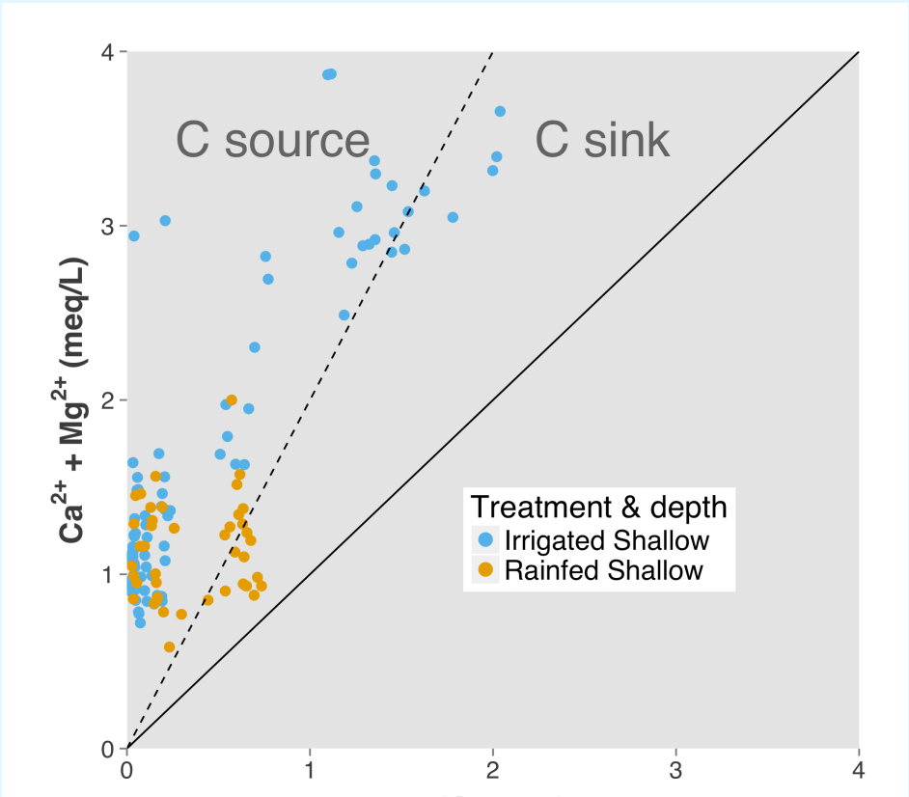
The data shown here are from May – Dec. 2014. Samples were collected weekly (approximately). Porewater samples are filtered and refrigerated within two hours of collection and analyzed for a suite of hydrochemical variables, including the ones reported in the next section.

4 Results



These ***soil pH data*** demonstrate the acidifying effect of N fertilizer (x-axes) and the buffering effect of groundwater irrigation (compare left and right panels). You can also see the buffering effect of liming in May 2012 (compare the red and green lines).

(Results continued)

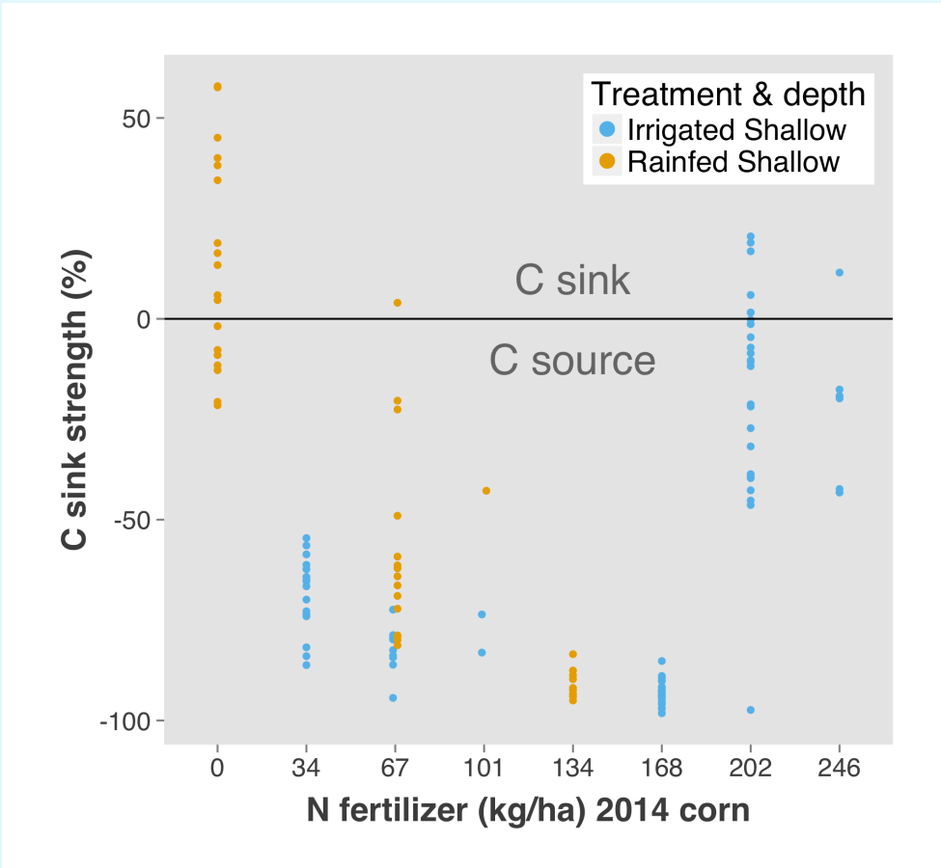


Ask me how this plot works to determine whether a porewater sample is a C source or sink.

