Mass Fluxes of Nitrogen and Carbon from Soil Water to a First-Order Mountain Stream in a Pristine Costa Rican Rain Forest in Response to Individual Rain Events

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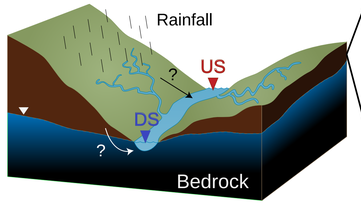
1. Introduction

Can we infer the dominant reactions that explain the chemical changes observed in tropical headwaters?



1) Udands (Andisols)
- Short-range order minerals (poorly crystalline Fe/Al-rich): imogolite, ferryhydrite, allophane
- High OM content

2) Humults (Ultisols)
- Old soil; minerals resistant to weathering, such as Fe/Al-oxides: goethite, hematite, gibbsite
- High OM content

Figure 1. A) Schematic cross section of study watershed with description of prominent soil types along hillslopes and differential stream gauging sites: upstream (US) and downstream (DS). B) field picture of V-notch weir located as DS.

What are the fractional contributions from soil water to stream discharge and net mass fluxes of carbon and nitrogen over 48 hours?

2. Study Site & Methodology

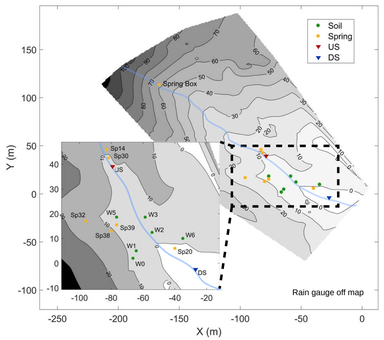


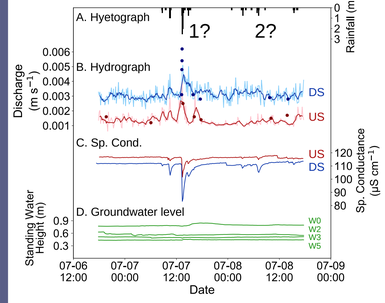
Figure 2. Topographic map of study site and sampling locations: US (red), DS (blue), W (soil water wells; green), and Sp (spring seeps; yellow).

1. What's in the water?
→ Field sampling and chemical analyses

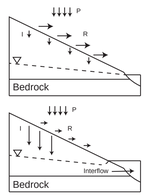
2. What are the fractional contributions from the sources?
→ End Member Mixing Analysis (EMMA)
⟶ Hydrograph separation

3. What are the processes that lead to the final solution chemistry?
→ PHREEQC
⟶ Inverse Modeling

3. Ambient Stream Conditions



Conceptual Runoff Models:

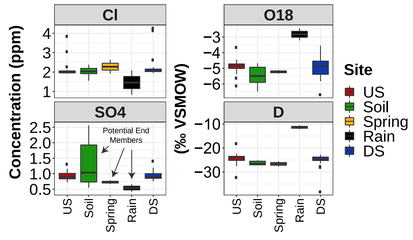


1) Infiltration-Excess Overland Flow
- Shallow soil interaction

2) Groundwater Ridging
- Deep soil interaction

Figure 3 (left). Time series of A) rainfall, B) volumetric discharge in the two stream gauges, C) specific conductance in the two stream gauges, and D) standing water height in the groundwater wells.

4. EMMA



- Unmixing stream contributions requires conservative tracers
- PCA reduces dimensionality
- Likely missing end member (see DS17-22 in Fig. 5C)

Figure 4 (left). Boxplots of "conservative" solute concentrations and stable water isotope signatures of potential end members and stream data.

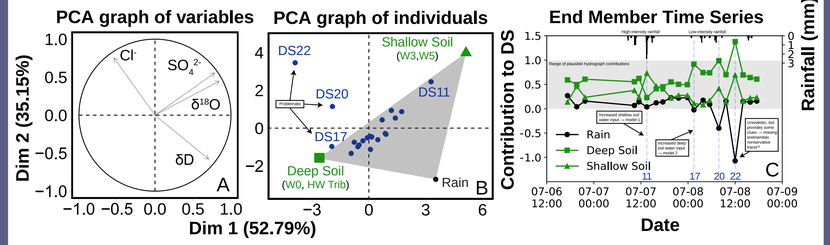


Figure 5. Results of EMMA for DS: A) PCA variable factor map with conservative tracers, B) PCA individual factors map with end members projected onto the stream U-space (PC1 and PC2), and C) fractional contributions to the hydrograph.

Probable evidence of both shallow and deep soil water input to streams

5. Inverse Modeling

- Primary minerals should readily dissolve and release Fe^{2+}, oxidize, and lead to formation of amorphous Fe-oxides (additionally Al-oxides)
- Formation of Al- and Fe-oxides may limit DOC transport
- If we know input and output chemistry, we can inversely model possible reactions that contribute to observed carbon and nitrogen imbalances

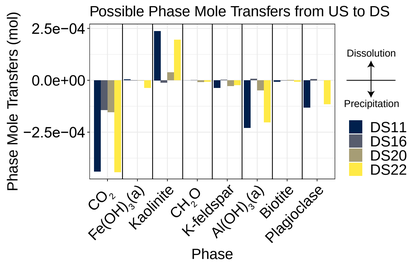


Figure 6. One output of inverse modeling reactions between US and DS for selected events: 11 (rain), 16 (dry), 20 (rain), and 22 (rain). Modeled phase mole transfers above zero indicate dissolution of the selected phases, and vice versa for precipitation.

6. Key Findings

Mass fluxes of carbon and nitrogen species are greater at DS than US

US → DS

Organic matter dissolution? > Precipitation of SRO minerals and adsorption?

- Evidence for infiltration-excess overland flow and groundwater ridging during high and low-intensity rainfall events, respectively
- Shallow soil and deep soil inputs are both important
- Although we see the precipitation of SRO minerals, the mobilization of DOC and TDN via rainfall events outweight adsorption onto these mineral surfaces

7. Acknowledgements & More!

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