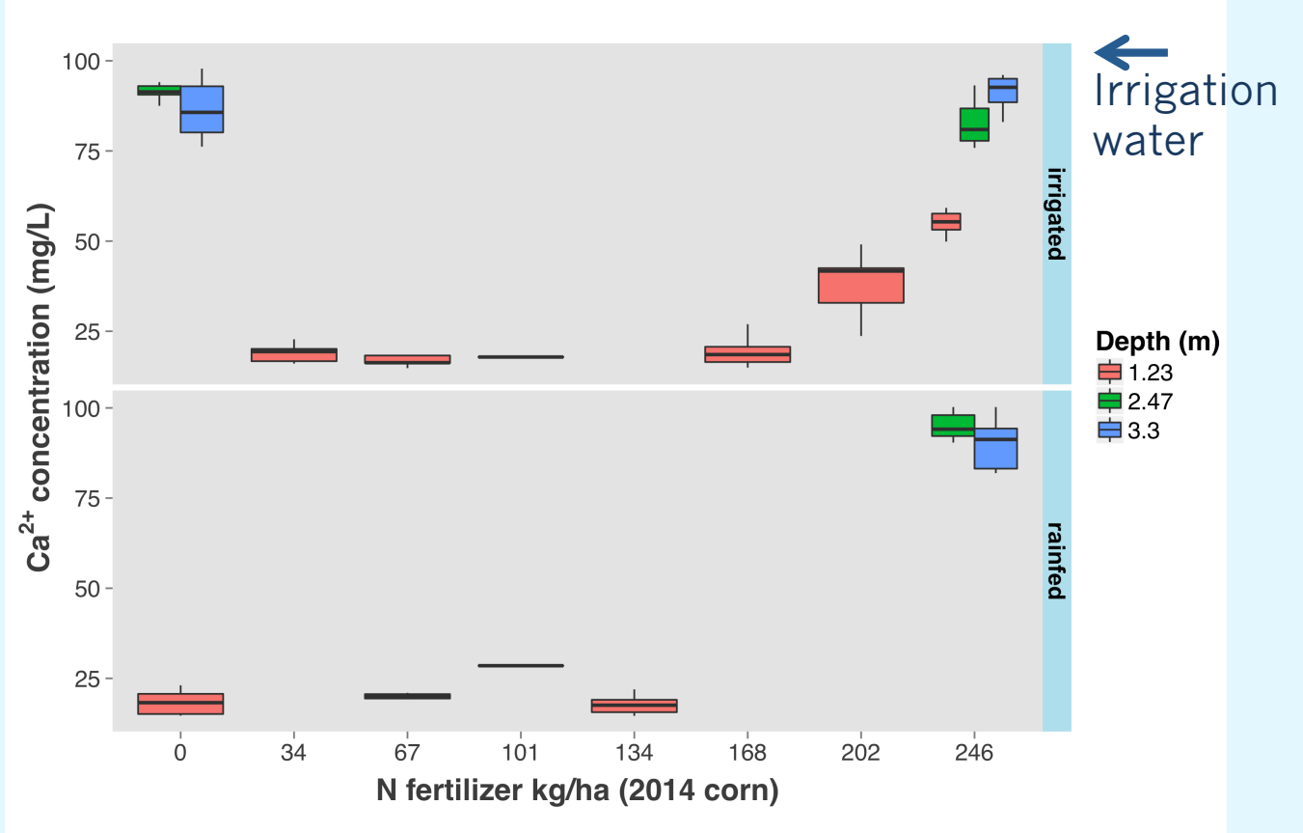
Q1 (C fate): Some porewater samples from irrigated plots show higher levels of Ca^{2+}, Mg^{2+}, and HCO_3^- than the rainfed plots--suggesting the chemical fingerprint of the irrigation water on the soil porewater. But what is the role of N in determining if a sample represents a C sink or source? First, we calculate the C sink strength for each sample:

$$\text{C sink strength (\%)} = \frac{(HCO_3^-\ \textbf{\textit{meq/L}} - 0.5(Ca^{2+}\textbf{\textit{meq/L}} + Mg^{2+}\textbf{\textit{meq/L}}))\ {*}100}{0.5(Ca^{2+}\mathit{meq/L} + Mg^{2+}\mathit{meq/L})}$$

Where negative values = C source and positive values = C sink.

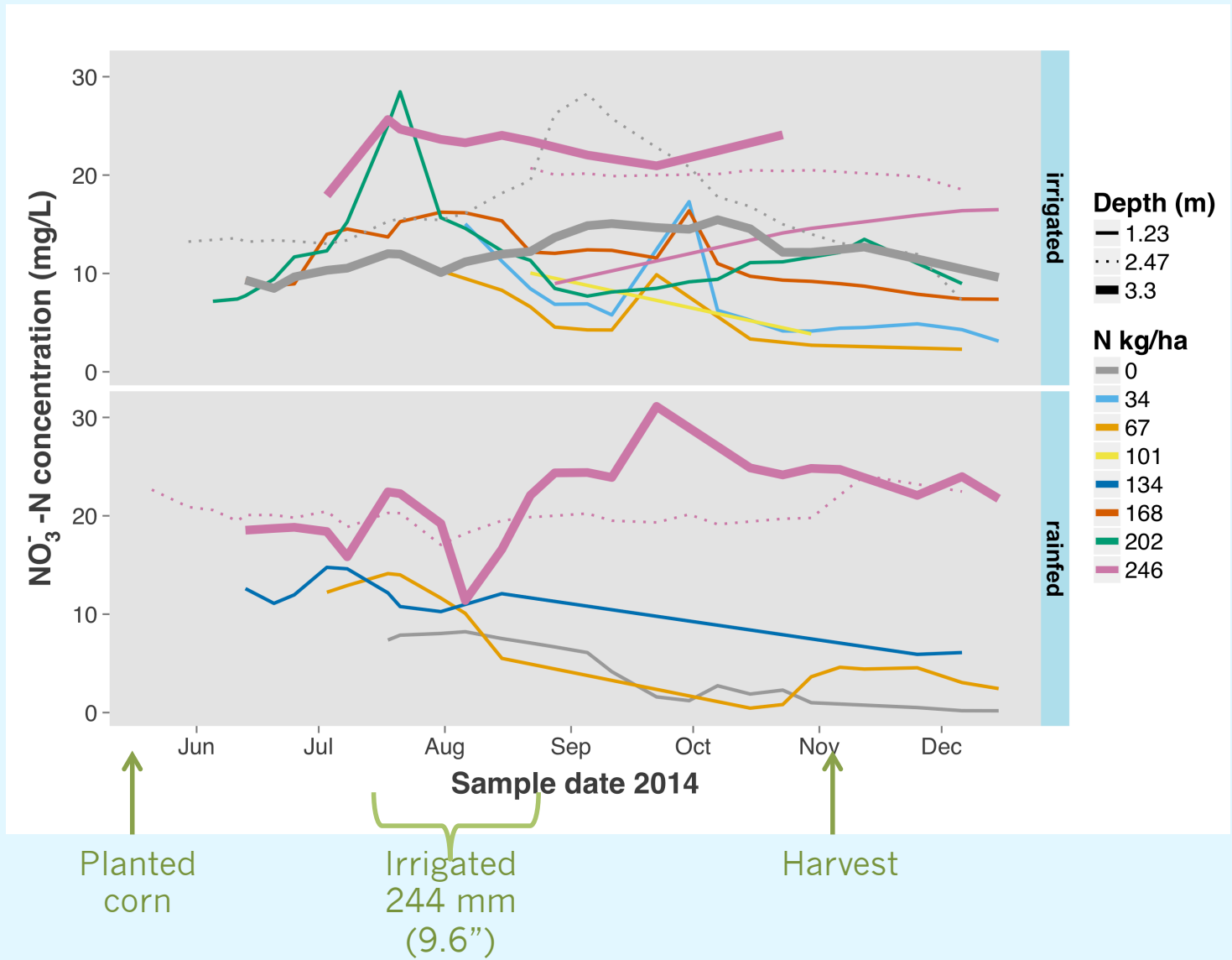


Now we can see how N fertilizer amount is related to C sink strength (left). These data suggest a negative relationship, where plots with greater N fertilizer tend to be a stronger C source. ***However,*** the C sink strengths for plots at the two highest N fertilizer levels do not fit this pattern. We're not sure yet how to explain this. ***Feedback welcome!***



Q2 (depth): Calcium data by depth at left. The 2.47 and 3.3 m samplers reflect the native carbonate zone chemistry, while the 1.2 m samplers reflect the leached zone. We think that the upward trend in shallow samplers with higher N may be because these plots were limed more heavily than low N plots in 2012.

Q3 (time): Nitrate data at right. We have a bromide tracer study underway that will allow us to quantify the lag time between surface events and the different depths.



5 Take home points

While date from just one growing season is not enough to draw any robust conclusions, there are some interesting patterns already apparent: groundwater irrigation has a strong effect on soil pH; plots with greater N fertilizer amounts seem to be greater C sources (except at the highest N levels); the carbonate leached zone and the native carbonate zones have very different soil porewater chemistry; and porewater chemistry can show dramatic changes over time. Stay tuned for 2015 growing season data!

*Hamilton, S. K., A. L. Kurzman, C. Arango, L. X. Jin, and G. P. Robertson. 2007. Evidence for carbon sequestration by agricultural liming. Global Biogeochemical Cycles **21**.

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